BEFORE THE
FLORIDA PUBLIC SERVICE COMMISSION

DOCKET NO. 070650-EI

In the Matter of:

PETITION TO DETERMINE NEED FOR TURKEY POINT NUCLEAR UNITS 6 AND 7 ELECTRICAL POWER PLANT, BY FLORIDA POWER & LIGHT COMPANY.
_______________________________________/

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PROCEEDINGS: MIAMI SERVICE HEARING

BEFORE: CHAIRMAN MATTHEW M. CARTER, II
COMMISSIONER LISA POLAK EDGAR
COMMISSIONER KATRINA J. MCMURRIAN
COMMISSIONER NANCY ARGENZIANO
COMMISSIONER NATHAN A. SKOP

DATE: Wednesday, January 9, 2008

TIME: Commenced at 4:00 p.m.
Concluded at 7:51 p.m.

PLACE: Miami Dade College
Wolfson Campus Auditorium
Building 1000, 2nd Floor, Room 1261
300 NE 2nd Avenue
Miami, Florida

REPORTED BY: LINDA BOLES, RPR, CRR
Official Commission Reporter
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APPEARANCES:

PATRICK BRYAN, ESQUIRE, and WADE LITCHFIELD, ESQUIRE, 700 Universe Boulevard, Juno Beach, Florida 33408-0420, appearing on behalf of Florida Power & Light Company.

BOB and JAN KRASOWSKI, 1086 Michigan Avenue, Naples, Florida 34103-3857, appearing pro se (Krasowski).

J. R. KELLY, PUBLIC COUNSEL, and CHARLES J. BECK, ESQUIRE, Office of Public Counsel, c/o The Florida Legislature, 111 W. Madison St., Room 812, Tallahassee, Florida 32399-1400, appearing on behalf of the Citizens of Florida.

KATHERINE FLEMING, ESQUIRE, and JENNIFER BRUBAKER, ESQUIRE, FPSC General Counsel's Office, 2540 Shumard Oak Boulevard, Tallahassee, Florida 32399-0850, appearing on behalf of the Commission Staff.

I N D E X

WITNESSES

WITNESSES

EXHIBITS

P R O C E E D I N G S

CHAIRMAN CARTER: Call this hearing to order. Ask staff to read the notice, please.

MS. BRUBAKER: Pursuant to notice, this time and place has been scheduled for the purpose of conducting a service hearing for Docket 070650-EI. The purpose of the service hearing is set forth more fully in the notice.

CHAIRMAN CARTER: Okay. Good afternoon, everyone. Can y'all hear me because I can't hear myself? Good afternoon.

I want to thank you all for coming this afternoon for this opportunity to share with you from the Florida Public Service Commission. With me today are my fellow Commissioners, Commissioner Edgar, Commissioner Argenziano, Commissioner McMurrian and Commissioner Skop. And at this point in time we will have -- we'll take appearances.

MR. BRYAN: Good afternoon. Patrick Bryan and Wade Litchfield on behalf of FPL.

CHAIRMAN CARTER: Okay.

MRS. KRASOWSKI: Good afternoon. Jan Krasowski, Intervenor.

MR. KRASOWSKI: Good afternoon. I'm Bob Krasowski, FPL ratepayer/Intervenor as well. And congratulations, Commissioner Carter, on your new chairmanship.

CHAIRMAN CARTER: Thank you. Now office of Public Counsel.

MR. KELLY: J. R. Kelly and Charlie Beck, Office of Public Counsel.

CHAIRMAN CARTER: Okay. Staff.

MS. BRUBAKER: And on behalf of the Commission, Jennifer Brubaker. I'd also like to enter an appearance for Katherine Fleming.

CHAIRMAN CARTER: Okay. Also with us on the platform, Mr. Tom Ballinger from our staff. We also have additional PSC staffers out here. You've probably got a better view of me than I have of you, so I'd ask all of our staffers, would you please stand so they can see our PSC staffers here. We have some outside at the table and some here within the confines of the facility. Thank you very much. Thank you very, very much.

I want to welcome you here to our hearing this afternoon. But before I get started, I wanted to kind of start with some housekeeping matters. Not the kind you think. First of all, I'd like to recognize Mr. Rolando Montoya, who is our host for the evening. Would you please come and make some remarks, please, sir?

MR. MONTOYA: Good afternoon, Mr. Chairman and Commissioners. Welcome to Miami. Welcome to Miami-Dade College. We are really glad to offer this space to you, and we are very grateful for the opportunity that you are providing to this community to express their opinions to you, and we hope that you have a very productive afternoon. Thank you so much for being here.

CHAIRMAN CARTER: Thank you, Mr. Montoya, for your outstanding hospitality.

Commissioner Argenziano.

COMMISSIONER ARGENZIANO: I just -- I guess you can hear me. I just want to give a special thanks. We were having a little bit of a problem getting a good meeting place so that the good people of Miami could come in to speak to us. And I did want to mention that Senator Villalobos helped us. And thank you so much to Miami-Dade College because you were right there and got us a place immediately, and we really appreciate that.

MR. MONTOYA: Our pleasure.

COMMISSIONER ARGENZIANO: Thank you.

CHAIRMAN CARTER: Thank you. Let me make a few comments here and then we'll go from there. I've got to make a few comments here just for the, for the record to get us kicked off here and then we'll officially get kicked off. Is that, as I said, I wanted to welcome all of you here this afternoon for this opportunity to listen as well as hear what we're hearing from Florida Power & Light. They've asked the Commission to make a determination regarding whether there's a need for the nuclear power plant that they're proposing to build in Dade County. To make this determination our statutes require us to examine the need for electric system reliability and integrity, including fuel diversity, the need for baseload generating capacity, the need for adequate electricity at a reasonable cost, and whether renewable energy sources and technologies as well as conservation measures are utilized to the extent reasonably available.

In addition, the Commission may consider other relevant matters that are within our jurisdiction. Today we want to hear anything that you have to say regarding the need for the proposed power plants and the issues that I've just described. There will be -- separate public hearings will be held before other agencies that consider the environmental and other impacts of the proposed plants.

Our need determination hearings are typically divided into two portions. In the first portion we take testimony from members of the public regarding the need determination that's been requested in this docket. Normally that would take place only in Tallahassee, but in this instance we thought we'd schedule an additional session of public testimony here in Dade County. And this evening we'll -- after this evening's meeting we'll resume in Tallahassee on January 30th to continue our hearings. Once the public testimony portion of the hearing is concluded in Tallahassee and everyone has had an opportunity to speak, then we'll go into what we call an evidentiary portion of the hearing where the parties will present their witnesses and other evidence and cross-examination and things of that nature. And after the conclusion of the evidentiary hearing, then the parties will file briefs before the Commission and the Commission staff will make a recommendation, they will present it to those of us at the Commission, and we will take a decision scheduled currently for March 18th at our conference.

And the public -- I just want to say that the public testimony portion of the hearing is an important part of our process. It's important because it's our best opportunity to hear from members of the public on what FPL has proposed, and we appreciate the fact of you taking out time from your very busy schedules to be with us here today. Before I go on, let me introduce to some Ms. Elena Menendez, who will be, who will be a translator for anyone that wants to speak Spanish or needs assistance in speaking Spanish. So thank you for being with us today. We sincerely appreciate that.

And let me kind of give you the lay of the landscape. It may be redundant, but that's okay too. Is that when we get into our public testimony portion of the presentation, we'll swear you in before you make your comments and that will be after we have a presentation given by FPL. And in the process of that, if there's any person that wants to be heard, you can sign up with our staff outside and we'll get your name and present that. If there's any person that wants to be heard but you don't want to speak, you just want to send in some comments, there's a green sheet that's outside. You can just take that, put your comments on that, it folds into a mailer, and you can send it into the Commission and we'll make it part of the record. So I just want to make sure and let you know that you'll have ample opportunity to be heard on this issue.

And in the process when we do go into our testimony portion of it, the first thing we'll do is we'll recognize our public officials and hear from them, and then we'll go into the process of hearing from our people that are here.

Let me just kind of -- another housekeeping note, when you do speak into the microphone, as you'll notice, what we had to do is we had to pull them a little closer, get a little bit intimate with the microphones so we can kind of hear you clearly. And we have a court reporter here who's taking down everything we say here.

So at this portion in time before I hear from FPL, Mr. Kelly, would you want to make a statement or anything?

MR. KELLY: Sure.

CHAIRMAN CARTER: Yes, sir. You're recognized.

MR. KELLY: Thank you, Mr. Chairman. I just wanted to introduce myself. I'm J. R. Kelly. I'm here with Charlie Beck. We're with the Office of Public Counsel. And for those of you that are not familiar with our office, we are independent from the Florida Public Service Commission. We represent the, the state ratepayers, consumers' interests for all Floridians. And we're very anxious to hear your comments today and we encourage everybody to please share anything that you wish to say, and you'll hear the Chairman continue that, and we echo that same sentiment. Thank you, Mr. Chairman.

CHAIRMAN CARTER: Thank you very kindly.

Ms. Brubaker, are there any other preliminary matters?

MS. BRUBAKER: Staff is aware of none.

CHAIRMAN CARTER: Okay. Then --

COMMISSIONER EDGAR: Mr. Chairman.

CHAIRMAN CARTER: You are recognized --

COMMISSIONER EDGAR: Thank you.

CHAIRMAN CARTER: -- Commissioner Edgar. I almost said Chairman. Commissioner Edgar, you are recognized.

COMMISSIONER EDGAR: Thank you, Mr. Chairman.

I did have one preliminary question, and maybe Ms. Brubaker can make it clearer to me. I noticed that when we were taking appearances from counsel to represent parties that Mr. and Mrs. Krasowski came forward, and I'm always glad to see the Krasowskis, they've participated in a number of our proceedings and I know follow along these issues very closely. But I was not aware that other parties had been granted intervention status in this case.

MS. BRUBAKER: That's correct. A number of other entities have sought intervention in this case. For instance, FMPA, FMEA. That status is still pending. If they are present, which I don't believe that they are, and wish to speak, we would recommend that they be permitted to participate as a party would at this point, and that way their process is reserved if the intervention is granted. I'm not aware that they are actually present at this time, however. Does that answer your --

COMMISSIONER EDGAR: Well, not really, but let me try again. I maybe wasn't clear. So for -- just so that I am clear -- and maybe the Krasowskis are crystal clear on their status but I guess I am not.

MS. BRUBAKER: Oh, I apologize. I understand. They have been granted intervention in this matter.

COMMISSIONER EDGAR: They have been granted intervention?

MS. BRUBAKER: They have and there's been an order issued. My apologies.

COMMISSIONER EDGAR: Okay. So they will be in a position to be able to ask questions of, of people who are coming forward.

MS. BRUBAKER: That's correct.

COMMISSIONER EDGAR: All right. Thank you very much.

COMMISSIONER SKOP: Commissioner.

CHAIRMAN CARTER: Commissioner Skop.

COMMISSIONER SKOP: Thank you, Commissioner.

CHAIRMAN CARTER: Get intimate with it.

(Laughter.)

COMMISSIONER SKOP: Thank you, Mr. Chair.

Ms. Brubaker, if you could also clarify just that it is limited intervention to the specific --

MS. BRUBAKER: Correct. Currently the parties, the officially recognized parties in this docket are Florida Power & Light, the Office of Public Counsel, of course, and Jan and Bob Krasowski.

CHAIRMAN CARTER: And, Commissioners, before we go further, any further questions by any Commissioner?

In a moment, in a moment we'll hear from Florida Power & Light, FPL and their presentation. But let me just kind of say when we get ready to start taking public testimony, we'll swear you in as a group, and I'd like to wait until after they do their presentation. That way if there are people that are still coming in, we can kind of, you know, get more bang for the buck, so to speak. But additionally as you're coming up to speak, as I said, please be intimate with the microphone so we can really hear what you have to say.

The other thing is that you may or may not get questions from the parties and you may or may not get questions from the Commissioners. So just be aware of that.

Commissioners, anything further?

Okay. FPL, you're now recognized.

MR. BRYAN: Thank you, Chairman Carter and Commissioners.

Good afternoon. My name is Patrick Bryan. I am an attorney for Florida Power & Light Company. And first of all, I'd like to thank you, thank each of you for coming out this afternoon. Your input is invaluable to FPL and we take it very seriously.

In a moment you will hear from Eric Silagy, who is FPL's Vice President of Development, who will give a short presentation. But first I wanted to inform any of our customers who are here this afternoon that we have brought several customer service representatives along with us. They are equipped with online computers and are available to meet with any customer who has an issue, a question or problem concerning his or her electric account or service. With their computers they can bring up your account information immediately, and we will make every effort to resolve your issue this afternoon before the conclusion of the hearing, if that's possible. In fact, FPL's Vice President of Customer Service, Marlene Santos, is here as well in attendance. She will oversee those efforts and assist as necessary. Our customer service representatives have set up shop in a room just outside the auditorium to the right. I encourage any customer with an issue to take advantage of this opportunity. If you are interested, we have representatives in the back of the room right there who will be happy to assist you and direct you to the room.

At this time then I would like to introduce Eric Silagy, FPL's Vice President of Development. Eric.

MR. SILAGY: Good afternoon, Mr. Chairman, Commissioners. My name is Eric Silagy, and I am the Vice President of Development for Florida Power & Light. And in that capacity I am in charge of overseeing the process for building new generation meeting our capacity needs here in Florida. On behalf of the entire leadership team and the more than 11,000 FPL employees, I want to thank the Commission for holding this important hearing on potential new nuclear generation in Florida and for giving us the opportunity to make this brief opening statement. I want to also thank the members of the public who have taken the time to be here today. Your concerns and views are all very important to us.

We come to you having just received affirmation for this project from the Board of County Commissioners of Miami-Dade. The Commission overwhelmingly supported FPL's efforts to bring this important project to our customers. Florida Power & Light has been providing Floridians with reliable and affordable power for more than 80 years, and for nearly half that time nuclear power has been a cornerstone of our power generation portfolio. For it was nearly 35 years ago last month that FPL first brought clean, safe, reliable nuclear power here in Florida with the beginning of the commercial operations for Turkey Point Unit 3. Today nuclear power represents an important part of our generating portfolio, about 20 percent. At a time when demand for electricity is growing vigorously, we expect nuclear power will play an even more important role in the future by helping us meet the growing needs of our customers while increasing our energy independence and reducing greenhouse gas emissions. Keep in mind, however, that even with the addition of Turkey Point 6 and 7, the relative contribution of nuclear power within FPL's generating fleet increases only modestly. Simply stated, nuclear power is the right, proven solution for our community and our environment.

I'd like to briefly review six reasons why as part of our commitment to a cleaner, smarter, greener tomorrow FPL intends to continue pursuing the option of building two additional nuclear facilities at Turkey Point. Not all of these necessarily are issues that will be before you as part of a need determination proceeding because other regulatory agencies such as the Nuclear Regulatory Commission will have to review specific areas such as safety and approve the project. However, given that we have a number of customers here today who are here for information, we feel that we'll try to present a somewhat broader frame of reference for the project. I would ask that you not be concerned with the order in which I present these because, frankly, these are all very important issues.

Nuclear power is a reliable and affordable source of energy capable of providing large amounts of electricity to meet Florida's increasing needs. Over the next decade, FPL is projecting that we're going to increase approximately 85,000 new customer accounts each year. Larger homes, expanding businesses and the more extensive use of a vast array of electronic devices add to the growing demand for power.

A good portion of FPL's electric demand continues to be met through our industry leading energy efficiency and conservation programs. To date, the successful partnership with our customers has eliminated the need to build the equivalent of 11 power plants. And although these energy efficient programs will continue to help us stem the demand, these programs alone are not enough to avoid the challenges that we face. As a matter of fact, FPL will need 37 percent more electricity by the summer of 2020 than we currently do in 2007. So we must continue to build power plants.

Nuclear energy has the lowest production costs of any widely used fuel to generate electricity, even coal, largely due to the significantly less amount of fuel that is required. So although initially expensive to build, the overall costs make it one of the most cost-effective energy sources available.

As such, it provides what is known in the industry as baseload generation. That is generation that's capable of producing large amounts of electricity 24 hours a day, seven days a week, and that's what our customers need. The new Turkey Point units would add between 2,200 and 3,000 megawatts to our system, or enough power to meet the needs of nearly half a million customers.

Nuclear energy means greater independence for Floridians and protecting us and our economy from being too reliant on fuel, including oil and natural gas. Having different fuel sources in generation is very important so that we're less affected by fluctuating prices and fuel supply constraints whenever they may occur.

At present, just over half of the electric power that FPL generates is done so using natural gas, and that percentage is expected to increase in the future. There are currently two primary gas pipelines that serve Florida, and a large portion of that natural gas comes from the Gulf of Mexico. FPL faced significant challenges in managing its fuel requirements during the 2005 hurricane season when natural gas supplies from the Gulf of Mexico were disrupted due in particular to the two severe storm events that we had.

Growing our nuclear power portfolio would also help us gain more energy independence. As Governor Crist said this summer, and I quote, we know we must reduce our dependence on foreign oil. Renewable energy such as ethanol and biofuels, solar, wind and nuclear energy can help us be more independent from oil from other countries, end quote.

Adding two nuclear units at Turkey Point would help us maintain the balance in the fuel mix and help us reduce our dependence on oil and natural gas.

Nuclear power is a clean source that does not produce greenhouse gases. FPL is committed to providing clean energy to a growing Florida. Nuclear power is the best option to meet Florida's growing demand for electric power and reduce greenhouse gas emissions.

While FPL is already a leader in renewables, has made a commitment to invest in research and development of these technologies in the State of Florida and is proactively pursuing several renewable projects, renewable energy sources simply do not have the capacity to generate the amount of electricity we will need to meet our electrical needs in the future, at least not at this moment. Nuclear power can meet the clean energy needs of our customers today.

Nuclear power is the only source, energy source, excuse me, capable of producing large amounts of energy which does not emit any gases such as CO2 to our environment. It's been a key contributor to our ability to keep FPL's emissions rates among the lowest of all utilities in the United States. In fact, in 2006 FPL's nuclear units avoided over 15 million tons of CO2 emissions that otherwise would have been emitted using fossil fuels. Now, according to the United States Environmental Protection Agency, that's the equivalent of taking 4 million cars off the roads.

For 35 years nuclear power has proven to be a safe source of power for FPL customers. Although safety of nuclear plants is regulated by the NRC, we understand it to be of interest to all in the community, and we at FPL take our responsibility very, very seriously to protect the public health and it is a top priority.

Our nuclear power units, like the more than 100 across this country, meet strict safety standards designed to protect employees and ensure public health and safety. Our plant operators are highly qualified professionals, trained and tested through certified and accredited programs and then continuously retrained to ensure safety and secure operations.

State-of-the-art technology continuously monitors and tests equipment to identify potential problems before they occur. FPL's nuclear plants are equipped, excuse me, with multiple backup systems to protect against equipment failures and severe weather events such as hurricanes, tornados, fires and floods. And, in fact, many of you who live in Miami-Dade know Turkey Point withstood Category 5 Hurricane Andrew, Category 5 Hurricane Andrew in 1992.

And, again, like all U.S. nuclear power plants, the U.S. Nuclear Regulatory Commission as well as other federal, state and local agencies closely monitor our operations. FPL nuclear facilities also work with federal, state and local agencies to develop and exercise sophisticated emergency response plans to protect the public health and safety in the unlikely event that a situation occurs. That means at Turkey Point, for example, we work very closely with Miami-Dade County, Monroe County, the State of Florida officials, as well as the Nuclear Regulatory Commission and the Federal Emergency Management Agency. And I might note that all these agencies participate in graded exercises or dry runs, as we sometimes call them, and we've always earned high marks at the Turkey Point facility.

Going hand in hand with safety is security. Nuclear power plants are extremely secure; designed and operated with extensive security guidelines to ensure all of our protections. U.S. nuclear power plants, FPL's included, are capable of withstanding severe impacts from natural disasters and terrorist attacks, including impacts from large commercial aircraft.

Nuclear security programs and personnel are a large, are part of a large local and national security network which routinely reviews and tests facilities on collaborative drills. A two-day national security simulation in Washington, D.C., which occurred in 2002, conducted by the Center for Strategic and International Studies concluded that nuclear plants, and I quote, are probably our best defended targets, end quote. Plant security resources and procedures are designed to prevent intrusion and we regularly drill against very challenging scenarios.

And finally, why Turkey Point? Before we chose Turkey Point as a potential location for these new additional units, FPL performed a comprehensive assessment of numerous sites throughout our service territory and more than a dozen underwent detailed study. Turkey Point was selected because it, one, makes sense to utilize an existing site that has successfully filled its role for the past 30 years. Using an existing site allows us to minimize the impact on Florida's lands and other natural resources. It benefits from existing facilities already paid for by the customers such as electrical transmission interconnections, roads and support buildings. It helps balance the demand and strengthen the reliability of South Florida, and it makes sense for the environment to add generation without adding additional greenhouse gases.

Members of the Commission and the public, I'd like to take a few moments then just to summarize. We at FPL commend the Commission for holding this hearing and for your attention here today. We're very proud of our operating record and for providing reliable and cost-effective power to generations of Floridians. We're equally proud of our safe operational record and that nuclear power has been a cornerstone to that effort, and we believe it should play a greater role going forward. Nuclear power is affordable and it is reliable. It means less reliance by Floridians on natural gas from the Gulf of Mexico, more energy independence from foreign oil, and especially important in a world more concerned than ever about environmental issues it means we're able to generate emissions-free power. Nuclear power plants are proven, safe and secure. Turkey Point is a great choice because it minimizes the impact on Florida's resources, it makes use of existing infrastructure and it strengthens the electric reliability of all of South Florida.

Our team at FPL is not only doing the right thing for the future of Florida across our planning for new generation and through our current operations, but the project before you now, our proposed additional two units at Turkey Point, is very simply the right project being done at the right time and it's in the right location, and we believe we're doing it the right way.

We're very pleased and proud that three weeks ago we obtained an overwhelming vote of support and formal and use approval from the Miami-Dade Commission to move forward with this project. The county's technical staff and FPL worked hand in hand to bring to Miami-Dade County a recommendation of approval with conditions that satisfy the county's agency requirements. These concerns -- excuse me. At that hearing, as I'm sure today, a number of individuals expressed concerns about issues such as water source and discharge, environmental sensitivity, site elevation and other matters, and these concerns are also our concerns. We are very proud that the approval granted by Miami-Dade County expressly makes sure that the approval process ahead of us satisfies each of these issues. And we're equally proud that every single Miami-Dade department, including water, environment, public works, public safety and zoning were fully satisfied by the approval granted by the Miami-Dade Commission.

Fulfilling a utility's obligation to serve, as we've done for the past 80 years, is a high calling in and of itself. But incorporating additional nuclear power into our fuel mix is a responsibility that we must take extremely seriously, and we're doing just that. And I might add to us that it's personal. We live here, we raise our family and our children here and we work in these communities, as do our neighbors and all of you here today.

We recognize there are a number of individuals here today, as there were a few weeks ago at Miami-Dade County, to express their views and their concerns about the project. We welcome your input, your views here and at every point in the regulatory process, so that when it comes time to make a decision on the future of new nuclear power in Florida and in our drive to a cleaner, smarter and greener future, we can all make sure that the best interests of Floridians have been secured.

Thank you very much for your interest, your time and your concerns today. Thank you, Mr. Chairman.

CHAIRMAN CARTER: Thank you. Commissioners, before we go forward with swearing in the public to speak, do you have any questions for FPL at this point in time? Otherwise, we'll -- okay. Hearing none, if there's anyone that's come since I made my statements earlier, please note that if you're interested in speaking today, out front at the table staff has sheets for you to sign up to speak. Those of you that just want your voices to be heard but you don't really want to speak, there's some green sheets out there. Just tear the back page off and you can write your comments, and there's a mailer you can send in to the Public Service Commission and we'll take those comments from you and make them as part of the record. So if there's anyone that's interested in speaking today, would you please stand and I'll swear you in and we can move forward with our public testimony. All of those interested in speaking, would you please stand.

(Witnesses collectively sworn.)

Please be seated. Thank you. If there's anyone that's in need of assistance for Spanish, we have Ms. Menendez that will assist you.

Ms. Brubaker, would you please call our first --

wait. Let -- hold on one moment. Let me do this before I get carried away. I don't want to get carried away before myself. I want to meet myself going and coming. First of all, let's take a moment to hear from some public officials that are here with us today. First of all, Mr. Jon Burgess from the City of Homestead. Mr. Burgess.

MR. BURGESS: Good afternoon, Mr. Chairman and Commissioners. Thank you very much for having me here today. My name is Jon Burgess. I'm the Vice Mayor of the City of Homestead. We just came here today to show our support for FP&L and let you know that we have passed a Resolution approximately one month ago down there on a unanimous vote to let our good neighbor FP&L move forward, hopefully move forward with their project. They've been a good neighbor to us down there. And as the largest municipality that's directly affected by the influx of the building and all going on down there, we welcome it and look forward to having it in our, in our backyard. And I won't take up a lot of time here today because I know there's a lot of people and we're on a short time. But if I could enter the Resolution that we passed into the record for the, for the Commission, I would appreciate it. Thank you.

CHAIRMAN CARTER: Ms. Brubaker.

MS. BRUBAKER: Chairman, it would be my recommendation that we have that marked, identified as our first exhibit for the hearing. It's my recommendation that for all exhibits that are identified and marked by the speakers today that they be numbered. However, it is also my recommendation not to move them into the record at this time in order to afford all parties to this proceeding an opportunity to review all of those documents.

CHAIRMAN CARTER: So this will be marked for identification purposes as Exhibit Number 1.

MS. BRUBAKER: Number 1.

(Exhibit 1 marked for identification.)

CHAIRMAN CARTER: Thank you so kindly.

Commissioners, do you have any questions for Mayor Burgess?

MR. BURGESS: I'd just like to say thank you very much.

. CHAIRMAN CARTER: Commissioner Argenziano.

COMMISSIONER ARGENZIANO: Just a quick question. I don't know if there are other people here from the City of Homestead, but how do -- how does the population or the citizenry of your city, have you heard from them on your Resolution?

MR. BURGESS: We had a hearing, well, we opened it up at our council meeting for the hearing when we passed the Resolution, and we had nobody with a negative view towards it show up at the council meeting. We did have several people that had positive views. And I think as a whole economically and everything that it could do for us down there, I believe the entire community -- or let me not say the entire, but the majority of the community is in favor of it with what they think it can bring us down there in the southern end. And the demand that we have, as some of you may not know, we are the largest growing city of that size. So we've got a lot of demand going for power and stuff down there. And we've got our own power system, but we also buy from FP&L and they run half of the city. So we're looking forward to having quite a bit more demand down there too that we're going to need to satisfy, and we think that this will help us also; not just us, the entire state and nation. So thank you.

COMMISSIONER ARGENZIANO: Thank you.

CHAIRMAN CARTER: One moment. Thank you so kindly. Commissioners?

Next we'll have Mr. Sylvester Jackson from -- Mr. Krasowski.

MR. KRASOWSKI: Mr. Chairman, I was wondering, in light of the presentation by FP&L, if I as an Intervenor might make a brief comment prior to the public speaking so the public can understand that there are people that have differing views and are pursuing the process so as to determine whether or not this project is the best option available.

CHAIRMAN CARTER: Let me do this, Mr. Krasowski. Let me finish hearing from our governmental officials, and at that point in time I can hear from legal and I'll get back with you at that point in time. Okay?

MR. KRASOWSKI: I just said what I wanted to say, so.

CHAIRMAN CARTER: You said what you wanted to say?

MR. KRASOWSKI: Yeah. So thank you very much. I just wanted to make sure the public knew there were people here that were not in agreement with those statements. Thank you.

CHAIRMAN CARTER: Then you've been very efficient. Thank you for your efficiency. (Laughter.) Brevity is appreciated.

Next we'll hear from Sylvester Jackson from the mayor's office at Florida City.

MR. JACKSON: Thank you, Mr. Chairman and Commissioners. My name is Sylvester Jackson. I'm representing Mayor Wallace and our Commissioners of the City of Florida City, sister city actually to Homestead. We're a little bit closer actually to FP&L and we have considered FP&L without question a great community partner for us. They have provided, I think -- and the actual structure that we've tried to establish with them and the relationship has been more of a public/private type of partnership. We have found that they have been very community oriented, they have provided a lot of insight to us and the customers as well. They've been providing a lot of projects and assistance in various facilities that we have within our city. We're quite encouraged, I think, by the new endeavor actually for Turkey Point, and I think they bring something that is very necessary, as they've already communicated to you in their presentation. So our city without question, we feel comfortable and we're encouraged by the new endeavor of enhancing Turkey Point at this time. And I don't want to extend any longer comments than necessary. I'm sure, as I said earlier, a lot of people want to speak as well. And I thank you for the opportunity to, for us to at least speak before you today.

CHAIRMAN CARTER: One moment, please.

Commissioner Argenziano.

COMMISSIONER ARGENZIANO: Yes. Mr. Jackson, just the same question, have you had a public hearing or have you heard from the citizens of your city?

MR. JACKSON: The good thing about FP&L, we have found that they appear before our Commission on numerous occasions. They came to us and presented their Turkey Point project, as a matter of fact. And the citizens in attendance, as we find in all of our city commission meetings, were not negative in any way about the actual presentation that they made to us.

COMMISSIONER ARGENZIANO: Thank you.

CHAIRMAN CARTER: Thank you very much, Mr. Jackson.

MR. JACKSON: Thank you.

CHAIRMAN CARTER: Next we'll ask Horace Feliu, the Mayor of South Miami. And please forgive me if I mispronounce your name. It wasn't my pronouncing. It was the writing that I saw before.

MR. FELIU: You were very close. It's Feliu.

Thank you, Mr. Chair and esteemed Commissioners. Thank you for coming down here and taking time from your busy schedules to listen to the public.

About two years ago I sponsored a Resolution in the City of South Miami, which basically is the Freedom From Fossil Fuels Acts. We requested from our county officials, our state legislators and our federal government to do their part in freeing ourselves from the use of fossil fuels and at the same time create a type of situation or incentives whereby we eliminate the greenhouse effects and carbon-based products that contaminate our environment. So this is right in line with exactly what we had in mind. We know it's a clean energy source. FP&L has been an environmentally-friendly corporate neighbor to all of us, and I'm here just to speak on that and just basically let you know how we feel about it.

We realize that there's issues regarding the use of water and everything else, but that is being addressed. FP&L has done their homework. I've listened carefully to their presentation at the county level, which was passed pretty much unanimously, and I'm in favor of this product -- of this project. Thank you.

CHAIRMAN CARTER: Thank you. One moment, please. Commissioner Argenziano.

COMMISSIONER ARGENZIANO: Same question, have you heard from the citizens of your city of South Miami?

MR. FELIU: Basically when I found out about it it was in the paper. And we always have public discussions at the commission meetings, and no one has ever spoken against this project. And we're very close to that Turkey Point location. We're in South Miami.

COMMISSIONER ARGENZIANO: Thank you.

MR. FELIU: You're welcome.

CHAIRMAN CARTER: Ms. Brubaker, these were all the names I had so far for our public officials. Are there any other additional public officials whose names I did not have?

MS. BRUBAKER: I don't have any indicated, so.

CHAIRMAN CARTER: Okay. At this point in time would you please call the first witness, please?

MS. BRUBAKER: Certainly. And please let me apologize in advance if I mispronounce your name. My apologies. One thing we've found very effective in the past is I will call three names in a row just to let you know who's kind of next up to bat, so to speak, and that way there's no excessive delay between calling names. And with that, the first three people to speak in the order I provide the names are Onil Maruri, Johennys Leiva and Ignacio Quirch.

CHAIRMAN CARTER: And please help us, if your name was not pronounced properly, please help us.

MS. BRUBAKER: Yeah. If, if you would also, if it's perhaps not a common last name or name, if you could spell it for the benefit of our court reporter and also just briefly provide your address for the record.

Whereupon,

ONIL MARURI

was called as a witness on behalf of the Citizens of the State of Florida and, having been duly sworn, testified as follows:

DIRECT STATEMENT

MR. MARURI: No problem. My name is Onil Maruri. That's O-N-I-L M-A-R-U-R-I. Address is 8025 Southwest 13th Terrace, Miami, Florida 33144. Anything else?

Well, it's a great surprise to be number one. I didn't think I was going to be the first one to speak, and I believe I might be the youngest in the house today. That is wonderful.

First, I wanted to start by saying good afternoon, ladies and gentlemen and members of the audience, and, of course, members of the Commission. I am a member of the South Florida community. Like I said, I live here in South Florida and Miami. I am a third-year student at Florida International University, and I believe that nuclear power is the right way of going. My studies in the university are of business management and also environmental studies, so I'm very familiar with the environment. And I understand that there are some views that are different and I will be more than happy to listen to them, because I believe, as Florida Power & Light, we always like to listen to all of the views.

I represent several leading web sites in the automotive industry, and I'm here mostly to talk about that. If I'm not mistaken, I believe I have two minutes to talk. Is that correct? I don't see a timer anywhere, but I believe it is about two minutes.

CHAIRMAN CARTER: Two minutes, yes, sir.

MR. MARURI: Okay.

CHAIRMAN CARTER: We don't want to be blatantly obvious, but we want everybody to have an opportunity to speak. So, yes, sir.

MR. MARURI: Those websites are HondaSpace.com and FordSpace.com, which have a strong following here in South Florida. I'm in favor of clean, secure and low-cost nuclear energy because, of course, we have this growth in demand in Florida. And as I believe was said before, about 85,000 new clients per year, I believe that's great growth and that we certainly need to address that. Another reason would be that I believe that there's this new generation coming for the electric car, and that's my main point of speech here.

I have here an image of the Chevy Volt. And if I pass this around, it's in Spanish, so I don't know how much help it would be. But this is a car that's in the works by General Motors and it's a green electric car. And my big concern is that in the future this car, which is set to start production in the year 2010, this is less than two years from now, in the future when this car starts production, what's going to happen in Florida if we have this growth in demand by consumers, by 85,000 new customers per year, and then we have this influx of cars into the state? And I'm concerned that prices of electricity might go up affecting customers. We know that today -- in the last month oil hit a record price of $100 a barrel. It's very concerning because a lot of customers will in a blink shift over to electric cars because they're cheaper, and my concern is that that will drive the price of electricity for customers in the entire state. That would affect millions of customers just because of this new addition of possibly an electric car and of high oil prices.

Toyota and other companies have also taken notice of this and they're also in the works of similar cars, and it's concerning when you have over 60,000 of these cars which are set to enter the market the first year alone. This is according to Bloomberg reporting on the news from General Motors. This could be found on their website in the reportings for August of 2007. This is just one car. There's going to be many other cars entering the market in the next five years.

Now I'm close to this because obviously I represent many in the automotive industry, mostly consumers from these websites I mentioned. Also, among the options I believe are available, nuclear power seems to be the cheapest and the cleanest to produce. I understand that coal is another option, but definitely it's not as clean and is possibly much more expensive.

I did my research on Florida Power & Light and I believe that they seem to be a very green company and that they were recently named, if I'm not mistaken, the utility of the year by an industry magazine. I thought that was something good to recognize because it definitely sets them apart from any other electric companies, and I believe that's important because we're dealing with somebody that's trusted by the industry.

I believe that I would say yes to nuclear power because it's important to have reliable electricity, especially when we have an increased need, and I believe that from a younger generation, my generation, the X generation, I believe it's important for us to also have power available for our future for our growth, and I see this new generation coming of the electric car, B1 (phonetic), and I believe that it's important for me to voice my views. Thank you very much for your time and I appreciate it.

CHAIRMAN CARTER: Thank you. Thank you very much. Would you hold for a moment, please, just in case?

MR. MARURI: Of course.

CHAIRMAN CARTER: Thank you so kindly. I mean, you're never too young to participate. That's what democracy is all about, and we sincerely appreciate you participating.

Commissioners, any questions?

COMMISSIONER ARGENZIANO: Just bravo for participating in your government.

CHAIRMAN CARTER: Thank for throwing this up, your research, and just keep on. In fact, probably, staff, would you give him information so he could forward those website addresses because I missed them? But you can just get the web site addresses to them. Thank you so kindly.

MR. MARURI: You're welcome. Thank you.

CHAIRMAN CARTER: Mr. Krasowski, do you have a question?

MR. KRASOWSKI: I would like to -- is this on? I can't tell if it's on.

CHAIRMAN CARTER: Yes, sir. We can hear you fine.

MR. KRASOWSKI: Thank you.

CHAIRMAN CARTER: You're recognized.

MR. KRASOWSKI: I would like to ask the gentleman a question, if I may.

CHAIRMAN CARTER: You're recognized.

CROSS EXAMINATION

BY MR. KRASOWSKI:

Q Okay. Sir, and I apologize for not remembering your name, but I was curious to know if you are being paid or compensated by anyone to be here this evening.

A I am not. I can tell you that in my web sites we support the members of the community. A lot of these members are drivers of cars, and I believe that I'm voicing their concern because I see a new generation of automobiles. No, I'm not being paid by anyone to be here today.

Q I understand your points. I think they're excellent, excellent information. Also what I'd like to know is do you have any personal financial expectations of benefiting from the building of this plant?

A Well, I have concerns. I don't have any benefits in, any direct benefits. I would say I don't own any stock from FPL or anything like that.

Q Anything like that. Okay. Thank you. Thank you very much.

A You're welcome.

CHAIRMAN CARTER: Again, thank you so much for participating. Thank you.

Ms. Brubaker.

MS. BRUBAKER: Johennys Leiva.

MS. LEIVA: I have to waddle.

CHAIRMAN CARTER: That's all right. Waddling is appreciated.

(Laughter.)

MS. LEIVA: Two weeks to go, so waddling is good.

CHAIRMAN CARTER: Please spell your name for us.

Whereupon,

JOHENNYS LEIVA

was called as a witness on behalf of the Citizens of the State of Florida and, having been duly sworn, testified as follows:

DIRECT STATEMENT

MS. LEIVA: Yes. It's Johennys, J-O-H-E-N-N-Y-S, last name is Leiva, L-E-I-V-A. Address is 6175 Northwest 167 Street, Unit G2, Miami, Florida 33015.

I basically came here to support FPL. They were an integral part of my startup business. I own Empire Mortgage Brokers and Lenders. When I originally opened my company I rented at a commercial site, so a lot of the suggestions that FPL gave me for energy conservation I wasn't ready to implement as it was going to be costly for me and not beneficial because I didn't own the site. I currently do own, and I've already implemented a lot of the original suggestions that they gave me in my energy study. I want them to come back out because the location is not the same to see if they have any additional suggestions that I can conserve energy, do my part.

I really do believe that this is what we need to do because ten years from now when we don't have enough power to service the growing community, that's going to impact my business. And this is going, this nuclear power plant is going to allow us to keep our costs low. That means, yes, it does impact my business. I also believe in the go green, so this works. It's a win-win. I really don't have anything further to say.

CHAIRMAN CARTER: Thank you so kindly.

MS. LEIVA: Thank you.

CHAIRMAN CARTER: One moment before you go. Commissioners, do we have any questions?

COMMISSIONER ARGENZIANO: Thank you.

CHAIRMAN CARTER: Mr. Krasowski, I see you heading to the mike. You are recognized, sir.

MR. KRASOWSKI: Thank you. I want to be fair to all speakers.

CROSS EXAMINATION

BY MR. KRASOWSKI:

Q Ma'am, are you being paid or compensated by anyone to be here?

A No. I came, I came on my own recognizance.

Q And on your comments, I understand your relationship to what you believe to benefit from, if anything.

A Yes.

Q Okay. Thank you very much.

A Okay. Thank you.

CHAIRMAN CARTER: Thank you so kindly.

MS. BRUBAKER: The next speaker is Ignacio Quirch. The next three after that will be Nancy Lee, Alan Farago and Mary Olsen.

CHAIRMAN CARTER: And please help us with pronouncing your name.

Whereupon,

IGNACIO QUIRCH

was called as a witness on behalf of the Citizens of the State of Florida and, having been duly sworn, testified as follows:

DIRECT STATEMENT

MR. QUIRCH: My name is Ignacio, that's I-G-N-A-C-I-O. Last name Quirch, Q-U-I-R-C-H. Address is 4940 Southwest 77th Street, Miami, Florida 33143.

I came here on my own accord. I'm not being paid by anyone to be here. I run a family business, me and my brothers, my father. We've been in business for 45 years now. We have a fleet of over 100 tractor-trailers going throughout the State of Florida. And as we all know here, fuel is killing every business. It's killing everyone. We rely way too much on fossil fuels. My -- our fuel bills have increased 200 percent, which affects the food that everyone is eating because we are food distributors. It affects everyone day to day.

Biofuels I don't think is the future either. Corn is used for biofuels. Corn is used to feed cattle, poultry, pigs, everything. So biofuels made with corn do not help.

We need something clean, we need something that's going to last. Nuclear power is going to last. We are going to run out of fossil fuels one day, fifty years, 100 years from now, so we cannot abuse on those fossil fuels. We need to use alternate fuels. Basically that's all I've got.

CHAIRMAN CARTER: Thank you.

Commissioners? And I think you already answered Mr. Krasowski's questions. Thank you so kindly.

Ms. Brubaker.

MS. BRUBAKER: Nancy Lee. Excuse me. Nancy Lee.

Whereupon,

NANCY LEE

was called as a witness on behalf of the Citizens of the State of Florida and, having been duly sworn, testified as follows:

DIRECT STATEMENT

MS. LEE: Hi. I'm Nancy Lee. Do I have to give my address?

CHAIRMAN CARTER: Give us your name again.

MS. LEE: Nancy Lee.

CHAIRMAN CARTER: Okay. Yes, ma'am, if you wouldn't mind.

MS. LEE: 20448 Northeast 34th Court, Aventura; as far in Dade County as you can get from this plant.

You asked us to comment here, but Florida Power & Light's plan is like Jell-o. How can we comment on something when we don't know the details, the real costs? When the costs are firmed up, maybe we can comment intelligently. Because everyone is saying it's cheap. We don't really know that it's cheap because we don't know how much it's going to cost.

I feel like my hands are tied. You are a very young group of people. I was part of the citizens that fought Shore Power Plant in New York. I watched the horrors of Chernobyl on TV. The benefits do not outweigh the risks as far as I'm concerned. This is not bringing in enough energy for the cost, and safety is a cost. Having a long pipe miles long that could be blown up doesn't make me feel safe. Safe -- and talk about safe, the man from Florida Power & Light said it was safe. They had six guards caught sleeping by the Nuclear Regulatory Commission, they had a hole drilled in a cooling pipe, and they had a $100,000 reward for that. You know, that doesn't make me feel safe, and I thank God I don't live in Homestead or Florida City.

I want you to think of our checkbooks. Steve Seibert, I think he was the head of DEP or DCA, proposes that every house should have solar panels on it now, and I think that's a really good idea. I don't think we have concentrated on conservation.

The pipe -- because of where this power plant is next to the park you can't get the water from the water right in front of it so you have to pipe the water in. They want to bring the water possibly 26 miles in a pipe from Virginia Key, and that's reused water. Now this pipe -- Katy Sorensen, the County Commissioner asked how much it would cost, and they said about $600 million for the pipe. Okay. So we have to pay for the pipe, then we have to pay for the pumping, but we don't know that they're going to actually use this pipe because they don't really have a plan yet. So we don't know where they're getting -- what is it 90,000 gallons, 90 million gallons a day that they're going to use of water. And Katy Sorensen said nuclear power, that the nuclear power is using one natural resource to save on another. And using up that much water when we have such a bad water problem doesn't make sense to me.

So we don't how much the pumping is going to cost, we don't know how much the pipe is going to cost. They could go out past the reef to the ocean, which would be about a 13-mile pipe. Again, you know, leaving 13 miles of pipe for terrorists to blow up, I'm not really feeling safe.

They have to increase the grade 200, for 200, 250 acres by 20 feet above sea level because this is in lowlands. If you figure on $30 a cubic yard for fill, that's two or three hundred thousand dollars just to fill to start building the plant. So I don't know where all this cheap energy is coming from. Okay. Everyone is putting this forth as the cheap way. Well, for me it's not. I think it's the dangerous way. And I know that in Germany they're stopping using nuclear power and I know that they're stopping in a lot of different places and I don't think we should be starting again. I'm going to give you my little map here. And thank you all. You're all so young. You don't know about what we went through.

COMMISSIONER ARGENZIANO: Mr. Chairman.

CHAIRMAN CARTER: One moment, please. One moment, please.

COMMISSIONER ARGENZIANO: I just want to thank you for telling me I look so young. My son just turned 35, so I really appreciate it. Maybe you just can't see me from there.

(Laughter.)

MS. LEE: No. I've seen you many times.

COMMISSIONER ARGENZIANO: Thank you.

CHAIRMAN CARTER: One moment before you leave. Mr. Ballinger. You said you wanted to give us a document?

MS. LEE: It's a map with a 25-mile and a 10-mile circle drawn around it so you can see how much population is being affected by the plant and you can see the -- I drew in the -- if they use this pipe, I drew the pipe in where it would go from and to.

CHAIRMAN CARTER: You don't mind if we keep it?

MS. LEE: Oh, that's what I want you to do. I have it on my computer.

CHAIRMAN CARTER: Thank you so kindly.

Commissioners, any questions? One moment, please. I'm sure Mr. Krasowski wants to ask you his standard two questions.

MR. KRASOWSKI: Generic questions.

CROSS EXAMINATION

BY MR. KRASOWSKI:

Q Good afternoon, ma'am. Are you being compensated or paid by anyone to be here today?

A No.

Q No. Okay. And do you foresee any benefit, personal financial benefit from the building of this plant?

A No.

Q Okay. Thanks.

CHAIRMAN CARTER: This for identification purposes will be Exhibit Number 2, for identification purposes only.

(Exhibit 2 marked for identification.)

Ms. Brubaker.

MS. BRUBAKER: Alan Farago, please.

Whereupon,

ALAN FARAGO

was called as a witness on behalf of the Citizens of the State of Florida and, having been duly sworn, testified as follows:

DIRECT STATEMENT

MR. FARAGO: Good afternoon, Mr. Chair. My name is Alan Farago, 534 Menendez Avenue in Coral Gables.

This is the first time I've, I've ever testified before the Public Service Commission, and it's an interesting experience, an educational one as well. Most of what I do as an environmental advocate is before the County, and what, what I'd like to say just from the outset is to make sure that on the record at least you know that the, that the County approval of the special exemption for FPL recently was highly contested and quite controversial.

I don't think you'll find any disagreement from any, anyone in the audience that we need to lessen our dependence on foreign sources of oil for our national security and for our economy. But when FP&L represents that nuclear is, is the lowest and the most affordable source of energy, lowest cost and most affordable source of energy, I really think that, you know, we have to question very hard whether or not we have exhausted every last measure to conserve energy in the State of Florida because of the inherent risks in nuclear power.

This site, Turkey Point, it's true it does have nuclear capacity there today, but it will be a very highly contested site as well through the entire permitting process. You as the PSC, I think, could do the State of Florida and ratepayers a great favor if you would interrogate Florida's utilities on the issue of conservation and to ask the Florida

Legislature to ensure that every single watt of saved energy is wrung not from the ratepayers, not just, you know, not just, you know, individual citizens coming up here, but doing what California is doing, for instance, as reported on the front page center story in the Wall Street Journal today.

The article says, "Utilities amp up push to slash energy use," and talks about California policymakers setting the most ambitious conservation targets in the United States. The three -- it states three major investor-owned electric utilities were told last summer to reduce their combined energy use by the equivalent of three power plants to earn big bonuses or face the possibility of big penalties if they fail. Essentially what California is trying to do is to incentivize utilities to lower the production of energy through conservation. And I think that the best we can do for Florida, given the risks of nuclear power, is to insist that every last watt of energy be wrung out of the system in terms of conservation before embarking on sort of this risky strategy to shoehorn more nuclear power into Florida.

It gets to the point, I think, of -- and, again, I'm new to a lot of this, to the nuclear power plant siting issue of you needing to evaluate renewable energy sources and technologies as well as conservation measures and to ensure that they're utilized to the extent reasonably available. And I think that there will be a lot of argument about what is, what constitutes being reasonably available. I'm not sure that nuclear power is sort of a reasonable alternative at this point, given the fact that the State of Florida has not exhausted its opportunities for conservation and for saving money for ratepayers and also saving many, many unanticipated costs for putting a nuclear power plant at sea level in the age of sea level rise. So thank you very much.

CHAIRMAN CARTER: Thank you so kindly. Would you wait for a moment, please?

MR. FARAGO: Yeah.

CHAIRMAN CARTER: Commissioners, any questions?

Mr. Krasowski. One moment. Commissioner Argenziano.

COMMISSIONER ARGENZIANO: Maybe just a quick one. What I'm hearing from you is I think most of your opposition is the planning, the site planning; is that correct?

MR. FARAGO: Most of my opposition is to the use of nuclear power before the exhaustion of every single conservation measure as a matter of state policy. And I believe that the Florida utilities -- and FPL, of course, is a major corporation. It knows perfectly well what's going on in California. It, along with other Florida utilities, has resisted reform in terms of how companies might be compensated in terms of reducing power production as opposed to expanding power production. So, in other words, I think that the State of Florida has a long way to go, and that really the only way to get there is for you to tell the utilities, you know what, it may be something that we have to consider in the future, but let's do everything we can right now to get you guys to follow the line of conservation as a matter of how you generate corporate profits.

COMMISSIONER ARGENZIANO: Thank you.

CHAIRMAN CARTER: Commissioner Skop.

COMMISSIONER SKOP: Thank you, Mr. Chair. And just in contrast, I do appreciate the argument for conservation. How do you contrast that argument in the face of the explosive growth that we have in Florida?

MR. FARAGO: Well, I think that California also had explosive growth, and I think California was able to manage through lots of crises with respect to energy policy over the last two or three decades without having to build anymore new nuclear power plants.

I think that at the end of the day almost anything is preferable to having nuclear power, except losing the planet. So as an environmentalist, you know, I wouldn't, I wouldn't write nuclear power off the books, but I certainly would say that distributing power generation to consumers, being more proactive in terms of allowing net metering and those kinds of things -- I mean, we don't know as citizens in the State of Florida what we can do because we are in a straight jacket by the utilities that are very much like Detroit, by the way, in terms of advocating, you know, this whole issue of, of growth at any cost, you know, continuous expansion of power production. And what the State of Florida can do is set policies that reward these utilities for actually slashing their production of energy without affecting our standard of living. Personally I would rather have, I would rather have less access to electricity throughout 24/7 than to deal with the nuclear, the growth of the nuclear industry in a place that is inappropriate.

CHAIRMAN CARTER: Commissioner.

COMMISSIONER SKOP: Thank you. And just as a follow-up, I noticed you mentioned net metering. And I just wanted to briefly respond as a point of information that this Commission recently passed a proposed rule for interconnection and net metering which addresses a lot of the distributed generation issues that you've mentioned. So the state is working on those issues.

MR. FARAGO: I know the State of Florida is working very hard on all these issues, but this is a big one.

COMMISSIONER SKOP: Thank you.

CHAIRMAN CARTER: Thank you. Commissioners, any?

Mr. Krasowski. One moment, please, sir.

CROSS EXAMINATION

BY MR. KRASOWSKI:

Q Sir, are you being paid or compensated by anyone to be here today?

A No.

Q And then do you have any personal financial expectation of benefiting from the building of this plant or do you have any expectation of being funded by, by anyone who would be supporting your activities regarding any opposition to this plant?

A No.

Q Thank you.

CHAIRMAN CARTER: Thank you very much.

Ms. Brubaker.

MS. BRUBAKER: Next to speak is Mary Olsen. The next three speakers after are --

CHAIRMAN CARTER: Hold on. Wait one second. Mary?

MS. BRUBAKER: Olsen.

CHAIRMAN CARTER: Mary Olsen. Thank you.

MS. BRUBAKER: Next will be Peter Sipp, Dawn Shirreffs and Agustin Rodriguez.

CHAIRMAN CARTER: Ms. Olsen, you're recognized.

Whereupon,

MARY OLSEN

was called as a witness on behalf of the Citizens of the State of Florida and, having been duly sworn, testified as follows:

DIRECT STATEMENT

MS. OLSEN: Good afternoon. I'm Mary Olsen, and I'm the Southeast Regional Coordinator for an organization called Nuclear Information and Resource Service. We are an educational organization with members in all 50 states, so I'm here on behalf of our members in Florida. And, yes, I am paid and, yes, I believe my members will benefit if this nuclear power plant proposal is rejected, but I think it will be mainly in their health, their safety and quality of life. So I'm here to express their view that there is no need for this nuclear power plant at this time. We have plenty of power here right now and, in fact, there will be no need later.

I want to correct the record. Nuclear power is not emissions free. There is continuous or fairly continuous radioactive emissions to air, to water and continuous production of radioactive waste. There is also considerable dependence on fossil fuels and therefore release of greenhouse gases primarily in the front end of the fuel cycle. But you can't operate a reactor without fuel. So as long as we're talking about uranium, which is what Florida Power & Light is talking about, although it may not be in Florida, there are considerable CO_2 impacts from nuclear power. It is not emissions free.

I want to appreciate the previous speaker's points. I support them completely. While we're talking about fuel diversification in this case, it disturbs me that we're kind of -- quite frankly, I think we're stuck in a paradigm and a frame in a way of, you know, the mandate that you have, the rules that you're following predate the era we're living in. And I hope that you're going to be able to figure out how to shift your mandate enough to be able to respond to the era we're living in because, believe me, if you don't, we're all in trouble.

So I'd like to think that you would consider fuel-free technologies as part of fuel diversification. The wind is not a fuel per se, the sun is not a fuel per se, the Gulf Stream is not a fuel per se. Those are diversifications of an energy base for this state that are very viable.

Just this week the New York Times' science section reports experts once again debating, but no debate that the ocean is rising. They all agree the next ten years are crucial. You cannot put off for another 60 years the impact -- the actions that could prevent the impact 60 years out. And the new numbers are 2- to 7-foot rise in the ocean. If that's not a driver for the public interest in this state, I don't know what is. Your decisions today about the appropriate use of consumer money is going to drive the outcome of that equation. And these reactors that are being proposed have zero impact on that. They will not contribute to greenhouse gas reduction in the next ten years. Sorry. They won't even be built that quick. So you will be sacrificing the possibility to affect that outcome with an approval of something that's not needed in order to address that outcome. And nuclear power cannot address that outcome now and it won't be able to address it later because, in fact, if that outcome is shifted, it's because your body and other bodies invest significantly in energy efficiency, in conservation.

It is seven to ten times more cost-effective to prevent the use of power than to build new generating capacity. This country has the ability to go, not only to half, but if we match what Japan does for energy per dollar of GDP one-third, we could cut two-thirds of our power if we got really smart about it. So we have to stop using the words conservation efficiency, start talking smart, prudent, reliable, stable in relation to efficiency.

Okay. I'm going to keep my comments short. I have a couple of more things to add. I am going to be offering a written statement with some supporting documents in your written comment section.

But I think particularly in terms of the justification for collecting money from the ratepayer, from the consumer in the near future, you have only one agenda item: Are you going to turn around the climate crisis or not? How is Florida Power & Light building two new nuclear power reactors that don't come online in the next ten years going to do that? How do you justify that? Because they're using this as a justification. If you privilege their proposal because they're claiming that they're CO_2 free, they're claiming they're going to help the climate, make them substantiate it. Because I'm here to tell you you're going to have to substantiate it.

Okay. Other possible things that you should consider. This is just a quick laundry list. The Barnwell so-called low-level radioactive waste site where they're currently shipping the so-called low-level waste will be closing June 1st of this year. Where are they going to send their so-called low-level waste?

CHAIRMAN CARTER: Excuse me. We're having trouble hearing you. Slow it down a little bit.

MS. OLSEN: I'm sorry. Okay.

CHAIRMAN CARTER: Passion is appreciated, but slow it down a little bit. We want to hear you. Okay?

MS. OLSEN: Okay. All right. This is a little laundry list of issues. And they're ones that are kind of way below the radar screen, so I'm bringing them to you.

The so-called low-level waste that's generated by nuclear power plants and will be for these new units proposed, the so-called low-level waste goes to a place right now in South Carolina called Barnwell. It's a shallow landfill trench style dump. It's closing June 1st this year. So it's a big question nationwide what's going to happen to that stuff because it's really the only site that takes the full spectrum. That's a cost consideration.

Personally the radiation standards should always be looked at as a privilege. The level of protection provided for radiation is a fraction -- as a matter of fact, it's thousands of times less than what is provided for toxic chemicals. I already mentioned the emissions, but they are continuous and a real cost if the reliability ever catches up. You have to consider that.

And, finally, the high-level nuclear waste, the irradiated fuel is sitting at the FPL site. There's a tremendous push from the industry to move it. But where are they going to take it? There is no place for it to go. It has sat there since they started making it. I really believe it's incumbent upon state officials to begin considering the permanence of high-level nuclear waste as an ongoing cost in this state because there is no confidence at the Nuclear Regulatory Commission either in a high-level nuclear waste plan. They are pushing for a new plan, but there isn't one right now.

And finally in terms of costs, the largest industrial accident ever was the explosion of the Chernobyl reactor in 1986. Some of you were children at that time. I'm not going to go into all the details, but I need you to know that in the act in the United States that was passed to make insurance possible for nuclear plants since the commercial industry, insurance industry would not touch nuclear plants, Mr. Price and Mr. Anderson passed the Price-Anderson Act. It was renewed in 2004 in the Energy Policy Act. But in the definition section it says that if it's an act of war or an enemy of the state, there is no Price-Anderson Act -- completely exempted. So as you know, the Price-Anderson Act provides for all utility, you know, nuclear reactor owners nationwide to pay into the fund that would cover up to $10 billion of up-front costs. Beyond that it's capped. Actually maybe they raised it to 11 or 12, but it's within that range. So, you know, beyond that it's capped and ostensibly the taxpayer or the victim would have to pay. But these -- this has happened. This is not a hypothetical maybe. This has happened. And you as a regulatory body need to know that you've got zero insurance if anybody who is identified as an enemy of the state were to be the one to maliciously act against a nuclear reactor, and that applies to your current units and it would apply to the new units as well.

So the final thing I have to offer you, and I will include in my written comment, is that there is some hope on the, on the horizon. The good news is that we got in this mess because of unsustainable things like making waste we don't know what to do with and putting carbon in the atmosphere. So if we turn this big ship around, we will do so because we are adopting sustainable practices. And there's a marvelous first look at a scenario of what that would look like that's really complete called Carbon Free, Nuclear Free: A Road Map for U.S. Energy Policy. And, as I say, I will submit that with my written testimony. But I think it's very, very important for people to know and understand that we're not just talking about problems. We're also talking about solutions. And we're asking and challenging you to find solutions that will actually deliver the goods because this proposal will do nothing. Thank you.

CHAIRMAN CARTER: Thank you so kindly. Would you remain there for a moment, please? Commissioners, any questions? Mr. Krasowski, one moment, please.

Commissioner Skop.

COMMISSIONER SKOP: Thank you, Mr. Chair. And thank you for appearing today. I think that you've raised some excellent points.

Just in the interest of fairness, and I do think it's a fair question because it appears to be a recurring theme, but I've heard Chernobyl mentioned at least twice now, and I was just wondering whether you'd be familiar with the differences between Russian and U.S. reactor design technology and also the differences in the reactor physics?

MS. OLSEN: I can comment. I'm not a physicist, but I'd be more than happy. I should have mentioned at the offset, my organization, and I will answer your question, but my organization is, as we say in our name, Information and

Resource Service. And part of our resource is written information and part of it is knowing experts from across the spectrum, independent people as well as people within the industry. So part of my job is to refer people to proper expertise. So I'm not going to pretend to be a physicist for you.

But, yes, there is a difference between the Soviet style reactor -- the Chernobyl reactor was inside the Soviet Union at the time the accident happened. And one of the differences is that some U.S. reactors, not all, have a major structure around the reactor pressure vessel which is called the containment structure. Unfortunately, we have over 50 reactors in the United States that are boiling water reactors that do not have that type of containment. So the comparison breaks down a little bit, you know, in terms of saying the U.S. is different.

Yes, the reactor design is significantly different. They had a, instead of a liquid around the uranium that was fissioning they had graphite, which, by the way, is the new design for pebble bed reactors, if you hear of that one. It's a graphite moderated reactor as well. So we're considering those for the United States now. But at that time it was an explosion, there's still controversy was it a nuclear explosion, in which case it was good there was no containment because there were three reactors right next-door. A nuclear explosion can't be contained. They might have had four times the radiological consequences if it had had containment with a nuclear explosion. If it was a chemical explosion -- in either case the graphite started burning, it's combustible, and that was what caused the 14-day plume. There was certainly enormous impact that a United States reactor would not have. However, it was Mohammed ElBaradei, the Secretary of the International Atomic Energy Agency, who went on record exactly seven days after September 11th, on the 18th of September, 2001, and saying that no reactor on the planet, including the United States, could withstand a direct hit by a jumbo jet with a lot of fuel on it. And the consequences, to quote that man, Dr. ElBaradei, would be quote, a Chernobyl.

COMMISSIONER SKOP: Thank you. And just, Mr. Chair, as a follow-up. I guess what I was getting at is would you agree that the Russian-based reactor's design would never be licensed in the United States due to its inherent safety concerns?

MS. OLSEN: I would agree that we would not license a Chernobyl reactor here. Yes.

COMMISSIONER SKOP: Okay. And also with respect to the comment you made with respect to the catastrophic event, I do believe -- are you aware of some other alternate studies that suggest that U.S. reactor design basically could withstand a direct impact from a large Boeing aircraft, I think was used in the studies, and survive impact with full maximum gross takeoff weight with high air speed and survive the event? I think there's been some additional studies.

MS. OLSEN: I would be more than happy to trade studies with you. I'd be very interested in seeing your study, but I can back it with several of my own that indicate different findings.

COMMISSIONER SKOP: Yes, ma'am. And I'm not debating which study is correct. I'm just merely suggesting that there are studies which suggest the opposite of what you --

MS. OLSEN: I would like to add one further comment, if I might, on this point, and that is that the irradiated fuel, which is actually the greatest burden of radioactivity cumulative at the site, is not in containment, the irradiated fuel pools. The high-level nuclear waste, the irradiated fuel pools where the fuel that has come out of the reactor core that's millions of times more radioactive than the uranium that went in, that fuel is stored onsite currently because there is no federal program to receive that fuel. And the majority of it in Florida, I believe all of it is in fuel pools. So it's a cumulative backlog of radioactivity. Enormous amounts are not in containment. They are outside.

COMMISSIONER SKOP: Thank you.

CHAIRMAN CARTER: Thank you very kindly. Would you please remain for a moment, please?

Mr. Krasowski, you're recognized, sir.

CROSS EXAMINATION

BY MR. KRASOWSKI:

Q Good afternoon, Ms. Olsen. Pleasure to finally meet you.

A Pleasure.

Q We've spoken on the phone.

A I'd like to give you my written comments before we --

Q Sure. Okay. I appreciate that. You've already mentioned that you are a paid employee of an organization, and I think you spoke to funding, the question on funding.

I'd like to ask you about this -- who's the author of the Carbon Free, Nuclear Free document that you're going to be submitting? Who is that?

A Dr. Arjun, A-R-J-U-N, Makhijani, M-A-K-H-I-J-A-N-I. And I put it fully in the record because I feel this document is so important for our collective future.

Q We agree as Intervenors, we have access to that document as well and plan on presenting it and discussing it in the process of the hearing. But thank you very much for your presence here tonight. Thank you.

CHAIRMAN CARTER: Mr. Ballinger, that will be marked as Exhibit Number, Exhibit Number 3 for identification purposes.

(Exhibit 3 marked for identification.)

Wait. Excuse me, ma'am. Wait a minute. Wait a minute. Hold on. Hold on. We've got an order here. Are you next in line?

UNIDENTIFIED SPEAKER: I just wanted to say I also have a question for Ms. Olsen, if at all possible.

CHAIRMAN CARTER: No, ma'am.

UNIDENTIFIED SPEAKER: No?

CHAIRMAN CARTER: I'm sorry. You could probably talk to her afterwards, but we have a proceeding here. We're doing it for the court reporter. We're taking it for -- it's actually going to be an ongoing process. Maybe you were not hear when I opened the hearing and all. I'm sorry. We do not allow that except for the parties.

UNIDENTIFIED SPEAKER: No more questions? Okay.

CHAIRMAN CARTER: Thank you so kindly. But, please, ma'am, by the way, if you do have questions pertaining to this, outside there's a green report here and you can put them in writing and we'll take them on as part of our, the record itself. And we appreciate having you here.

By the way, there may have been some others that have come in since I made the announcement, and those that have spoken have been sworn. And if you have not been sworn in and you would like to speak at this hearing, when your name is called and you have not been sworn in, please state so and we'll -- it's just a simple matter of me swearing you in for the record. Okay?

MS. BRUBAKER: Mr. Chairman, may I ask a clarification question, if I may, of Ms. Olsen?

CHAIRMAN CARTER: Yes, ma'am. Ms. Olsen, are you still here with us?

MS. BRUBAKER: Thank you. I note that in addition to the document which you specifically identified, there's also a number of additional materials in the folder that's provided to us. Do you wish all materials to be identified as the exhibit or simply the article that you identified?

MS. OLSEN: Quite frankly, I was planning to mail this to you, but I was handing Mr. Krasowski his to save postage. So I would like that all to be considered as a written comment that's coming with supporting documents, which I put in electronically because I thought it would save your support staff time to receive them in that form.

MS. BRUBAKER: Okay. So all documents are part of the exhibit?

MS. OLSEN: Yes.

MS. BRUBAKER: Thank you.

CHAIRMAN CARTER: So that would be composite Exhibit 3 for identification purposes only.

MS. BRUBAKER: Number 3. That's correct.

CHAIRMAN CARTER: Thank you so kindly. Ms. Brubaker.

MS. BRUBAKER: Next speaker, please, Peter Sipp.

CHAIRMAN CARTER: Say again.

MS. BRUBAKER: Peter Sipp.

CHAIRMAN CARTER: Okay.

Whereupon,

PETER SIPP

was called as a witness on behalf of the Citizens of the State of Florida and, having been duly sworn, testified as follows:

DIRECT STATEMENT

MR. SIPP: Thank you. I am going to spell my last name. It's Sipp, S-I-P-P. First name is Peter. And my address is 17 Phillips, with two Ls, Road in Burnsville, North Carolina.

My mom lives in Naples, and on my way home I wanted to come over and tell you about something that's very exciting. It'll fit the need of several people who have commented on the, one of the long-lasting sources of energy. And right about a month ago I was listening to NPR like I usually do in the morning, and this story was about Florida Atlantic University. They're making a study in the Gulf Stream. And you've -- a couple of you -- okay. And so I want to mention it, I came all the way here to mention it so, so that people can understand that the Gulf Stream has been going by the State of Florida. Florida is really blessed.

CHAIRMAN CARTER: Mr. Sipp? Mr. Sipp?

MR. SIPP: Yes.

CHAIRMAN CARTER: Would you please address your comments -- we've got the court reporter. She's got to look at you, too.

MR. SIPP: Okay.

CHAIRMAN CARTER: Excuse me. I mean, we want to get this on the record, so we're here to take testimony.

MR. SIPP: Sure. Thanks for helping me get it right.

CHAIRMAN CARTER: Thank you.

MR. SIPP: Sure. So Florida is really fortunate to have the Gulf Stream going by. And in the story the people said that there's enough energy in what they're testing on -- when they get through with the test, they want to put some big ones out on the Gulf Stream. And they say that they can make enough energy the same as three nuclear plants. And so that's something that would go on 24/7. There would be no shutdowns, there would be no danger of any terrorists wanting to blow it up. There would be so many pluses to using that. And then it would be a baseload. It would go on from now until as long as the Gulf Stream is going. Nuclear plants are only good for 40 or maybe 50 years and then it's decommissioning. And the radioactive problems just won't be there with the Gulf Stream generator.

And, let's see, it sounds like they could go online before Turkey Point would even begin -- before they could even start these could be done.

And, also, Florida is the sunshine state. It says so on a whole lot of license plates. (Laughter.) And, and the money that's not spent on the nuclear plants could be put into photovoltaic panels. And would there be enough roofs to put them? Because when I lived in Georgia I witnessed the building of the Plant Vogtle up there. And they told us, oh, yeah, it was going to be too cheap to meter. Well, I didn't add even so much as a night light in my house and my light bill went up three times what it used to be. And so nuclear power is really the Midas touch in reverse, and so it's important that we, that we really get that. And like I said earlier, they're only good for 40 years; whereas, the Gulf Stream will just keep on going. And that's, that's the essence of my, of my comments. Thanks a lot.

CHAIRMAN CARTER: Thank you, Mr. Sipp. Would you hold on for one second, please? Thank you so kindly for your participation.

Commissioners, do you have any questions?

Mr. Krasowski.

CROSS EXAMINATION

BY MR. KRASOWSKI:

Q Hello, Mr. Sipp. Mr. Sipp, are you being paid or compensated by anyone to be here today?

A I am not.

Q Well, thank you very much.

A Sure.

CHAIRMAN CARTER: Thank you very kindly.

MR. SIPP: Sure. I got to remembering that I should mention that you could check with the NPR website, if you wanted to watch the story. It's just a few minutes long. And if you'd like me to, I could send it down to you.

CHAIRMAN CARTER: We'll just have the court reporter to take it -- you saw it today?

MR. SIPP: No. No. It was a month ago. Yeah. Right about a month ago.

CHAIRMAN CARTER: Okay. Mr. Ballinger, just get the information from him so we could put that in the record. Thank you so kindly. Mr. Ballinger will come down and get that from you.

Ms. Brubaker.

MS. BRUBAKER: Dawn Shirreffs, please.

CHAIRMAN CARTER: I'm sorry. The acoustics in here are terrible. Please forgive me, but would you state your name for us, please?

Whereupon,

DAWN SHIRREFFS

was called as a witness on behalf of the Citizens of the State of Florida and, having been duly sworn, testified as follows:

DIRECT STATEMENT

MS. SHIRREFFS: Sure. It's Dawn Shirreffs, S-H-I-R-R-E-F as in Frank, F as in Frank, S as in Sam. I work for Clean Water Action at 190 Ives Dairy Road in Miami, Florida.

CHAIRMAN CARTER: Excuse me. I'm so sorry. The court reporter, none of us can hear you. Could you pull the mike a little closer, speak a little slower.

MS. SHIRREFFS: Get personal?

CHAIRMAN CARTER: Okay. And start over because --

MS. SHIRREFFS: Sure. It's Dawn Shirreffs, S-H-I-R-R-E-F as in Frank, F as in Frank, S as in Sam, and I work with Clean Water Action at 190 Ives Dairy Road in Miami. I wanted to thank you for coming all the way down here for the opportunity to share our questions and concerns.

Clean Water Action is a non-profit organization of more than 50,000 members in the State of Florida who are really concerned about the exorbitant costs and incomplete information and permitting methods being employed in an effort to add two new reactors in South Florida. The water needs of this project and how they will be met are undetermined at this time. It is therefore impossible to project the direct and indirect costs of water supply to Florida Power & Light ratepayers and the community of operation of this nuclear expansion.

Amongst other options, Florida Power is examining the installation of a 26-mile pipe to procure reclaimed water from the Virginia Key plant. Cost estimates for that option are nearly $700 million, not accounted for in FPL's use of the Tennessee Valley Authority's August 2005 study on costs.

There are additional concerns about many costs that weren't incorporated, and unfortunately most of that information is confidential when there are answers, and most times in this scenario there are not. One of our major concerns is about the current spent fuel storage pool capacity at Turkey Point. How long until it's necessary that alternative solutions for the storage of spent fuel become necessary? We don't have answers to where we're going to put the fuel. If dry cask storage of spent fuel is planned, what's that going to cost, and have those costs been factored in along with the fuel that will be required to provide those measures?

The American Council for an Energy Efficient Economy report released in June of 2007 found that adoption of 11 specific policies for enforcement of efficiency and renewable resources that are available in Florida can be implemented to reduce future energy demands by 29 percent in the next 15 years.

According to a 2001 study by the United States Energy Information Administration, Florida ranks third in total energy consumption. That's not population, that's energy consumption. Florida Power's achievements in demand-side management nationally are not reflected in the State of Florida where less than 1 percent of its energy is generated from renewables.

That information is from the same report.

It is critical that the State of Florida demand a commitment and innovation from public utilities on par with efforts being led by private corporate interests to adjust the public need.

Florida Power & Light cites Florida's second place ranking in renewable production from the U.S. Department of Energy when hydroelectric and geothermal resources are excluded. This application fails to note the Department of Energy -- the Department of Energy has found that Florida has vast low temperature resources suitable for geothermal heat pumps. This technology is presently available for heating and cooling Florida businesses and residences. This technology can severely lower peak demands, alleviating the need for additional baseload capacity. Restaurants are among the most intense users of energy. Industry pioneers such as McDonald's are currently opening multiple facilities using energy-efficient geothermal technology. In addition to other entities, the University of Central Florida has outfitted three buildings on campus with energy efficient technologies. The Public Service Commission cannot responsibly approve this application when such serious cost questions about water supply, waste disposal, waste storage, fill materials and plant design are likely to remain unanswered for the foreseeable future.

Florida Statutes require that Florida, that the Public Service Commission determine whether the proposed plant will provide the most cost-effective source of power. It is incumbent on the Commissioners to first determine the undeniable economic issues connected with the expansion of a nuclear power plant before finding FPL's application as a more cost, cost-effective option than renewable and DSM alternatives.

Clean Water Action will ask on behalf of all of its members and Florida ratepayers that the Public Service Commission deny Florida Power's petition on the grounds that insufficient information has been furnished to demonstrate that the proposed plant is the most cost-effective alternative available, and that this application fails to demonstrate that renewable energy resources and technologies have been utilized to the extent reasonably available as required by the Florida Statutes. Thank you for your leadership and your time.

CHAIRMAN CARTER: Thank you so kindly. Would you remain there for a moment? Commissioners, any questions?

Mr. Krasowski.

CROSS EXAMINATION

BY MR. KRASOWSKI:

Q Good afternoon. Are you being compensated or paid by anyone to be here today?

A Yes. I'm a paid employee with Clean Water Action.

COMMISSIONER ARGENZIANO: What is the group?

CHAIRMAN CARTER: Say again. We didn't hear the --

MS. SHIRREFFS: Yes. I'm a paid employee with Clean Water Action.

CHAIRMAN CARTER: With Clean Water Action, did I get --

MS. SHIRREFFS: Uh-huh.

BY MR. KRASOWSKI:

Q And if I may state for the record, it's not like I think there's anything wrong with being paid for what you do. It's just --

A Well, it's a non-profit. It has mostly warm fuzzy feelings.

Q There's a lot of volunteers involved. Okay.

And then also, and I was interested in knowing if you have any expectation of benefiting through your organization through grants or funding that would result from your fight against -- well, not fight against -- your effort?

A I'm not aware of anywhere. We're funded on past performance generally, but not specific to this project.

Q Okay. And one other question. You mentioned the water issue in terms of this plant. There were a number of options for water but there's only one left. Is that -- the only one that's allowed to be used is the, is the reused water; is that correct?

A Based on the application that went through the county commission here in Miami-Dade, reuse is supposed to be the first priority if it's found to be viable. The Floridan Aquifer is still an option.

Q Okay.

A And so there's some discussion about whether or not that's even viable if they're pulling from the Floridan Aquifer and how that would -- the energy costs and well field damage and different types of options. Because they haven't said, we haven't been able to fully assess the ramifications of where the water source will be.

Q Okay. The ramifications of the economics of the whole water --

A Uh-huh.

CHAIRMAN CARTER: Sorry. The court reporter is really having trouble.

BY MR. KRASOWSKI:

Q Oh, okay. By her comment on ramifications, assessing the ramifications of the water choice, I'm asking you that you're meaning also the economics of the cost of water to be brought into the facility?

A Yes. Since we do not know whether this water is going to come from a reuse plant that may need to be erected or if it's going to be drawn from the Floridan Aquifer and treated we are unable to assess the cost of water supply of 70 to

90 million gallons a day.

MR. KRASOWSKI: Thank you.

CHAIRMAN CARTER: Thank you.

COMMISSIONER ARGENZIANO: Mr. Chair.

CHAIRMAN CARTER: One moment, please.

COMMISSIONER ARGENZIANO: Just a question now to that response. The water would be, would need to be treated to go through to cool? What kind of treatment would you need at the -- and I'm just asking because she may know more than I do. What kind of treatment would need to take place?

MS. SHIRREFFS: It depends on where in the Floridan Aquifer the water is pulled. It's not clean water like the Biscayne Aquifer is. So I don't have the technological information to answer that, but it's not -- it would need some sort of processing just as reuse needs processing because it's not --

COMMISSIONER ARGENZIANO: Right. And my reason for that is, one is for potable use, and the other is I didn't know. I wasn't sure. I think what you're saying is there's a possibility that some treatment, not for potable purposes or drinking purposes but for mechanical or whatever.

MS. SHIRREFFS: Right. The lower Floridan or the Floridan isn't considered, you know, readily available to be potable.

COMMISSIONER ARGENZIANO: Oh, I know about it. I know about it. I just didn't -- what I'm trying to differentiate is treatment for drinking purposes and treatment for plant purposes. I didn't even know that they had to treat water for, for a nuclear power plant. So that's what you're getting at.

MS. SHIRREFFS: Well, my -- yeah. What the County documents sort of suggested was that they were going to perform a feasibility study on whether reuse could be used in the operation of this plant, but that information is not yet known.

COMMISSIONER ARGENZIANO: Okay. Mr. Chair, if we can find out, I'd love at some point to know if water needs to be treated. Because if that has an economic basis to it, then we have something to say or have to, definitely have to look into that. If it's purely an environmental issue, which I'm not disregarding, but that's not our jurisdiction. But if it has an economic issue, then I would like to know.

CHAIRMAN CARTER: Commissioner Skop.

COMMISSIONER SKOP: Thank you, Mr. Chair. And I would also ask, and I think Ms. Shirreffs, and hopefully I'm pronouncing that correctly but it was very hard to hear, thank you for your comments.

And with respect to the water supply issue, I just kind of -- for my own information I think some of that has to do with historically reactor plants have been able to use direct pass-through cooling, like if they're proximate to a water source. Like, for instance, I believe St. Lucie 1 and 2 uses it directly through the ocean pass-through and then back out. I think Crystal River 3 also does that also. But if FPL could briefly perhaps clarify some of this for us, I think it might be helpful to my colleagues. And also with respect to the treatment of water, because it's my understanding it's a closed-loop system, so you're just using water as a heat exchanger to your closed loop that is the reactor plant water. So I think some clarification might be in order. Thank you. And, Dawn, if you could probably stay there.

CHAIRMAN CARTER: Before FPL, do you have any more questions for this witness?

COMMISSIONER SKOP: No.

CHAIRMAN CARTER: Okay. Thank you so kindly.

MR. KRASOWSKI: Excuse me, Commissioner. FP&L didn't stand to be sworn in. So if we could do that before they provide any testimony, I'd appreciate it.

CHAIRMAN CARTER: This is their attorney. Their attorney does not have to be sworn in. He's --

MR. KRASOWSKI: Sorry. I didn't realize they didn't have --

CHAIRMAN CARTER: We never swore you in, Mr. Krasowski. Okay?

MR. KRASOWSKI: I did -- but okay. Okay. Thank you.

MR. BRYAN: Excuse me. I would just like a clarification. Commissioner Skop, were you asking for somebody today to --

CHAIRMAN CARTER: If you don't have the person here today, certainly we'd like to have that sent to us and for the record in terms of the economic aspects of the water use pertaining to this project here.

COMMISSIONER ARGENZIANO: Treatment, I think.

CHAIRMAN CARTER: Treatment of the water for this process. I think it would probably be better to submit that so we can have that for the evaluation and we can review that just in case any other Commissioners have any questions. Once we see that, there may be some other questions. Again, as I said at the opening, this is the first stop. Our formal final hearing on this will be on the 30th and we can go from there. But I think it would be more inclusive if we could get that in writing.

Commissioner Skop.

COMMISSIONER SKOP: Thank you. And just as a quick follow-up, Mr. Bryan. I guess what I was looking for was perhaps the change in regulation that spurs the need to bring in water because pass-through cooling is no longer allowed. I think that's accurate. I'm not 100 percent sure. But I think that that would alleviate or inform both myself and my colleagues with respect to the cooling issue. Thank you.

MR. BRYAN: Very good. Certainly we will comply with that request.

CHAIRMAN CARTER: Thank you. And again to the public that's here, as I said, some of you that were not here when we started a couple of hours ago is that this is our public testimony where we're taking information from the public to put as part of our record. This will be the first one. We normally have this in Tallahassee, but because of the nature of this we thought it important enough for us to come down from Tallahassee to be with you here today and hear from you directly. We'll have a subsequent hearing in Tallahassee, and after we have the hearing from the public, then we'll go into a more evidentiary hearing where we have people, cross-examination, information, witnesses, experts and things like that. But we did, as a Commission we thought it important enough to us to come and hear from the people that are directly impacted by this. So we thank you and we appreciate your comments for now.

Ms. Brubaker.

MS. BRUBAKER: The next speaker is Agustin Rodriguez. And the next three after will be Mark Oncavage, Tim Weller and Pedro Capo.

CHAIRMAN CARTER: And just for the record, if you have not been sworn in, please state so. As I said, there's some people that came in after I had sworn in the first group of people. And if you have not been sworn in, please let me know and we can take care of that and we'll go from there.

Whereupon,

AGUSTIN RODRIGUEZ

was called as a witness on behalf of the Citizens of the State of Florida and, having been duly sworn, testified as follows:

DIRECT STATEMENT

MR. RODRIGUEZ: Good afternoon, Commissioners, and good afternoon, Chair. My name is Agustin Rodriguez and I'm here representing the Alliance for Aging. Primarily I'm here to support FP&L in their efforts that they have had in regard to assisting primarily our elders and their caregivers.

Basically FP&L has been a partner with the Alliance for Aging in providing assistance to our elders who at times have issues of not being able to pay for their electricity primarily through different programs that we have with them. And also their meter readers are people who are aware of elders and frail people who do not have people out there in the community that assist them.

We do support FP&L in their ventures. But primarily I do not have anything to really say in regard to the nuclear plant because primarily our whole issue with FP&L has to do with services that we do provide, and they assist us with those services to our elders and their caregivers. And pretty much that's all I have to say. Thank you very much.

CHAIRMAN CARTER: Thank you. Thank you. One moment, please. Commissioners? Thank you so kindly. Thank you.

Ms. Brubaker.

MS. BRUBAKER: The next speaker is Mark Oncavage.

CHAIRMAN CARTER: Say again, please.

MS. BRUBAKER: Mark -- and, again, just for the record let me apologize for any mispronunciations. Mark Oncavage.

CHAIRMAN CARTER: And if you could please help us with the pronunciation of your last name, sir.

Whereupon,

MARK ONCAVAGE

was called as a witness on behalf of the Citizens of the State of Florida and, having been duly sworn, testified as follows:

DIRECT STATEMENT

MR. ONCAVAGE: Ms. Brubaker was absolutely correct. I am Mark Oncavage, O-N-C-A-V-A-G-E. I live at 12200 Southwest 110th Avenue in Miami. I am the Conservation Chair of Sierra Club, Miami group, and I am speaking on behalf of the Miami group. I have requested that handouts be passed out. I do not wish to read all ten pages of the handout, so I hope you'll work with me a little bit on this.

I have authored four documents and these are the four documents that are before you. We have been on a trail trying to find where the cooling water is going to come from for the nuclear power plants. If you look at the second page of

Document Number 1, this is pretty much boilerplate kind of questions as to what sort of processes are involved, what sort of sources for the, for the cooling water and processed water and blowdown and fire protection that are going to be there.

We had a meeting, two environmental groups and two county agencies, about the water, about the water supply. And of all these questions that were offered to these agencies only parts of two answers came. One was that we know that the processed water is going to come from the Newton Water Treatment Plant and it's going to be 100,000 gallons a day. We also found out that there was going to be a requirement for 70 million gallons a day of cooling water. And the question went to the agencies, Miami-Dade Water and Sewer and the Department of Environmental, Department of Environmental Resource Management, where the water is going to come from and they had no idea. They were absolutely buffaloed with this.

So please turn to Document Number 2. The environmental groups had a meeting with Florida Power & Light and the questions that I gave to them in writing were not answered. We don't know where this water is going to come from. These questions have been around for a number of months and Florida Power & Light has just never bothered to come up with answers for us. So we are again stymied as to trying to find out what sort of economic costs, what sort of environmental costs are going to be involved with trying to cool these two nuclear reactors.

If you look at Document Number 3, this was a recommendation from the Miami-Dade County Development Impact Committee. We have a set of laws called the Jennings Law that says we are not allowed to speak to county commissioners about a quasi-judicial zoning variance hearing. So all of this was handled by the county agencies beforehand, keeping our commissioners totally in the dark on this.

Again, where is the water going to come from? It's, it's 60 to 90 million gallons a day. One idea that came through was that we're going to have reused water from a sewage treatment plant. Now Turkey Point is located right next to a sewage treatment plant, and this plant is slated to go into water reuse to cleanse the water, but it's part of a comprehensive Everglades restoration project and all of the reused water from this plant is slated to go elsewhere. There is a discrepancy as to whether the water should go for wetlands rehydration or whether it should go for aquifer recharge, and finally the South Florida Water Management District decided it was going to go for wetlands rehydration.

So the story that comes out piece by piece is that the next location for where this amount of water can be had is the sewage plant on Virginia Key, 22 miles away. And the suggestion was offered that they should drill a tunnel under Biscayne Bay, which is now standing Florida water, underneath

Biscayne National Park to bring sewage in so that it can be cleaned up and that it can be offered to Florida Power & Light as cooling water. This -- we don't know so many things. We don't know if it's feasible to do this. We don't know what the costs are going to be. We don't know whether it's going to be one or two pumping stations that are going to provide this. We don't know who is going to own this pipeline. And we don't know who's going to be responsible for accidents and mistakes and sabotage and cleanup. So we have some real problems trying to figure out where the cooling water is going to come from. If it comes from Virginia Key, it is going to be horrendously expensive.

Just cleaning up the water from the plant that's going to be built in the South Dade area is going to cost $1.6 billion, but that water cannot go to Florida Power & Light. So the question is is there going to be another $1.6 billion plant that Florida Power & Light has to build to get cooling water?

If you go to the fourth document, this was -- we had a commission meeting with the Miami-Dade County Commission, and they were very proud that they had just concluded negotiations for a 20-year consumptive use permit with the South Florida Water Management District. We also found out that Florida Power & Light and their request for 60 to 90 million gallons a day of water is not included in this 20-year consumptive use permit. It's mentioned. It's mentioned that people have to start getting together and talking and looking, but there is no dedication anywhere of this water being available to Florida Power & Light.

The County staff is struggling to meet the requirements of this 20-year consumptive use permit from the South Florida Water Management District. I've been a member of a panel that was helping the development community find ways of saving water. This was through Miami-Dade County. We're finding out now that starting this coming Tuesday, January 15th, we are moving from Phase 2 water restrictions to Phase 3 water restrictions. We are very short of water. We are very concerned for the health of Lake Okeechobee. It is dropping and it is not being replenished. Lake Okeechobee is the county's backup water supply from the Biscayne Aquifer.

One of the rulings, one of the restrictions is that Dade County has to reduce over the next 20 years, the consumptive use permit, its actual use of water by 20 million gallons a day. This is in spite of increases in population. They have to go through alternate water supplies, they have to go through conservation programs, they have to do all kinds of different things. They have to start using sewage water over and over again just to, just to get to this point where any withdrawals from the Biscayne Aquifer in addition to what is happening right now have to be replaced. They have to be recharged.

What we would like to see is the Public Service Commission adopt the same philosophy that in the next 20 years we have to reduce electrical consumption. I think that would be the most beneficial thing that we could do, not only for water, but for electricity, for fossil fuels, for gasoline, for all these things.

So, please, if you go to the very last page of the handout, there are three questions that I had for the Miami-Dade County Commission: What is the source of the 90 million gallons of cooling water, how much will it cost, and who pays the cost? The Public Service Commissioners might want to ask these same questions for Florida Power & Light. Thank you very much.

CHAIRMAN CARTER: One moment before you go. Commissioners -- and for the public, let me just kind of -- our court reporter has been going for well over, in excess of two hours, so she's going to need to take a break, and we've got a lot of people signed up and we want to hear from everyone. So we're looking forward to the opportunity to hearing from everyone. That's our purpose for being here, to hear from the public. And so we -- those of you that have already said the same thing that your neighbors have said, if you could say, you know, I agree or disagree or whatever the case may be. But we want to hear from everyone, but we've only got the room for just, just over another hour or so. But we do have to give the court reporter a break. So after this witness we're going to take a ten-minute break, then we'll kind of get ourselves together for that. We appreciate everyone's enthusiasm and information and all like that, but we did come to hear from the public. And a lot of the organizations, we appreciate the information that we're getting from you, but we do want to hear from the public at large.

So, Commissioners, any questions for this witness? Commissioner Skop.

COMMISSIONER SKOP: Thank you, Mr. Chair. And thank you, Mr. Oncavage, for -- hopefully I pronounced that properly -- for submitting the three final questions at the end. And hopefully, on behalf of myself and my colleagues, those questions that you presented will be adequately addressed and discussed and we'll have answers during the course of our proceedings. Thank you.

CHAIRMAN CARTER: Thank you very kindly. Commissioners -- oh, Mr. Krasowski, oh, I'm so sorry. You're recognized.

MR. KRASOWSKI: Thank you, sir.

CROSS EXAMINATION

BY MR. KRASOWSKI:

Q Mr. Oncavage, are you being paid or compensated by anyone to be here today?

A I am very much unpaid.

Q And do you have any expectation of being funded throughout the course by, throughout the course of this event or hearing?

A No.

Q Okay. Thank you very much.

CHAIRMAN CARTER: Ms. Brubaker, I think we'll have this marked for identification purposes only as Exhibit Number 4.

MS. BRUBAKER: Number 4. Correct.

(Exhibit 4 marked for identification.)

CHAIRMAN CARTER: And I think what we'll do is in fairness of time, I will ask the Public Counsel what time do you have so we can take ten minutes from your time, sir?

MR. KELLY: I'll tell you if I can see.

CHAIRMAN CARTER: Put on your glasses. Put your glasses on. (Laughter.)

MR. KELLY: I have 5:59.

CHAIRMAN CARTER: 5:59. We'll take a ten-minute break, give the court reporter a chance to do that. And those of you that are part of organizations, if you're pretty much the same, please allow the public an opportunity to be heard. Thank you, sir. We shall return at 6:59.

MR. BECK: Whoa. Whoa.

MR. KELLY: No. Whoa. That's an hour. 6:10.

CHAIRMAN CARTER: Oh, 6:10. Well, you see, that's why I asked somebody else for the time. (Laughter.)

(Recess taken.)

We are back on the record. As we get our seats here, I made some comments initially and I want to kind of let you know where we are is that, first of all, as I said, is that because we wanted to hear from the public -- we normally just have the hearing in Tallahassee, but we came down here because we wanted to hear from the public directly, those that are most affected by this. We've got about 28 more people signed up to speak. We've got the building only until about 8:00. What that's going to do is -- I've been kind of -- we really need you to stick to within two minutes. And those of you, please consider the time that you've taken over that two minutes as you're keeping your neighbor from having his or her say. And, again, if you have more than that to say, just use the green sheets here that I mentioned three times before. Please make your statements here and send them up to us. Those of you that feel that you, two minutes is not appropriate, we have another hearing in Tallahassee. We'd be more than happy to have you there. But, again, because we really wanted to hear from the public we came.

So, please, ma'am, please, sir, as you come up, please be advised that we want to hear from your neighbors, we want to hear from everyone. That's why we're here. This is an extraordinary event for us to do that. But we wanted to hear. So as you get up, please -- my grandmama taught me not to be rude, so I really don't want to gavel anybody down, out. Please use your two minutes so your neighbors can be heard. We sincerely, sincerely from the depths of our heart appreciate Miami-Dade allowing us to use their facility here, but we only have it for, until 8:00, and I really want to hear from as many people as possible. So I don't want to be rude. That's why I want to let you know up-front we did have this extraordinary hearing because of what was happening here, we wanted to come down, but you do have another opportunity in Tallahassee to be heard. And if your two minutes doesn't allow you to say everything that's on your heart, please use the sheets. We'll put that as part of the record. With that, Ms. Brubaker.

MS. BRUBAKER: The next speaker is Pedro Capo. And if I could call the next three after will be Rhonda Roff, Deb Arnason and Renny Ramai.

Whereupon,

PEDRO CAPO

was called as a witness on behalf of the Citizens of the State of Florida and, having been duly sworn, testified as follows:

DIRECT STATEMENT

MR. CAPO: Good afternoon. My name is Pedro Capo. I'm at 4200 Northwest 167th Street, Miami, Florida.

CHAIRMAN CARTER: Could you please spell your last name for us?

MR. CAPO: Capo, C-A-P-O.

CHAIRMAN CARTER: Thank you.

MR. CAPO: Yes. I've been living here in Miami for the last 41, almost 41 years. I came when I was a little boy from Cuba. There was hardly anything here. And I've seen the growth that especially South Florida has had. And FP&L has been around for much longer than that. Since the very beginning in the business world FP&L approached us to help us in our business to be able to save, energy consumption, better roofs, recycling, the whole gamut. I've heard some of the negative comments about FP&L not actually having an interest in the savings part of it, and I'm a testament to that in our buildings. We have more than a million square feet in South Florida of buildings that need to be cooled and lit. We've got about close to 1,000 employees that live off of those buildings in the retail community. And FP&L has actually been a very instrumental entity in recommending reflective roofs, high energy units, either being new construction or replacements, the lighting issue throughout the entire facilities, either it being the showrooms or the warehouse, low dimmers, all kinds of things that are profitable to our company as a, as a business. So in the sense of being part of the community and trying to help the community and save the environment, I would say that I would give 100 points to FP&L on that end.

We definitely need to have better power. We need to have better reaction when we have hurricanes. I know Florida is a very specific kind of state, much different than most of the states that have been mentioned here in this meeting. We had a number of hurricanes a few years ago. I lost two of my stores because of hurricanes. I know what FPL was able to do. I know about the damage to sunroof and all that kind of stuff that is not necessarily appropriate for Florida. I'm not an engineer. I don't know if the, if the best solution at this time is a nuclear plant or not. But I do, I can say that if I was to give the authority to, for any company or any entity or any kind of government agency to install a nuclear plant, I would give it to somebody that would be experienced, that has the knowledge and the track record that FP&L has had for the last 30 some years in the Turkey Point plant.

CHAIRMAN CARTER: Thank you. Thank you, Mr. Capo. We appreciate that.

MR. CAPO: Thank you.

CHAIRMAN CARTER: The -- I'm sure Mr. Krasowski would ask you whether or not you've been paid.

MR. CAPO: No, I have not been paid. And I will not benefit, only to get a better rate hopefully.

CHAIRMAN CARTER: Thank you so kindly. Commissioners?

COMMISSIONER ARGENZIANO: No.

CHAIRMAN CARTER: Thank you so kindly.

Ms. Brubaker.

MS. BRUBAKER: Rhonda Roff, please.

Whereupon,

RHONDA ROFF

was called as a witness on behalf of the Citizens of the State of Florida and, having been duly sworn, testified as follows:

DIRECT STATEMENT

MS. ROFF: My name is Rhonda Roff, R-H-O-N-D-A, last name is R-O-F like in Frank, F like in Frank. My address is Post Office Box 1953, Clewiston, Florida. Do you need the zip, phone number?

I wrote my talking points out to spare you my rambling, so I hope you don't mind if I read. I really want to thank you all for coming down to Miami. It's a big state. It's really hard to get up to Tallahassee, especially when you have young children that you have to leave with somebody else. So this is really wonderful that you're all here. And I really, really appreciate you changing the date of this hearing to tonight rather than tomorrow. As you know, many of us will be over at Sanibel/Captiva tomorrow for the Everglades Coalition meeting, and I wish that you could all join us because we're going to have some fairly lively discussion about Everglades restoration.

Now to the point, we thought we had shown nuclear power to be unsafe almost 30 years ago after the Chernobyl and Three Mile Island accidents. In the years since the accidents, a new generation of decision-makers has grown up, excuse me, and in the absence of institutional memory lacks the component of caution that we have earned by frightful experience. I was going to Rutgers, I was a chemistry student at Rutgers at the time when Three Mile Island had its accident. And I was directly downwind of it and it was very frightening. I remember having to take potassium iodine tablets and I remember all the milk from the dairy farms in Pennsylvania and the Harrisburg area needed to be disposed of because of the radionuclides that were taken up by the milk cows. It's possible. I think it's possible that we have accidents and we need to be mindful of that.

In 2005, the Florida Legislature approved cost recovery for nuclear during a time that it was not on the public's mind. No doubt there's a need as long as we continue growing and consuming the way we do now. I don't really know why the rest rooms need to be equipped with electrically managed hand towels, but we consume, we consume far more than we absolutely need to.

Meeting that need, to flood the grid with nuclear generated capacity will likely remove incentive to grow truly clean renewable capacities such as solar and implement conservation measures and practices. These components were mandated by Governor Crist by Executive Order at the Climate Summit held this past summer right here in Miami.

My husband and I are doing our part to build a zero energy home. While we're allowed to add 10 kilowatts of photovoltaic capacity to our home and interconnect that to the grid, the engineering calculations say that we're going to need less than five and maintain all of our power use that we currently do, that's air conditioning. And that's south of Clewiston. It's very hot in the summer there. And although I would dry my clothes out on the line and not use the clothes dryer, sometimes it rains and that becomes inconvenient. So we expect to use our full load and do it entirely on solar PV building-integrated laminates on the roof.

Now regarding the cost for this nuclear expansion, there are some knowns clearly: The construction, operation, protection from terrorist attacks, certain components of the waste storage and evacuation plans. But there are also unknowns: Long-term waste storage, water availability. I live in an agricultural area that is currently just shuddering from the drought. We're having to feed -- we run cattle and we're having to feed our cattle hay because we just don't have enough water in the pastures right now to grow the grass for them.

The radionuclide contamination to the --

CHAIRMAN CARTER: Ms. Roff, could you summarize, please? Remember, I wanted to hear from all of your neighbors.

And I'm really trying to keep this -- we've got -- I want to hear from everybody, so I'm not, as I said earlier, I'm not being rude. I'm just trying to keep us within that time frame so everyone can be heard.

MS. ROFF: Okay. I'll speak, I'll speak quickly. I'll speak quickly.

CHAIRMAN CARTER: So you've got like 30 seconds.

MS. ROFF: Well, we spent 20 minutes listening to an FP&L advertisement, with all due respect, and I wasn't pleased with it.

CHAIRMAN CARTER: Yes, ma'am. Part of your 30 seconds you're using now. So we want to hear from everybody.

MS. ROFF: They aren't required to have an MPDS permit because it's a closed-loop system, so we can't estimate the radionuclide contamination to the water. Sea level rise is almost certain. Sea level is -- sea water is very corrosive through its salinity to concrete and steel from which most of the buildings are built. It is also well-known that regulated utilities do not profit from selling kilowatts. They profit from capital investments. They need to do this, and you're required to approve or not approve it. But that is the cost of reality involved here. And it will only be a reasonable cost to the ratepayer if the operations run smoothly. We --

CHAIRMAN CARTER: Thank you so kindly. And as I said to the members earlier, is that -- wait for one moment, please.

As I made my opening statements, I really did not want to be rude. I wanted to make sure we heard from everyone. Let me just ask you those questions so you don't have to listen to Mr. Krasowski. Are you being paid by anyone else to be here?

MS. ROFF: I have invested a tremendous amount of my own personal savings into this. No, I am not paid, and I will not profit from this.

CHAIRMAN CARTER: Okay. Thank you so kindly.

COMMISSIONER ARGENZIANO: Mr. Chair, may we just ask if she would like to submit her additional writings so that we can read that?

CHAIRMAN CARTER: Could you do that, please, just submit that to us in writing? And as I said earlier, we have these forms here. Just if you -- I know two minutes is not a lot of time, but we want to hear from everyone. We only have the room for a little bit amount of time. We've got 28 people. As fair, as much as possible to hear from everyone that took the time out from their day to be here. So, please, ma'am, make your comments here and we'll have staff to pick it up. And as I said, I apologize, but I'm trying to make sure that we get a chance for everyone to be heard.

Ms. Brubaker.

MS. BRUBAKER: Deb Arnason. Thank you.

Whereupon,

DEBBIE ARNASON

was called as a witness on behalf of the Citizens of the State of Florida and, having been duly sworn, testified as follows:

DIRECT STATEMENT

MS. ARNASON: Arnason, Debbie Arnason, A-R-N-A-S-O-N. Okay. I live at 12 Dill Street, Alva, Florida. I am an FPL ratepayer. I was part of the -- actually I attended the Public Service Commission April 16th, 2006 -- 2007, this past year. I'm sorry. And, and we were very fortunate that the PSC did refuse the coal plant that they were planning for the heart of our endangered Everglades. Now at that time they said they couldn't do anything but coal until they were denied, and then they found they could partner with OSRA (phonetic) and they could do 1,000 megawatts of coal. But they still needed this extra nuclear. Now I don't believe that and I don't believe what FPL has been telling me all along. I know they provide good energy and we have reliable energy and that's great and their prices are reasonable, but the truth is that I was paying for that, the Green Energy Program and getting, getting conned. They were using my money to buy $100,000 fire trucks for Glades County and other counties surrounding where they were going to put in the coal plant. They were not doing anything seriously about solar, and that's why I'm here.

Solar is the alternative. I heard things today, I heard about -- I have 360 signatures of people who say no coal, no nuclear, go solar, especially if we as the ratepayers are going to be asked to subsidize. I call it subsidizing our own demise.

I do not want to pay for nuclear waste, and that brings me to the next topic. When Mr. Silagy said we are, something about the best defended targets, and that's exactly what I think of as a nuclear plant is a target. Solar panels are not a target, you know, and they can be integrated into the existing grid in local communities. So if the whole grid goes down, we've still got some solar generation there. There's many things that can be done.

I have worked for my brother's aerospace metals business, and not only do I have Time Global Warming, which recommends solar, I have Mother Earth, I have Renewable Energy World, I've got solar, solar, solar and wind, of course, and algae, and there's a lot of other doables and they're being done. I want this in the record for FPL, and I hope they write this down. I would really appreciate it. The Renewable Energy World Trade Magazine is available to anyone, anyone on the panel up here for free at WWW.REW-subscribe.com to receive a free copy. There are incredible solar solutions.

And I would like to say, I know that time is very, very short now, because this is in a conference, it's called the Concentrated Solar Power Summit and it's in San Francisco and it's January 28th and 29th. But I think FPL has enough money to make a last-minute arrangement for one of their representatives to attend this conference. And here's what it says: "How to build and run a profitable concentrated solar power plant. Everything you need to know to get a CSP plant up and running fast." And it's got everything. It's got the cost reduction and the technology updates and so on and so forth in construction. So I see no excuse whatsoever except for the money. This is going to be charged to ratepayers. I'm losing some of my papers here. But I will tell you that I wasn't planning to talk on this. I was going to talk on the fossil fuel addiction because this is just another form of actual fossil fuel addiction.

And I do, if I can find it, want to hold up my picture which I'll include with my paperwork, which is Uncle Sam and he's drunk on his butt over here and he's surrounded by empty oil cans. And I put a lump of coal in there. I don't know if that's, if I shouldn't have done that. But anyway it's from USA Today August the 13th. And he's reaching for a nuclear canister. "Just what I need, a little eye opener." It's a fossil fuel addiction, and we need to get off the fossil fuels and into the sunlight of the spirit and into the solution and not waste our money on it.

CHAIRMAN CARTER: Thank you. Now do you have those that you would like to have submitted to the record?

MS. ARNASON: I sure do. I sure do.

CHAIRMAN CARTER: And while we're getting ready for

Mr. Ballinger to get those from you, let me just ask you those questions so you don't have to.

MS. ARNASON: Oh, sure. Sure.

CHAIRMAN CARTER: Do you remember Mr. Krasowski's questions?

MS. ARNASON: Yes, I am totally -- yes, I was thinking about giving you the response when I first got up here. I am totally unpaid. I am just a very caring, concerned citizen, and at a great expense to get here, and I may even come up to Tallahassee to give you the rest of my comments.

CHAIRMAN CARTER: We look forward to seeing you.

MS. ARNASON: Thank you, thank you so much for coming. I appreciate it.

CHAIRMAN CARTER: Thank you.

COMMISSIONER ARGENZIANO: Thank you.

CHAIRMAN CARTER: Thank you so much. We really are sincerely trying to get everyone here. We came this far to hear from everybody.

Ms. Brubaker.

MS. BRUBAKER: The next speaker is Renny Ramai. And the next three after will be Don Ehat, Eileen Smith and George Cavros.

CHAIRMAN CARTER: The name, the first name you said?

MS. BRUBAKER: Renny.

CHAIRMAN CARTER: Renny?

MS. BRUBAKER: Ramos. Ramai.

CHAIRMAN CARTER: If Mr. Ramos is not here, we'll move to the next person on the list.

MS. BRUBAKER: Okay. And that will be Don Ehat.

CHAIRMAN CARTER: Say the name again.

MS. BRUBAKER: Last name is E-H-A-T. Eileen Smith.

CHAIRMAN CARTER: Ms. Smith? Thank you so kindly.

Whereupon,

EILEEN SMITH

was called as a witness on behalf of the Citizens of the State of Florida and, having been duly sworn, testified as follows:

DIRECT STATEMENT

MS. SMITH: Thank you for making the trip. Eileen Smith, and my address is 3940 North 56th Avenue, Hollywood.

Efficiency and cost-effectiveness, these new reactors are neither. Their great cost to residents of this state are just simply unacceptable, especially since we haven't taken the many steps that are available to us through energy efficiency, which is a virtual cost-free alternative that's also risk free, and I think that's very important. Because this is really the very definition of efficiency that I think your Commission is looking for.

The risks that I mentioned are important and they're diverse. I am really not convinced by drills and by reassurances. More reactors close to Miami's major airport in an age of security concerns doesn't make us secure. I've heard the study with the jumbo jet flying into nuclear reactors, and I don't want to belittle it, but I just want to say we once thought that the World Trade Center was secure and we thought the same thing about the Titanic and the Hindenburg and a lot of other examples throughout history. My point is really that we are not infallible. We are very fallible and so are our creations, and it's really important to factor that into the cost of this.

Of course, other people have mentioned unresolved transportation of waste and the major storage issues for nuclear waste, and these are items we can't ignore because their cost is inevitable sooner or later. It's not, as FPL says, cleaner, greener and smarter to make a mess when we don't know how to clean it up. It's irresponsible and it will be expensive to our generation but also to future generations. I hope you'll factor in those externalities. These reactors will be water hogs, as other people have said, and we need our water for people, for agriculture, not for parched reactors.

Finally, an issue that hasn't been mentioned so much and it's health. I really urge the Commission, because I can't do it in two minutes, to do their own research and to examine very carefully rates of thyroid cancer, leukemia and breast cancer, as well as cancer mortality in cities likes Philadelphia, which happens to have 13 reactors within 90 miles of it. The rates are very high. I can't show cause and effect today; I sure can't do it in the time limit. I can only say that it's definitely not worth the potential increased risk in Florida to our state, the costs to our healthcare system and the unaccountable, the costs we really can't measure to our children.

In closing, in my opinion first we need more efficiency, then we need more solar for which the technology improves each and every day. Then maybe we'll need natural gas at Turkey Point, but we don't need more nuclear because the price is way too high in too many ways for way too many people.

CHAIRMAN CARTER: Thank you so very, very kindly. And before you go, you know, I'm going to ask you the questions so we don't have to do that.

Are you being paid for, to be here?

MS. SMITH: I am not being paid, but I do perceive a benefit for this plant as a private citizen, and it is that we will have that cleaner, greener and smarter future that FPL mentioned, but we'll have it without nuclear.

CHAIRMAN CARTER: Thank you. And, again, just before our next speaker comes up, again, those of you -- we obviously want to hear from everyone possible. But, please, ma'am, please, sir, if you have additional comments, please use these sheets and we will take them up to Tallahassee, make them part of the record so that when we complete our public hearing, it will be on the 30th, we'll have all of the information.

Ms. Brubaker.

MS. BRUBAKER: Before the next name I just would note for the record, I received Ms. Arnason's comments. I would ask that those comments be identified as Exhibit Number 5.

CHAIRMAN CARTER: Exhibit Number 5. Show them marked for identification purposes.

(Exhibit 5 marked for identification.)

MS. BRUBAKER: Thank you. The next speaker is George Cavros. The next three after will be Jen Rock, Steve McGonigle, Eric Knowles.

CHAIRMAN CARTER: Mr. Cavros, you're recognized.

Whereupon,

GEORGE CAVROS

was called as a witness on behalf of the Citizens of the State of Florida and, having been duly sworn, testified as follows:

DIRECT STATEMENT

MR. CAVROS: Thank you, Chairman. This is going to be an abbreviated presentation. My name is George Cavros. I'm here on behalf of the Natural Resources Defense Council and the Southern Alliance for Clean Energy, both non-profits that support clean energy solutions.

My first point is that I don't want the Governor, Governor's initiatives of trying to place us in a leadership role and a clean energy future to be viewed as a green light for nuclear power plant construction. There are -- clean energy future depends on investment, aggressive investment in energy efficiency implementation and also renewable technology development, and large baseload generation plants draw investment away from those areas. It's a, by all accounts it's a disincentive to a clean energy future.

But you have a really focused view here, so let's go straight to the plant. First consider the cost of new nuclear construction. Estimating costs has been really hard to gauge. There hasn't been a nuclear reactor built in this country in 30 years. Cost in 2000 from vendors and the government for nuclear construction was about 1,500 to 2,000 a kilowatt of capacity. And then in, in that -- some utilities were actually quoting that figure as early as 2007, early 2007.

In mid-2007, the Keystone Center, a non-profit research organization with financial support from companies like Duke Energy, Southern Company and FP&L, in a June report concluded that the cost of new nuclear construction is about 4,000 a kilowatt of capacity. And most recently Moody's Investor Services estimated the cost at 6,000 kilowatt of capacity just several months ago. So while estimates vary somewhat, two things are very clear: Number one, the construction costs for nuclear are astronomical. And let me tell you exactly what I mean by that. Each ratepayer will be hit with a de facto surcharge of $4,000, and that's each ratepayer's share that -- in a likely scenario with an $18 billion construction cost, over 4.5 million ratepayers for early cost recovery. And I encourage you to do the math yourself. Also, costs are rising rapidly. They've doubled and tripled just in the last year. They've gone from $2,500 to $4,000 to $6,000 just in one year. Typically, FP&L has been candid about the cost of the two units. In the press which I gave you as Exhibit 1, FP&L admits that the units will cost from $12 billion to $18 billion. And the FPL quote in the press equates to about an $18 billion or, rather, about a 6,000 kilowatt per capacity construction cost.

Additionally, supply options, supply options can't be considered in a vacuum. Before you is a question of what has the applicant done to mitigate supply-side costs to consumers through energy efficiency measures? Now back in 1994, pursuant to your legislative mandate, under state and federal law you adopted the rate impact measure. Today, Florida -- as a cost-effective test for screening energy efficiency. Today, Florida is the only major state in the nation that still uses the rate impact measure test as the ultimate screen for judging the cost and effectiveness of energy efficiency measures, and that's represented in Exhibit 2, which is from the United States Environmental Protection Agency. You know, and that should raise a red flag for this Commission. Why don't other states use it as an exclusive screen? Other states have moved.

away from this screen because it doesn't capture all cost-effective energy efficiency. In fact, your own staff has reported to you that the rate impact measure screens out aggressive energy efficiency, and that's found in Exhibit 3. If you turn to Page 2 and Page 3, there's a bullet down there that says, "Programs with relatively high kilowatt reductions will result in higher revenue losses and reduce the potential to be cost-effective under RIM." And if you look at, turn the page to Page 3, bottom bullet, that bullet says, "Because revenues losses are not included, programs with relatively higher kilowatt reductions are more likely to be cost-effective." And that's what we're looking for is kilowatt reductions, and we're not getting it under the present screen that this Commission and Florida utilities are using. The RIM test is often referred to as the no losers test because it doesn't put upward pressure on rates. But what it should be referred to as is the no winners test since it precludes aggressive cost-effective energy efficiency. It's important to note that people pay bills, they don't pay rates. Other states have found there's a net benefit to increasing rates for aggressive energy efficiency because it mitigates and eliminates the need for new and more expensive supply-side construction.

CHAIRMAN CARTER: Thank you, Mr. Cavros. Thank you very much. I did give you additional time, and I'm sure we'll see you again in Tallahassee. Let's mark this Exhibit Number 6 for identification.

(Exhibit 6 marked for identification.)

You know the questions that Mr. Krasowski is asking. You've been paid to be here and --

MR. CAVROS: And, Chairman, if I might just add --

CHAIRMAN CARTER: I really want to make sure that we hear from the public.

MR. CAVROS: Absolutely. Because I'm not --

CHAIRMAN CARTER: I'm doing the best I can. I want to be as fair as I can. The more time we use for one person, the less time other citizens get an opportunity to be heard.

MR. CAVROS: Sure. I just wanted to, you know, to impress upon that energy efficiency is central to your questions by statute in 403.5194. Has the applicant performed adequate? Have they, have they attained reasonable, attainable energy efficiency, have they captured that? And I think you have --

CHAIRMAN CARTER: Okay. Let me do this. Let me impress upon you and everyone here, if this were not important to us as a Commission, we wouldn't have scheduled an extra meeting that's not required for us to be here. It's extremely important to us and we appreciate that. That's why we want to hear from as many people as possible. So Ms. Brubaker.

MS. BRUBAKER: The next speaker is Jen Rock.

MR. KRASOWSKI: Excuse me. Could we please have the courtesy of an answer to our question that was posed to everyone?

MR. CAVROS: I apologize. Yes.

CHAIRMAN CARTER: He said that he's been paid to be here.

MR. CAVROS: The answer would be no, and --

CHAIRMAN CARTER: You didn't say that?

MR. CAVROS: I'm sorry. Yes and no.

CHAIRMAN CARTER: Okay. I guess we'll take a yes and a no then.

Next we have -- Ms. Brubaker? Your name again, please.

Whereupon,

JENNIFER ROCK

was called as a witness on behalf of the Citizens of the State of Florida and, having been duly sworn, testified as follows:

DIRECT STATEMENT

MS. ROCK: Hi. My name is Jennifer Rock.

CHAIRMAN CARTER: Jennifer?

MS. ROCK: Yes.

CHAIRMAN CARTER: And your last name?

MS. ROCK: Rock, R-O-C-K.

CHAIRMAN CARTER: Thank you.

MS. ROCK: I have not been paid or compensated to be here, and I don't have anything to profit from the construction of this reactor.

CHAIRMAN CARTER: Excellent. Thank you. Thank you so kindly. Good to see young people here with us.

MS. ROCK: I live at 3201 183rd Street in Aventura. That's 33132. Nuclear power is not the answer to the electric needs of Florida in terms of adequate reliable power. If there is an emergency at the reactor and it needs to reduce or pause power reduction, the electric grid goes into crisis and often the only backup is generators. This actually happened at the Vermont Yankee reactor in Vernon, Vermont, when I was a resident in Vermont.

Nuclear power, although it does not rely on fossil fuel or natural gas specifically at the reactor, the mining and processing of uranium as well as the transportation of the uranium and depleted fuel rods, spent fuel rods is extremely energy intensive. Overall greenhouse gas emissions becomes equivalent to coal power.

When air pollution was first recognized as a problem, the response was to build taller smoke stacks. Now that we are concerned with climate change and dependence on fossil fuel we've become shortsighted enough to think that nuclear power is a clean alternative.

As FPL aims for the long-term stability, I ask them how to address the issue of nuclear waste and claim, and how they can claim there's any stability in a waste product that outdates any foreseeable future when a depleted uranium -- when depleted uranium reprocessing is also closely tied to nuclear weapons production. Who pays for the waste management? It is not the responsibility of FPL. It belongs to the federal government, and they are not holding up their commitments to waste management. 10,000 years is a very, very long time. Constructing a nuclear reactor is a huge commitment. And when we all realize it's not clean, safe or affordable, it will be too late. Nuclear power is dangerous, it is dirty, it is not sustainable and we do not want it.

Finally, I have one question for Mr. Nathan Skop. I'm not sure it's appropriate for me to ask questions, but I'd like to get it on the record either way.

CHAIRMAN CARTER: You can put your question on the record.

MS. ROCK: I read that you worked as a business manager for FPL Energy. And I'm wondering if you experience a conflict in interest as you try to decide what is best for the residents of Florida and have such a close relationship with FPL.

Thank you all so much for your time. Oh -- okay.

CHAIRMAN CARTER: Thank you. Before you go, do you remember the questions? Have you been sworn?

MR. KRASOWSKI: She did. She answered it.

MS. ROCK: I said it when I started.

CHAIRMAN CARTER: Okay. Good.

MS. ROCK: Oh, and I have one exhibit. This is a sign made by concerned citizens of the city. There are lots of people standing outside on the corner trying to spread information to folks who aren't inside. And I would like to enter it as an exhibit. Is that what it is?

CHAIRMAN CARTER: It's a bit unorthodox, but we'll take it.

MS. ROCK: Thank you so much.

MS. BRUBAKER: Demonstrative.

CHAIRMAN CARTER: Yeah. We'll just put that under demonstrative evidence.

MS. BRUBAKER: I believe that would be Number 7.

CHAIRMAN CARTER: This will be marked as Exhibit -- what's that number?

MS. BRUBAKER: Exhibit Number 7.

CHAIRMAN CARTER: Exhibit Number 7.

(Exhibit 7 marked for identification.)

MS. BRUBAKER: Next speaker is Steve McGonigle. Mr. McGonigle. Sorry. Thank you.

MR. McGONIGLE: I have a handout.

CHAIRMAN CARTER: And before he starts, this will be marked as Exhibit --

MS. BRUBAKER: Number 8.

CHAIRMAN CARTER: Exhibit 8. Exhibit 8.

(Exhibit 8 marked for identification.)

Whereupon,

STEVE McGONIGLE

was called as a witness on behalf of the Citizens of the State of Florida and, having been duly sworn, testified as follows:

DIRECT STATEMENT

MR. McGONIGLE: My name is Steve McGonigle, M-C-G-O-N-I-G-L-E. I reside at 2304 Northwest 54th Street in Tamarac. Good afternoon. My name is Steve McGonigle. I am an organizer and do political outreach with the Service Employees International Union, which is the largest security officer union in the United States representing approximately 50,000 private security officers and public safety personnel.

The SEIU would like to share with you its concerns regarding public safety and security at Turkey Point nuclear plant. Wackenhut Nuclear Services, part of Wackenhut Corporation, provides contract security at the Turkey Point nuclear plant. This is the same Wackenhut that was recently fired from guarding ten nuclear power plants operated by the country's largest provider of nuclear power, Exelon.

Exelon terminated its relationship with Wackenhut last fall at its Peach Bottom plant in Pennsylvania after the U.S. Nuclear Regulatory Commission confirmed that Wackenhut guards were inattentive to their duties on multiple occasions in the plant's ready room. This means they were asleep on the job. Videotape of sleeping guards confirmed the reports and was broadcast on CBS television in New York City.

The chief executive of Exelon told the Washington Post that they felt the incident with the sleeping guards was the last straw. But the same kind of incidents involving the same company have been found to have been going on right here at Turkey Point Nuclear Power Plant, and Wackenhut remains on the job there to this day.

As reported by the Miami Herald on October 30th, 2007, the U.S. Nuclear Regulatory Commission sent a factual summary of an investigation that had been initiated in 2006 regarding inattentive security officers at the Turkey Point Power Plant. The NRC found that between 2004 and 2006 Wackenhut security officers were found inattentive on several occasions. Five security officers admitted to being inattentive on separate occasions. One Wackenhut guard admitted to standing as a lookout for two other officers so they could be inattentive to duties without risk of getting caught. There is a disturbing multiyear repeat record of Wackenhut nuclear security officers being found inattentive, meaning asleep on the job at commercial nuclear sites.

CHAIRMAN CARTER: Mr. McGonigle, we're going to mark your Exhibit 8 for identification to enter into the record. We appreciate that. The questions would be, from Mr. Krasowski would be, one, are you being paid to be here?

MR. McGONIGLE: Yes, I'm on the clock.

CHAIRMAN CARTER: And, two, would you benefit either, whether the plant is built or not, your organization financially?

MR. McGONIGLE: No, I wouldn't. No, I wouldn't.

CHAIRMAN CARTER: Thank you so kindly. Ms. Brubaker.

MS. BRUBAKER: Eric Knowles. And the next three speakers are Julie Hill, Jaap Donath and Sharon Griemsman.

Whereupon,

ERIC KNOWLES

was called as a witness on behalf of the Citizens of the State of Florida and, having been duly sworn, testified as follows:

DIRECT STATEMENT

MR. KNOWLES: Mr. Chairman, Commissioners, my name is Eric Knowles. I reside at 4800 Garfield Street, Hollywood, Florida. I am the Chairman of the Miami-Dade Chamber of Commerce, and I am here speaking on behalf of the board that we are in favor of FP&L building a nuclear site. We are in support of their efforts that they do in the community, and we look forward to the jobs and the business opportunities that will be developed through this development. Thank you.

CHAIRMAN CARTER: Thank you very kindly. Thank you very kindly. Thank you so kindly. I sincerely appreciate your courtesy.

Ms. Brubaker.

MS. BRUBAKER: Julie Hill, please.

CHAIRMAN CARTER: Welcome, Ms. Hill. It is Hill, right, H-I-L-L?

Whereupon,

JULIE HILL

was called as a witness on behalf of the Citizens of the State of Florida and, having been duly sworn, testified as follows:

DIRECT STATEMENT

MS. HILL: Yeah. J-U-L-I-E H-I-L-L. Nice and boring. (Laughter.)

Thank you so much for coming down here. I'm here on behalf of Audubon of Florida. I am a paid employee as the Everglades Policy Associate. And I'm going to keep my comments very short and we will submit written comments for the record with more detail.

CHAIRMAN CARTER: Thank you so kindly.

MS. HILL: So, first of all, of course, we want to thank you for coming down here and giving us the opportunity to comment. Audubon of Florida feels that any determination of need for new energy generation using sources such as nuclear power should only occur once all of the possible methods for reducing demand, conserving energy and developing clean energy sources have been implemented. A full investment in energy efficiency, conservation and renewable energy should be the first priority to achieve fuel diversity in the State of Florida, rather than falling back on nuclear.

Nuclear power should not be considered until we have invested in all of these other options. And Audubon of Florida urges the Commission to adopt a strategy to provide for all options to reduce demand and conserve energy, including incentives for demand-side management, before determining the need for Turkey Point Units 6 and 7. Thank you.

CHAIRMAN CARTER: Thank you, Ms. Hill. And you've heard the questions that have been proposed to all the witnesses by Mr. Krasowski? Would you just respond for the record, please?

MS. HILL: Yeah. I am a paid employee of Audubon of Florida. I have no personal outcome in this economically and I have no knowledge of any economic benefit my organization would be getting from this project.

CHAIRMAN CARTER: Thank you so kindly. Ms. Brubaker, what I'd like to do now is Mr. Ehat stepped out when we called his name. E-H-A-T, I think. Is that the correct spelling? Come on, sir, and give us your two minutes. We're going to try to get everybody in. And thank you for being -- members, I apologize to you, but I really want to make sure that we hear from everybody.

Whereupon,

DON EHAT

was called as a witness on behalf of the Citizens of the State of Florida and, having been duly sworn, testified as follows:

DIRECT STATEMENT

MR. EHAT: I don't think I need two minutes. And I'm putting you in for sainthood for the way you have handled this event.

I was a management consultant and spent a lot of time in nuclear power plants, so I'm, I'm familiar with how, how professional and careful management, the management of nuclear power is exercised. However, it's important to realize that, that the waste is going to be a gift to our grandchildren and their grandchildren and their grandchildren forever. And I have not heard anyone give a good cost figure for what it's going to take to keep that waste safe, and I'm interested in hearing that. Thank you.

CHAIRMAN CARTER: Thank you so kindly. And as I said, is that we're having -- please don't leave yet. As I said earlier several times, that we have another hearing in Tallahassee which will also be a public hearing. Following from that we'll have a technical hearing, an evidentiary, and we ask that you please follow those proceedings. Those of you that can't be in Tallahassee, please watch us on the Internet or check with us or either the Office of Public Counsel. But we wanted to make sure that everyone is fully involved and fully informed. I've not been asking the questions.

Mr. Krasowski -- excuse me for messing up the name -- has been asking questions. So for the sake of time, could you just -- he was asking --

MR. EHAT: I've been available but nobody offered. (Laughter.)

CHAIRMAN CARTER: Thank you so kindly.

Ms. Brubaker.

MS. BRUBAKER: Dr. Donath, please.

Whereupon,

JAAP DONATH, Ph.D.

was called as a witness on behalf of the Citizens of the State of Florida and, having been duly sworn, testified as follows:

DIRECT STATEMENT

DR. DONATH: Good evening. My name is Jaap Donath. I'm with the Beacon Council here in Miami-Dade County. I'm located at 80 Southwest 8th Street, Miami 33130. My name is spelled J-A-A-P, last name, D-O-N-A-T-H.

The Beacon Council is the economic development organization for Miami-Dade County and we promote Miami as a place to do business. And as part of it we work with companies and try to bring them to Miami-Dade County either as expansion or a relocation into our community. And one of the issues that we face on a regular basis is the energy question. Especially the larger projects, they want to hear is there enough energy available for the things we want to do in Miami-Dade County?

And so for us as an organization and the growth we see in Miami-Dade County from the population and business side, it's important to have a reliable source of energy so that we can bring those companies in and grow our economy and create jobs for all the people in Miami-Dade County. So we support the efforts by FPL, and I'm open for any questions.

CHAIRMAN CARTER: Okay. Thank you so kindly, Mr. Donath. And --

DR. DONATH: Yes and yes.

CHAIRMAN CARTER: Thank you. Thank you very much. He said a yes and a yes to Mr. Krasowski's questions.

DR. DONATH: No and no.

CHAIRMAN CARTER: No and no? Was that no and no, Mr. Donath?

DR. DONATH: I don't get paid and I don't get a benefit out of --

CHAIRMAN CARTER: I'm sorry. Could you -- we're recording this for the court reporter.

DR. DONATH: I'm sorry. The answer is no and no.

CHAIRMAN CARTER: No and no to Mr. Krasowski's questions. Thank you so kindly.

Ms. Brubaker.

MS. BRUBAKER: The next speaker is Sharon Griemsman, and then the three after that will be Laura Sue Wilansky, Barry Johnson and Jeanne Jacobs.

Whereupon,

SHARON GRIEMSMAN

was called as a witness on behalf of the Citizens of the State of Florida and, having been duly sworn, testified as follows:

DIRECT STATEMENT

MS. GRIEMSMAN: Good evening. I'm Sharon Griemsman and I'm with -- that's G-R-I-E-M-S-M-A-N, and I'm a paid employee of United Way of Miami-Dade. I am here this evening and I wish to just say that I'm speaking on behalf of our CEO, Harve Mogul, who asked me to share our organization's statement regarding FP&L as a responsible community steward.

United Way shares a long-standing relationship of almost half a century with FP&L. FP&L's corporate commitment, leadership and compassion to help others is demonstrated through their partnership with United Way. FPL's community-centered mission lives within the organization, and that is shared and acted upon by its leaders, management and labor, its employees, contractors and vendors. Through the years FP&L has fostered an impressive track record that reads as a top-rated report card for the most philanthropic-minded entities in the country.

FP&L provides its annual United Way investments to our local communities through its volunteer service on our board committee -- our board and committees. Excuse me.

CHAIRMAN CARTER: Excuse me, Ms. Griemsman. Could you -- the court reporter is having trouble. Could I ask one of the gentlemen in the audience, would you be so courteous to step up and adjust the microphone?

MS. GRIEMSMAN: Is that better?

CHAIRMAN CARTER: Can you hear her now?

Ms. GRIEMSMAN: Yeah. That's better. I'm so sorry, dear.

CHAIRMAN CARTER: And also, Ms. Griemsman, your written comments, will you submit those to us as well?

MS. GRIEMSMAN: I certainly will. I'd be glad to.

CHAIRMAN CARTER: Continue, please.

MS. GRIEMSMAN: I'll just finish up because I know our time is short. But FP&L provides an annual commitment to our community through its investments through volunteer service advocacy by sharing information and supporting our ability to provide citizens with opportunities for human service benefits and community planning and development as it serves as a information resource for providing professional -- by providing their professional time and expertise for the development of solutions to meet our community's most urgent needs.

They also provide us with resources. They annually direct in excess of $2 million to our local community here in South Florida, and since 2000 have topped well over $10 million in community service investments here in South Florida. We are proud and honored to be here today to say that FP&L has proven that it is a responsible community-conscious partner. And thank you very much.

CHAIRMAN CARTER: Thank you so kindly. And do you remember the questions that Mr. Krasowski was asking?

MS. GRIEMSMAN: Yes. I am a paid employee, but we will not benefit either for -- from or from not.

CHAIRMAN CARTER: Okay. Thank you. And do you have written comments?

MS. GRIEMSMAN: Yes, I do.

CHAIRMAN CARTER: Thank you.

MS. BRUBAKER: And, Chairman, by my count that would be identified as Exhibit Number 9.

CHAIRMAN CARTER: Exhibit Number 9.

(Exhibit 9 marked for identification.)

MS. BRUBAKER: The next speaker is Laura Sue Wilansky, please.

CHAIRMAN CARTER: I'm having trouble hearing you.

MS. BRUBAKER: I'm sorry. Laura Sue Wilansky.

CHAIRMAN CARTER: Laura Sue, you've got to help me with the spelling.

MS. WILANSKY: Absolutely. Thanks.

CHAIRMAN CARTER: Thank you for being here.

Whereupon,

LAURA SUE WILANSKY

was called as a witness on behalf of the Citizens of the State

of Florida and, having been duly sworn, testified as follows:

DIRECT STATEMENT

MS. WILANSKY: Thank you very much. Thank you to all of you for being here. My name is Laura Sue, it's W-I-L-A-N-S-K-Y. I'm also widely known as the Silver Nightingale. I'm a musician. A lot of people know me by that name, not the other name. This is my first opportunity to attend a Public Service Commission hearing or to speak. And I wanted to let you know that today is my birthday, and this was the best thing that I felt that I could do on my birthday was to come here today. So you know this is very important to me.

COMMISSIONER ARGENZIANO: Happy birthday.

CHAIRMAN CARTER: Happy birthday.

MS. WILANSKY: Thank you. Thank you very much. I'm also an FP&L customer, and I've been an environmental activist for about 40 years. My academic training and professional background include extensive work with computers. And it has become clear to me through this work that neither computers, people or physical materials are or can be made 100 percent infallible, and these are the elements of which nuclear plants are composed. So there is no way to guarantee at any nuclear plant that there will never be some kind of accident. And nuclear power is the only form of energy generation in which even a small accident could literally mean the end of life on earth. That's my main point.

FP&L and other utilities are now trying to sell nuclear energy as clean, green energy as other people have discussed, but there is no such thing as clean, safe, affordable nuclear power. If the true costs of nuclear waste disposal are factored into the equation, it's clear that nuclear power is not cheap. The costs of an accident are impossible to calculate and too high for us to bear. One example is the countless children who are growing up or not growing up with severe heart defects, a condition that has come to be known as Chernobyl heart. If nuclear power was truly affordable and viable, utility companies would not find it impossible to insure their plants through normal commercial channels and would not have recently gone to Congress to obtain billions of dollars of loan guarantees at taxpayer expense.

The purpose of this hearing is to examine whether there is a need for this expansion. If we in Florida take full advantage of the abundant solar resource that we have available here and maximize our conservation, there will be no need for this expansion. It's time for a Manhattan project for renewable energy, not for further huge investments in this failed and extremely dangerous energy technology. And I'd like to enter or give you materials. This is a song I wrote about 30 years again called the No Nukes Swing, which discusses my --

CHAIRMAN CARTER: The title of it again.

MS. WILANSKY: The No Nukes Swing.

CHAIRMAN CARTER: The No Nukes Swing.

MS. WILANSKY: It discusses my feeling about nuclear plants and nuclear weapons. And I'm also going to give you a card with a link to my personal nuclear free zone, which has links to many wonderful organizations, some of which are represented here. It's a great place to do your own research. I think everyone should educate themselves. Thank you so much for the opportunity to speak.

CHAIRMAN CARTER: Thank you from the Silver Nightingale. This will be Exhibit Number 10.

MS. BRUBAKER: That's correct.

(Exhibit 10 marked for identification.)

MS. WILANSKY: And your questions: I'm not being paid to be here. In fact, I took a day off work to be here. I have no financial stake unless this song becomes famous and sells lots of copies, in which case I'll probably donate the profits to one of these great organizations. (Laughter.)

CHAIRMAN CARTER: If you become famous, just remember, you know, you heard it here first.

MS. WILANSKY: Yeah. That would be great.

CHAIRMAN CARTER: I am also a lawyer. No.

Let me just say as Mr. Ballinger collects that and brings it forward -- and, Mr. Ballinger, I need to see you. Let me just say to my fellow Commissioners how much I appreciate you yielding your time for questions so that we can hear from all of the public, and I sincerely appreciate that from the depths of my heart. It is our goal to hear from everyone that came today, so we're trying to do that, and thank you so kindly.

COMMISSIONER ARGENZIANO: Thank you.

CHAIRMAN CARTER: Ms. Brubaker.

MS. BRUBAKER: The next speaker is Barry Johnson.

Whereupon,

BARRY JOHNSON

was called as a witness on behalf of the Citizens of the State of Florida and, having been duly sworn, testified as follows:

DIRECT STATEMENT

MR. JOHNSON: Good evening. Mr. Chairman, members of the Commission and staff, welcome to Miami. It's great to have you here. My name is Barry Johnson. I'm the President and Chief Executive Officer of the Greater Miami Chamber of Commerce, 1601 Biscayne Boulevard. And I will be brief, hopefully as brief as Eric Knowles.

I'm here basically to support FP&L because of three reasons, one of which is energy, and we're running out of energy in Miami. If you've come here from up north, you probably found a different Miami when you landed than you have seen in, in years prior because we're growing very, very quickly here. We need energy and we need a lot of energy.

As a matter of fact, right now Florida Power & Light is exporting or, excuse me, importing into South Florida 40 percent of all the energy because it cannot meet the needs of Miami today. So we have an energy crisis on our hands that we have to solve. We also have a very safe nuclear power plant in south Dade County that's been very efficient, operating for 35 years and with a very experienced company at the helm, withstanding Hurricane Andrew, as we heard earlier. We've already built that, the ratepayers have already built that. It just makes sense to expand on that because it is probably the most logical and cost-effective way to meet the energy needs of our community.

Second is jobs. We are -- we do not have big corporations based in South Florida. We are a small business town. Jobs are very important to us and the growth of jobs. Building in addition to the power plant here will bring good quality construction jobs and, following that, supervisory jobs from FP&L to sustain the job growth that we need in this community.

Finally is trust. We have a company that we trust. It's been a solid citizen of our community. It's been a member of our chamber for more than 60 years. They're very active in support of what's good about South Florida and trying to make it a better place to live, work and play. And as you probably know, when the Governor had his Going Green Symposium, FP&L was right there. They're recognized nationally as one of the best power companies in America and they're a company with a track record to be trusted. So the chamber supports this. I'm pleased to support it.

I'm not being paid to be here. I am a paid advocate. And will I, will I benefit from this? Frankly, every resident of Miami-Dade County will benefit with this power plant because we need the energy here. Thank you very much.

CHAIRMAN CARTER: Thank you so kindly for being here. Ms. Brubaker.

MS. BRUBAKER: The next speaker is Jeanne Jacobs, to be followed by Joe Chi, Ana Rodriguez and Ed Redlich.

Whereupon,

JEANNE JACOBS

was called as a witness on behalf of the Citizens of the State of Florida and, having been duly sworn, testified as follows:

DIRECT STATEMENT

MS. JACOBS: Mr. Chair, members of the Commission, welcome to Miami-Dade College again, and we're certainly glad to have you here. I am Jeanne Jacobs, the Campus President of Miami-Dade College, Homestead Campus. And I'm pleased to speak in support of FP&L and our ongoing partnership specifically with Turkey Point as we have been able to establish a professional training pipeline. And that pipeline supports the economic growth in our local community and it also helps develop and retain local talent in Miami-Dade County.

We've had a successful, long history with FP&L and we've recognized that this industry has a growing demand for highly skilled workers and that it is facing work force shortages. So together we've been able to collaborate and develop an associate's degree in electrical power technology. And I would say to you that we have in that program a very diverse group of incumbent workers and students. It's been very successful. And when these students leave this program, they're qualified for positions in nuclear and other power facilities.

Finally I'd say to you that FP&L has been in the Homestead community for over 30 years. For 17 of those 30 years FP&L and Miami-Dade College, Homestead Campus, have been very good neighbors. We certainly will continue our collaboration. We believe we enrich or communities and we support this effort. Thank you.

CHAIRMAN CARTER: Excuse me, Madam President. Thank you so kindly for your hospitality, by the way, with your colleague here at this wonderful and beautiful facility. The questions that have been asked today were were you being paid to be here and would you benefit from the plant being here? That was from one of the parties.

MS. JACOBS: And my answer would be no and no.

CHAIRMAN CARTER: Thank you so very kindly. Ms. Brubaker.

MS. BRUBAKER: Joe Chi, please.

Whereupon,

JOE CHI

was called as a witness on behalf of the Citizens of the State of Florida and, having been duly sworn, testified as follows:

DIRECT STATEMENT

MR. CHI: Hello there, Commission members. It's been exhausting, to say the least. You must be really feeling it. I'm here representing -- I'm a private businessman, Maxim's Import Corporation.

CHAIRMAN CARTER: Please tell us your name.

MR. CHI: And my name is Joe Chi. I reside at 8545 --

CHAIRMAN CARTER: Could you spell your last name, sir?

MR. CHI: C-H-I. Yeah.

CHAIRMAN CARTER: C-H-I. Thank you. Okay.

MR. CHI: 8545 Southwest 120th Street. And I'm also here representing Camacol, the Latin Chamber of Commerce, as the Secretary of the Board. We're in full support of this petition for FP&L to build the nuclear power plant at Turkey Point down in the, in the southern part of Miami. We believe that this will have enormous and repercussive benefits for the whole community, and not only that, but also for the future of our children.

Before I leave I would like to say a few personal comments on how I feel about this. My point is that we need to embrace every form of alternative energy as they become feasible, solar, wind, geothermal, ocean current, nuclear, as long as we carefully institute all the necessary precautions. FP&L has an excellent record in this regard. We also need to make sure that the future energy needs of our generations are met. We must be careful not to implement so-called conservation schemes that actually turn out to be counterproductive in the long run.

I'll give you an example. California, I admit, has been a pioneer in many of these schemes, some of which have resulted in unintended consequences like massive power outages out west recently.

We support the progress of this great nation and responsible companies like FP&L who have provided the means for this progress. We should reasonably incorporate all the options on the table, including the nuclear option. I came here believing that your job, and I'm sure it is, is to protect the interests and to ensure that resources are available for the public for the future. If they are not, we will all be hearing from a much larger base of concerned citizens, the millions of FP&L consumers during possible power outages and failures.

To conclude, I would like to thank all of our concerned citizens and organizations today for coming here today. Sure, there will be technical difficulties, as there always is, but I would like you not to succumb to paralysis of analysis. Work with FP&L to solve these issues. FP&L is a responsible corporate citizen, not a corporate monster plotting our collective demise. Thank you very much.

CHAIRMAN CARTER: Thank you. And you remember the questions that were asked?

MR. CHI: No and no.

CHAIRMAN CARTER: And Mr. Krasowski asked the questions of whether or not you've been paid to be here today. Would you please stand before the mike so we can get it on the record?

MR. CHI: No, I was not paid to be here. Actually I'm paying to be here -- (Laughter.)

CHAIRMAN CARTER: And I think the other question, and I think the other question he asked was --

MR. CHI -- in more ways than one.

CHAIRMAN CARTER: Would you benefit in any way whether or not the plant is built?

MR. CHI: Hopefully through lower energy costs for myself and everybody involved.

CHAIRMAN CARTER: Thank you so kindly.

MR. CHI: Thank you.

CHAIRMAN CARTER: Ms. Brubaker.

MS. BRUBAKER: The next speaker is Ana Rodriguez.

CHAIRMAN CARTER: You got cold, didn't you?

MS. RODRIGUEZ: Hi. Yes, I did.

Whereupon,

ANA RODRIGUEZ

was called as a witness on behalf of the Citizens of the State of Florida and, having been duly sworn, testified as follows:

DIRECT STATEMENT

MS. RODRIGUEZ: My name is Ana Rodriguez. I'm an FP&L customer from West Palm Beach.

CHAIRMAN CARTER: Would you mind spelling your last name for us, please?.

MS. RODRIGUEZ: Uh-huh. R-O-D-R-I-G-U-E-Z. Do you need my address? It's written on the signup sheet.

CHAIRMAN CARTER: Okay. Thank you.

MS. RODRIGUEZ: Okay. Wonderful. All right. No carbon emissions and greenhouse gases is not equivalent to toxic -- not equivalent to clean energy when it is traded in for toxic emissions and radioactive waste. It is definitely not clean and it is definitely not the cleanest. Sustainable renewable technology is available right now and in use. Florida deserves it as well as its remaining natural areas.

One of the Commissioners was asking earlier whether some of the people in the audience had been to gatherings or meetings where people had shown discontent for this project or disapproval for it. I have been to many, and there is many concerned citizens who definitely disapprove of nuclear power in Florida. The existing and definitely additional degradation to Biscayne National Park and other parks which FPL has permits pending to degrade all over Florida.

I do not believe that FPL is a good neighbor. I think that if people test the teeth in their infants and their elderly, they will find that there's some substantial evidence that they're not that good of a neighbor, especially not anywhere near nuclear reactors. There have been many, many scientific studies made to that effect.

Which brings me to the question of information, which is related to what I was saying earlier about no negative public comments at meetings, especially business-oriented meetings. As we know, FPL does have --

CHAIRMAN CARTER: No -- I didn't hear you. No negative?

MS. RODRIGUEZ: No negative comments or comments of disapproval from the public.

CHAIRMAN CARTER: Okay. Thank you.

MS. RODRIGUEZ: I have been to a lot of FPL meetings and I find that the information is coming mostly from FPL, not very, not very many scientists are represented in these meetings and other studies which are very, from credible sources, from scientists and from environmentalists. And I believe that, you know, FPL tells its partners that they have the cleanest, the safest and the most affordable energy, and they have them completely star struck with these ideas of how they're going to be the cleanest in the future. And they speak of the future and they speak of renewable energy and sustainable energy and how they're moving that direction in the future. Meanwhile, they have permits all over Florida, and especially extremely close to national -- to natural wildlife refuges and national parks, which I'm actually wondering if they have, like, something against endangered species and threatened species. Are they just trying to put them out of their misery or something? Apparently so because all their plants are really, really close mostly to natural areas, the very few remaining ones.

I don't know exactly where the business community is getting their information, but I have suspicion that they're getting most of their information from FPL representatives and their positive PR lectures. I also know that a lot of these people have partnerships with FPL. Unfortunately, a lot of even the environmentalist community has been given -- I don't know a really polite way of saying it -- for lack of a better word, I'm a little bit nervous, I'm going to say that, you know, FPL buys off a lot of people. They have given even the Arthur R. Marshall Wildlife Foundation money. And then coincidentally a few days later the Arthur R. Marshall

Foundation sends their representatives to hearings where we're supposed to be discussing permits for FPL, and they say, "I have nothing to profit from this power plant, I have nothing to profit from this, but FPL is a wonderful partner to us and has done a lot for us." I have nothing personally against that. I understand the business world and I know that it's necessary. I just feel that it's a little bit unjust the way that things are working. And especially I would be very wary in regards to where people are getting their information.

I have actually been told by Commissioner Santamaria up in Palm Beach County whenever discussing a FPL permit that he was disappointed that the public did not bring enough scientific information to back up their disapproval of the power plant. I don't think that the public needs to take time off of work and to come and inform commissioners on why not to give permits to FPL. These people are getting paid to be here to further profit from their permits. We're taking time off work. We're not professionals, we're not scientists, we're not nuclear physicists, and we have to come over here and supposedly make this whole argument on what there is already books and major scientific and environmentalist studies to defend, which is that nuclear power is not good.

CHAIRMAN CARTER: Thank you so kindly. And I think by your statement the answer to Mr. Krasowski's questions would be --

MS. RODRIGUEZ: I do not get paid for anything, and I have much heartache coming from the struggles against FPL's projects and permits all around my very treasured wildlife refuges.

CHAIRMAN CARTER: Thank you for coming. And let me just say this on behalf of the Commission is what we're doing now. This is a public -- all of our decisions allow us to hear from the public. We'll be in an evidentiary perspective with adversaries, with other parties and all like that, but prior to making a decision as a Commission we go out and get information from the public. It is important to us. This is the people's government. I'm sure you heard the Governor said that, you know, it's the people's government. That's not just a slogan, that's the way it is. And that's why it was important to us to come down. I mean, we're required to do one hearing in Tallahassee, but we thought enough about the people here -- I realize it's a hardship to go from your job, so we were able, thanks to Senator Villalobos and the wonderful people here at Miami-Dade, to open the doors to us and to be able to move the time around to hear from wonderful people like yourself.

MS. RODRIGUEZ: I have to praise you guys. This is definitely one of the fairest commissioner hearings I have been to. I will definitely say that.

The one thing that I would maybe suggest, and I don't know if this is a good hearing to suggest it, but I have been to plenty, is that I always hear a lot of information coming from FPL representatives but I don't see another side. Maybe if it could be more inclusive in regards to a scientist also speaking and saying what their side of it is.

CHAIRMAN CARTER: Let me answer that for you, is that this is the public hearing --

MS. RODRIGUEZ: Somebody professional other than the public.

CHAIRMAN CARTER: This is the public hearing portion of it. The other phase I mentioned about in Tallahassee will be an evidentiary. They'll have scientists coming in taking oaths and they'll have scientists, engineers and all people like that under oath. The evidentiary hearing is something different. But what we want to make sure we do is hear from the public. We sincerely appreciate you being here. Thank you so kindly. You've already answered Mr. Krasowski's questions?

MS. RODRIGUEZ: Yeah. No and no, I will definitely not profit from further --

CHAIRMAN CARTER: Okay. Ms. Brubaker.

MS. BRUBAKER: The next speaker is Ed Redlick or Redlich. The next three will be Richard White, Miguel Fuentes and Cathy Gilbert.

Whereupon,

ED REDLICH

was called as a witness on behalf of the Citizens of the State

of Florida and, having been duly sworn, testified as follows:

DIRECT STATEMENT

MR. REDLICH: Good evening and happy new year. My name is Edward Redlich, R-E-D-L-I-C-H. My address is 8725 Northwest 18 Terrace, and that's in Miami.

I am the current Chairman of the Board of Vision Council. It's a non-profit organization. Basically it's made up of members of the South Dade business leaders in the community. Some of our members are the City of Homestead and Chevrolet, for example. If you're familiar with Miami-Dade County's Beacon Council, it's very similar to that, only we're a lot smaller and we just focus on the geographic area of South Dade.

Our goal is economic development for our community, and secondly it's job creation. The City of Homestead, according to the U.S. Census Bureau, is the fastest, if not one of the fastest growing cities in the United States of America with a population of 50,000 people or more. We believe at the Vision Council that the commercial development is soon to follow. We are seeing growth in the office, retail and industrial manufacturing businesses right now. So on behalf of Vision Council, our members, the Board of Directors, we are supporting the FPL proposal for clean source energy, reliable and affordable power. And by the way, I'm here of my volition. I don't expect compensation now or in the future. Thank you.

CHAIRMAN CARTER: Thank you so kindly. Ms. Brubaker.

MS. BRUBAKER: Richard White. Is Mr. White in attendance? Miguel Fuentes.

Whereupon,

MIGUEL FUENTES

was called as a witness on behalf of the Citizens of the State of Florida and, having been duly sworn, testified as follows:

DIRECT STATEMENT

MR. FUENTES: Good evening. Miguel Fuentes, 295 West 79th Place, Hialeah, Florida. I am the Political Director for the Florida Carpenter's Regional Council, a labor organization that is in strong support of the expansion at Turkey Point. We have 4,000 members statewide, 1,200 in the Miami-Dade area, many of which have worked at the Turkey Point plant doing regular maintenance and shutdowns and things like that. Been there 30 years and we haven't had one incident yet where one of our guys hasn't been safe. So I'm pretty confident that it's safe there and they follow all the precautions needed to make sure that not only the folks around the surrounding power plant but even inside are healthy and well.

Florida Power & Light has been a great partner and a good corporate citizen. You probably don't expect hearing that from a labor organization. But I tell you what, any time we've had a discussion or a dispute or even any disagreement, we got down on the table, we talked about it, we figured it out and moved on. During the hurricane seasons when their guys are out restoring power for everybody, leaving their homes unattended, our guys would go out and take care of their homes. So we work together for the community to make sure things are flowing. Nothing is perfect. I understand that. I think the rest of the world knows that. I hear about planes and security guards and all sorts of things that happen. But those are unintended consequences that we won't even know will happen or not happen. So long as from their record, and their history has proven that they are responsible, they're going to make sure that some of the things that they can control are in place so it's safe, I'm confident that they will do that, and their history proves what they will do in the future. I support it, my members support it. And the only ones who are paying me are the members I represent. I don't expect to gain anything personally from it. If they have a better job and the people in the community have a job behind it with benefits, healthcare, things that are very hard to come by, I'm all for the project. Thank you very much. I don't have stock in the company either.

CHAIRMAN CARTER: Thank you so kindly. Ms. Brubaker.

MS. BRUBAKER: Cathy Gilbert. Following Ms. Gilbert, Rebecca Wood, Eric Pontaleon and Fiz Heintz.

Whereupon,

CATHY GILBERT

was called as a witness on behalf of the Citizens of the State

of Florida and, having been duly sworn, testified as follows:

DIRECT STATEMENT

MS. GILBERT: Hello. My name is Cathy Gilbert, G-I-L-B-E-R-T. I'm at 2301 Northeast 6th Avenue, Miami.

CHAIRMAN CARTER: Excuse me. Would you mind -- could you put it just a little closer to you there?

MS. GILBERT: Is that better?

CHAIRMAN CARTER: Yes, ma'am. I hope you don't mind. I'm going to ask you to start over, please.

MS. GILBERT: Yes. My name is Cathy Gilbert, G-I-L-B-E-R-T. I live here in Miami. I'm at 2301 Northeast 6th Avenue. I'm also with the Green Party of Florida and will present a statement, a written statement from my, from the Green Party of Florida.

I just wanted to also -- I need a double pair here. I just wanted to mention a few other things besides the statement here. The nuclear industry does spend billions promoting itself as a clean and safe and cheap energy source. None of these, I believe, are true. And if we even just look at just the operational phase and not at the toxic phases before or after, the toxic emissions that are released on a daily basis cause all cancers and other disease.

There's a study that shows, there's a baby tooth study that somebody, Ana Rodriguez referred to earlier, I think, or alluded to. They collect and test baby teeth to show the strontium levels, the strontium-90 in baby teeth. And it shows that South Florida, I think, has the highest levels in that study. So we here are definitely contaminated by the radiation emissions.

There are, there are also studies showing that the rates of cancer, asthma, baby mortality rates and so forth can echo -- some of these diseases will show up much sooner after emission rates peak or, you know, spike and so forth. But you can see almost like an echo chart. I've seen them especially with asthma where babies -- low weight rates and so forth, you'll show an echo of the emission rates, showing a close correlation there.

I'm just going to read briefly the statement that I, the private statement here. The Green Party of Florida and Miami-Dade Green Party strongly oppose the construction of new nuclear power plants in Florida, and we call upon the Public Service Commission in Florida to reject proposals for new reactors at Turkey Point and other Florida sites.

There is one more thing I wanted to mention before that. Just the fact that nuclear power, nuclear power plants are dependent on the grid to, to keep the cooling going on. And so here on the coastline they were vulnerable to hurricanes having power outages and so forth. If it's not able -- if it -- if we go as much as 45 minutes without power supported cooling going on we go into meltdown. So, you know, we're particularly, I think, vulnerable here on the coast of Florida to continue with this.

In the context of the, of the escalating global climate crisis it is imperative that all public funds invested in the production of electrical power be focused exclusively on clean, renewable energy production and sustainable solutions. Our commitment to the security and survival of not only our own society but the global human community obligates us to reject false solutions such as the nuclear power option and instead work together to end dependence on the polluting energy industries that endanger the health and well-being of all life on the planet.

CHAIRMAN CARTER: Ms. Gilbert?

MS. GILBERT: Yes.

CHAIRMAN CARTER: You're going to actually give us that?

MS. GILBERT: Yes, I'll give that to you.

CHAIRMAN CARTER: I would sincerely appreciate that, and we thank you for your participation. Mr. Ballinger will come down and we'll mark that. What's that exhibit number now?

MS. BRUBAKER: Exhibit Number 11.

MS. GILBERT: Okay. Very good.

CHAIRMAN CARTER: Exhibit Number 11.

(Exhibit 11 marked for identification.)

MS. GILBERT: And I have -- I'm not funded in any way and I am not going to see any benefit.

CHAIRMAN CARTER: Thank you so very kindly for participating.

Ms. Brubaker.

MS. BRUBAKER: Rebecca Wood, please. Is Ms. Wood present? The next speaker would be Eric Pantaleon.

Whereupon,

ERIC PANTALEON, M.D.

was called as a witness on behalf of the Citizens of the State of Florida and, having been duly sworn, testified as follows:

DIRECT STATEMENT

DR. PANTALEON: Good evening to all of you. My name is Eric Pantaleon, P-A-N-T-A-L-E-O-N. I'm a licensed physician with the State of Florida. I live at 4505 Southwest 152nd Avenue in Miramar, 33027. I am the Director of the Florida Urgent Care Centers. We right now have three centers. Florida Power & Light has been instrumental in assisting us being as efficient as possible in the use of energy in all aspects, as well as I've been doing the same thing in my home. I was raised in the Dominican Republic where we paid ten times for the kilowatt that we pay here. We don't have enough energy. We have a lot of power outages. We have to be very efficient. And, as a matter of fact, among my peers and my neighbors I am the one with the lowest bill from FP&L. But there is a limit to how much we can save, there's a limit to how much we can do nowadays.

You know, I used to play with little plastic swords. My kids have computers and we keep using energy no matter what. This is not maybe the best situation, but you know what, we don't have yet all the tools to have all the renewable energy that we wish we had, and probably right now still nuclear is the safe way to go.

France uses 70 percent or more of their energy from nuclear plants. I've seen in Holland all the windmills, not the windmills, the wind turbines. They have a lot of energy. But that's not always feasible everywhere. We have to maximize. I understand Florida Power & Light is doing that in terms of getting more wind turbines and trying to get more solar, solar photovoltaic cells. But that's going to take some time and I don't see in the near term how we're going to meet our needs. And we keep growing unfortunately. It may not be the best solution, but like in medicine, the best treatment for a patient sometimes is not feasible. And we've got to really put in a balance and see what is better for ourselves and actually for our future generations, because I have two adolescents. Thank you very much.

CHAIRMAN CARTER: Thank you so kindly.

DR. PANTALEON: I have not been paid, I have not been coerced, and I won't profit from anything.

CHAIRMAN CARTER: Thank you so very, very much.

DR. PANTALEON: You have a good one.

CHAIRMAN CARTER: Ms. Brubaker.

MS. BRUBAKER: The next speaker is Fiz Heintz. Is Mr. Heintz present to speak? Then the next speaker would be Bobbie Messer, to be followed by Suzette Rice and Steve Showen.

Whereupon,

BOBBIE MESSER

was called as a witness on behalf of the Citizens of the State of Florida and, having been duly sworn, testified as follows:

DIRECT STATEMENT

MR. MESSER: Excuse me. I'm diabetic. Bobbie Messer, M-E-S-S-E-R. My address is 1885 Southeast 13th Street in Homestead. In fact, I think I'm the only Homestead resident that spoke or going to speak.

I'm retired.

CHAIRMAN CARTER: Do you need a minute? Do you need a minute?

MR. MESSER: No, sir. I'm going to do it and then I'm going to get out and get something to eat.

CHAIRMAN CARTER: All right. Yes, sir.

MR. MESSER: Just a couple of things real fast. I didn't find out about this happening -- I'm sure FPL, you know, published it to the, the governments in the county, but my city didn't notify me, there were no town meetings. I don't know about Florida City or the other municipality, I think it was

South Miami, the government officials were here and said they thrashed it around. But the citizens of those communities I don't think were given the opportunity to voice their opinions. That should be brought to the forefront, I would say.

And as much as FPL -- they're doing a good job. In fact, my light bill, believe it or not, is sometimes less than my water bill. So you're doing a good job. And that brings me to the water. I overheard that there's between 70 and 90 million gallons required to cool these reactors. Well, you know, I'm six miles, seven miles from it, and FPL is a good neighbor. But I'm concerned about where that 90 million gallons plus or minus is coming from. Will it affect me as a resident of Homestead, South Florida, will it affect the aquifer? I'm not a PETA person, I'm not an environmentalist, so I don't know what the impact, you know, the environmental impact, nor do I understand what the economic impact will be to South Florida, but I'm concerned about those questions and I would hope this Commission would also be concerned for it. But that's my biggest concern. No. No. Have a good evening.

CHAIRMAN CARTER: Thank you so very kindly. Please get something to eat right away.

MS. BRUBAKER: Suzette Rice.

Whereupon,

SUZETTE RICE

was called as a witness on behalf of the Citizens of the State

of Florida and, having been duly sworn, testified as follows:

DIRECT STATEMENT

MS. RICE: Hi. I think I'm the other one from South Dade. My name is Suzette Rice. I live at 7860 Southwest 181 Terrace. I'm really pleased that you all came down for this hearing. I'm sorry you couldn't be outside to enjoy the weather. We had a week of bad weather and now we had a couple of days of great and here we are.

I just wanted to point out, and I believe Mr. Messer did, the most important element of this entire element isn't here and that's the people. The real folks aren't here. You're 40, you're about 40 miles from the power plant. The area of our heaviest growth in this county has been directly within the ten-mile circle, radius from the plant -- actually to the west since you've got water on the other side. I'm very concerned about it. I have followed this since 2001 when they had their relicensing hearings. I just -- I'm very disappointed that the education isn't there.

And FP&L has been very good to the community. I'm friends with, with Raymond, who is their liaison in South Dade, he's always there and he's always willing, but that's not the problem. The problem is there's been absolutely no public debate, there's been no public education. And I don't necessarily think it's FP&L's responsibility because they are a business, but the community is going to be blindsided because they don't know, and that was my thing.

I don't think we're ready for two more plants. They publish a pamphlet and I'm imagining you guys will see it, if you haven't, of security and how, how to take care of yourself if the plant goes wrong. I will tell you that most people don't read it. They always mail it to us. I have one for every year since I've lived in my house. Most people don't read it. Most people wouldn't know where to find the tablets. If you took this, we have a police station -- actually now we have, I guess, three or four because of the cities. If you took this guide and you asked a street officer where you could do a pickup in case of a nuclear accident, they have no clue. I promise you. My son is a police officer. I know. But he's not, he's not down here, so -- and he's too young.

But, anyway, it's a concern because I'm a community person and I have worked in the community for 15 years and it's scary. It's scary. Because I live there -- and I noticed, by the way, as I was looking at the little circles that FP&L has on their map, they've conveniently hopped it over -- 184th used to be the cutoff. They're now including my blocks, which are two over, so I'm now officially in the radius. But the thing is we're not ready. We're not educated.

If you listen to the, the monthly testing of their facilities -- I don't know if you've ever heard the testing of the speakers, the warning system. If you've ever gone to

McDonald's on a bad day, that's what those speakers sound like. If you sit in your house, and I have one, I guess, that's about a block and a half from my house, it sounds like somebody has swallowed a microphone. You cannot understand it. You have sirens, you have no idea why. And I know that with the people moving into this community, and, again, that's where our heaviest population growth is, if they haven't read the book, they have no idea. And, you know, my neighborhood after Hurricane Andrew is probably 90 percent, I will guarantee you 90 percent new residents, and they've never had a homeowners association meeting discussing the power plant. So that's all I'm going to say.

CHAIRMAN CARTER: One second.

COMMISSIONER ARGENZIANO: I'm sorry. I don't mean to ask you a question and prolong things but I have to. Because I live near a nuclear power plant also, the Crystal River plant. And I've got to be honest with you, when the company sends me something to read, I read it. So I don't know the point you're trying to make. If the company is sending you something and the people aren't reading it, I don't know what else the company could do. Maybe the homeowners association should make a meeting and say we've got to learn about what the siren means. I know every Friday at 12:00 when I hear that siren, I know it's a test. I know if I hear that siren some other time, I know I've got to take evacuation methods or do something.

And I just maybe, maybe -- and I understand. Maybe FP&L could help with the homeowners association, I know they have outreach programs, to maybe get people to understand it is important to read those things.

MS. RICE: On a grassroots levels -- and I have just spent nine, nine years working in the political system as a community liaison. These people in our communities don't know. And I say that -- and I will go out, I promise you, from today and I will start asking questions and I will submit them to you in the future. But we just -- I hate to say we're clueless, but I just, I just, I don't have the confidence, okay, that we're, as a community that we would know what to do. We wouldn't.

COMMISSIONER ARGENZIANO: Okay. Thank you.

CHAIRMAN CARTER: Thank you so kindly.

MS. RICE: And one last thing, and this is just coincidental. When I was reading up, I was surfing the net, I came across a news article from Saturday, January 5th, 2008. It's from the Tehran Times. These people in Iran have got on their front page of their website the story of our Wackenhut guards here in Miami, and personally that doesn't make me feel very secure. Okay. And I'll give you the copies.

CHAIRMAN CARTER: Before you go, Ms. Rice.

MS. RICE: No and no.

CHAIRMAN CARTER: Thank you so kindly. Thank you, Mr. Ballinger.

MS. BRUBAKER: And that would put us at Exhibit 12, Chairman.

CHAIRMAN CARTER: Exhibit 12.

(Exhibit 12 marked for identification.)

MS. BRUBAKER: The next speaker I have is Steve Showen, and I would note that that is the last speaker I have signed up to speak at this time.

CHAIRMAN CARTER: And before we do that, Steve, Steve, would you bear with us for a second, please?

MR. SHOWEN: Sure.

CHAIRMAN CARTER: Hold on before you go, Steve.

MR. SHOWEN: Yes, I will.

CHAIRMAN CARTER: I need like one second. Hold on one second here.

(Pause.)

What I'm trying to do is that there were a couple of people that when we went through that were not in the room, and I know that we've got to go, but if at all possible I want to get them. So those three names -- Steve, before you start, we want to call their names in case they're back in the room so we can hear from them. If at all possible, I want to hear from everyone. So Ms. Brubaker.

MS. BRUBAKER: Shall I go ahead and call them?

CHAIRMAN CARTER: Yes, ma'am.

MS. BRUBAKER: Renny Ramos. Ramos.

CHAIRMAN CARTER: And these people will be following Steve as he finishes.

MS. BRUBAKER: Richard White. Richard White. And Rebecca Wood.

CHAIRMAN CARTER: Okay. Steve, you're recognized.

Whereupon,

STEVE SHOWEN

was called as a witness on behalf of the Citizens of the State of Florida and, having been duly sworn, testified as follows:

DIRECT STATEMENT

MR. SHOWEN: Thank you. My name is Steve Showen, S-H-O-W-E-N. I live at 2301 Northeast 6th Avenue. And I thank you for this opportunity to speak before the Commission.

CHAIRMAN CARTER: Steve, get a little, get a little intimate with that.

MR. SHOWEN: Yeah. Can you hear me now? Cool. I'm here representing the Green Party, the Miami-Dade Green Party and the Green Party of Florida, and I'm the co-chair of the Miami-Dade Green Party, one of them. And I receive no monies for that position or for being here or any monies about my position or relationship to FP&L or any such thing.

So I'm reading a statement that we prepared. The Green Party of Florida and the Miami-Dade Green Party strongly oppose the construction of nuclear power plants in Florida, and we call upon the Public Service Commission of Florida to reject the proposals for new reactors at Turkey Point and other Florida sites.

In the context of the escalating global climate crisis, it is imperative that all public funds invested in the production of electric power be focused exclusively on clean, renewable energy production and sustainable solutions.

Our commitment to the security and survival of not only our own society, but the global human community, obligates us to reject false solutions such as the nuclear power option, and instead to work together to end dependence on the polluting industries that endanger the health and well-being of all life on the planet.

The nuclear power industry owes its very existence to massive government subsidies, and the current attempt to revive this industry under the guise of combating global climate change is little more than a scheme by corporate profiteers to enrich themselves once again at the public's expense, and the expense of our future quality of life.

Increased nuclear energy production will not and cannot solve the climate crisis. The construction of new nuclear power plants would be prohibitively expensive when all costs are factored in, and in any case they would not be brought online to meet the CO2 reduction goals that must be met to avert catastrophe.

Among the hidden costs of nuclear power we have the poisoning of indigenous people and the ecosystems in the mining and extraction of uranium; the consumption of massive amounts of fossil fuels in the production process, including the mining, the refining and the transportation of uranium; the use of massive amounts of water for the cooling of the plants; placing unnecessary demands on the supply of our ever more precious water supply; the long-term health risks associated with ongoing radioactive emissions from nuclear plants as referred to by others here in this meeting; the negative environmental impacts on marine life in the plant's discharge zone; the ever present potential for catastrophic failure; the permanent need for security to prevent attacks on nuclear facilities; the long-term handling and storage of highly radioactive nuclear waste, which remains a threat to public health and safety for Millenia.

CHAIRMAN CARTER: Excuse me, Mr. Showen. Are you going to submit that as an exhibit?

MR. SHOWEN: Yes, I am.

CHAIRMAN CARTER: We would appreciate that. And so that would be Exhibit -- we'll show that marked as Exhibit Number 13. Commissioners?

MR. SHOWEN: May I finish? I only have a small amount to go.

CHAIRMAN CARTER: We'll just put it into the record.

I really want to make sure that I give everybody an opportunity to be heard, Steve. And I think you want me to be fair with everybody, don't you?

MR. SHOWEN: I do. Are there others waiting?

CHAIRMAN CARTER: Let me ask this. Mr. Ballinger has taken that. That will be Exhibit 13 and we'll put it into the record. It'll be read into the record, sir.

(Exhibit 13 marked for identification.)

MR. SHOWEN: Thank you, sir.

CHAIRMAN CARTER: Let me ask this -- Mr. Ballinger. You've already answered Mr. Krasowski's questions. No problem with that. Go ahead. He'll get it from you.

Anyone in the audience, out of an abundance of caution? It's extremely important to us as a Commission to make sure that we heard from everyone. Is there anyone that did not get an opportunity to speak that wants to be heard? We've heard from everyone that signed up, and those that were not here, we went over them. But out of an abundance of going above and beyond the call of duty, is there anyone here that wanted to speak that didn't get a chance to speak? We're more than happy to hear from you at this point in time. Otherwise, we'll move into statements from the Commissioners.

Would you like to speak, sir?

MR. FLINT: I'd like to say something.

CHAIRMAN CARTER: Would you come on down? And have you been sworn in, sir?

MR. FLINT: No, sir.

CHAIRMAN CARTER: It won't take me a second to do that. And, staff, staff, would you get a statement so we can sign him up? Staff.

(Witness sworn.)

Thank you, sir. Would you please state your name for the record. And you have two minutes.

Whereupon,

STEVE FLINT

was called as a witness on behalf of the Citizens of the State of Florida and, having been duly sworn, testified as follows:

DIRECT STATEMENT

MR. FLINT: My name is, my name is Steve Flint. I'm a member of the International Brotherhood of Electrical Workers, Local 359, Miami, Florida. I'm also employed by Florida Power & Light Company. So I guess I'm being paid, not now, no one asked me to be here, but I do get a salary from FP&L and the International Brotherhood of Electrical Workers.

I've been employed at Turkey Point for 35 years. It's been a great place to work. We have over 300 members working at that site, and our members wouldn't be there if it was an unsafe area to work at. The safety that's put into place is above and beyond any kind of reproach or anything. It's a very safe plant to work at. We fish outside in front of the plant. I have a ten-year-old grandson. We've spent many hours out there fishing out in front of the plant; some of the best fishing in the South Florida area, red fish, snook, trout, whatever you want to catch.

It's a great place to work, and I really think that it will bring a lot of new technology. There's so much interest to work in a nuclear power plant with some of the advanced technology with the way the systems are set up, the way they run. And I just think that if no one has ever been to a nuke plant, you need to take a tour of a nuke plant. Thank you.

CHAIRMAN CARTER: Thank you so kindly.

Members, thank you for your indulgence, and I appreciate you allowing me as Chairman to go above and beyond the call of duty to hear from everyone here. At this point in time, members, we'll go through final comments beginning in this order: With Commissioner Edgar, then Commissioner McMurrian, then Commissioner Argenziano, then Commissioner Skop. And if there's a minute left, I may say something. Commissioner Edgar, you're recognized.

COMMISSIONER EDGAR: Thank you. And I'd just like to thank everybody who has come out this evening. I know we've gone a little over time, but I appreciate everybody who came to participate. And I would ask that if there is somebody, friends, neighbors, family that was not able to come this evening, please share with them the opportunity to write in comments and participate in our process as well. And, Chairman Carter, thank you for running an excellent meeting.

CHAIRMAN CARTER: Thank you. Commissioner McMurrian.

COMMISSIONER McMURRIAN: I echo those comments. Thank you all for being here. And as the Chairman has said several times, we're here to hear from you and we appreciate you sticking in with us 'til the end. Thank you so much.

CHAIRMAN CARTER: Commissioner Argenziano.

COMMISSIONER ARGENZIANO: I just want to thank Miami-Dade College again. Is this -- can you hear me?

CHAIRMAN CARTER: Wait a sec. Can we get sound?

COMMISSIONER ARGENZIANO: I can yell. I think y'all can hear me now.

CHAIRMAN CARTER: No. No. We want it on the record.

COMMISSIONER ARGENZIANO: Okay. There we go. I just want to thank Miami-Dade College once again and Senator Villalobos for allowing the people of Miami to have a place to come and talk to the Public Service Commission. And, of course, I'm very proud that everybody showed up today to speak to us, and I will be doing my part as a Commissioner to look into what our jurisdiction allows us to look into. And I'm pleased to have all the comments that we will have taking back with us. And if there's anything additional, as our Commissioners have said already, please send it to us and keep participating in the process. Thank you, Mr. Chairman.

CHAIRMAN CARTER: Commissioner Skop.

COMMISSIONER SKOP: Thank you, Mr. Chairman.

First on a procedural note, just for the record I would like to briefly respond to the question that was presented by, I believe, Ms. Jennifer Rock.

Simply put, there is no conflict of interest either past or present which would preclude me from hearing this case. Also I would like to respectfully note for the record that I am a member of the Florida Bar in good standing, an officer of the court and appointed official sworn to uphold the duties and the highest ethical standards of the position which I hold. So while the question is welcome and proper, there is no showing that my judgment would be biased nor compromised and that I could not remain impartial in the course of this proceeding. Thank you.

On a global note, I'd like to also thank everyone for attending, again, and also thank Miami-Dade College as well as the local governmental officials that have taken their time to appear, as well as the consumers and the various stakeholders. We welcome the input from the community. It's very important in our decision-making. And, again, I would like to thank everyone for staying the course and coming out and offering their input. Thank you.

CHAIRMAN CARTER: Thank you, Commissioners, to our

Public Counsel, to our staff, to the court reporter. I prayed for your fingers. And to our neighbors, we are a government of neighbors. We are concerned about our fellow citizens and that's why we're. And, Commissioners, thank you for your confidence in me for allowing me to go above and beyond and for us to have this opportunity to come down, even though -- thank you, Commissioner Edgar, for your leadership over the years and how we were able to put this together where we had this change so we could accommodate more people additionally, so that we could have an additional hearing over and above the hearing that we would have in Tallahassee.

And to those that it may have seemed that I was a little short with you, it's far more important to me as the Chairman of this Commission to make sure that everybody is heard. And if you've got something that you need to say that's beyond two minutes, we have these forms available. We have these forms available. Please, ma'am, please, sir, we have plenty of them out there. So even if you had an opportunity to speak and you forgot something, put it on there. If you say I don't like Commissioner Carter's tie, you know, write that down and put it in there. We won't make it part of the record, but it'll be good for me to read. I'll take it home and show it to my wife.

COMMISSIONER ARGENZIANO: I think I'll write that down. (Laughter.)

CHAIRMAN CARTER: But, again, on behalf of my fellow Commissioners, thank you for your confidence in me and thank you for the opportunity that we were willing to go above and beyond the call of duty and hear from our fellow citizens. And if there's anything else for the good of the order -- Ms. Brubaker.

MS. BRUBAKER: Staff has nothing further.

CHAIRMAN CARTER: Nothing further. With that this hearing is adjourned.

(Service Hearing adjourned at 7:51 p.m.)

STATE OF FLORIDA)
: CERTIFICATE OF REPORTER
COUNTY OF LEON)

I, LINDA BOLES, RPR, CRR, Official Commission Reporter, do hereby certify that the foregoing proceeding was heard at the time and place herein stated.

IT IS FURTHER CERTIFIED that I stenographically reported the said proceedings; that the same has been transcribed under my direct supervision; and that this transcript constitutes a true transcription of my notes of said proceedings.

I FURTHER CERTIFY that I am not a relative, employee, attorney or counsel of any of the parties, nor am I a relative or employee of any of the parties' attorneys or counsel connected with the action, nor am I financially interested in the action.

DATED THIS 18th day of January, 2008.

Linda Boles

LINDA BOLES, RPR, CRR
FPSC Official Commission Reporter
(850) 413-6734

EXHIBITS

NUMBER:		ID.
1	City of Homestead Resolution	29
2	Nancy Lee Document	48
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RESOLUTION NO. 2007-12-153

A RESOLUTION OF THE CITY COUNCIL OF THE CITY OF HOMESTEAD, FLORIDA, SUPPORTING FLORIDA POWER AND LIGHT'S PETITION TO BUILD ADDITIONAL NUCLEAR REACTORS AT THE TURKEY POINT POWER PLANT SITE TO MEET SOUTH FLORIDA'S GROWING DEMAND FOR ELECTRICITY; PROVIDING FOR EFFECTIVE DATE.

WHEREAS, the City of Homestead (the "City") recognizes the essential role of nuclear power in the national energy policy of the United States and in its role to meet the growing need for electricity of Florida; and urges Miami-Dade County, the State of Florida and The United States Nuclear Regulatory Commission to allow Florida Power & Light to make steady progress in their efforts toward building new nuclear units within Miami-Dade County in a manner which is environmentally sound ; and

WHEREAS, Florida Power & Light Company has the obligation to provide adequate, safe and efficient electric power to its customers; and

WHEREAS, meeting the increasing demand for continuous and reliable, electricity is essential for supporting the economic growth which is necessary to maintain the South Florida community's standard of living and quality of life; and

WHEREAS, alternative renewable sources of electricity and energy conservation initiatives are not sufficient at this time to meet the growing demand for electricity in South Florida; and

WHEREAS, the City, recognizes the value of nuclear power in generating safe, consistent, affordable, and emission-free electricity; and

FLORIDA PUBLIC SERVICE COMMISSION
DOCKET NO. 070650-EI EXHIBIT 1
COMPANY City of Homestead
WITNESS Resolution
DATE 01/09/08

WHEREAS, nuclear energy is an alternative fuel source that protects our economies by achieving diversity of energy sources, and decreasing the dependence of Florida and the nation upon foreign fuel sources; and

WHEREAS, Florida Power and Light has pointed out that nuclear power plants do not produce harmful emissions or greenhouse gases and can provide flexibility in meeting the state's and nation's goals for clean air at lower costs than other sources of power; and

WHEREAS, the construction of additional nuclear power facilities will promote economic development through the creation of jobs and tax revenues and the availability of a stable and reliable source of energy in the South Florida community; and

WHEREAS, the Florida Power & Light Turkey Point generating facility has been a good corporate citizen, a great neighbor and member of the community and has provided numerous job opportunities; and

WHEREAS, Florida Power & Light has assured the City that the Turkey Point generating facility complies with all the necessary safeguards including environmental safeguards.

NOW, THEREFORE, BE IT RESOLVED BY THE CITY COUNCIL OF THE CITY OF HOMESTEAD:

Section 1. Recitals Adopted. That each of the above-stated recitals is hereby adopted and confirmed.

Section 2. Support. That the City of Homestead supports the increased use of nuclear power and the construction and development of new nuclear energy production facilities within Miami-Dade County (at the Turkey Point Power Plant site) and within the State of Florida, subject to compliance with all applicable health, safety and environmental standards and regulatory procedures .

Section 3. **Effective Date.** That this Resolution shall be effective immediately upon adoption hereof.

PASSED AND ADOPTED THIS 17th day of December , 2007.

Lynda Bell
LYNDA BELL
Mayor

ATTEST:

Sheila Shedd
SHEILA PAUL SHEDD, CMC
City Clerk

APPROVED AS TO FORM AND LEGAL SUFFICIENCY:

WEISS, SEROTA, HELFMAN, PASTORIZA, COLE & BONISKE P.L.
City Attorney

Motion to adopt by Councilwoman Sierra seconded by Councilwoman Lobos .

FINAL VOTE AT ADOPTION

Mayor Lynda Bell	*YES*
Vice Mayor Jon Burgess	*YES*
Councilwoman Wendy Lobos	*YES*
Councilman Melvin McCormick	*YES*
Councilwoman Nazy Sierra	*YES*
Councilwoman Judy Waldman	*YES*

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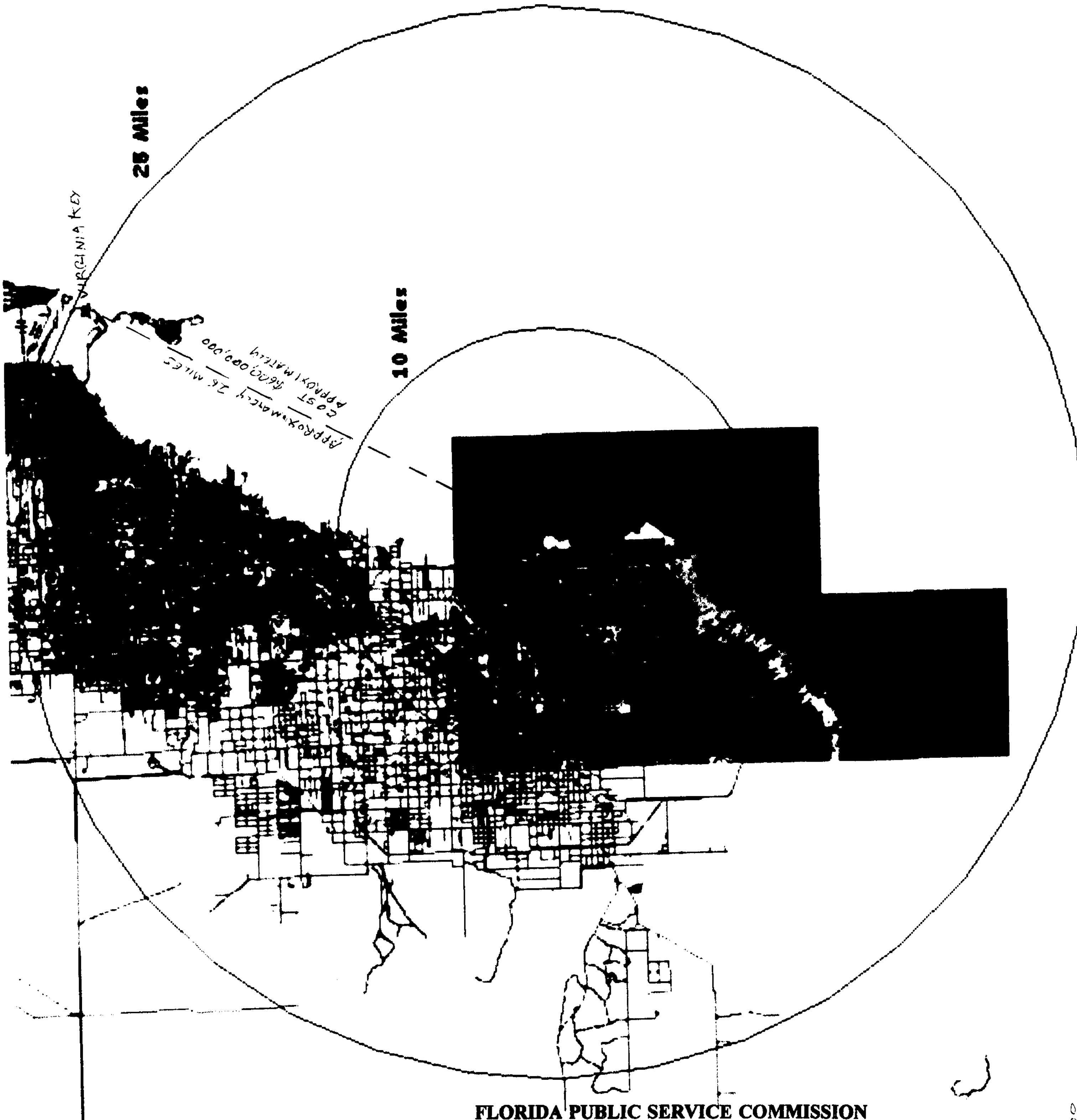
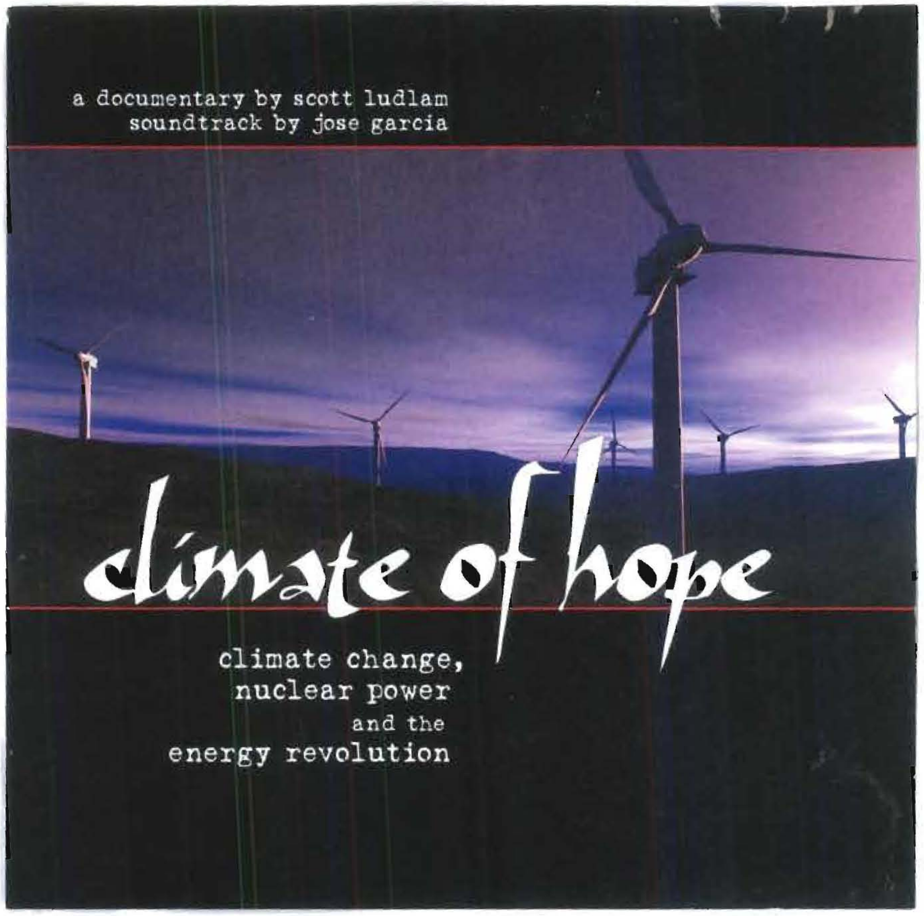


FLORIDA PUBLIC SERVICE COMMISSION
DOCKET NO. 070650-EI **EXHIBIT** 2
COMPANY Nancy Lee - map showing
WITNESS the population that will be affected by the plant
DATE 01/09/08

Written comments +
supporting documents +
Nuclear Information +
Resource Service
to
Florida Public
Service Commission

FLORIDA PUBLIC SERVICE COMMISSION
DOCKET NO: 070650-EI EXHIBIT 3
COMPANY Mary Olsen - Written Comments
WITNESS + supporting documents - Nuclear Info + Resource Svc.
DATE 01/09/08


a documentary by scott ludlam
soundtrack by jose garcia
climate of hope
climate change,
nuclear power
and the
energy revolution

climate of hope

The threat of climate change is now widely accepted in the community. The potential for a host of nuclear power stations in Australia has raised questions about the best strategy for our country to move to a low-carbon economy.

This animated documentary takes viewers on a tour through the science of climate change, the nuclear fuel chain, and the remarkable energy revolution that is under way.

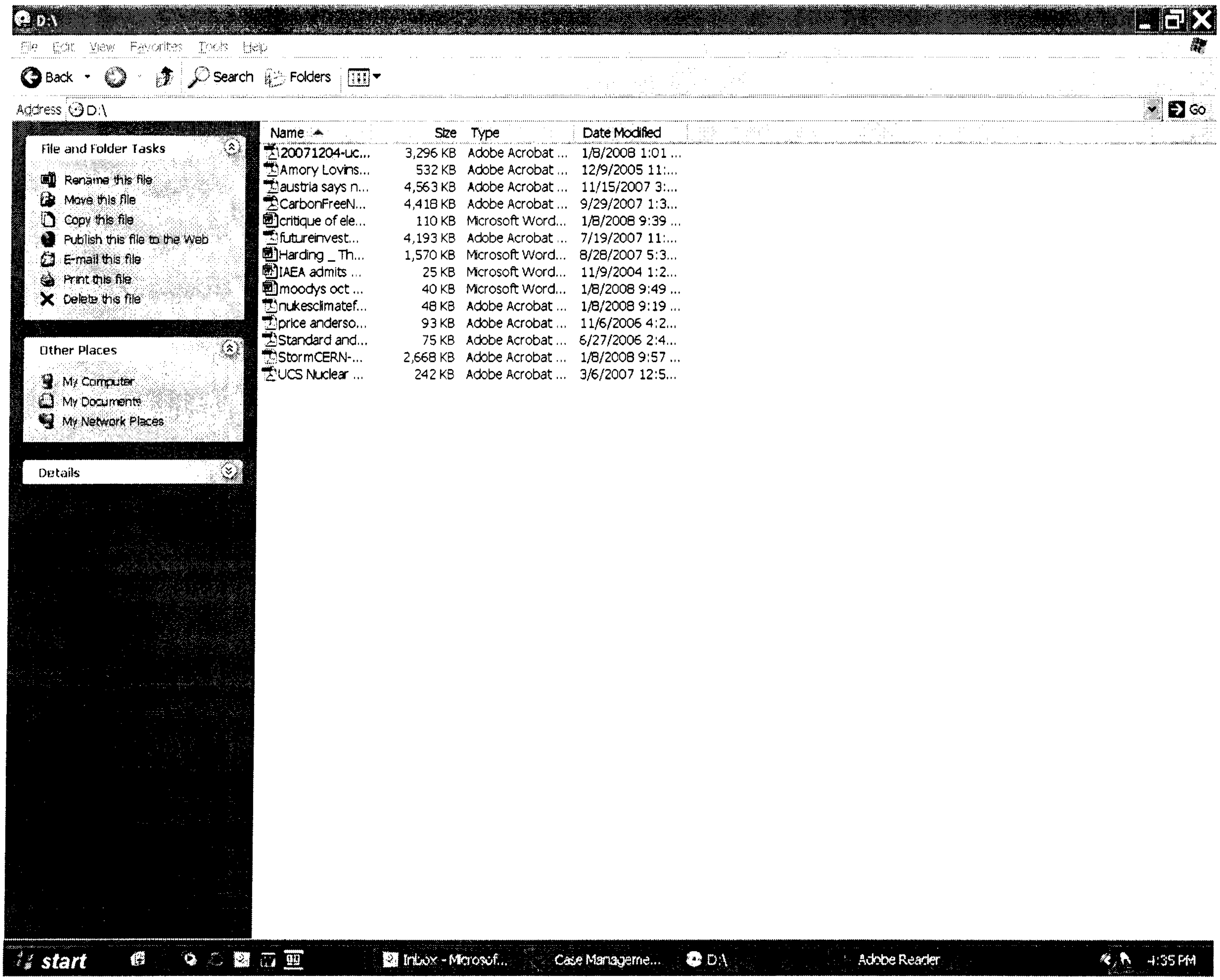
This production is copyleft - you are welcome to copy it and pass it on.

Produced in 2007 by Scott Ludlam and Jose Garcia for the Anti-Nuclear Alliance of Western Australia.

Huge thanks to everyone who made this possible.

http://www.anawa.org.au


2008
FL
Doc
SOUTHEAST



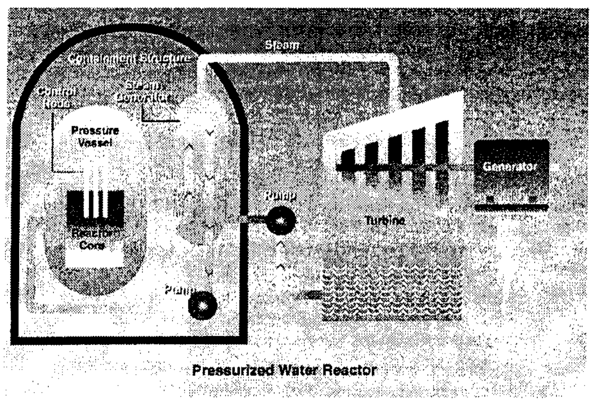
Wednesday, Jan 23, 2008 04:35 PM

Union of Concerned Scientists
Citizens and Scientists for Environmental Solutions

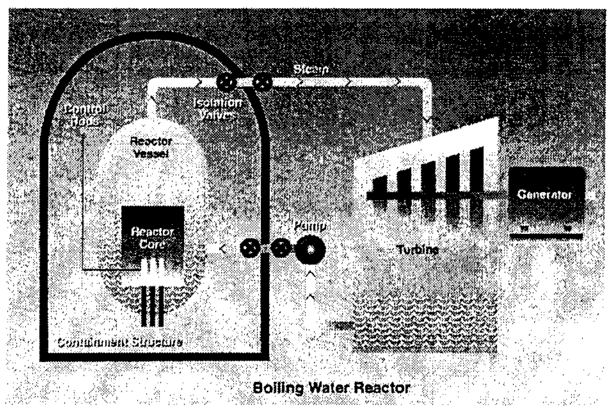
GOT WATER?

Nuclear power plants are usually built on the shores of lakes, rivers, and oceans.[1] This practice is not for the aesthetics such locales provide, but because the readily available water can absorb the waste heat produced by the plants. Nuclear power plants consume vast amounts of water during normal operation to absorb the waste heat left over after making electricity, and also to cool the equipment and buildings used in generating that electricity. In the event of an accident, nuclear power plants need water to remove the decay heat produced by the reactor core and also to cool the equipment and buildings used to provide the core's heat removal. This issue brief describes the reliance of nuclear power plants on nearby bodies of water during normal operation and under accident conditions.

All of the 104 nuclear reactors currently licensed to operate in the United States are light[2] water reactors. Sixty-nine (69) are pressurized water reactors (PWRs) and 35 are boiling water reactors (BWRs).



In a PWR, water flowing through the reactor core is heated by its thermal energy. Because this water is maintained under high pressure (over 2,000 pounds per square inch), it does not boil even when heated to over 500°F. The hot water flows from the reactor vessel and enters thousands of metal tubes within the steam generator. Heat passes through the thin tube walls to boil water at lower pressure that surrounds the tubes. The water leaves the tubes about 10°F cooler and returns to the reactor vessel for another cycle. Steam leaves the steam generator and enters the turbine. The steam spins the turbine, which is connected to a generator that produces electricity. The steam exits the turbine into the condenser. Water from the nearby lake, river, or ocean flows through thousands of metal tubes in the condenser. Steam flowing past outside these tubes cools and changes back into water. The condensed water flows back to the steam generator for another



In a BWR, water flowing through the reactor core is heated by its thermal energy to the boiling point. The steam flows from the reactor vessel to the turbine. The steam spins the turbine, which is connected to a generator that produces electricity. The steam exits the turbine into the condenser. Water from the nearby lake, river, or ocean flows through thousands of metal tubes in the condenser. Steam flowing past outside these tubes cools and changes back into water. The condensed water flows back to the reactor vessel for another cycle. The water leaves the condenser tubes nearly 30°F warmer and returns to the nearby lake, river, or ocean.

---

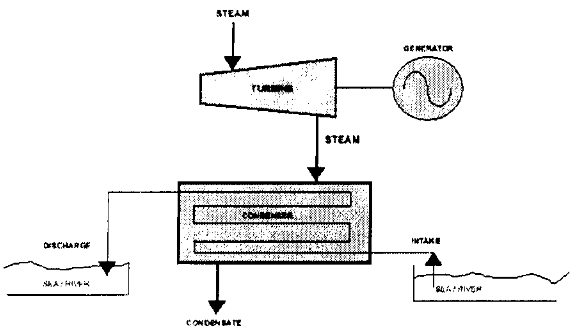
[1] An exception to the rule is the Palo Verde nuclear plant. Built in the arid region west of Phoenix, Arizona, cooling water is brought to the facility.

[2] Another type of reactor uses "heavy" water – water enriched in deuterium, an isotope of hydrogen, that makes it heavier than regular or "light" water.

Washington Office: 1707 H Street NW Suite 600 • Washington DC 20006-3919 • 202-223-6133 • FAX: 202-223-6162
Cambridge Headquarters: Two Brattle Square • Cambridge MA 02238-9105 • 617-547-5552 • FAX: 617-864-9405
California Office: 2397 Shattuck Avenue Suite 203 • Berkeley CA 94704-1567 • 510-843-1872 • FAX: 510-843-3785

cycle. The water leaves the condenser tubes up to 30°F warmer and returns to the nearby lake, river, or ocean..

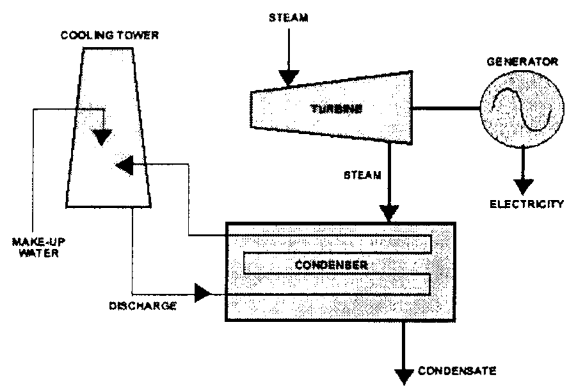
The required amount and usage of water by PWRs and BWRs is essentially identical. Both types of nuclear power reactors are about 33 percent efficient, meaning that for every three units of thermal energy generated by the reactor core, one unit of electrical energy goes out to the grid and two units of waste heat go into the environment. Two modes of cooling are used to remove the waste heat from electrical generation: once-through cooling and closed-cycle cooling.



OPEN CYCLE ONCE-THROUGH COOLING SYSTEM

In the once-through cooling system, water from the nearby lake, river or ocean flows through thousands of metal tubes inside the condenser. Steam flowing through the condenser outside the tubes gets cooled down and converted back into water. The condensed water is re-used by the plant to make more steam. The water exits the condenser tubes warmed up to 30°F higher than the lake, river, or ocean temperature and returns to that water body.

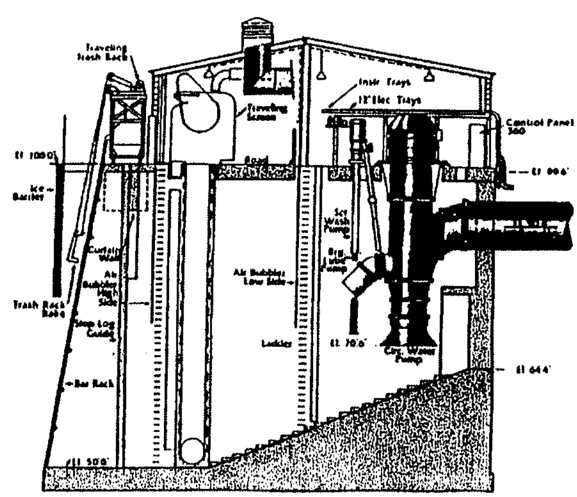
In the closed-cycle cooling system, water flows through thousands of metal tubes inside the condenser. Steam flowing through the condenser outside the tubes gets cooled down and converted back into water. The condensed water is re-used by the plant to make more steam. Water exits the condenser tubes warmed nearly 30°F higher than upon entry to the condenser tubes. The water leaving the condenser tubes flows to a cooling tower. Air moving upward past the water spraying downward inside the cooling tower cools the water. The water collected in the cooling tower basin is pumped back to the condenser for re-use. Water from the nearby lake, river, or ocean is needed to make-up for the water vapor carried away by the air leaving the cooling tower.



TYPICAL CLOSED-CYCLE COOLING SYSTEM

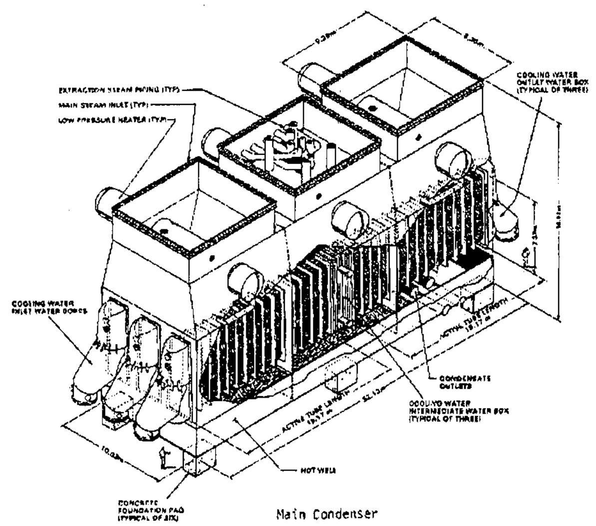
ONCE-THROUGH COOLING SYSTEMS

The once-through cooling system begins at the intake structure. A typical intake structure is shown in the graphic. The river, lake, or ocean is on the left and the plant is on the right. The bar rack is a lattice of metal bars intended to prevent large debris (e.g., logs, two-liter bottles, etc.) from entering, and the traveling screen is a small metal mesh that moves in a loop to prevent small debris and fish from entering. Depending on the location, intake structures, such as the one shown, can be equipped with protection against ice with an outer barrier guarding against chunks of ice in the water and air bubblers to ward off ice buildup on the traveling screens. Nuclear power plants use two to four circulating water



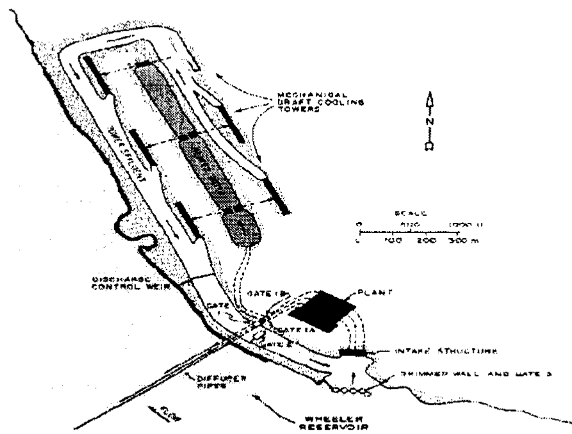
pumps for each reactor unit. Each circulating water pump with its electric motor stands nearly 40 feet tall and supplies over 100,000 gallons of water. The piping from the discharge of the circulating pumps runs underground from the intake structure to the turbine building.

The circulating water system pipes rise from the ground to deliver water to the main condenser located directly beneath the low pressure turbines in the turbine building. The main condenser typically consists of three metal barn-like structures called waterboxes. Each low pressure turbine exhausts steam into its own waterbox, and the circulating water pipes route water within thousands of metal tubes through the waterboxes. Heat is transferred from the steam flowing past the outside of the tubes through the thin metal walls to the water inside. The steam cools and changes back into water, which collects in the bottom of the waterboxes in what is called the hotwell. In some plants, such as the one illustrated in the graphic, the condenser tubes run the length of the waterboxes; in other designs the condenser tubes run the width of the waterboxes. After exiting the condenser tubes, the warmed water flows back to the lake, river, or ocean. The water from the hotwell is recycled by the condensate and feedwater pumps back to the steam generators (in PWRs) and to the reactor vessel (in BWRs) to make more steam.

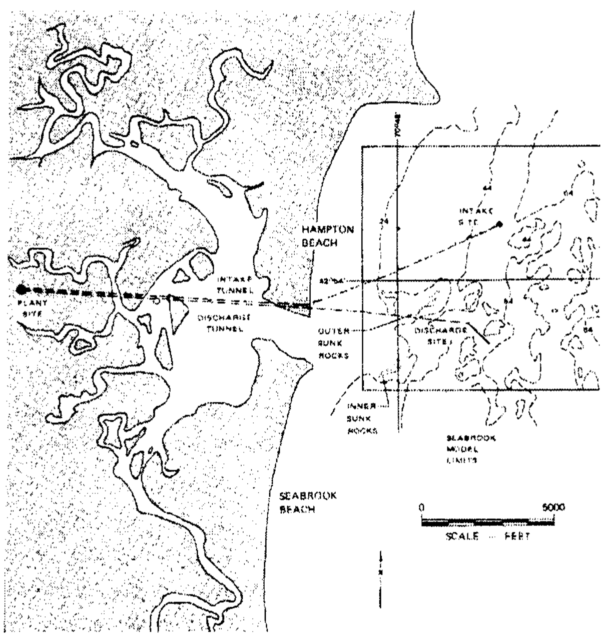


The design and operation of the main condensers in once-through and closed-loop cooling systems prevents radioactively contaminated water from leaking into the nearby lake, river, or ocean if one or more of the condenser tubes breaks. The cool water flowing inside the tubes condensing steam outside the tubes creates a vacuum inside the waterboxes relative to the outside pressure. That vacuum helps "pull" steam out of the low pressure turbines sitting atop the condenser waterboxes. In addition, should one or more condenser tubes break, the vacuum causes lake, river, or ocean water within the tubes to leak into the waterboxes rather than radioactively contaminated water within the waterboxes from leaking into the tubes.

◄
Lake: This image shows the thermal discharge from a nuclear plant into a lake. The warm water (red) discharged from the circulating water system enters the lake via a long canal and then cools as it flows counterclockwise around the lake, guided by a long weir wall. The cooled water (dark blue) is drawn back into the plant's intake structure for another cycle.



River: This drawing shows the discharge piping routed along the river bottom to diffuse the warm water discharged from the circulating water system into the river. The diffuser pipes extend out into the river along its bed for optimal mixing between the warm discharge water and the cooler river water.



Ocean: This drawing shows the underground piping routed from offshore intake and discharge points for a coastal nuclear plant. The intake and discharge points in this case are nearly one mile offshore.

The water usage by a once-through cooling system depends on the size of the nuclear power reactor it services. As detailed in Attachment 1, the minimum amount of water needed in a once-through cooling system can be estimated from the following equation using the electrical output of the reactor in megawatts (Mwe) and the differential temperature of the cooling water passing through the condenser (ΔT, °F):

$$\text{Flow, gpm} = \frac{14{,}295 * \text{Mwe}}{\Delta T}$$

For example, the typical 1,000 Mwe nuclear power reactor with a 30°F ΔT needs approximately 476,500 gallons of water per minute. If the temperature rise is limited to 20°F, the cooling water need rises to 714,750 gallons per minute. Some of the new nuclear reactors being considered are rated at 1,600 Mwe. Such a reactor, if built and operated, would need nearly 1,144,000 gallons per minute of once-through cooling for a 20°F temperature rise.

Actual circulating water system flow rates in once-through cooling systems are 504,000 gpm at Millstone Unit 2 (CT); 918,000 gpm at Millstone Unit 3 (CT); 460,000 gpm at Oyster Creek (NJ); 311,000 at Pilgrim (MA); and 1,100,000 gpm at each of the two Salem reactors (NJ).

Once-through cooling systems have posed problems for nuclear power plants when the cooling water fails to go through once. Among many examples:

- The operators at Point Beach Unit 2 in Wisconsin manually tripped the reactor from 100 percent power on May 15, 2004, after a diver inspecting the intake structure for potential damage from the previous winter became snagged and a rescue diver was unable to free him. After the reactor was tripped, the operators shut down the circulating water pumps. Both divers emerged unhurt from the water. The reactor resumed operations five days later.

- The operators at Point Beach Unit 2 in Wisconsin manually tripped the reactor from 70 percent power on June 27, 2001, after a large number of Alewives blocked the traveling screens. The reactor resumed operations five days later.

- On April 4, 1998, a diver entered the intake bay for Calvert Cliffs Unit 1 in Maryland to lower a stop log. A problem developed and the diver was transported to the Calvert Memorial Hospital and pronounced dead on arrival.

- In January 1996, the Wolf Creek nuclear plant in Kansas experienced the build-up of frazile ice at its intake structure that led to a reactor trip and impairment of the essential service water system. The NRC fined the plant's owner $300,000 in July 1996 for not taking steps to prevent the ice build-up and for less than a stellar response to the build-up once it did occur.

- The NRC fined the owner of Salem Unit 1 in New Jersey $500,000 in October 1994 for violations stemming from an event on April 7, 1994, when marsh grass floating in the Delaware River blocked the traveling screens at the intake structure. The operators reduced the reactor power level as the build-up decreased the amount of cooling water flowing through the plant. They made a series of mistakes along the way and the reactor automatically shut down for safety reasons.

- On December 22, 1991, a 36-inch diameter pipe carrying cooling lake water to the Perry nuclear plant ruptured just outside the plant's buildings. Approximately 2.9 million gallons of water spilled from the broken pipe before operators closed a valve to isolate the broken piping section. Some of the water leaked into the plant and caused minor flood damage. The reactor, which had been running at 73 percent power, was manually shut down by the operators.

- Operators shut down the FitzPatrick nuclear plant in New York on October 19, 1990, after high winds blew lake debris onto the traveling screens at the intake structure. The heavy buildup increased the pressure across the traveling screens, causing them to bow. When debris started slipping past the bowed section of the screens, the operators shut down the plant to minimize the impact of the debris intrusion.

- Operators shut down Millstone Unit 1 in Connecticut on October 4, 1990, after a storm caused a heavy build-up of seaweed on the traveling screens at the intake structure. The build-up caused the instruments monitoring the differential pressure across the screens to go offscale high. The operators initially did not believe this instrumentation and delayed shutting down the circulating water pumps. By the time the pumps were shut down, three of the five traveling screens had collapsed from excessive pressure.

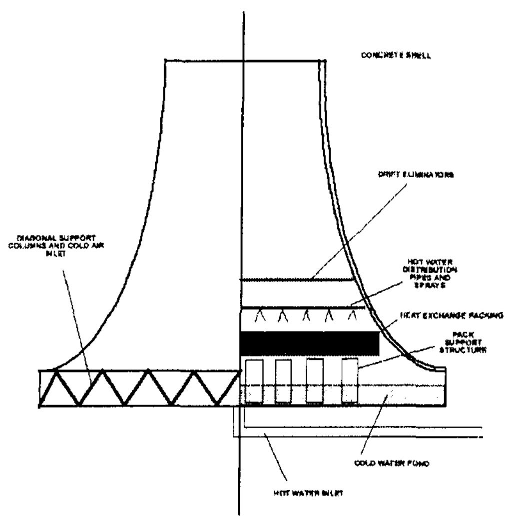
- In September 1984, a flotilla of jellyfish "attacked" the St. Lucie nuclear plant in Florida, forcing both of its nuclear reactors to shut down for several days due to lack of cooling water.

- Operators shut down Millstone Unit 1 in Connecticut on September 1, 1972, after condenser tube failures allowed water from the Atlantic Ocean to be pumped into the reactor vessel. Serious chloride corrosion from the sea water disabled 114 of the 120 local power range monitors in the reactor core and required replacement of feedwater spargers and several other components before the reactor could restart.

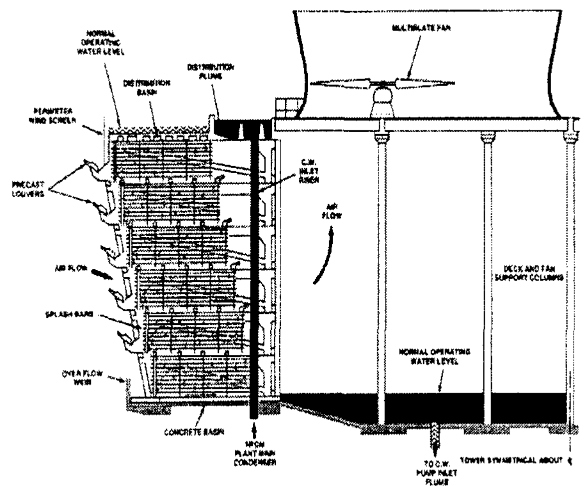
Closed-Loop Cooling Systems

If cost were the only factor in the decision nearly all nuclear power plants would feature once-through cooling systems, because pumping vast amounts of water through the condenser is usually the cheapest option. Closed-cycle cooling systems are used when the nearby water source lacks sufficient water volume to allow the large flow rate needed for once-through cooling or when environmental limits on thermal pollution dictate that waste heat be rejected into the air and not just into the body of water.

Two types of cooling towers are used in closed-cycle cooling systems: natural draft and mechanical type. The natural draft cooling towers have become iconic symbols of nuclear power plants even though not all nuclear power plants have them and many non-nuclear power plants also use them.



PART SECTION OF A NATURAL DRAUGHT COOLING TOWER - COUNTER FLOW



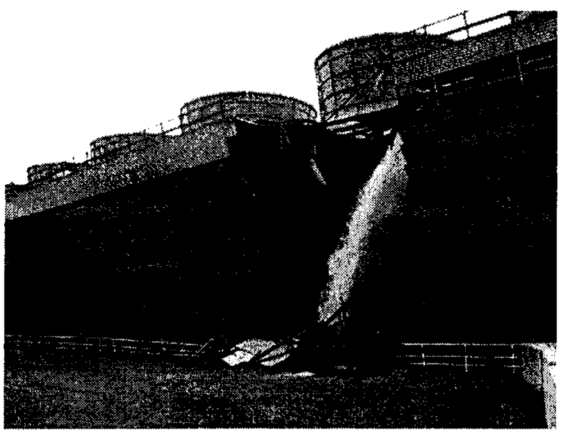
Natural Draft Cooling Tower*: Underground piping carries warm water from the condenser in the turbine building to the tower. The pipe rises vertically in the center of the tower. Smaller distribution piping branches out from the main pipe to spray the warm water onto a feature labeled "heat exchange packing" in the graphic. This device functions to further diffuse the water spray into small water droplets. This enhances the cooling by the air drawn upward through the "rainfall" by the chimney effect. The cooled water collects in the cooling water basin where another underground pipe carries it back to the condenser. Natural draft cooling towers are quite tall. For example, the tower for Unit 2 at the Nine Mile Point nuclear plant in New York is approximately 540 feet tall and 450 feet in diameter at the base. The tower's reinforced concrete walls are 36 inches thick at the base and the lip and 8 inches thick at the throat. It required nearly 16,500 cubic yards of concrete and 1,230 tons of reinforcing steel.*

Mechanical Type Cooling Tower*: Underground piping carries warm water from the condenser in the turbine building to the tower. The pipe rises vertically to force the water to the distribution plume at the top of the tower. Smaller piping and conduits branch out from the plume to distribute the warm water onto louvers. This flow path diffuses the watery into small droplets. This enhances the cooling by the air drawn through the water droplets by the motor-driven fans. The cooled water collects in the cooling water basin where another underground pipe carries it back to the condenser. Mechanical type cooling towers are shorter than natural draft cooling towers. For example, each of the two mechanical type cooling towers at Vermont Yankee are approximately 50 feet tall, 60 feet wide, and 463 feet long.*

The closed-cycle cooling system label is a bit of a misnomer because plants with mechanical type cooling towers also consume water from nearby lakes, rivers, and oceans and return water to those bodies. Water is needed to compensate for the water vapor leaving the cooling towers with the cooling air flow. The amount of makeup is far less than the amount of water needed for once-through cooling systems, but it is not negligible. When both reactors at the Susquehanna nuclear plant in Pennsylvania operate in summer, nearly 30 million gallons of makeup water per day (or nearly 21,000 gallons per minute) are needed from the river to compensate for cooling tower drift. Water must also be discharged from closed-cycle cooling systems in order to control the chemistry of the recycled water and to limit the build-up of sediment and other debris in the cooling tower basins. The Susquehanna nuclear plant uses another 11 million gallons per day (about 7,600 gallons per minute) from the river that balances the discharge flow rate back to the river for cooling tower basis chemistry control.

Actual circulating water system flow rates in closed-loop cooling systems are 480,000 gpm at Davis-Besse (OH); 552,000 gpm at Hope Creek (NJ); and 580,000 gpm at Nine Mile Point Unit 2 (NY);

Closed-loop cooling systems have also posed problems for nuclear power plants:



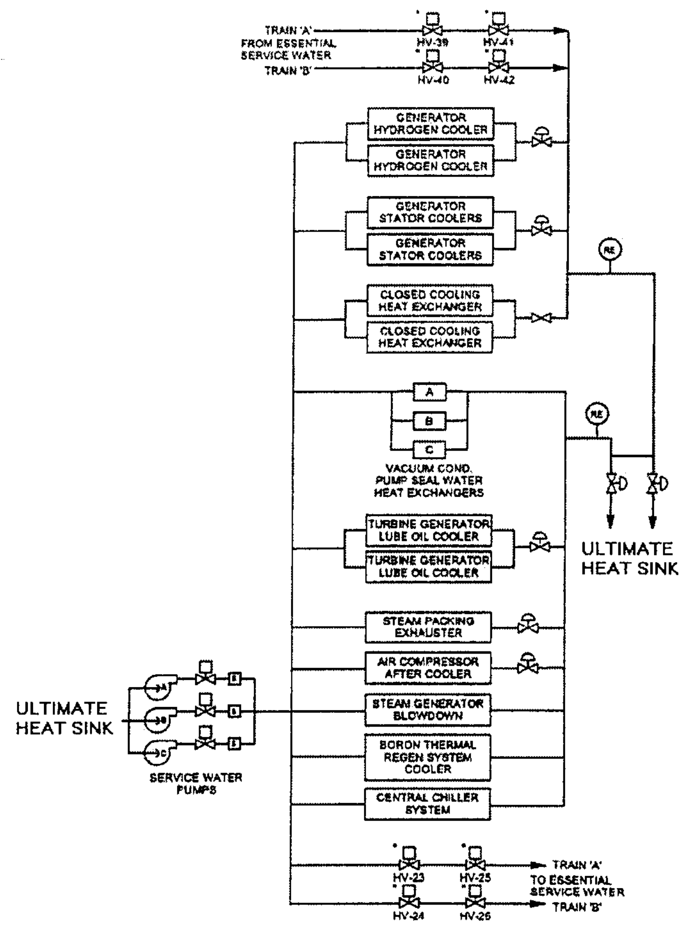
- The operators reduced the power level of the Vermont Yankee nuclear plant to less than 60 percent on August 21, 2007, after a cell collapsed in one of two mechanical type cooling towers. The company blamed the collapse on wooden supports weakened by years of iron salt and fungus. The repaired cooling tower was returned to service on September 13, 2007.

- On May 22, 2006, the Catawba Unit 2 cooling tower overflowed when its upper level screens clogged. The overflow followed unsealed electrical conduit penetrations into the 1A Diesel Generator Room. Workers discovered the water intrusion and stopped it before the emergency diesel generator was damaged from flooding. A subsequent evaluation of the existing flood protection measures showed that the emergency diesel generator could have been damaged by flooding in 15 minutes under design maximum rainfall conditions. Workers sealed penetrations to restore adequate flood protection capabilities.

- The owners of the Palisades nuclear plant in Michigan informed the NRC on February 1, 1977, that the transmission lines and towers had heavy ice build-up from the cooling tower vapor drift. Prior to this event, the plant's safety studies had considered the simultaneous loss of all four reactor coolant pumps to be incredible. The owner maintained the reactor power level below 60 percent until analyses of the de-energization of the reactor coolant pumps and the structural integrity of the transmission towers were completed.

SERVICE WATER SYSTEMS

In addition to the water used by once-through or closed-cycle cooling systems to handle the waste heat rejected from the condensers, nuclear power plants also take water from the nearby lakes, rivers, and oceans to cool other equipment. The service water system takes water from the nearby water source and supplies it to plant equipment such as the chillers for air conditioning units, lubricating oil coolers for the main turbine, aftercoolers for air compressors, and heat exchangers for closed-loop cooling systems providing cooling water to other equipment like the spent fuel pool heat exchangers. After cooling these components, the service water system returns the warmed water to the nearby source, labeled 'ultimate heat sink' in the diagram.



Unlike once-through and closed-cycle cooling systems that are not used when the nuclear plant is shut down (explaining why the visible plumes from cooling towers cease when plants shut down for refueling), the service water systems operate 24 hours a day, seven days a week. During periods when the reactor is shut down, the service water system cools the components that are in turn cooling the reactor.

Actual service water system flow rates are 37,000 gpm in winter and 52,000 gpm in summer at Hope Creek (NJ); 24,000 gpm at Millstone Unit 2 (CT); 30,000 gpm at Millstone Unit 3 (CT); and 13,500 gpm at Pilgrim (MA).

Service water systems have posed problems at nuclear power plants, including:

- Operators shut down Unit 1 at the LaSalle nuclear plant in Illinois on June 28, 1996, and Unit 2 on the following day following the discovery of foreign material in the service water tunnel. Contractors had been injecting a polymer foam sealant into cracks in the concrete floor of the pump house. They drilled holes near the cracks to better seal the cracks. Some of the holes passed completely through the concrete, enabling the polymer foam sealant to collect in the service water tunnel. The NRC fined the company $650,000 for failure to manage the activity. The NRC stated *"The injected foam sealant material created a significant safety issue by threatening to block the intake of both units' safety-related service water systems, systems required to mitigate the consequences of a design basis accident."*

- Operators shut down the Perry nuclear plant in Ohio on March 26, 1993, after the rupture of an underground 30-inch pipe carrying service water from the pump house at the lake to the turbine building. Water from the broken pipe flooded portions of the site and entered unsealed electrical conduits, creating water levels in some buildings of six to eight inches. Operators stopped the service water pumps 16 minutes after the pipe ruptured.

- In November 1991, the NRC fined the owner of Millstone Unit 3 in Connecticut $50,000 for inadequate corrective actions after workers identified reduced service water flow but did not fix the problem until a test conducted to answer NRC's questions demonstrated that emergency diesel generator B was getting only 15 percent of the cooling water flow it required. Following this discovery, operators manually shut down Millstone Unit 3 on July 25, 1991, to disassemble and clean the service water system piping.

- A security officer responding to an alarm on the door to the service water tunnel discovered two contract workers smoking marijuana. The workers were fired and escorted from the plant site.

- Workers entered the containment building at Indian Point Unit 2 in New York on October 17, 1980, to investigate the probable cause for an automatic reactor trip earlier that day. They discovered water on the containment floor – a lot of water. A small service water leak from components inside the containment collected over an extended period of time until the lower nine feet of the reactor vessel was submerged. Approximately 100,000 gallons of water had leaked, undetected, over an undetermined period of time.

- Operators shut down the Unit 2 reactor at Arkansas Nuclear One on September 3, 1980, after the NRC resident inspector determined that the service water flow rate though the containment cooling units was less than that required by the technical specifications. Workers found that Asiatic clams caused extensive flow blockage of the service water system.

Got Dilution?

Nuclear power plants, whether using once-through cooling or closed-loop cooling, continuously discharge large amounts of water back into the nearby lake, river, or ocean. When leaks develop in the tubes within the condensers, the higher pressure of the lake, river, or ocean water within the tubes causes it to leak *into* the plant rather than radioactively contaminated liquid leaking out from the plant. But the water being discharged from nuclear plants often contains radioactivity.

Nuclear power plants have systems – called liquid radwaste systems – that collect and treat radioactively contaminated water. The liquid radwaste systems have demineralizer and filter units to treat the water. To the extent possible, the treated water gets recycled to the plant. At times, the liquid radwaste systems release the treated water to the nearby lake, river, or ocean. Such releases are controlled and monitored. The liquid radwaste system tank to be discharged is sampled to ascertain its radioactive contents (i.e., radioactive concentrations times the amount of water in the tank). If the radioactive contents are below federal limits on liquid releases, the water in the tank can be pumped into the discharge flow from the once-through or closed-loop cooling system. Mixing the liquid radwaste system release flow with the discharge flow dilutes the radioactivity concentration, which is further reduced when the discharge mixes with lake, river, or ocean water.

Thus, when the water discharged from a nuclear power plant contains radioactivity, it is by design and not by accident.

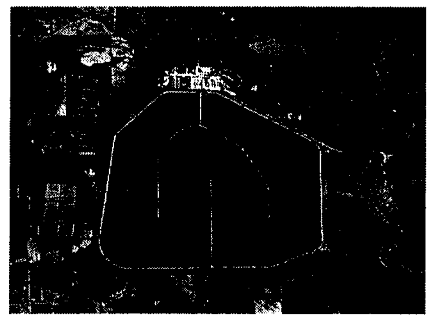
WATER NEEDS DURING ACCIDENT CONDITIONS

The discussions above regarding once-through cooling systems, closed-loop cooling systems, and service water systems apply to water needs during normal operating conditions, the day-to-day process of making electricity. This section covers the water needs of a nuclear power plant in the event of an accident.

An accident at a nuclear power reactor reduces, but does not eliminate, the amount of cooling water needed by the plant. The reactor unit will no longer be generating electricity, so the tremendous volume of water needed by a once-through cooling system and the makeup volume of water needed to compensate for water vapor lost from a closed-loop cooling system are no longer required. It is additionally assumed that the reactor unit is disconnected from its electrical grid during the accident, so the volume of water needed by the service water systems for cooling of components normally used in day to day operations is also not needed.

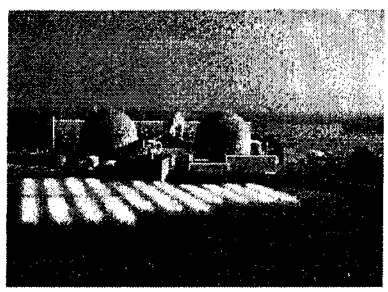
But what is needed during an accident is a volume of water to remove the heat still being generated by the reactor core and to cool emergency equipment and the rooms housing it. Three things are required: a source of water (called the Ultimate Heat Sink or UHS), two or more pumps to move water between the UHS and the plant, and a source of electricity for the motor-driven pumps.

◄ *The Limerick Generating Station in Pennsylvania uses two natural draft cooling towers (center) to remove heat during normal operation and a pond with water sprays (oval at upper left) as the UHS during accidents for the two reactors below the cooling towers.*

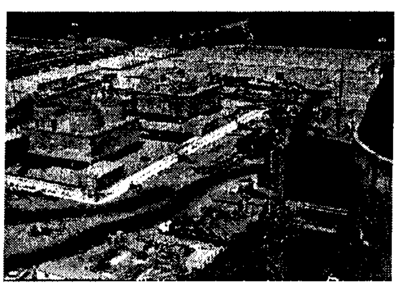


▲ *The South Texas Project uses a large lake for cooling during normal operation and a much smaller U-shaped pond for its UHS.*

The Grand Gulf Nuclear Station in Mississippi uses a natural draft cooling tower during normal operation and mechanical type cooling towers (upper left) in the event of an accident. ▼

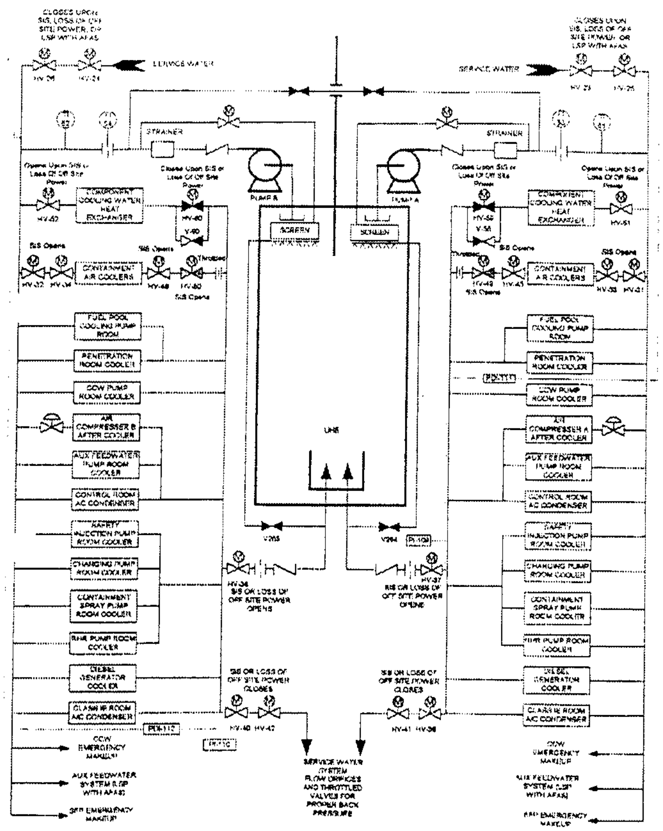


◄ *The North Anna Power Station in Virginia, like Limerick, uses a pond with water sprays – running here – as its UHS.*



► *The Vermont Yankee nuclear plant uses two mechanical type cooling towers during normal operation and two special cells in one of those towers in the event of an accident.*

The UHS can be the same nearby lake, river, or ocean used by the nuclear plant to absorb waste heat during normal operation or it can be a different, dedicated water source. However configured, the UHS is supposed to provide all of the nuclear power reactor's cooling water and makeup water needs for the first 30 days of an accident.



Two or more pumps are used to take water from the UHS and supply it as cooling water or makeup water during the reactor. The schematic drawing to the left of the emergency service water (ESW) system for the Wolf Creek nuclear plant in Kansas represents the typical post-accident cooling system. ESW pump A to the upper right draws water from the UHS and provides cooling water to emergency components like the control room's air conditioning condenser, the cooler for the emergency diesel generator, the containment air coolers, and the cooler for the safety injection pump room. After cooling these components, the water flows back to the UHS. ESW pump A can also provide makeup water to the component cooling water (CCW) system, the auxililary feedwater system, and/or the spent fuel pool (SFP) via the piping lines shown in the lower right corner. ESW pump B to the upper left mirrors the cooling and makeup water functions provided by ESW pump A for the redundant set of emergency components.

When a lake, river, or oceans serves as the UHS, the water needed by the ESW system during an accident are in the 10,000 to 30,000 gallons per minute range.

Because the normal supply of electricity – backfeed from the electricity generated by the nuclear plant itself or power from the electrical grid – cannot be relied upon in the event of an accident, nuclear power plants[3] have emergency diesel generators (EDGs) onsite. The EDGs provide the electricity to emergency equipment during an accident, including the ESW pumps. The EDGs and the ESW pumps have a symbiotic relationship – most EDGs[4] have their engines cooled by water supplied by the ESW pumps, while the ESW pumps have their motors powered by electricity supplied by the EDGs.

Nuclear plants have experienced ESW system problems, including:

- In January 2004, the NRC sanctioned the owner of the Perry nuclear plant in Ohio for allowing workers – twice – to reassemble an ESW pump improperly, leading to its failure.

- The operators at the Ginna nuclear plant in New York reduced the reactor power level from 97 percent to 50 percent on January 20, 2004, because ice build-up on the intake structure's screens partially blocked the in-flow of water from the lake. The water level in the intake structure – the source of water for the pumps – dropped nearly nine feet below normal. Had the water level dropped another foot, the ESW pumps would have been unable to supply water to emergency equipment and procedures would have guided operators into declaring a Site Area Emergency.

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[3] The exception to the rule being the Oconee nuclear plant in South Carolina, which relies on backup power from the nearby Keowee hydroelectric dam.
[4] The exception to the rule is a small handful of nuclear power plants with air-cooled EDGS.

- The NRC fined the owner of Nine Mile Point Unit 1 $200,000 in May 1991 for conducting maintenance at the intake pump screenhouse without realizing that the ESW system had been unintentionally disabled by the positioning of a gate.

- With the River Bend reactor in Louisiana shut down for refueling on April 19, 1989, workers applied a freeze seal to a 6-inch diameter ESW pipe. By freezing the water in this section of the pipe, workers would be able to open the downstream piping to perform maintenance. When the freeze seal failed, approximately 15,000 gallons of water poured out of the opened piping onto the auxiliary building floor. The flood damaged electrical equipment – causing a short that started a fire in one electrical cabinet – and disabled the system being used to cool the reactor core at the time.

- Operators at Susquehanna Unit 1 in Pennsylvania declared an emergency on May 24, 1986, when the ESW system was declared inoperable. The operators manually shut down the reactor, which had been operating at 100 percent power. Two days earlier, the shaft on one of the two ESW pumps sheared. Workers determined the cause to be excessive corrosion and that the shaft on the remaining ESW pump was susceptible to the same failure mode.

- On June 10, 1972, an operator supporting maintenance on a 10-foot diameter butterfly valve in the circulating water system at Quad Cities Unit 1 inadvertently caused it to close. The valve's closure caused the pressure in the piping to rise, until a rubber expansion joint in a recirculating line ruptured. In the six minutes it took to contact the control room and have the operators turn off the circulating water pumps, the water pouring from the ruptured expansion joint flooded the turbine building basement to a depth of nearly 16 feet. The flood submerged the four ESW pumps as well as the cooling water pumps for two emergency diesel generators.

NUCLEAR BORN KILLERS

Nuclear power plants, whether using once-through or closed-cycle cooling, withdraw large amounts of water from nearby lakes, rivers, and oceans. In doing so, aquatic life is adversely affected. A 2005 study, for example, of impacts from 11 coastal power plants in Southern California estimated that the San Onofre nuclear plant impinged nearly 3.5 million fish in 2003 alone – about 32 times more fish than the other 10 plants combined. Untold numbers of fish larvae and other life entrained in the water do not survive journeys through nuclear power plants. The more water the plants use, the more aquatic life we lose.

SUMMARY

Nuclear power plants use water when they are operating, when they are shut down, and if they have accidents. Nuclear power plants need water all of the time. Some nuclear power plants rely on cooling towers to lessen their water needs, but even the reduced needs can require tens of thousands of gallons per minute.

The connection between a nearby lake, river, or ocean and a nuclear power plant might suggest the primary nuclear safety hazard is radioactively contaminated liquid leaking into the water being discharged back into that source. But as the accidents and incidents detailed in this backgrounder suggest, the real hazard involves the water not getting to the plant or the water leaking into the plant.

Prepared by: David Lochbaum
Director, Nuclear Safety Project
Union of Concerned Scientists

Attachment 1: Got Math?

The minimum flow rate of water needed in a once-through cooling system to remove the waste heat from a nuclear power reactor is given by the following equation:

$$Q = m * C_P * \Delta T$$

where:

Q = waste heat load, BTU per hour
m = once-through cooling system flow rate, pounds mass per hour
C_P = specific heat of water, $\approx$ 1 BTU/pound mass °F
ΔT = temperature difference, °F

A nuclear power reactor generating one thousand megawatt hours of electricity (1,000 Mwe-hours) has a waste heat load of nearly 2,000 megawatt hours.

$$Q = 2{,}000 \text{ megawatt hours} * 1{,}000{,}000 \text{ watts / megawatt} * 3.413 \text{ BTU / watt}$$

$$Q = 6{,}830{,}000{,}000 \text{ BTU per hour}$$

Assuming the water flowing through the condenser rises 30°F (e.g., ΔT = 30°F), the once-through cooling system flow rate is calculated:

$$m = Q / (C_P * \Delta T)$$

$$m = 6{,}830{,}000{,}000 \text{ BTU per hour} / (1 \text{ BTU per pound mass °F} * 30\text{°F})$$

$$m = 228{,}000{,}000 \text{ pounds mass per hour}$$

Converting this flow rate from pounds mass to gallons:

$$\text{Flow} = 228{,}000{,}000 \text{ pounds per hour} * (0.1256 \text{ gallons / pound}) * (1 \text{ hour / 60 minutes})$$

$$\text{Flow} = 476{,}000 \text{ gallons per minute} = 686 \text{ million gallons per day}$$

A more general equation for estimating the minimum flow rate in a once-through cooling system:

$$\text{Flow} = \text{Mwe} * 14{,}295 / \Delta T$$

where:

Flow = once-through cooling system flow rate, gallons per minute
Mwe = electrical output of the nuclear power reactor, megawatts
ΔT = temperate rise of the once-through cooling system water, °F

Some of the new nuclear power reactors being discussed have an electrical output of 1,600 megawatts. For a 30°F temperature rise, a 1,600 Mwe nuclear power reactor needs:

Flow = 1,600 Mwe * 14,295 / 30°F = 762,384 gallons per minute

Unless the nearby source of water is an ocean, large river, or large lake, it may be incapable of absorbing all of the waste heat being rejected by a nuclear plant using a once-through cooling system. The equation, slightly modified, can be used to assess the potential impact of once-through cooling on a river.

$$Q = m * C_P * \Delta T$$

where:

Q = waste heat load, BTU per hour
m = river flow rate, pounds mass per hour
C_P = specific heat of water, ≈ 1 BTU/pound mass °F
ΔT = temperature difference, °F

Taking the waste heat rejected from that 1,000 Mwe nuclear power reactor (6,830,000,000 BTU per hour) and assuming that the thermal pollution discharge cannot cause the river water temperature to rise more than 5°F, the equation can be rearranged to determine the minimum river flow rate:

$$m = Q / (C_P * \Delta T)$$

m = 6,830,000,000 BTU per hour / (1 BTU per pound mass °F * 5°F)

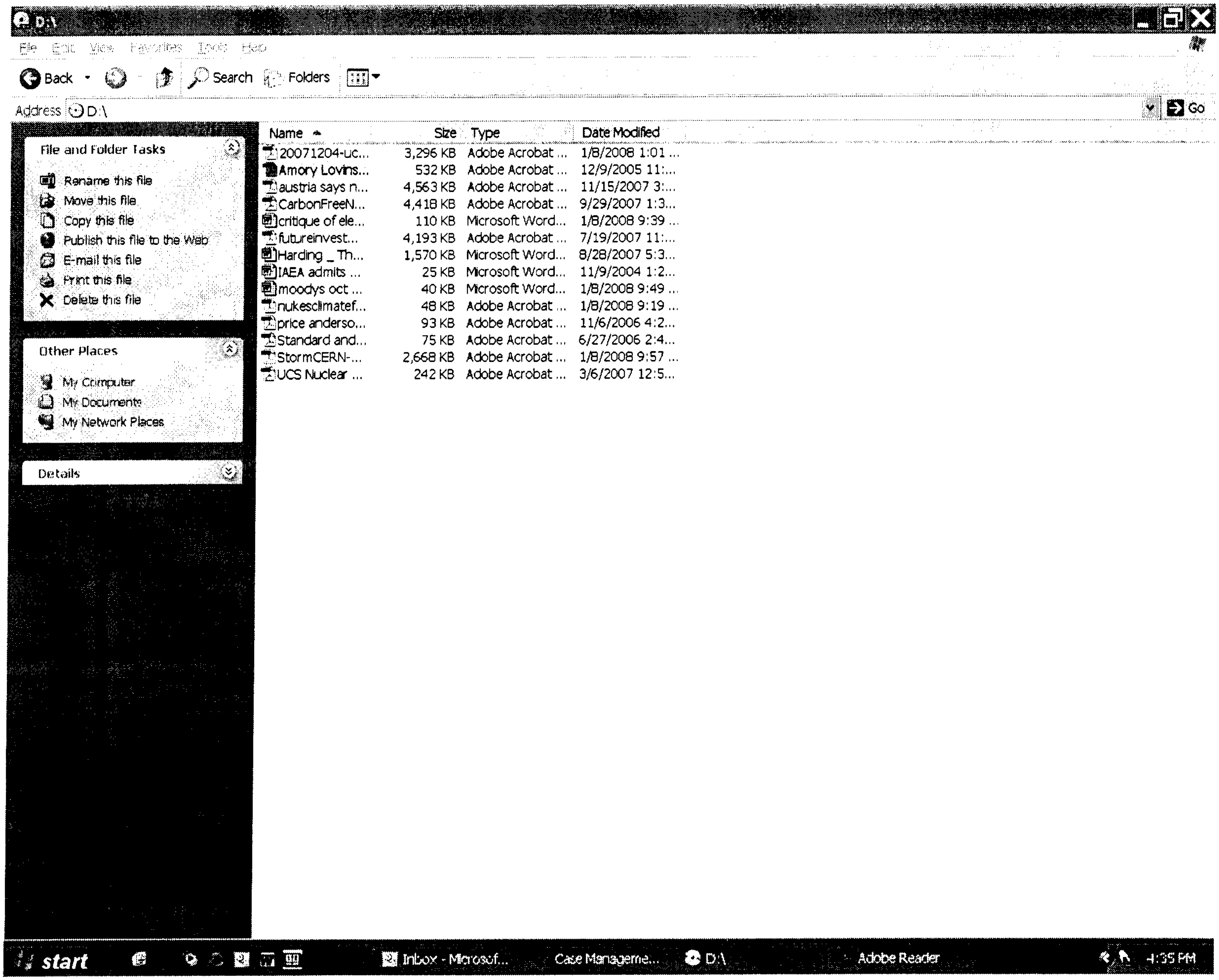
m = 1,370,000,000 pounds mass per hour

Converting this flow rate to cubic feet per second (cfs), a more conventional river flow measure:

cfs = 1,370,000,000 pounds mass / hour * (1ft^3 / 62.4 pounds) * (1 hour / 3600 seconds)

cfs = 6,077 cubic feet per second

The U.S. Geological Service maintains an online National Water Information Service at **HTTP://WATERDATA.USGS.GOV/NWIS/RT** that provide real time reporting of river flow rates. For example, the USA Streamflow Table on November 2, 2007, reported results from 8,428 monitoring locations across the country. The results show that only one – the Pamlico River near Washington, NC at 7,920 cfs – of several dozen monitored locations in North Carolina had a flow rate exceeding 6,077 cfs.



Wednesday, Jan 23, 2008 04:35 PM

MORE PROFIT WITH LESS CARBON

BY AMORY B. LOVINS

Focusing on energy efficiency will do more than protect Earth's climate—it will make businesses and consumers richer

A basic misunderstanding skews the entire climate debate. Experts on both sides claim that protecting Earth's climate will force a trade-off between the environment and the economy. According to these experts, burning less fossil fuel to slow or prevent global warming will increase the cost of meeting society's needs for energy services, which include everything from speedy transportation to hot showers. Environmentalists say the cost would be modestly higher but worth it; skeptics, including top U.S. government officials, warn that the extra expense would be prohibitive. Yet both sides are wrong. If properly done, climate protection would actually *reduce* costs, not raise them. Using energy more efficiently offers an economic bonanza—not because of the benefits of stopping global warming but because saving fossil fuel is a lot cheaper than buying it.

The world abounds with proven ways to use energy more productively, and smart businesses are leaping to exploit them. Over the past decade, chemical manufacturer DuPont has boosted production nearly 30 percent but cut energy use 7 percent and greenhouse gas emissions 72 percent (measured in terms of their carbon dioxide equivalent), saving more than $2 billion so far. Five other major firms—IBM, British Telecom, Alcan, NorskeCanada and Bayer—have collectively saved at least another $2 billion since the early 1990s by reducing their carbon emissions more than 60 percent. In 2001 oil giant BP met its 2010 goal of reducing carbon dioxide emissions 10 percent below the company's 1990 level, thereby cutting its energy bills $650 million over 10 years. And just this past May, General Electric vowed to raise its energy efficiency 30 percent by 2012 to enhance the company's shareholder value. These sharp-penciled firms, and dozens like them, know that energy efficiency improves the bottom line and yields even more valuable side benefits: higher quality and reliability in energy-efficient factories, 6 to 16 percent higher labor productivity in efficient offices, and 40 percent higher sales in stores skillfully designed to be illuminated primarily by daylight.

The U.S. now uses 47 percent less energy per dollar of economic output than it did 30 years ago, lowering costs

BURNING FOSSIL FUELS not only contributes to global warming—it wastes money. Improving the energy efficiency of factories, buildings, vehicles and consumer products would swiftly reduce the consumption of coal and oil, curbing the damage to Earth's climate while saving immense amounts of money for businesses and households.

CARY WOLINSKY (*photography*); JEN CHRISTIANSEN (*photoillustration*)

by $1 billion a day. These savings act like a huge universal tax cut that also reduces the federal deficit. Far from dampening global development, lower energy bills accelerate it. And there is plenty more value to capture at every stage of energy production, distribution and consumption. Converting coal at the power plant into incandescent light in your house is only 3 percent efficient. Most of the waste heat discarded at U.S. power stations—which amounts to 20 percent more energy than Japan uses for everything—could be lucratively recycled. About 5 percent of household electricity in the U.S. is lost to energizing computers, televisions and other appliances that are turned off. (The electricity wasted by poorly designed standby circuitry is equivalent to the output of more than a dozen 1,000-megawatt power stations running full-tilt.) In all, preventable energy waste costs Americans hundreds of billions of dollars and the global economy more than $1 trillion a year, destabilizing the climate while producing no value.

CROSSROADS FOR ENERGY

THE PROBLEM

- The energy sector of the global economy is woefully inefficient. Power plants and buildings waste huge amounts of heat, cars and trucks dissipate most of their fuel energy, and consumer appliances waste much of their power (and often siphon electricity even when they are turned off).
- If nothing is done, the use of oil and coal will continue to climb, draining hundreds of billions of dollars a year from the economy as well as worsening the climate, pollution and oil-security problems.

THE PLAN

- Improving end-use efficiency is the fastest and most lucrative way to save energy. Many energy-efficient products cost no more than inefficient ones. Homes and factories that use less power can be cheaper to build than conventional structures. Reducing the weight of vehicles can double their fuel economy without compromising safety or raising sticker prices.
- With the help of efficiency improvements and competitive renewable energy sources, the U.S. can phase out oil use by 2050. Profit-seeking businesses can lead the way.

If energy efficiency has so much potential, why isn't everyone pursuing it? One obstacle is that many people have confused efficiency (doing more with less) with curtailment, discomfort or privation (doing less, worse or without). Another obstacle is that energy users do not recognize how much they can benefit from improving efficiency, because saved energy comes in millions of invisibly small pieces, not in obvious big chunks. Most people lack the time and attention to learn about modern efficiency techniques, which evolve so quickly that even experts cannot keep up. Moreover, taxpayer-funded subsidies have made energy seem cheap. Although the U.S. government has declared that bolstering efficiency is a priority, this commitment is mostly rhetorical. And scores of ingrained rules and habits block efficiency efforts or actually reward waste. Yet relatively simple changes can turn all these obstacles into business opportunities.

Enhancing efficiency is the most vital step toward creating a climate-safe energy system, but switching to fuels that emit less carbon will also play an important role. The world economy is already decarbonizing: over the past two centuries, carbon-rich fuels such as coal have given way to fuels with less carbon (oil and natural gas) or with none (renewable sources such as solar and wind power). Today less than one third of the fossil-fuel atoms burned are carbon; the rest are climate-safe hydrogen. This decarbonization trend is reinforced by greater efficiencies in converting, distributing and using energy; for example, combining the production of heat and electricity can extract twice as much useful work from each ton of carbon emitted into the atmosphere. Together these advances could dramatically reduce total carbon emissions by 2050 even as the global economy expands. This article focuses on the biggest prize: wringing more work from each unit of energy delivered to businesses and consumers. Increasing end-use efficiency can yield huge savings in fuel, pollution and capital costs because large amounts of energy are lost at every stage of the journey from production sites to delivered services [*see box on opposite page*]. So even small reductions in the power used at the downstream end of the chain can enormously lower the required input at the upstream end.

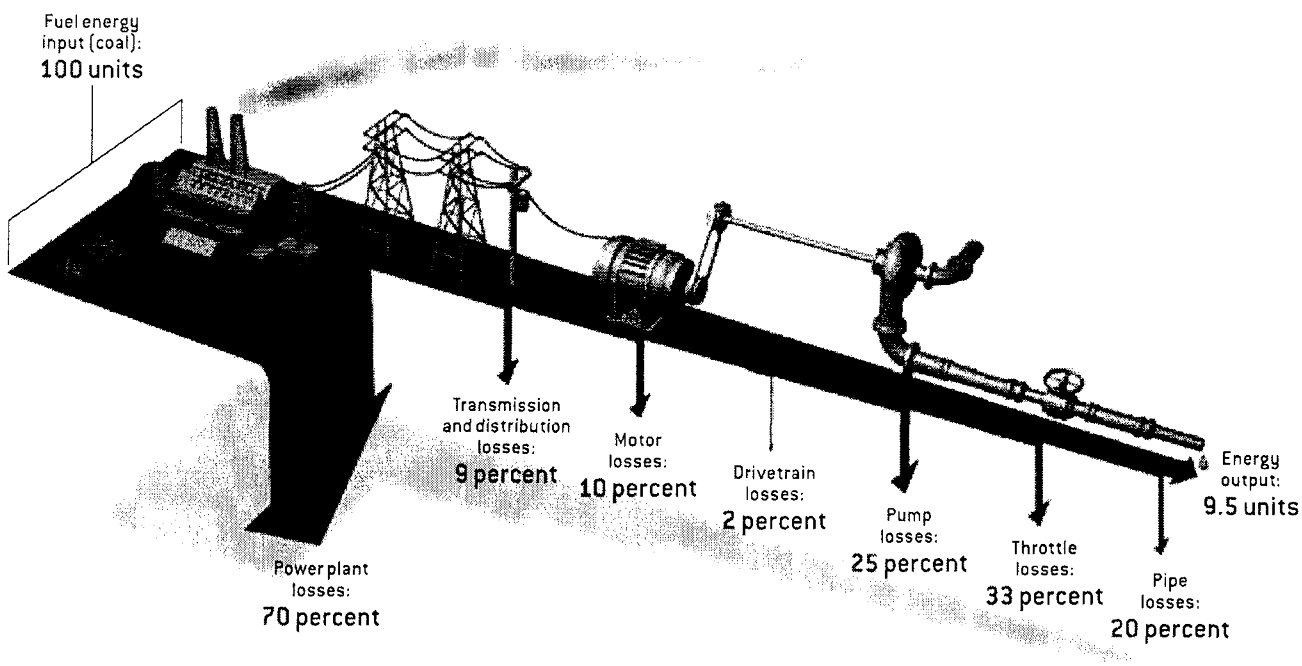
The Efficiency Revolution

MANY ENERGY-EFFICIENT PRODUCTS, once costly and exotic, are now inexpensive and commonplace. Electronic speed controls, for example, are mass-produced so cheaply that some suppliers give them away as a free bonus with each motor. Compact fluorescent lamps cost more than $20 two decades ago but only $2 to $5 today; they use 75 to 80 percent less electricity than incandescent bulbs and last 10 to 13 times longer. Window coatings that transmit light but reflect heat cost one fourth of what they did five years ago. Indeed, for many kinds of equipment in competitive markets—motors, industrial pumps, televisions, refrigerators—some highly energy-efficient models cost no more than inefficient ones. Yet far more important than all these better and cheaper technologies is a hidden revolution in the design that combines and applies them.

S. STRONG *Solar Design Associates, Inc.*

COMPOUNDING LOSSES

From the power plant to an industrial pipe, inefficiencies along the way whittle the energy input of the fuel—set at 100 arbitrary units in this example—by more than 90 percent, leaving only 9.5 units of energy delivered as fluid flow through the pipe. But small increases in end-use efficiency can reverse these compounding losses. For instance, saving one unit of output energy by reducing friction inside the pipe will cut the needed fuel input by 10 units, slashing cost and pollution at the power plant while allowing the use of smaller, cheaper pumps and motors.



For instance, how much thermal insulation is appropriate for a house in a cold climate? Most engineers would stop adding insulation when the expense of putting in more material rises above the savings over time from lower heating bills. But this comparison omits the capital cost of the heating system—the furnace, pipes, pumps, fans and so on—which may not be necessary at all if the insulation is good enough. Consider my own house, built in 1984 in Snowmass, Colo., where winter temperatures can dip to −44 degrees Celsius and frost can occur any day of the year. The house has no conventional heating system; instead its roof is insulated with 20 to 30 centimeters of polyurethane foam, and its 40-centimeter-thick masonry walls sandwich another 10 centimeters of the material. The double-pane windows combine two or three transparent heat-reflecting films with insulating krypton gas, so that they block heat as well as eight to 14 panes of glass. These features, along with heat recovery from the ventilated air, cut the house's heat losses to only about 1 percent more than the heat gained from sunlight, appliances and people inside the structure. I can offset this tiny loss by playing with my dog (who generates about 50 watts of heat, adjustable to 100 watts if you throw a ball to her) or by burning obsolete energy studies in a small woodstove on the coldest nights.

Eliminating the need for a heating system reduced construction costs by $1,100 (in 1983 dollars). I then reinvested this money, plus another $4,800, into equipment that saved half the water, 99 percent of the water-heating energy and 90 percent of the household electricity. The 4,000-square-foot structure—which also houses the original headquarters of Rocky Mountain Institute (RMI), the nonprofit group I cofounded in 1982—consumes barely more electricity than a single 100-watt lightbulb. (This amount excludes the power used by the institute's office equipment.) Solar cells generate five to six times that much electricity, which I sell back to the utility. Together all the efficiency investments repaid their cost in 10 months with 1983 technologies; today's are better and cheaper.

In the 1990s Pacific Gas & Electric undertook an experiment called ACT^2 that applied smart design in seven new and old buildings to demonstrate that large efficiency improvements can be cheaper than small ones. For example, the company built a new suburban tract house in Davis, Calif., that could stay cool in the summer without air-conditioning. PG&E estimated that such a design, if widely adopted, would cost about $1,800 less to build and $1,600 less to maintain over its lifetime than a conventional home of the same size. Similarly, in 1996 Thai architect Soontorn Boonyatikarn built a house near steamy Bangkok that required only one-seventh

DON FOLEY

the air-conditioning capacity usually installed in a structure of that size; the savings in equipment costs paid for the insulating roof, walls and windows that keep the house cool [*see box on opposite page*]. In all these cases, the design approach was the same: optimize the whole building for multiple benefits rather than use isolated components for single benefits.

Such whole-system engineering can also be applied to office buildings and factories. The designers of a carpet factory built in Shanghai in 1997 cut the pumping power required for a heat-circulating loop by 92 percent through two simple changes. The first change was to install fat pipes rather than thin ones, which greatly reduced friction and hence allowed the system to use smaller pumps and motors. The second innovation was to lay out the pipes before positioning the equipment they connect. As a result, the fluid moved through short, straight pipes instead of tracing circuitous paths, further reducing friction and capital costs.

This isn't rocket science; it's just good Victorian engineering rediscovered. And it is widely applicable. A practice team at RMI has recently developed new-construction designs offering energy savings of 89 percent for a data center, about 75 percent for a chemical plant, 70 to 90 percent for a supermarket and about 50 percent for a luxury yacht, all with capital costs lower than those of conventional designs. The team has also proposed retrofits for existing oil refineries, mines and microchip factories that would reduce energy use by 40 to 60 percent, repaying their cost in just a few years.

Using energy more efficiently offers an economic bonanza—not because of the benefits of stopping global warming but because saving fossil fuel is a lot cheaper than buying it.

Vehicles of Opportunity

TRANSPORTATION CONSUMES 70 percent of U.S. oil and generates a third of the nation's carbon emissions. It is widely considered the most intractable part of the climate problem, especially as hundreds of millions of people in China and India buy automobiles. Yet transportation offers enormous efficiency opportunities. *Winning the Oil Endgame*, a 2004 analysis written by my team at RMI and co-sponsored by the Pentagon, found that artfully combining lightweight materials with innovations in propulsion and aerodynamics could cut oil use by cars, trucks and planes by two thirds without compromising comfort, safety, performance or affordability.

Despite 119 years of refinement, the modern car remains astonishingly inefficient. Only 13 percent of its fuel energy even reaches the wheels—the other 87 percent is either dissipated as heat and noise in the engine and drivetrain or lost to idling and accessories such as air conditioners. Of the energy delivered to the wheels, more than half heats the tires, road and air. Just 6 percent of the fuel energy actually accelerates the car (and all this energy converts to brake heating when you stop). And, because 95 percent of the accelerated mass is the car itself, less than 1 percent of the fuel ends up moving the driver.

Yet the solution is obvious from the physics: greatly reduce the car's weight, which causes three fourths of the energy losses at the wheels. And every unit of energy saved at the wheels by lowering weight (or cutting drag) will save an additional seven units of energy now lost en route to the wheels. Concerns about cost and safety have long discouraged attempts to make lighter cars, but modern light-but-strong materials—new metal alloys and advanced polymer composites—can slash a car's mass without sacrificing crashworthiness. For example, carbon-fiber composites can absorb six to 12 times as much crash energy per kilogram as steel does, more than offsetting the composite car's weight disadvantage if it hits a steel vehicle that is twice as heavy. With such novel materials, cars can be big, comfortable and protective without being heavy, inefficient and hostile, saving both oil *and* lives. As Henry Ford said, you don't need weight for strength; if you did, your bicycle helmet would be made of steel, not carbon fiber.

Advanced manufacturing techniques developed in the past two years could make carbon-composite car bodies competitive with steel ones. A lighter body would allow automakers to use smaller (and less expensive) engines. And because the assembly of carbon-composite cars does not require body or paint shops, the factories would be smaller and cost 40 percent less to build than conventional auto plants. These savings would offset the higher cost of the carbon-composite materials. In all, the introduction of ultralight bodies could nearly double the fuel efficiency of today's hybrid-electric vehicles—which are already twice as efficient as conventional cars—without raising their sticker prices. If composites prove unready, new ultralight steels offer a reliable backstop. The competitive marketplace will sort out the winning materials, but, either way, superefficient ultralight vehicles will start pulling

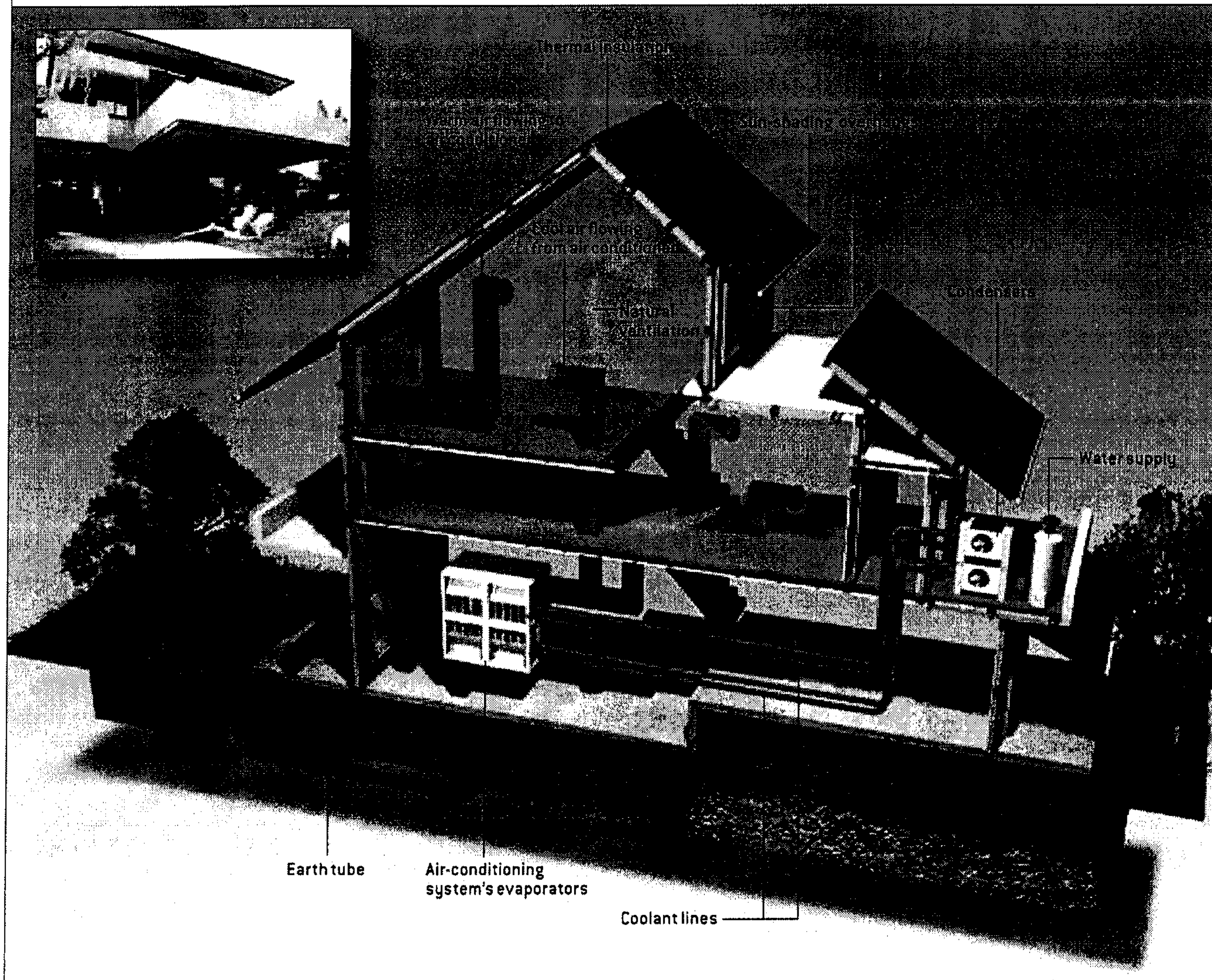
THE AUTHOR

AMORY B. LOVINS

LOVINS is co-founder and chief executive of Rocky Mountain Institute, an entrepreneurial nonprofit organization based in Snowmass, Colo., and chairman of Fiberforge, an engineering firm in Glenwood Springs, Colo. A physicist, Lovins has consulted for industry and governments worldwide for more than 30 years, chiefly on energy and its links with the environment, development and security. He has published 29 books and hundreds of papers on these subjects and has received a MacArthur Fellowship and many other awards for his work.

SAVING ENERGY BY DESIGN

How can you keep cool in tropical Thailand while minimizing power usage? Architect Soontorn Boonyatikarn of Chulalongkorn University used overhangs and balconies to shade his 350-square-meter home in Pathumthani, near Bangkok. Insulation, an airtight shell and infrared-reflecting windows keep heat out of the house while letting in plenty of daylight. An open floor plan and central stairwell promote ventilation, and indoor air is cooled as it flows through an underground tube. As a result, the house needs just one seventh of the typical air-conditioning capacity for a structure of its size. To further reduce energy bills, the air-conditioning system's condensers heat the house's water.



DON FOLEY (*schematic*); SOONTORN BOONYATIKARN *Chulalongkorn University* (*photograph*)

away from the automotive pack within the next decade.

What is more, ultralight cars could greatly accelerate the transition to hydrogen fuel-cell cars that use no oil at all [see "On the Road to Fuel-Cell Cars," by Steven Ashley; SCIENTIFIC AMERICAN, March]. A midsize SUV whose halved weight and drag cut its needed power to the wheels by two thirds would have a fuel economy equivalent to 114 miles per gallon and thus require only a 35-kilowatt fuel cell—one third the usual size and hence much easier to manufacture affordably [*see box on page 81*]. And because the vehicle would need to carry only one third as much hydrogen, it would not require any new storage technologies; compact, safe, off-the-shelf carbon-fiber tanks could hold enough hydrogen to propel the SUV for 530 kilometers. Thus, the first automaker to go ultralight will win the race to fuel cells, giving the whole industry a strong incentive to become as boldly innovative in materials and manufacturing as a few companies now are in propulsion.

RMI's analysis shows that full adoption of efficient vehicles, buildings and industries could shrink projected U.S. oil use in 2025—28 million barrels a day—by more than half, lowering consumption to pre-1970 levels. In a realistic scenario, only about half of these savings could actually be captured by 2025 because many older, less efficient cars and trucks would remain on the road (vehicle stocks turn over slowly). Before 2050, though, U.S. oil consumption could be phased out altogether by doubling the efficiency of oil use and substituting alternative fuel supplies [*see illustration on page 83*]. Businesses can profit greatly by making the transition, because saving each barrel of oil through efficiency improvements costs only $12, less than one fifth of what petroleum sells for today. And two kinds of alternative fuel supplies could compete robustly with oil even if it sold for less than half the current price. The first is ethanol made from woody, weedy plants such as switchgrass and poplar. Corn is currently the main U.S. source of ethanol, which is blended with gasoline, but the woody plants yield twice as much ethanol per ton as corn does and with lower capital investment and far less energy input.

The second alternative is replacing oil with lower-carbon natural gas, which would become cheaper and more abundant as efficiency gains reduce the demand for electricity at peak periods. At those times, gas-fired turbines generate power so wastefully that saving 1 percent of electricity would cut U.S. natural gas consumption by 2 percent and its price by 3 or 4 percent. Gas saved in this way and in other uses could then replace oil either directly or, even more profitably and efficiently, by converting it to hydrogen.

The benefits of phasing out oil would go far beyond the estimated $70 billion saved every year. The transition would lower U.S. carbon emissions by 26 percent and eliminate all the social and political costs of getting and burning petroleum—military conflict, price volatility, fiscal and diplomatic distortions, pollution and so on. If the country becomes oil-free, then petroleum will no longer be worth fighting over. The Pentagon would also reap immediate rewards from raising energy efficiency because it badly needs to reduce the costs and risks of supplying fuel to its troops. Just as the U.S. Department of Defense's research efforts transformed civilian industry by creating the Internet and the Global Positioning System, it should now spearhead the development of advanced ultralight materials.

The switch to an oil-free economy would happen even faster than RMI projected if policymakers stopped encouraging the perverse development patterns that make people drive so much. If federal, state and local governments did not mandate and subsidize suburban sprawl, more of us could live in neighborhoods where almost everything we want is within a five-minute walk. Besides saving fuel, this New Urbanist design builds stronger communities, earns more money for developers and is much less disruptive than other methods of limiting vehicle traffic (such as the draconian fuel and car taxes that Singapore uses to avoid Bangkok-like traffic jams).

ADDICTED TO OIL

28 million
Barrels of oil that will be consumed each day in the U.S. by 2025 if current trends continue

13 percent
The proportion of a car's fuel energy that reaches its wheels

$70 billion
Annual savings [by 2025] from improving the efficiency of oil use and finding substitutes for oil

Renewable Energy

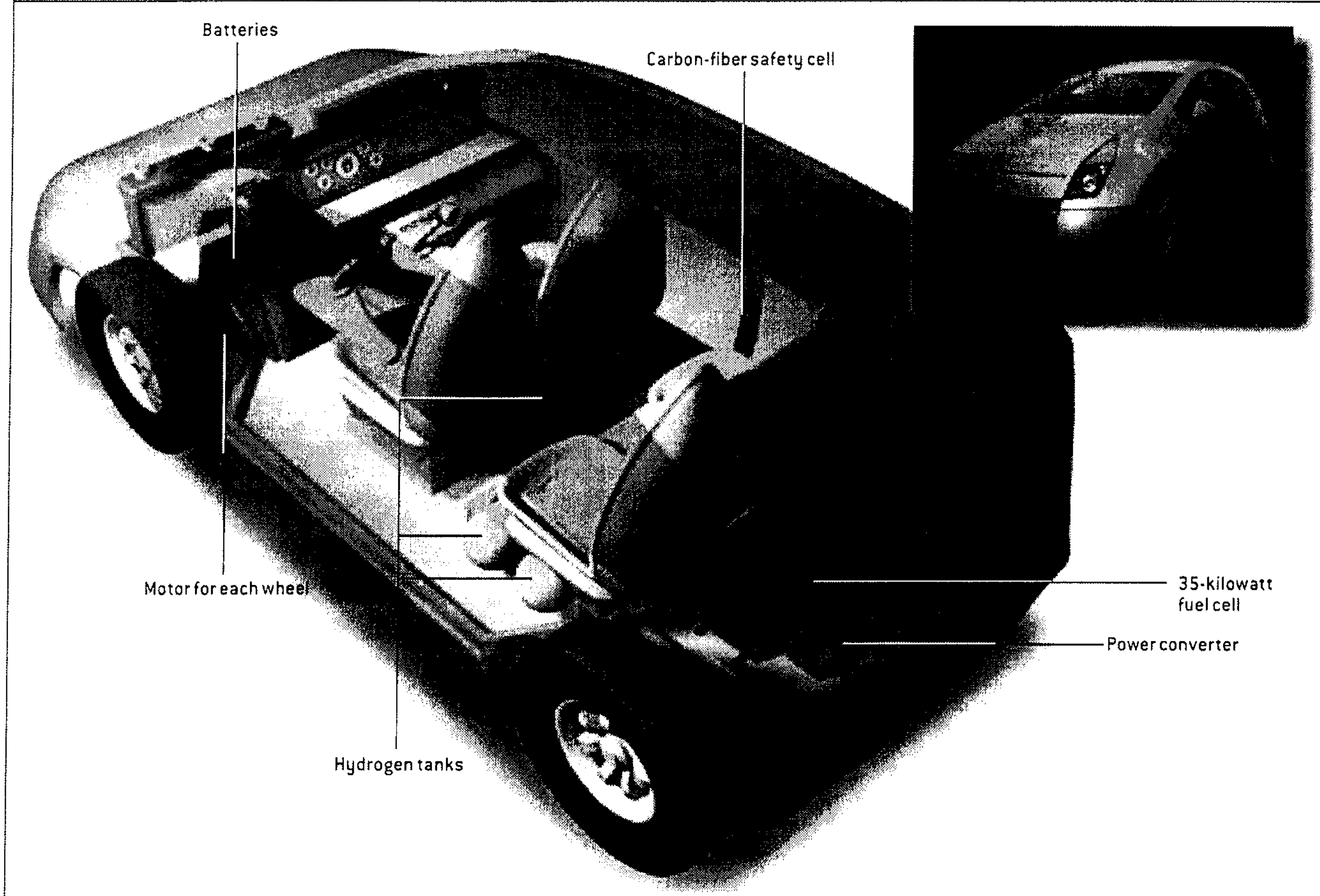
EFFICIENCY IMPROVEMENTS that can save most of our electricity also cost less than what the utilities now pay for coal, which generates half of U.S. power and 38 percent of its fossil-fuel carbon emissions. Furthermore, in recent years alternatives to coal-fired power plants—including renewable sources such as wind and solar power, as well as decentralized cogeneration plants that produce electricity and heat together in buildings and factories—have begun to hit their stride. Worldwide the collective generating capacity of these sources is already greater than that of nuclear power and growing six times as fast [*see illustration on page 82*]. This trend is all the more impressive because decentralized generators face many obstacles to fair competition and usually get much lower subsidies than centralized coal-fired or nuclear plants.

Wind power is perhaps the greatest success story. Mass production and improved engineering have made modern wind turbines big (generating two to five megawatts each), extremely reliable and environmentally quite benign. Denmark already gets a fifth of its electricity from wind, Germany a tenth. Germany and Spain are each adding more than 2,000 megawatts of wind power each year, and Europe aims to get 22 percent of its electricity and 12 percent of its total energy from renewables by 2010. In contrast, global nuclear generating capacity is expected to remain flat, then decline.

The most common criticism of wind power—that it produces electricity too intermittently—has not turned out to be a serious drawback. In parts of Europe that get all their power from wind on some days, utilities have overcome the problem by diversifying the locations of their wind turbines, incorporating wind forecasts into their generating plans and integrating wind power with hydroelectricity and other energy sources. Wind and solar power work particularly well together, partly because the conditions that are bad for wind (calm, sunny weather) are good for solar, and vice versa. In fact, when properly combined, wind and solar facilities are more reliable than conventional power stations—they come in smaller modules (wind turbines, solar cells) that are less likely to fail all at once, their costs do not swing wildly with the prices of fossil fuels, and terrorists are much more likely to attack a nuclear

A LEAN, MEAN DRIVING MACHINE

Ultralight cars can be fast, roomy, safe and efficient. A concept five-seat midsize SUV called the Revolution, designed in 2000, weighs only 857 kilograms—less than half the weight of a comparable conventional car—yet its carbon-fiber safety cell would protect passengers from high-speed collisions with much heavier vehicles. A 35-kilowatt fuel cell could propel the car for 530 kilometers on 3.4 kilograms of hydrogen stored in its tanks. And the Revolution could accelerate to 100 kilometers per hour in 8.3 seconds.

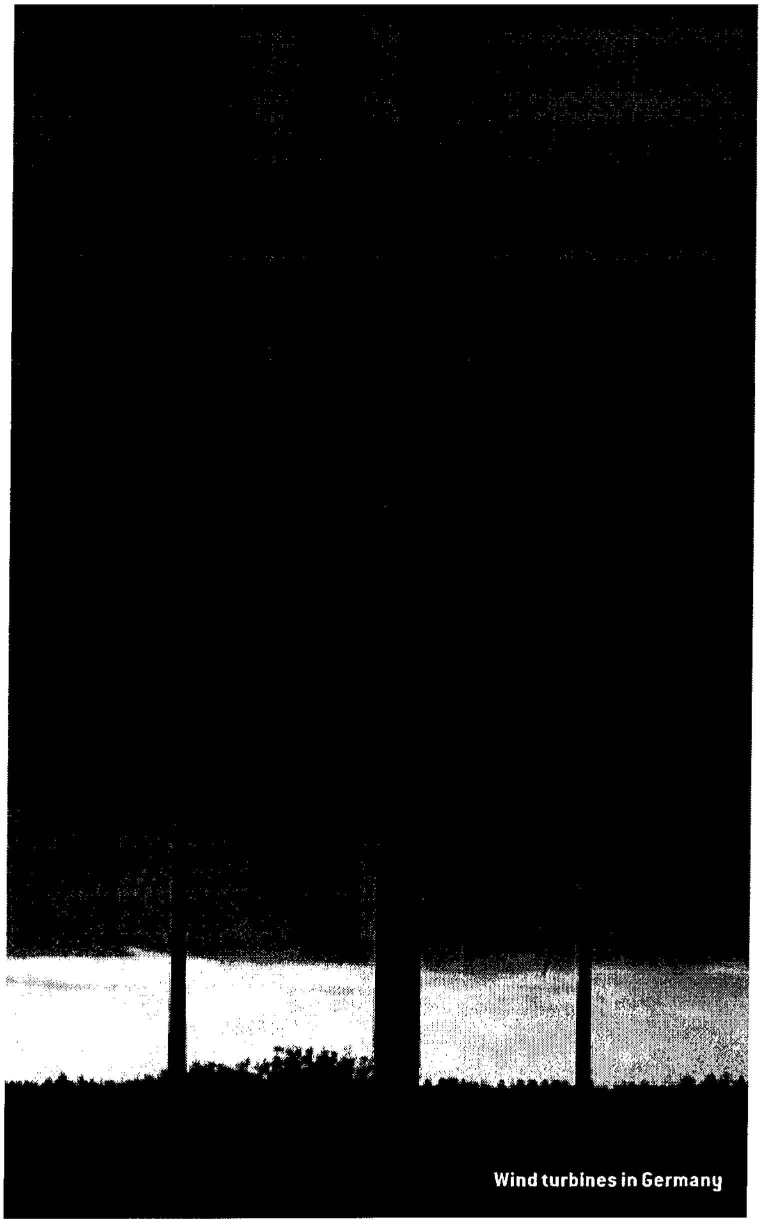


reactor or an oil terminal than a wind farm or a solar array.

Most important, renewable power now has advantageous economics. In 2003 U.S. wind energy sold for as little as 2.9 cents a kilowatt-hour. The federal government subsidizes wind power with a production tax credit, but even without that subsidy, the price—about 4.6 cents per kilowatt-hour—is still cheaper than subsidized power from new coal or nuclear plants. (Wind power's subsidy is a temporary one that Congress has repeatedly allowed to expire; in contrast, the subsidies for the fossil-fuel and nuclear industries are larger and permanent.) Wind power is also abundant: wind farms occupying just a few percent of the available land in the Dakotas could cost-effectively meet all of America's electricity needs. Although solar cells currently cost more per kilowatt-hour than wind turbines do, they can still be profitable if integrated into buildings, saving the cost of roofing materials. Atop big, flat-roofed commercial buildings, solar cells can compete without subsidies if combined with efficient use that allows the building's owner to resell the surplus power when it is most plentiful and valuable—on sunny afternoons. Solar is also usually the cheapest way to get electricity to the two billion people, mostly in the developing world, who have no access to power lines. But even in rich countries, a house as efficient as mine can get all its electricity from just a few square meters of solar cells, and installing the array costs less than connecting to nearby utility lines.

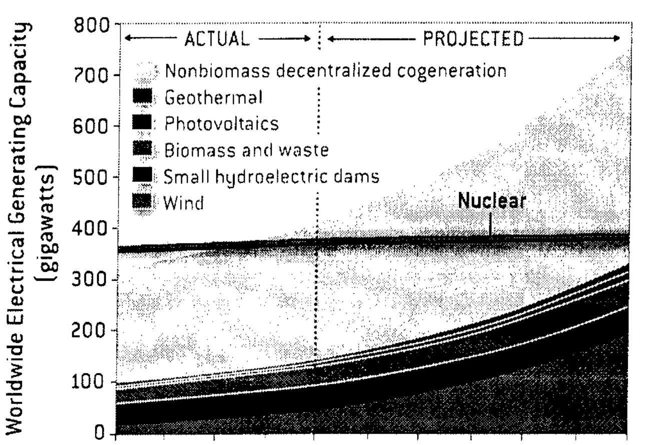
Cheaper to Fix

INEXPENSIVE EFFICIENCY improvements and competitive renewable sources can reverse the terrible arithmetic of climate change, which accelerates exponentially as we burn fossil fuels ever faster. Efficiency can outpace economic growth if we pay attention: between 1977 and 1985, for example, U.S. gross domestic product (GDP) grew 27 percent, whereas oil use fell 17 percent. (Over the same period, oil imports dropped 50 percent, and Persian Gulf imports plummeted 87 percent.) The growth of renewables has routinely outpaced GDP; worldwide, solar and wind power are doubling every two and three years, respectively. If both efficiency and renewables grow faster than the economy, then carbon emissions will fall and global warming will slow—buying more time to develop even



Wind turbines in Germany

ELECTRICITY ALTERNATIVES



DECENTRALIZED SOURCES of electricity—cogeneration (the combined production of electricity and heat, typically from natural gas) and renewables (such as solar and wind power)—surpassed nuclear power in global generating capacity in 2002. The annual output of these low- and no-carbon sources will exceed that of nuclear power this year.

better technologies for displacing the remaining fossil-fuel use, or to master and deploy ways to capture combustion carbon before it enters the air [see "Can We Bury Global Warming?" by Robert H. Socolow; SCIENTIFIC AMERICAN, July].

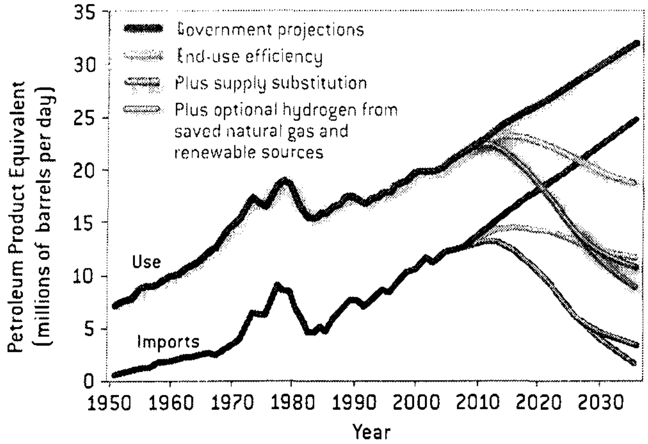
In contrast, nuclear power is a slower and much more expensive solution. Delivering a kilowatt-hour from a new nuclear plant costs at least three times as much as saving one through efficiency measures. Thus, every dollar spent on efficiency would displace at least three times as much coal as spending on nuclear power, and the efficiency improvements could go into effect much more quickly because it takes so long to build reactors. Diverting public and private investment from market winners to losers does not just distort markets and misallocate financial capital—it worsens the climate problem by buying a less effective solution.

The good news about global warming is that it is cheaper to fix than to ignore. Because saving energy is profitable, efficient use is gaining traction in the marketplace. U.S. Environmental Protection Agency economist Skip Laitner calculates that from 1996 to mid-2005 prudent choices by businesses and consumers, combined with the shift to a more information- and service-based economy, cut average U.S. energy use per dollar of GDP by 2.1 percent a year—nearly three times as fast as the rate for the preceding 10 years. This change met 78 percent of the rise in demand for energy services over the past decade (the remainder was met by increasing energy supply), and the U.S. achieved this progress without the help of any technological breakthroughs or new national policies. The climate problem was created by millions of bad decisions over decades, but climate stability can be restored by millions of sensible choices—buying a more efficient lamp or car, adding insulation or caulk to your home, repealing subsidies for waste and rewarding desired outcomes (for example, by paying architects and engineers for savings, not expenditures).

The proper role of government is to steer, not row, but for years officials have been steering our energy ship in the wrong direction. The current U.S. energy policy harms the economy and the climate by rejecting free-market principles and playing favorites with technologies. The best course is to allow every method of producing or saving energy to compete fairly, at honest prices, regardless of which kind of investment it is, what technology it uses, how big it is or who owns it. For example, few jurisdictions currently let decentralized power sources such as rooftop solar arrays "plug and play" on the electric grid, as modern technical standards safely permit. Although 31 U.S. states allow net metering—the utility buys your power at the same price it charges you—most artificially restrict or distort this competition. But the biggest single obstacle to electric and gas efficiency is that most countries, and all U.S. states except California and Oregon, reward distribution utilities for selling more energy and penalize them for cutting their customers' bills. Luckily, this problem is easy to fix: state regulators should align incentives by decoupling profits from energy sales, then letting utilities keep some of the savings from trimming energy bills.

JEN CHRISTIANSEN, SOURCE: ROCKY MOUNTAIN INSTITUTE (*graph*); ANDREAS RENTZ *Getty Images* (*photograph*)

AN OIL-FREE AMERICA



U.S. OIL CONSUMPTION AND IMPORTS can be profitably slashed by doubling the efficiency of vehicles, buildings and industries (*yellow lines in graph*). The U.S. can achieve further reductions by replacing oil with competitive substitutes such as advanced biofuels and saved natural gas (*green lines*) and with hydrogen fuel (*gray lines*).

Superefficient vehicles have been slow to emerge from Detroit, where neither balance sheets nor leadership has supported visionary innovation. Also, the U.S. lightly taxes gasoline but heavily subsidizes its production, making it cheaper than bottled water. Increasing fuel taxes may not be the best solution, though; in Europe, stiff taxes—which raise many countries' gasoline prices to \$4 or \$5 a gallon—cut driving more than they make new cars efficient, because fuel costs are diluted by car owners' other expenses and are then steeply discounted (most car buyers count only the first few years' worth of fuel savings). Federal standards adopted in the 1970s helped to lift the fuel economy of new cars and light trucks from 16 miles per gallon in 1978 to 22 miles per gallon in 1987, but the average has slipped to 21 mpg since then. The government projects that the auto industry will spend the next 20 years getting its vehicles to be just 0.5 mile per gallon more efficient than they were in 1987. Furthermore, automakers loathe the standards as restrictions on choice and have become adept at gaming the system by selling more vehicles classified as light trucks, which are allowed to have lower fuel economy than cars. (The least efficient light trucks even get special subsidies.)

The most powerful policy response is "feebates"—charging fees on inefficient new cars and returning that revenue as rebates to buyers of efficient models. If done separately for each size class of vehicle, so there is no bias against bigger models, feebates would expand customer choice instead of restricting it. Feebates would also encourage innovation, save customers money and boost automakers' profits. Such policies, which can be implemented at the state level, could speed the adoption of advanced-technology cars, trucks and planes without mandates, taxes, subsidies or new national laws.

In Europe and Japan, the main obstacle to saving energy is the mistaken belief that their economies are already as efficient as they can get. These countries are up to twice as efficient as the U.S., but they still have a long way to go. The greatest opportunities, though, are in developing countries, which are on average three times less efficient than the U.S. Dreadfully wasteful motors, lighting ballasts and other devices are freely traded and widely bought in these nations. Their power sector currently devours one quarter of their development funds, diverting money from other vital projects. Industrial countries are partly responsible for this situation because many have exported inefficient vehicles and equipment to the developing world. Exporting inefficiency is both immoral and uneconomic; instead the richer nations should help developing countries build an energy-efficient infrastructure that would free up capital to address their other pressing needs. For example, manufacturing efficient lamps and windows takes 1,000 times less capital than building power plants and grids to do the same tasks, and the investment is recovered 10 times faster.

China and India have already discovered that their burgeoning economies cannot long compete if energy waste continues to squander their money, talent and public health. China is setting ambitious but achievable goals for shifting from coal-fired power to decentralized renewable energy and natural gas. (The Chinese have large supplies of gas and are expected to tap vast reserves in eastern Siberia.) Moreover, in 2004 China announced an energy strategy built around "leapfrog technologies" and rapid improvements in the efficiency of new buildings, factories and consumer products. China is also taking steps to control the explosive growth of its oil use; by 2008 it will be illegal to sell many inefficient U.S. cars there. If American automakers do not innovate quickly enough, in another decade you may well be driving a superefficient Chinese-made car. A million U.S. jobs hang in the balance.

Today's increasingly competitive global economy is stimulating an exciting new pattern of energy investment. If governments can remove institutional barriers and harness the dynamism of free enterprise, the markets will naturally favor choices that generate wealth, protect the climate and build real security by replacing fossil fuels with cheaper alternatives. This technology-driven convergence of business, environmental and security interests—creating abundance by design—holds out the promise of a fairer, richer and safer world. SA

MORE TO EXPLORE

Hypercars, Hydrogen and the Automotive Transition. A. B. Lovins and D. R. Cramer in *International Journal of Vehicle Design*, Vol. 35, Nos. 1–2, pages 50–85; 2004. Available at www.rmi.org/images/other/Trans/T04-01_HypercarH2AutoTrans.pdf

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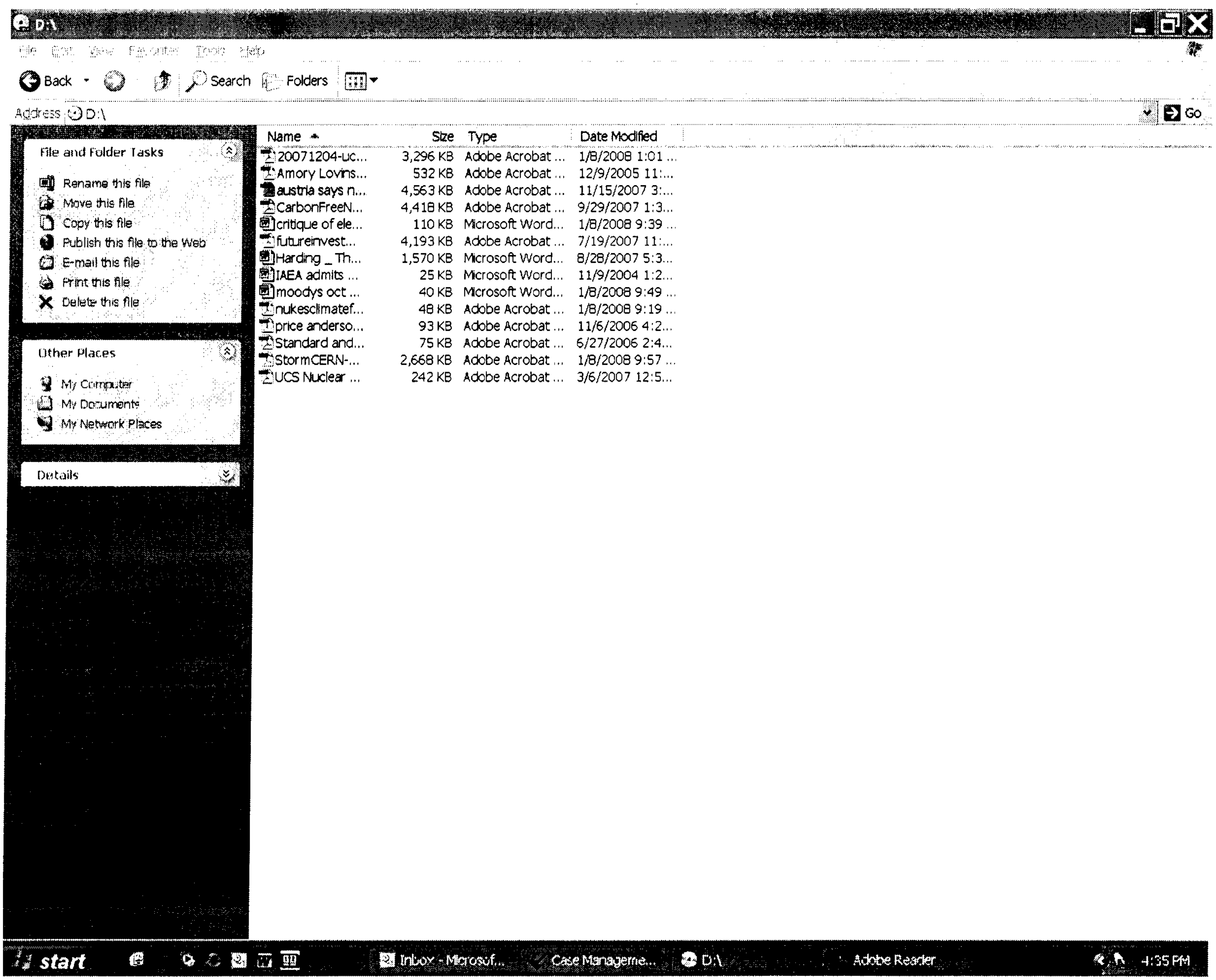
A complete list of references can be found online at www.rmi.org/sitepages/pid173.php#C05-05

JEN CHRISTIANSEN; SOURCE: RMI (*graph*); PROJECTIONS TO 2025 FROM U.S. ENERGY INFORMATION ADMINISTRATION; ESTIMATES AFTER 2025 FROM RMI



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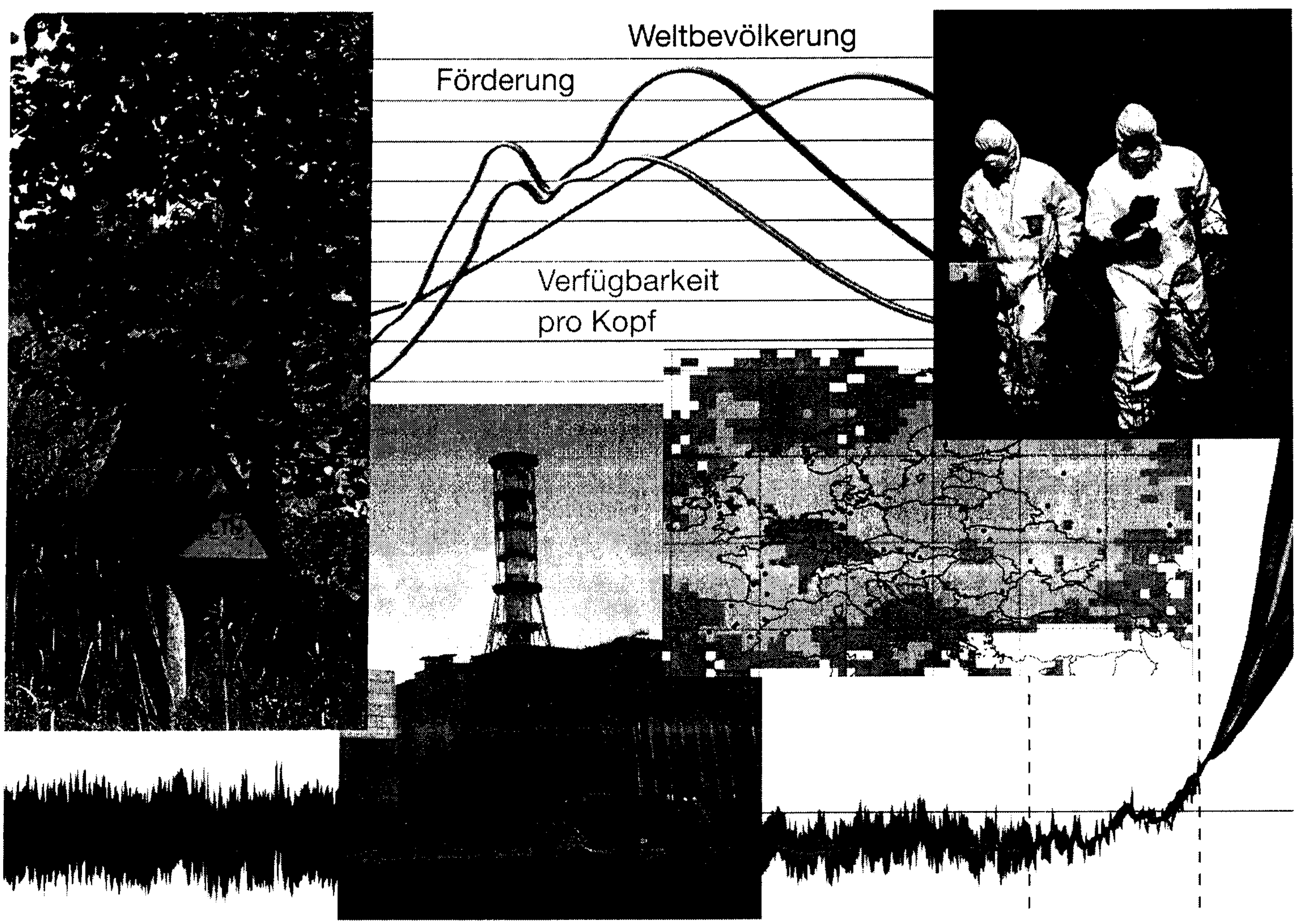
Nuclear Power, Climate Policy and Sustainability

An Assessment by the Austrian Nuclear Advisory Board



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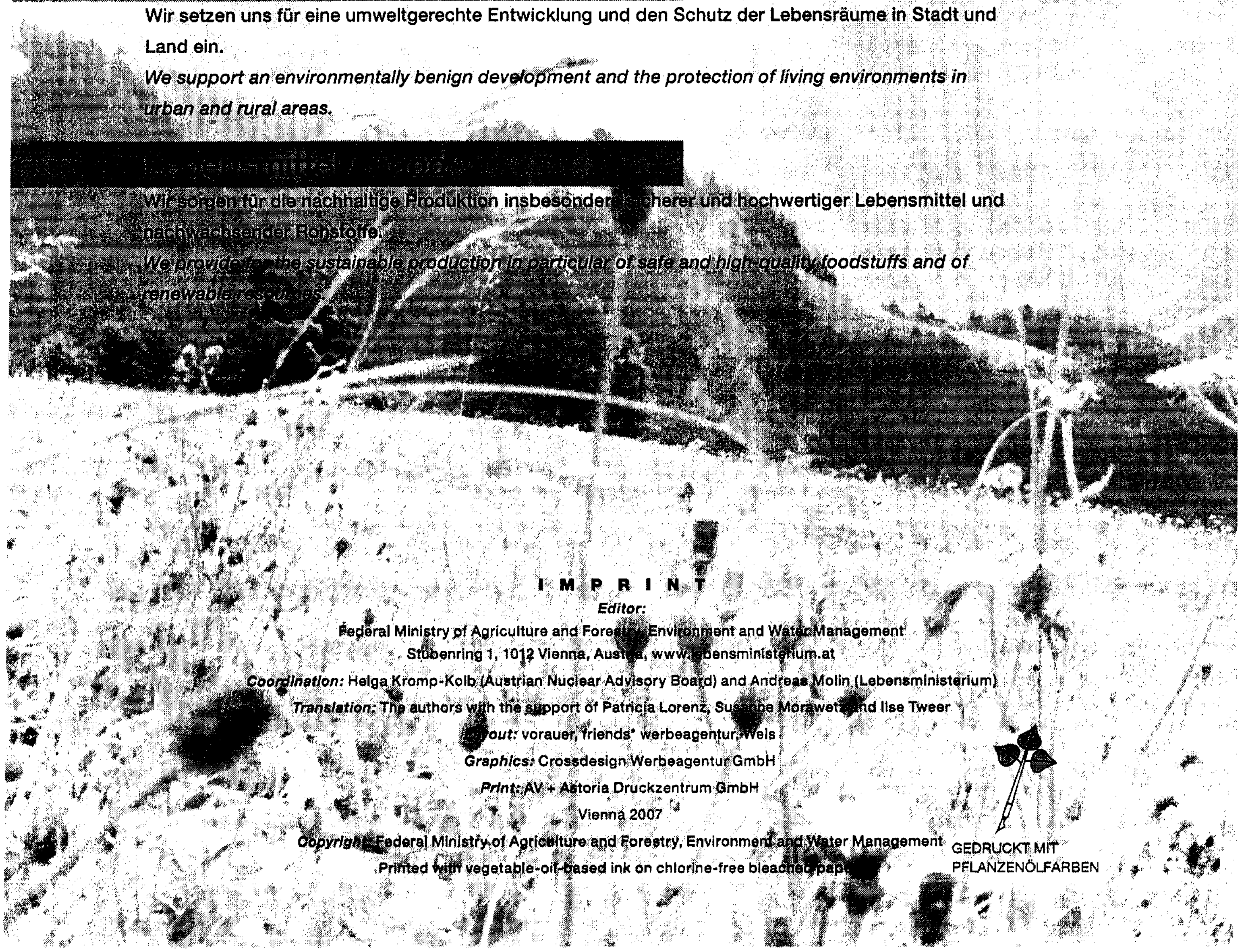

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Editor:

Federal Ministry of Agriculture and Forestry, Environment and Water Management

Stubenring 1, 1012 Vienna, Austria, www.lebensministerium.at

Coordination: Helga Kromp-Kolb (Austrian Nuclear Advisory Board) and Andreas Molin (Lebensministerium)

Translation: The authors with the support of Patricia Lorenz, Susanne Morawetz and Ilse Tweer

Layout: vorauer, friends* werbeagentur, Wels

Graphics: Crossdesign Werbeagentur GmbH

Print: AV + Astoria Druckzentrum GmbH

Vienna 2007

Printed with vegetable-oil-based ink on chlorine-free bleached paper

GEDRUCKT MIT PFLANZENÖLFARBEN

Preface

For many years Austria has followed a policy of exit from nuclear power. In the population and across all political parties there is wide-spread consensus that nuclear power is too risky an energy technology and that the use of nuclear energy burdens future generations irresponsibly with nuclear waste.

Meantime climate change has made the need to reduce green house gas emissions apparent. The foreseeable end of cheap oil and – somewhat later – of gas also requires a rethinking of energy policies.

Consequently I am frequently confronted with the question whether in the light of these developments a policy critical of nuclear energy was still legitimate, whether nuclear energy was not the lesser evil.

Policy, just like science, sometimes must pause and check its premises. In this spirit I have asked the Austrian Nuclear Advisory Board, the pertinent scientific advisory body of the Austrian Government, to take up this question. Have advances in science and technology made a revision of the Austrian energy policy regarding nuclear necessary, especially in view of climate change and "Peak Oil"? Has the nuclear option become sustainable?

The assessment has now been completed and the message is an inconvenient one: in spite of nominal safety improvements in nuclear power plants a long list of "near-misses" documents that severe accidents can never be excluded; nuclear installations can only marginally be protected against terrorist attacks; proliferation continues to be a serious problem and a sustainable solution of the radioactive waste problem is not in sight. But even if one were to overlook all these drawbacks a nuclear power scale-up would come too late to contribute significantly towards the solution of the challenges of climate change and "Peak Oil". Nuclear power is not even a cheap solution: energy efficiency measures and alternative energies are superior ecologically and economically. Maybe surprising for many: should nuclear be significantly up-scaled fissionable uranium would become scarce within a few decades, just like oil. The nuclear solution then leads to a plutonium economy – and fourth generation reactor concepts point in this direction – with all the associated dangers and significantly higher proliferation risks.

Thus nuclear power is not **the** convincing solution some claim; rather it is no solution at all. There is no reason to change the Austrian policy. Our focus on energy efficiency and alternative energies is far sighted and the right way to go. We are convinced that in following this path we also contribute to the awareness building that is necessary to achieve a sustainable and more responsible use of energy.

Josef Pröll
Minister for Environment

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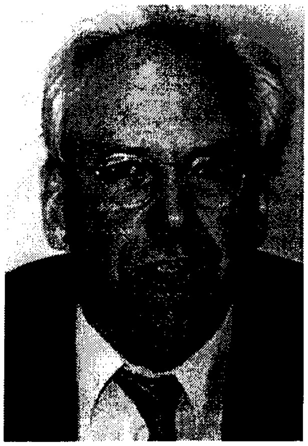
Dedication



The Austrian Nuclear Advisory Board dedicated this assessment to its founding member and Vice-Chairman **Univ.-Prof. Manfred Heindler**, an internationally renowned critical expert on nuclear fission and fusion technologies and their application. He was strongly involved in the first version of the Assessment in 2000 and in developing the concept for the present, significantly enlarged and updated version as long as his health permitted. He has not lived to see the finalisation of this work. He passed away on May 13th 2006 in Graz, Austria.

The members of the Austrian Nuclear Advisory Board will miss him, his vigour and optimism, his sharp criticism and his valuable and constructive contributions.

Synthesis: Nuclear Power, Climate Policy and Sustainability

An Assessment of the Nuclear Option with regard to Climate Policy and Sustainable Development

January 2007

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Abstract

In the past years the issue of Nuclear Energy has been raised at various occasions, in particular with regard to Climate Change and the necessity to reduce greenhouse gas emissions and in view of the foreseeable end of cheap oil ("Peak Oil") and their global implications. Following the UN Framework Convention on Climate Change (UNFCCC) and the EU Sustainable Development Strategy, the political and societal solutions to these problems must be environmentally sound and sustainable.

Austria takes the view that electricity production from Nuclear Energy is neither sustainable nor environmentally sound and is therefore not suitable to contribute to the solution of the climate problem or the peak oil crisis:

- Even when ignoring the possibility of severe accidents, Nuclear Energy is burdened with a large number of environmental problems and risks, such as possibly health damaging low level radioactive emissions in normal operation and the worldwide unresolved problem of final repositories for nuclear waste.

- Cost cuts necessary as a consequence of the deregulation of the energy market have negative effects on safety culture and safety margins during construction and operation.

- Investment in Nuclear Energy impedes or at least delays investments in efficiency measures and therefore impedes sustainable, resources preserving solutions.

- The increasing world population, the growing scarcity of resources and the increasing global inequity are likely to raise the number of wars and augment terrorist activities: this prohibits the support of technologies and structures that enhance the vulnerability of a region, and calls for a rapid dismantling of such technologies and structures and for transformation of these into decentralized technologies and structures with high error tolerance and low potential of damage.

From today's perspective, Nuclear Energy does not have the potential to contribute significantly to climate policy or to the solution of the problems connected to "Peak Oil":

- Limits to development potential and speed, availability of capital and qualified staff curb the possibilities of Nuclear Energy, even in case of strong political backing. In fact, the coming decade will more likely see a reduction of the contribution than an increase of the rather small nuclear contribution.

- As compared to energy efficiency, Nuclear Energy so far has not made a significant contribution to the reduction of greenhouse gas emissions; energy efficiency measures have proved to be

more effective and less costly and, in addition, have much higher potentials that can be drawn on in short term.

- Nuclear Energy could only make a substantial contribution towards the energy needs of the rapidly growing transportation sector through the nuclear production of hydrogen. In view of the large number of power plants needed to produce a relevant amount of hydrogen, this is not a viable option without solution of the above mentioned problems.

- The newer nuclear technologies in discussion at present offer no solution as the "inherent safety" is not yet proven nor all encompassing and as the development of Generation IV reactors seems to create more safety problems than it solves.

- Even an increase in technological safety of nuclear power plants would not reduce the risk they pose in view of war and terrorism; thus the vulnerability of regions with nuclear power plants would not decrease.

- Uranium reserves are limited. If Nuclear Energy is to contribute significantly to the global energy need the only path known at present leads to fast breeder reactors and the ensuing plutonium economy that is tied up with even greater safety problems and risks.

From a legal point of view the core of the applicability of the principle of sustainability lies in the distribution of the asset "environment" and the burdens of Nuclear Energy production between the present and coming generations. In analogy to the principle of proportionality of the law of the European Community the energy demand of the present generation must be kept as low as possible and at the least possible environmental costs; the costs and burdens of energy production are to be borne by the generations benefiting from it. The sustainability principle therefore rules out the use of Nuclear Energy in its present form and in others envisaged today.

Motivation and Context

In the past years the issue of Nuclear Energy has been raised at various occasions, in particular with regard to Climate Change and the necessity to reduce greenhouse gas emissions and with regard to the foreseeable end of cheap oil ("Peak Oil").

Climate Change and the human part in it are generally accepted scientific facts. Unfavourable impacts already observed and those yet to be expected have induced governments to take action toward climate protection. The UN Framework Convention on Climate Change (UNFCCC) signed 1992 defines a goal of "*...stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner*". The steps necessary to achieve these goals and the sanctions in case of failure to implement them are decided on in annual Conferences of the Parties to the Framework Convention (COP).

The UNFCCC also obliges the signatories to promote sustainable economies and to support developing countries in the achievement of the obligations from this convention and to give them access to environmentally sound technologies and know-how. This implies that climate protection is to be achieved primarily by sustainable and environmentally sound measures.

Oil, with a share of 40% of the total global energy consumption, is at present the most important source of energy. It is also one of the most important raw materials of which essential every day things are made: chemicals and solvents, plastic, colours and varnish, wrappings, artificial fibres (clothes, carpeting, curtains), articles of hygiene and cosmetics (soaps, perfumes, lipsticks, hair sprays), medicines, fertiliser, pesticides and building material for infrastructure (roads). This list illustrates that oil, its availability and price is of eminent importance for the economies of the world.

According to recent estimates about half of the known oil reserves have been consumed. The production of oil from individual sources as well as the overall oil production follow a bell shaped curve: close to exponential increase in the first phase of the exploitation, then, when the pressure in the reservoir decreases the withdrawal of the remaining oil is accomplished with increasingly costly methods and the production drops continuously from year to year. Most reserves aside from those in the Near East are at or beyond the point of maximum production. The exploitation of the remaining oil is costly and production can not keep up with demand increase at the present pace. Alternatives to the oil dominated economy must therefore be found within a time span of a few decades.

Nuclear Energy is presented by some as a suitable means to achieve the necessary reductions of greenhouse gas emissions and as a significant contributor to the resolution of the upcoming oil crisis. The transportation sector is seen as special field of interest for Nuclear Energy: hydrogen produced by Nuclear Energy is to replace oil as the primary source of energy (currently more than 97 %).

Austria takes the view that Nuclear Energy is neither sustainable nor environmentally sound and is therefore not suitable to contribute to the solution of the climate problem or the "peak oil" crisis.

The Basic Problem

Important as CO_2-emission reductions and availability of energy are, more is at stake: Sustainability is a concept that involves both, a wide human ecological context and a long term horizon. It is defined as "*a development that meets the needs of the present without compromising the ability of future generations to meet their own needs*" (Brundtland Commission 1987).

To comply with the requirements of sustainability a technology must be:

- environmentally and (macro-)economically sound and socially acceptable
- within human grasp (e.g. all potential technical, social and ecological consequences can be comprehensibly assessed)
- flexible and
- tolerant of errors.

The central criterion for the evaluation of a technology must be: Does the technology support or hinder sustainable development or is it neutral?

In the specific case it can be shown that Nuclear Energy

- degrades the environment (e.g. low level radiation is emitted in normal operation and there is a high potential for catastrophic events),
- is not acceptable socially, (e.g. is plagued with its close connection with nuclear weapons and therefore proliferation problems, is not adapted to socio-economic structures and safety cultures in developing countries, increases vulnerability of societies and regions due to threat by war and terrorism),
- is too complex and is associated with a damage and threat potential too great and reaching too far into the future to be within human grasp (e.g. reduction of safety in a deregulated energy market, final repository still unresolved, decommissioning of plants),
- is inflexible (e.g. requires follow-up measures through centuries and is tied to large units, difficult to steer due to intrinsic dynamics) and
- is intolerant of errors as past experience shows (e.g. Chernobyl accident) and the new reactor concepts tend to be even less tolerant than present plants.

This will be demonstrated in more detail in the following by reviewing some problem areas.

Problems of "Normal Operation"

Each phase of the nuclear cycle is associated with environmental loads – even if there are no events or accidents.

Uranium mining

After extracting uranium from the ore, remnants including decay products are left at the site and are stored on the surface as dumps or as mud in simple basins. This debris contains hazardous substances like the uranium decay product thorium-230 with a half-life of 77,000 years and its daughter products radium and the gaseous radon.

The isolation periods that would have to be reached in case of final disposal of these wastes are comparable to those of wastes from the operation of nuclear power plants.

For every ton of reactor fuel thousands to tens of thousands of tons of ore have to be mined. In the mining sites in New Mexico (USA) and Wismut (former DDR) more than 100 millions of tons of radioactive waste are deposited on the surface.

The Wismut region is so heavily contaminated that the German Radiological Protection Ordinance cannot be applied. Uranium mining in Eastern Germany has produced about 8,000 dumps and mud ponds. Rain water leaches out uranium, radium and other toxic substances that thus reach the groundwater. In case of sliding of dumps radioactive dust is released into the atmosphere. Clean up work is progressing and will continue till 2015, but surveillance will be necessary even after that.

The situation in other uranium mining areas is comparable. These facts are less publicised, especially if mines are located in the Third World or in less developed parts of industrial countries (e.g. where indigenous peoples live).

Normal Operation of Nuclear Power Plants

The discussion on the possible effects of increased cancer incidence near nuclear installations has been ongoing for many years. For the reprocessing plants at La Hague (France) and Sellafield (UK) there are numerous indications that cancer incidence is indeed enhanced. The evidence of increased occurrence of leukaemia, cancer and down syndrome near nuclear power plants is also growing. Recent findings are reported for Germany and the USA.

These results not expected by mainstream scientist might be an indication that the effects of low level radiation, especially in case of incorporation, are underestimated or that not all types of emissions are reliably monitored or possibly a combination of both. There are increasingly reliable indications for both explanations.

Uncertainties remain regarding the extent of the influence of low level radiation on genetic material, as the time scales to be considered are much longer. Applying accepted precautionary and safety principles of environmental protection, even low level radiation cannot be considered to be environmentally acceptable.

The Safety Problem

The type of risks nuclear power plants pose in case of severe accidents are of the type "Damocles" according to the sociological classification scheme: severe accidents have low probability of occurrence but catastrophic consequences. In the case of nuclear power plants, the consequences of severe accidents can be far reaching and long term in character.

Since the start up of the first nuclear power plant safety regulations had to be tightened repeatedly in reaction to unforeseen incidents in different power plants. A considerable number of operating power plants therefore does not fully satisfy the safety standards presently recommended by the IAEA. Also, the methods to assess the safety status of nuclear power plants are insufficient regarding their completeness and reliability.

As nuclear power plants age and infrastructure capacity declines, the risk of accidents rises. The liberalisation of the energy market tends to aggravate the situation further, as nuclear safety is expensive and the drive for cost reductions and higher share-holder values leads e.g. to reductions of staff and endangers safety investments. In the last years there have also been cases of downgrading of safety standards.

A sequence of incidents in nuclear power plants in Europe, Japan and America have induced appeals from representatives of the nuclear industry for more self-criticism, care and circumspection – in short: improved safety culture. Even though it is questionable whether these incidents can already be attributed to the deregulation of the electricity market or the aging of nuclear power plants, they do show clearly, that efforts to enhance safety culture and safety measures must be stepped up. It is difficult to see this happening in the present economic constraints, with overall costs of Nuclear Energy still above that of other energy sources, in spite of high oil and gas prices.

For the coming generation of reactors (Generation III) concepts were modified to address a large number of foreseeable accidents passively ("inherent safety") and reduce core damage frequency. However, the "inherent safety" has not been proven for any reactor so far, and applies only to design base accidents, not to external dangers and certainly not to acts of war or terrorism. Liberalization of the electricity market and the decreasing governmental support for the nuclear industry forced a further redesign to reduce capital costs (Generation III+).

Concepts for Generation IV – essentially fast reactors – are under development internationally with the declared goals to be "inherently safe", proliferation resistant, economic and free of long lived high radioactive waste. Fast reactors suffer from a handful of drawbacks, which make them expensive to build and hard to operate. Considerable doubts are voiced on the feasibility of meeting these goals simultaneously. Safety problems in Generation IV reactors differ widely from those known for the earlier generations. However, it is very difficult to assess their safety at the present time, as they are only in the design phase, and studies addressing safety aspects are still limited.

Due to the limited availability of fissile uranium – estimates range between a few decades and a century depending on assumptions regarding the extent of nuclear build up and uranium resources – fast reactors must be implemented if a substantial and long lasting contribution by nuclear energy is envisaged. This would imply a plutonium economy.

Catastrophes are inherent in complex and coupled systems and therefore unavoidable, although the likelihood of their occurrence can be reduced. Nuclear power production necessitates very complex and coupled systems involving the implementation of sophisticated safety concepts such as redundant and diverse defence in depth. The latter in itself constitutes a factor of increased vulnerability. But safety measures are imperative, as the enormous energies concentrated in a very small volume together with highly dangerous materials in amounts sufficient to contaminate large areas with persistent deadly radioactive pollutants in principle cannot be contained sufficiently safely nor can handling be made proof against the human factor. By impelling physical laws the causal chains triggering accidents can never be fully eliminated by safety provisions of material containments and technical structures, nor can the evolutionary biological constraints of human nature be overcome by administrative, legal or psychological security measures.

The Problem of Radioactive Waste

The problem of disposing of high and medium level waste is not resolved. In principle three different options for final disposal are under discussion – none of them available at present in practice:

1. Surface or near-surface disposal with control and intervention possibilities (retrievable).

2. Permanent disposal in deep geological repositories which makes misuse difficult and has no need for security measures, but allows only limited information on the state of the waste containers etc. and no intervention.

3. Partition and transmutation of long-living radio nuclides, reducing the hazardous time period to max. 1,000 years; storage for this time period.

None of these options fulfils the demands for safety and social acceptability from today's perspective.

In the case of deep geological repositories the limit of predictability by science is exceeded. Radioactive material could be released into the biosphere in some distant time, when people have even less knowledge or means to handle it than we do today. In the case of the near surface disposal, the limits of predictability of societal development are exceeded. Due to the long periods in question, safety can be guaranteed in neither case.

In the case of partitioning and transmutation there are open questions regarding safety and environmental pollution in addition to those of feasibility and affordability.

After several decades of nuclear power usage the industry still has not been able to present a socially, technically and economically accepted concept for final repositories. Instead, the number of interim storages and of nuclear power plants due for decommissioning grows. In a number of countries the capital necessary for decommissioning and storage has not been accumulated.

Thus, the justification of producing additional radioactive waste must be questioned. For the waste already produced a solution must be sought in a societal consensus procedure that minimises the disadvantages. A phase out of Nuclear Energy would limit the amount of nuclear waste and thus contribute to the minimisation of disadvantages.

Low level wastes are only partly disposed of in repositories. Large amounts are simply released into the environment for economic reasons. The resulting low level dosages are in contradiction with the precautionary principle that should be applied in health issues. This method of management of waste, although emitting radiation below established limits, also does not qualify as environmentally sound.

Transport, interim storage and reprocessing of radioactive waste are also connected with considerable risks.

Terrorism and War

In the present political situation and due to the rising world population, dwindling resources, climate change and increasing inequity military and terrorist activities must be expected to increase. "Small", long lasting and regionally limited wars, pre-emptive strikes as well as interventions directed against nations that pose a real, a perceived or a claimed threat to peace, are becoming more frequent. In countries or groups that feel overpowered this can trigger or enhance terrorism. Installations with a high potential for catastrophe are tempting targets for sabotage, terrorism and military attacks. There is no reliable protection against such threats.

Nuclear power plants are especially threatened – even the most advanced, future, so called "inherently safe" reactors. There are a number of reasons, which could individually or in combinations lead to the choice of a nuclear power plant as target of an attack:

- The symbolic value: nuclear plants can be seen as the embodiment of technological development, as typical "high-tech". In addition, nuclear plants represent a technology of dual character: civil and military.

- The long term effects: an attack can lead to large scale radioactive contamination by long lived radio nuclides. The social and economic consequences for affected states or groups of states can hardly be fathomed.

- The immediate effect on electricity production in the affected region: nuclear power plants are, where ever they are employed, important parts of the electricity supply network that feed into the net with high capacity. The sudden loss of such a plant can lead to the break-down of the whole system.

- The psychological effect on other nuclear states: a successful attack on one nuclear power plant could have far reaching effects on the nuclear industry also in other nuclear countries.

Similar considerations are valid for other nuclear installations or for nuclear transports.

A number of attempts at sabotage, terrorist and military attacks on nuclear plants document impressively the reality of this threat.

The vulnerability of nuclear plants to terrorism and war can be summarised as follows:

- All types of nuclear plants as well as transports of radioactive materials are vulnerable to terrorist attacks and war impacts. Significant releases with catastrophic consequences can be achieved.

- An attack on a nuclear power plant can lead to large radioactive releases. Relocation from large areas could be necessary and the number of deaths due to cancer could rise dramatically.

- The spectrum of the threat is extremely diverse and protective measures against terrorist attacks and impacts of war are only possible to a very limited extent. Some conceivable measures are in contradiction to the basic values of an open, democratic society.

Thus, also under the aspect of vulnerability to terrorist and military attacks clear draw-backs of a centralized, non-sustainable technology such as Nuclear Energy become apparent.

Emergency Planning

The necessary measures to minimise damage in case of an accident in a nuclear power plant and the inevitable consequences of severe accidents clearly demonstrate that Nuclear Energy is neither environmentally nor socially sound. This problem has been aggravated in the last few years by the increasing threat of terrorist attacks and war impacts on nuclear power plants.

In case of a severe accident a significant part of the highly toxic, radioactive components of the reactor core can escape into the atmosphere – possibly very soon after the initiation of the accident. The lead time that is available for emergency management measures is possibly extremely short.

The radiation exposure of the population, if high enough, can lead to immediate radiation damage and long term effects (cancer, genetic changes, etc.) endangering large parts of the population are certainly to be expected. Evacuations and relocations can lead to additional serious strains on the people affected.

In order to be prepared for such an event, a large number of very different measures need to be taken by the state. Early warning and alarm systems must be installed, plans for evacuation and stocking of supplies must be developed, infrastructure for decontamination and treatment of casualties must be put in place as well as many other things. This is a continuous, ongoing effort by the municipalities, states, etc., the costs of which generally are not covered by Nuclear Energy costs.

These efforts must also be made by countries on whose territory no nuclear power plants or other nuclear installations are in operation.

Within the last years efforts have been made to improve international catastrophe management. The aim is to develop generally accepted forecast models and other decision support instruments for events of large releases and to compile basic advance planning needs and reactive actions in a nuclear emergency. IAEA has earned merit in these efforts. And although the efforts are a step in the right direction, they also can not offer a sound solution. Even in case of optimal emergency planning and management one must expect that in case of an accident many of the measures envisaged will not be in force in time, due to short lead times and the uncertainties regarding accident development and extent. On careful examination these efforts only prove our helplessness in view of nuclear catastrophes.

Nuclear Proliferation Issues

The commercial nuclear fuel cycle provides two principal paths of proliferation – from enrichment facilities (by means of highly enriched uranium – HEU), and from reactor spent fuel (by means of reactor grade plutonium that is basically weapons usable).

Starting from fresh low enriched reactor fuel (about 3.5 % Uranium 235) highly enriched uranium (90 %) can be quite rapidly gained, because at 3.5 % enrichment over 80 % of the total enrichment work is already done.

Weapons made from reactor grade plutonium are more likely to pre-detonate and thus result in less than full yields – even so-called "fizzle" yields are possible. However, even the minimum expected fizzle yield for an implosion weapon fabricated from reactor grade plutonium is of the order of one kiloton. This is still 4000 times larger than the explosion of a typical 500-pound military bomb. If detonated in a large city it would have devastating consequences.

Producing a nuclear weapon from spent reactor fuel is considered to be within the technical capabilities of sub-national groups. The technology of reprocessing is described in open literature, and there was sufficient open literature on nuclear weapons even in the mid-1960s to allow three graduate students in the US to successfully design an implosion weapon with a 15 kiloton yield with two man-years of effort. The resources required for extracting weapons quantities of plutonium from spent fuel are relatively modest. A small, well-prepared group (of about six persons) could accomplish this in perhaps two months.

No other bulk electrical energy or process heat source (coal, oil, natural gas, hydroelectric power, wind power, solar power, biomass, etc.) has such proliferation concerns associated with it. The proliferation potential associated with the commercial nuclear fuel cycle is unavoidable with current and even more so with up-coming technology. Even in the best cases of future technology, the proponents of the technology call it "proliferation resistant" – not "proliferation-proof". The risk can be reduced, but it cannot be eliminated.

Timeliness

Every option that is to contribute to the achievement of the Kyoto goals must at the latest become effective in the period between 2008 and 2012. For time periods until 2020 and 2050 additional, even more ambitious greenhouse gas (GHG) emission aims are being negotiated. For the growing electricity demand and in view of the foreseeable scarcity of oil additional energy sources might be needed in about the same time frame. Bottlenecks in several areas make it improbable that Nuclear Energy, even if strongly backed by policy, would be in a position to make a significantly higher contribution than at present:

- In the very short term, nuclear energy can only respond to the increased demand and the call for GHG emission reductions by extending the life time of existing power plants. This, however, can only delay the loss of present capacities, it does not create new ones.
- The transition to so called "inherently safe" reactors, indispensable for significant further expansion of Nuclear Energy, will not be possible in time, as the time frame for development and testing is considered to be at least 12 years at present.
- For a demand oriented expansion of Nuclear Energy, expertise and work power are needed that cannot be supplied in sufficient quantities in time. Even now there are shortages of well trained staff in some nuclear countries.
- Even if these problems could be overcome the foreseeable scarcity of (cheap) fissionable uranium would limit the contribution of Nuclear Energy. Only the fast reactors envisaged for the next generation but one will not be dependant on fissionable uranium. However, most of these reactors, as presently planned, lead to a plutonium economy.
- Developments necessary to create acceptance for the increasing amounts of high radioactive waste and to minimise negative impacts are not in view.

If Nuclear Energy is to play a non-marginal role in reducing CO_2-emissions, its rate of use would have to be increased at least at a rate that would correspond to the anticipated increase in fossil fuel consumption. This would require a rate of commissioning of nuclear power plants, which is far above that experienced in the "golden" decades of Nuclear Energy, i.e. in the 1970ies and 1980ies. However, there is no basis for such a rate of deployment, neither regarding production capacity nor regarding the ability of host countries to absorb such a growth. It would also mean a drastic increase of the share of electricity in the energy mix, substantially above historical rates.

International Legal Framework

The economic use of Nuclear Energy entails transboundary risks which cannot be covered by national legal systems alone. This simple truism however is in clear contrast to the obvious interests of the nuclear power states to preserve their exclusive regulatory authority over their nuclear industry. For these reasons the respective international treaties and proposals for EAC directives do not go beyond stating general safety principles instead of safety standards. This position proves at deeper analysis to increase the potential threats and problems.

The Energy Perspective

Concepts that comply with the principles of sustainability and are thus environmentally and socially sound, free of potential for catastrophic events, flexible, transparent, etc. are called "alternatives":

- Alternative solutions in the more narrow sense are such that use energy fluxes rather than limited resources and that satisfy the criteria for sustainable technologies. An example for such an alternative is the use of passive solar energy or biomass.

- Alternative solutions in the wider sense are – as transitional solutions – technologies, which contribute substantially to the reduction of negative impacts or to the improvement of efficiency, such as e.g. co-generation systems.

Nuclear Energy is not considered to be an alternative solution of energy production.

An essential contribution to the reduction of energy demand and thus to the solution of the greenhouse problem is to be expected from service-oriented energy supply. Nuclear Energy is not service-oriented.

Nuclear Energy also proves to be a comparatively costly measure to reduce CO_2-emissions. Energy efficiency measures, renewable energies and alternative solutions in the wider sense replace 2.5 to 10 times as much CO_2 per unit investment.

While the search at first focussed on alternative means of energy production, it has become increasingly clear that the object must be to find alternatives to energy production, i.e. measures on the demand side (increased energy efficiency, reduction of demand by intelligent planning e.g. in the building and urban planning sectors).

Had the rate at which total world energy intensity decreased been slightly higher, e.g. 1.2 % instead of the historic 1 % per year, this would have equalled the total production of Nuclear Energy. A doubling of the rate to 2 %, which seems feasible, would lead to a world wide decoupling of economic growth and energy demand. This could be achieved through an economic policy of "true prices", i.e. with external costs included, rather than a policy of "cheap" energy. The reduction of CO_2-emissions due to Nuclear Energy and other CO_2-lean energy sources in the past was well below the contribution by efficiency increase and structural effects.

This implies that Nuclear Energy has the potential to slightly dampen the impacts of rising energy demand attached to desirable economic growth, while enhancing energy efficiency has the potential to avoid a rise in energy demand in a world with economic growth - and thereby initiate a successful climate policy.

There are studies that show that the Kyoto goals can be achieved in addition to nuclear phase out, if the political will is there. Even the long term aim of the European Union – the stabilisation of global temperature at +2 °C – is achievable without Nuclear Energy. Such scenarios include either the sequestration of a significant amount of CO_2 or a dampening of the energy demand curve.

The Economic Perspective

Even if only the energy production side is considered, increasing nuclear power is not a suitable instrument for climate protection from an economic point of view.

In a deregulated, competitive energy market investors prefer profitable options that have low and well-known technical, economic and political risks. Investment in Nuclear Energy is considered risky because of political risks (such as those arising from public opposition), technical risks related to safety and waste disposal issues, and economic risks associated with high initial investments, long and uncertain construction times and costs as well as liabilities for decommissioning and dismantling of nuclear power plants.

At present costs (planning, construction and operation) of electricity generated in nuclear power plants is expensive compared to that generated by coal and gas plants. Only if the present high prices for oil (above 30 US$ per barrel) remain valid over the operation time of 30 to 40 years or when assuming considerable, but not implausible cost reductions for all parts of nuclear power generation, but not for fossil energy, do prices converge. Increase of energy efficiency (reduction of energy intensity for supply of goods and services) is less costly and more effective regarding CO_2-emission reductions than any kind of additional energy supply.

The few nuclear power plants that have been ordered or are in construction in Europe (Finland) and the USA show that additional incentives are needed to trigger investments: government export credit guarantees, federal loan guarantees, low prototype costs, tax breaks, cost overrun guarantees in case of delays in the licensing process, assistance with historic decommissioning costs, etc. were offered.

The external costs and the need for regulation connected with the nuclear option are multiple and numerous compared to other energy options: on the national level specific regulatory bodies, radiation monitoring networks and costly emergency planning systems, on the international level especially the control of non-proliferation (e.g. CTBTO). The costs for these contributions, like the costs for environmental damages incurred in the complete fuel cycle, are generally not included in cost calculations for nuclear. Even the comprehensive comparative European study ExternE does not take account of the external costs for nuclear. Other subsidies also influence costs for nuclear: the advantageous regulations regarding decommissioning and waste management and the fact that the liability for damage resulting from severe nuclear accidents is not the sole responsibility of the operator but is partly borne by the state in which the plant is situated, partly by the member states of international conventions. In addition, liability is capped. It has been estimated that private insurance without a ceiling to liabilities would triple the electricity production costs in French nuclear power plants.

Hydrogen is no Solution

Hydrogen is not a primary energy source – it is an energy carrier, and must be created by using some other primary energy source (nuclear, wind, photovoltaic, biomass, etc.). Energy is required to create hydrogen, compress or liquefy it for storage, and distribute it. The overall efficiency of this centralized hydrogen economy is low and production methods are not yet mature.

Centralized, bulk hydrogen production, storage, and distribution carries with it risks of specific types of chemical accidents. A decentralized, "just-in-time" hydrogen economy is only just beginning to be explored. The security and terrorism threat implications of a hydrogen economy have barely begun to be considered.

The amount of hydrogen needed to support a hydrogen economy for light duty vehicles in the 25 EU states is of the order of 23 million metric tons per year. This is about half of the current world production. The production costs for this amount of hydrogen will run into the range of € 250-500 billion and require on the order of sixty EPR nuclear stations.

The environmental problems associated with the hydrogen economy, e.g. the effects of the release of hydrogen into the atmosphere, are only beginning to be addressed.

At present it is difficult to see hydrogen – nuclear or non-nuclear – as a significant contributor towards the solution of either the climate problem or the emerging energy gap; it is certainly not one that can be rapidly deployed.

Legal Aspects of Sustainability

The term "sustainability" as used in the Brundtland formula is not sufficiently clearly defined in the international legal context to be applicable to specific problems without concretion. It has to be augmented by additional values and objects.

The core of the principle of sustainability lies in an extended redistribution mandate: the distribution between the present and coming generations. Applied to Nuclear Energy this is a question of distributing the asset "environment" and the burdens of Nuclear Energy production among the present and coming generations.

The principle of proportionality of the law of the European Community may serve as base for concretizing the term "sustainability". In the energy context it requires that the present generations make do with the lowest possible energy demand and supply it with the least possible environmental costs. The costs and burdens of energy production should be borne solely by the generations benefiting from it.

Public International Law (especially international treaties) and Community Law show promising items with plausible procedural elements for giving the principle of sustainability legal relevance. Yet here too concretion is required for its applicability in individual cases.

The (IAEO) Convention on Nuclear Safety entered into force ten years after Chernobyl and about 40 years after the first nuclear power stations were put into operation. It contains only general safety principles, no specific safety standards. The legal autonomy of the nuclear power states remains untouched. Supervision of the compliance with the safety principles is restricted to a system of reports presented by the states to a tri-annual conference of the member states.

Attempts by the EU Commission to establish community wide security standards for Nuclear Energy failed, although they did not exceed the standards of the (IAEO) Convention already accepted by the EU Member States. However, in its first version, it contained a lean but promising system of supervision and provisions for the decommissioning of nuclear power stations. The real benefit of this attempt would have been the implicit establishment of the jurisdiction of the EAC and especially the European Court in matters of safety standards for nuclear power plants.

The costs of the dismantling of nuclear power stations, according to estimates by the EU Commission amount to 15 % of the total original investment, that is between 200 Million and 1 Billion Euro each. These costs arise after permanent shut down of the power plant, i.e at a time when no more income is procured. In view of planned life spans of 40 years this implies that the costs of decommissioning are shifted to a generation, that is not benefiting from the nuclear power plant.

The safety of permanent national repositories for spent nuclear fuel and high-level radioactive waste for the coming ten thousand years exceeds the capacity of all conceivable societal regulatory systems. In comparison: written human history covers 5000 years. In other words, the political systems of the nuclear power states are forced to project highly complex decision making systems over a period twice the span of hitherto written human history!

A closer look however reveals that the ten thousand years period is an arbitrary assumption. The half-life of many elements deposited is far higher – 16 million of years for Iodine-129 for example. The United States Court of Appeals for the District of Columbia Circuit in a judgement of July 9th, 2004 vacated the decision of the competent federal US authority to set up the Yucca Mountain permanent repository for spent nuclear fuel and high-level radioactive waste, because the compliance period of to 10 thousand years was considered insufficient.

The time dimension of the radiation problem ultimately proves the incompatibility of Nuclear Energy with the principles of sustainability.

Tuning In: Energy at the Turning-Point – From Oil to Sun

Peter Weish

April 2006

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Perspectives of Oil Production

The Age of Oil

The age of oil is about 100 years old. Cheap, abundant oil has manifested itself in many areas: huge urban concentrations, industrial complexes and gigantic traffic systems. Inexpensive energy also leads to inexpensive materials such as synthetics, steel, aluminium or glass. This resulted in a previously unimaginable economy of consumption and waste. The industrialization of agriculture has made food production completely dependant on oil.

The worldwide production of oil has now nearly reached its maximum, a situation that is called "Peak Oil". "*Today, we have extracted half of what is available, and know 90 % of all oil sources. We produce 22 Gb (Gigabarrel) per year, but discover only 6 Gb per year. Therefore we can say that today, for every four barrels of oil that we consume, only one barrel is found in addition. The present rate of oil field depletion is about 2 % per year.*" [Campbell 2000]

The Foreseeable End of Cheap Abundant Oil

Demand continues to increase, China is an impressive example, although production can no longer be increased at will. If demand supersedes production – and that could very soon be the case – significant, lasting price increases will be unavoidable.

"The coming years until the worldwide maximum of oil production is reached, there will probably be a series of dramatic ups and downs in oil price. Only after Peak Oil will the instability of the oil price be overcome. The market will then reflect the long term scarcity of oil. The price level will be significantly higher than the present level." [Schindler und Zittel 2000]

Gas prices will follow the price of oil. The result is higher energy costs for consumers, especially for heating and electricity, but finally, a rise in the price of goods in general will occur.

The Short-Sighted Societal Reaction

People, who in the past few decades have taken the rising oil consumption for granted, will probably look for direct replacements and will want to continue as before. The same is true for many sectors of economy that have become dependent on inexpensive energy and resources during the last decades.

The result is a supply oriented energy policy that calls for new energy sources and greater power plant capacity.

In order to cover increasing demand for fossil fuels, enormous investments in the further prospection and development of oil and "unconventional" energy sources would be needed. Ocean drilling, extraction of oil sands, etc. implies – besides environmental damage and high costs – an unfavourable energy balance.

Nuclear Energy

As the example USA shows, investments in armament and propaganda are being made in order to be able to resolve conflicts arising in the fierce competition for ever depleting supplies by force (war).

With the rise in price of natural gas, nuclear energy looses its cheaper competitor and is being propagated as more cost effective. Furthermore, because of its (supposed) lack of CO_2-emissions, nuclear energy has been publicized as the solution to the climate problem that - for many reasons - it cannot be. Even if one overlooks the undeniable dangers of nuclear energy, it still cannot be an alternative to oil, because it is dependant on non-renewable Uranium.

Jan-Willem Storm van Leeuwen and Philip Smith, summarize their detailed calculations: "*The use of nuclear power causes, at the end of the road and under the most favourable conditions, approximately one-third as much CO_2-emission as gas-fired electricity production. The rich uranium ores required to achieve this reduction are, however, so limited that if the entire present world electricity demand were to be provided by nuclear power, these ores would be exhausted within three years. Use of the remaining poorer ores in nuclear reactors would produce more CO_2-emission than burning fossil fuels directly.*" [Storm van Leeuwen and Smith 2003]

Insights published more than 30 years ago gain new actuality: "*By succeeding in tackling the environmental problem – the uncontrollable growth of energy consumption – at its root, energy shortage will prove to be a pseudo-problem and the development of nuclear technology will paradigmatically stand for a technological aberration.*" [Weish und Gruber 1973]

Hydrogen Economy as a Solution?

Hydrogen power is without a doubt a practical (it can be stored) and at first glance an environmentally friendly energy carrier, that must, however, be extracted e.g. from water with high energy input (preferably with electricity from solar panels). The large-scale conversion to a hydrogen powered economy would take a few decades and would inescapably cause considerably higher energy costs than those that current economy is adapted to. Currently there is a controversy considering the economic practicality of hydrogen power[1]. Critics point out that it would be more energy efficient to use the electricity needed for hydrogen production directly and additionally save the costs of installing a hydrogen infrastructure.[2]

A large scale hydrogen economy, with considerable leaks, appears from the ecological perspective to be not unproblematic [e.g. Schultz et al. 2003].

1 See references on hydrogen economy.
2 Compare Chapter 11 in this volume.

The Inevitable Crisis

The basic problem remains: the end of the oil age is not reached when the last barrel of crude oil is sold, but when cheap, abundant oil is no longer available. None of the alternatives envisaged can ever be as inexpensive as a "gushing" spring of oil. Because of this it is apparent that broad parts of the economy, such as the large scale traffic systems or the industrial agriculture cannot be maintained and if this is attempted, which must be feared, then significant damage to political economies is inevitable. For the loss of cheap energy, if not dealt with consequently and in time, means supply crises and breakdown of the economies. Jobs will be lost and high energy prices will lead to substantial reductions in energy services. Surprising and far-reaching "domino effects" with catastrophic consequences can be expected.

Industrial agriculture will become more expensive, food prices will increase (in industrial agriculture the production and provision of one Joule of food often demands 10-20 Joule of oil). Food provision can break down in large regions.

The consequences for economy and society can reach catastrophic dimensions.

Crisis and Chance

New Insights Gain Ground

The insight that the lavish use of energy and resources, as was possible in the age of oil, is not sustainable and that measures must be introduced immediately to reduce demand, initiates a healthy development towards a turning-point[3].

Consumer orientated energy policy, in many ways successful in many cases since the early 70's, but never consequently followed up upon, is finally given priority.

Investments for structural adjustments are being made in the direction of lowering energy demand, decentralization, developing renewable energy systems and solar architecture. Backwards oriented investments (like those in new highways, and shipping routes) are being avoided. In short, an "energy turn", as already conceptually developed in the early 70's, is being consistently pushed forward.

A dramatic decrease in demand (cuts in quantitative and qualitative[4] waste of energy and material) will be achieved as a requirement for an ecologically sustainable energy supply from renewable energy sources.

When using renewable energy, the focus lies on the development of "soft" technologies. Decentralised production of biogas in grassland can serve as a good example.

Thus the "Power Plant Grassland" concept has several impressive advantages: Combined heat and power production can supply valuable peak electricity, the energy production is CO_2–neutral,

[3] This turning-point is described in the following, so that this positive utopia may motivate and give power to civil society and politics for brave changes, to prevent the dire consequences from being realized to their full extent.

[4] An example for qualitative waste of energy is heating with electricity, a high quality energy.

and the sludge from biogas can be fed back to the grassland as valuable fertilizer. Because of its botanical compatibility it can be applied during the growth period, and there is no danger of contaminating ground water; the fertility of the soil is enhanced. Food and energy production can be coupled and even if this option is not taken, the maintenance of the agricultural system makes re-conversion to food production possible at anytime in the future.

The change in energy production consequently leads to a deceleration of the climate problem.

"Peak Oil" and the expected consequences present a decisive argument for the economy to address the dramatic downsizing of the use of fossil fuels as a source of energy in self interest[5]. It is apparent that every delay in making the necessary structural changes will be penalized by avoidable energy costs and is therefore, in the increasingly fierce competition, threatening survival. Economic selfishness develops in to a driving force for climate policy.

The current environmental situation could also improve, because the exaggerated production and the pursuant refuse are made increasingly unprofitable through a rise in energy and resource prices. Long-lasting goods and their upkeep would again have a better chance, with advantages for the user and the labour market.

"Eco-Taxes" and Legal Framework Create Meaningful Jobs

The alternatives friendly to life that were developed and implemented over the last few decades compliment each other.

Instead of the large scale energy consuming mono-culture of industrial agriculture, smaller scale forms of organic farming and gardening as well as new systems like perma-culture have developed. In this way, a secure supply of food is being secured for the future.

Generally, a process of decentralizing is being initiated. The orientation towards solar energy favours small-scale production close to consumers.

The "mega-cities" crisis-ridden by infrastructure problems that grew during the age of oil are beginning to "shrink for health". "Eco-villages" are being founded, in which people not only find meaningful "jobs", but create their "places for life" and a fulfilling and sustainable life style that is based on autonomy and self-sufficiency.

The environmentally damaging, resources squandering economy of waste will be replaced by a "society of repair".

The foreseeable dramatic rise in oil prices offers a chance for a relatively smooth conversion to a sustainable economy and society. The political challenge is to create the legal and economic framework for this development.

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[5] The political decision in Sweden to terminate dependence on oil and nuclear energy within the next 20 years is in the long term interest of the Swedish economy.

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1 The Revival of the Nuclear Debate: Climate Change and "Peak Oil"

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September 2006

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1 The Revival of the Nuclear Debate: Climate Change and "Peak Oil"

1.1 Motivation

As a result of the increasing manifestations of climate change and the foreseeable end of the era of cheap oil the debate on the use of nuclear power has experienced a revival in the last few years. The shortage of gas that threatened in consequence of the dispute over the price of gas between Russia and the Ukraine in the spring of 2006 has triggered a call for security of supply, enhanced energy autarky and a joint energy policy in Europe. This also brought nuclear energy back into the debate.

In about a dozen topical papers the present assessment of the Nuclear Advisory Board of the Austrian Federal Minister for the Environment discusses the question, whether the nuclear option could constitute a sustainable contribution to climate change and an alternative to fossil fuels when – sooner or later – the end of cheap oil sets in ("Peak Oil") or when politically or economically motivated scarcity of supply occurs.

Preceding these papers an overview is given of climate change and the expected further climate development on the one hand and the background and the indications for the foreseeable end of cheap oil on the other.

1.2 Climate Change

1.2.1 Introduction

Climate has been changing as long as we can reconstruct the state of the earth, the changes being due to a number of very different factors, such as the intensity of solar radiation, the geometry of the earth's movements in space or the composition of the atmosphere following the development of plants, volcanic eruptions, etc.. Recently, the influence of anthropogenic activities on the composition of the atmosphere and the reflectivity of the earth's surface contribute to climate change. These cycles and changes in the drivers of the earth's climate take place on very different time scales, ranging from millions of years to decades and years.

Changes in the earths orbit and inclination and their interactions e.g. lead to ice ages alternating with warm periods – a cycle on the order of 100,000 years, that can be reconstructed based on the analyses of sediments, ice cores, etc.. Changes in the intensity of solar radiation and volcanic eruptions are believed to have caused the "Little Ice Age", which lasted for about 300 years in Europe following the medieval warm period and is documented e.g. in Breughel's paintings of frozen canals in the Netherlands.

None of the "natural" drivers can, however, explain the rapid warming that has taken place globally over the last 150 years, and especially over the last few decades. Dynamic climate models based on equations describing the physical processes determining climate (so called General Circulation Models or Global Climate Models - GCMs), can only reproduce these features when anthropogenic influences are taken account of. This led the Intergovernmental Panel on Climate Change (IPCC), a scientific advisory body of the United Nations, to state in its Third Assessment Report in 2001 that "*there is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities.*"

In spite of continuous assertions of the opposite by the media, these essential facts of climate change are no longer disputed in the scientific world. There is also agreement on the scenarios of future global climate change, based on our understanding of past and present climate, although uncertainties are much larger in this case.

1.2.2 Observed Climate Change

The last decades have shown increasingly clearly that global climate is changing. This change can be observed in time series of measured meteorological data, such as temperature or precipitation, and in developments within the geo- and biosphere. Some examples are presented below.

The global average temperature in the last century has risen by about 0.6 °C, the speed of the temperature increase and the temperatures reached being the highest observed in the last 1000 years [IPCC 2001]. The temperature increase can be observed throughout the lowest 8 km of the atmosphere. Temperature has increased more strongly at night, thus reducing the daily temperature amplitude. The time series also show that on a global level, the speed of change is increasing: 0.07 °C per decade between 1901 and 2000, 0.15 °C per decade between 1981 and 2000 [Schönwiese et al. 2004].

Although climate change is a global phenomenon, it can be strongly modified at the regional or local scale: while global temperature has risen by 0.6 °C over the last 150 years, Austria e.g. has registered a rise of 1.6 - 1.8 °C in the same period [Auer et al. 2001] and the arctic even of more than 4 °C [Hassol 2004].

The observed changes in precipitation are spatially less homogeneous and statistically significant trends over larger regions can frequently not be found in the available data series. Precipitation has increased globally by 0.5 - 1 % / decade – somewhat less in the tropics and significantly more in northern Europe. Some regions, e.g. southern Europe, have become drier. Frequency of intense precipitation events is rising and cloudiness has also increased [IPCC 2001].

The very small scale structure of precipitation characteristics can be demonstrated taking Germany for an example: overall precipitation increased in Germany between 1971 - 2000 by 16 %, in winter even 34 %. The increase is especially pronounced in the west and the south, where increased frequency of extreme monthly and daily precipitation sums are observed. The increase is smaller in the east, where even a decrease is documented for summer and the risk of draughts is enhanced. Almost throughout the country trends for the likelihood of monthly precipitation above 180 mm in the period 1901 - 2000 are positive [Schönwiese 2004].

With a few exceptions (e.g. in Scandinavia or New Zealand) glaciers are retreating world wide and perma frost is thawing – in the mountains as well as in the tundra. In the arctic the decrease in ice thickness and of the area covered by ice is especially dramatic [IPCC 2001, Hassol 2004].

In Europe the onset and the length of spring and summer defined by the phenological stages of indicator plants have changed by almost two weeks in the last decade, as compared to the 30 year period before [DWD 2002]. Some birds are hatching earlier in the year, others have changed their migration habits [Bairlein und Winkel 1998]. Comparisons with historical data show the migration of species to higher regions. In the arctic the polar bear population is threatened by the melting of ice [Hassol 2004].

1.2.3 Climate Change Scenarios

The same models used to reconstruct and understand past climate can be used to calculate future climate scenarios, based on assumptions regarding the development of world population, on economic and technological development, etc. and the resulting greenhouse gas emissions.

According to the scenarios developed by IPCC for 2100, CO_2-concentrations between 550 and 950 ppm are to be expected. Depending on the extent of greenhouse gas emission reductions temperature increases between 1.4 and 5.8 °C must be expected in the coming 100 years [IPCC 2001]. The observed warming will continue for well beyond the present century.

Climate models with the normal scale resolution of some 150 km (GCMs) need to be scaled down to higher resolutions in order to reproduce local and regional climate with sufficient accuracy. Even though the downscaling results are of considerable uncertainty, they afford the possibility to study possible climate change effects at an impact-relevant scale.

The global temperature increase of 1.4 - 5.8 °C translates to an increase of 0.1 - 0.4 °C temperature rise per decade in Europe, somewhat lower on the Atlantic coast and higher in the South and Northeast. Even more rapid warming is expected in continental Russia in winter. In summer a strong North - South gradient will develop as the South warms at double the rate of the North. [Prudence 2006]

Going to an even smaller scale, precipitation trends observed in Germany will be subject to considerable change: for Hessen and northern Germany a precipitation increase of up to 60 % is expected by 2040 - 2050, while the south and northeast of Germany would experience a decrease of about 30 %. The summers are expected to be warmer and drier, while precipitation increase in winter continues [Enke 2004]. Local and regional events of extreme precipitation can occur throughout the country [Schönwiese 2004].

As a result of the warming of the surface ocean waters and of the melting of polar and alpine glaciers, a rise in sea level between 55 and 88 cm is expected by 2100 [IPCC 2001]. More recent calculations indicate that the sea level rise could be significantly higher, and could reach about 4 m [Overpeck et al. 2006].

Changes in a large number of other meteorological parameters are tied up with the changes in temperatures and precipitation but cannot be described in this brief overview.

1.2.4 Extreme Weather Events

There are indications that the transition to a warmer climate will be accompanied by an increasing number of extreme weather events such as intensive precipitation, storms, draughts and heat waves. As yet there is no strict scientific proof of a causal connection between climate change and individual extreme events. From a statistical point of view however, a change in mean temperatures, e.g., will – the distribution remaining unchanged – lead to an increase in frequency of very high temperatures. If climate variance increases at the same time – and there are indications that this was the case in former periods of climate change – then the effect is enhanced. Calculations for Switzerland have shown for example that the exceptionally warm summer of 2003 in Europe, a once in one thousand years event, could be considered almost normal in the period 2070 – 2100 due to the expected increase in temperature variance [Schär et al. 2004].

Based on considerations regarding the physical processes involved in climate change, increased temperatures and an enhanced water cycle could e.g. make heavy precipitation more likely.

1.2.5 Consequences of Climate Change

Climate change is likely to affect every single person and practically all economic sectors worldwide directly or indirectly. Some Small Island States are threatened in their existence due to rising sea levels. In other, partly very densely populated countries like Egypt and Bangladesh, millions of people will loose their home and livelihood as land is lost to the sea. IPCC assessments show that developing countries, due to the limited means of adaptation, are especially vulnerable to climate change: scarcity of fresh water and significant yield losses e.g. for grains could lead to famine and mass migrations. Overall destabilisation of the world and increasing potential for conflicts must be expected. [IPCC 2001, Schwartz et al. 2003, WBGU 2003]

1.2.6 Climate Policy and Reduction Schemes

The first official reaction to climate change on a global level was the UN Framework Convention on Climate Change, signed by 154 states in Rio de Janeiro in 1992. It aims at the "*...stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner.*" The Convention does not define the steps necessary in signatory states to achieve these goals, but it does give guidelines for future development. The concrete steps and the sanctions in case of failure to implement them are decided on in annual Conferences of the Parties to the Framework Convention (COP).

At the COP in 1997 in Kyoto, Japan, reductions in greenhouse gas emissions were agreed on for every signatory state that, in sum, amount to a reduction of 5 % of the emissions of industrialised nations in 1990. This is well below the reduction necessary from a scientific point of view to even stabilise greenhouse gas concentrations in the atmosphere. Nevertheless, the Kyoto Protocol is of great significance as it is – on becoming effective in 2005 - the first international treaty to prescribe in a binding way reductions of greenhouse gas emissions.

Meanwhile discussions about the post Kyoto period (beyond 2008 - 2012) have set in: the European Union is proposing emission cuts that are intended to limit the global temperature rise to 2 °C as compared to the pre-industrial period. When crossing this limit, severe consequences are expected and an unacceptable increase of the likelihood of large, non-controllable changes such as the die-down of the thermohaline circulation[1]. In order to achieve the 2 °C goal by the

[1] Frequently addressed as the Gulf Stream coming to a standstill.

year 2050 greenhouse gas emissions must be reduced globally by about 50 % compared to 1990, in industrialized states by about 80 %. This could be achieved by several energy paths, some of which include an increased contribution by nuclear energy and / or the sequestration of carbon dioxide, while others accomplish the same goal without either. It is important at what time "peak oil" occurs and how far energy efficiency has progressed by then and whether renewable energy sources have been implemented on a large scale. [WBGU 2003]

1.2.7 Possible Consequences for the Production of Nuclear Energy

Climate policy calls for measures to reduce greenhouse gas emissions (mitigation) and to adapt to changed climatic conditions (adaptation). Both types of measures can have effects on nuclear energy production.

The possible contribution of nuclear energy to greenhouse gas emission reductions is extensively discussed in other contributions to the Assessment. The essential conclusion of those papers is, that nuclear energy based on present day technology or technologies now in development, will not be able to make a significant contribution to the mitigation aims of the UNFCCC or, more specifically, the Kyoto Protocol. This includes the nuclear production of hydrogen to replace fossil fuels in the transport sector.

The shift of the demand for energy from winter (heating) to summer (cooling) due to climate change in mid- and higher latitudes is an example for adaptation. Whereas electric power supplies only a small part of the energy used for heating, it is at present the chief energy carrier for cooling. This means that whereas electricity demand in winter will not decline significantly, the electricity demand in summer will probably rise in the coming years. This could encourage further development of nuclear energy. However, technological developments leading away from the use of electricity for cooling are already emerging.

Finally, climate change can also influence the safety of nuclear power plants. This topic is discussed in the paper on nuclear safety in this volume.

1.3 "Peak Oil"

1.3.1 Introduction

"The conventional wisdom of the prevailing economic theories relies on the axiom that worldwide economic growth of a nature which implies continued growth in the production and consumption of energy-consuming hardware can continue for an indefinite length of time. That market forces will ensure that new resources and new technologies will always be at hand when access to the resources upon which our societies depend becomes restrained and present technologies therefore become obsolete.

History shows that man has hitherto succeeded in making life easier by means of new energy sources and technologies. From manpower to horsepower. From horsepower to coal-fired steam engines. From steam engines to oil-engines. Thus economic development has, so to speak, been a ride downhill with the wind behind us. However, there is nothing in sight which is so easy and cheap to get, handle, store, and to use in cars, buses, trucks, tractors, ships, and aeroplanes as oil from oil wells. Therefore, unless something unknown today turns up or our oil-based consumer *culture takes a turn towards less oil-dependent activities, we face an arduous ride uphill against a headwind when one day the supplies of cheap conventional oil become restricted.*

History may reveal that the prevailing axiom of sustainable economic growth is a theoretical derivative of the cheap-oil era. In contradistinction to economic theory, oil geologists have voiced concerns about future oil supply." [Illum, K. 2004]

1.3.2 The Role of Oil

Oil contributes about 40 % to the world energy consumption and is still the most important energy source of the world economy. Of all economic sectors it is most dominant in the area of mobility: 50-60 % of the oil is used in the mobility sector and 90 % of the energy for this sector comes from oil and gas.

Oil is also one of the most important raw materials of the world, many essential things of every day life are produced from oil:

- chemicals and solvents
- plastic
- paint and varnish
- wrappings, foils and plastic covers
- artificial fibres (carpets, clothes, curtains)
- articles of hygiene and cosmetics (soaps, perfumes, lipsticks and hairsprays)
- infrastructure construction (roads)
- medicines
- fertilizers and pesticides

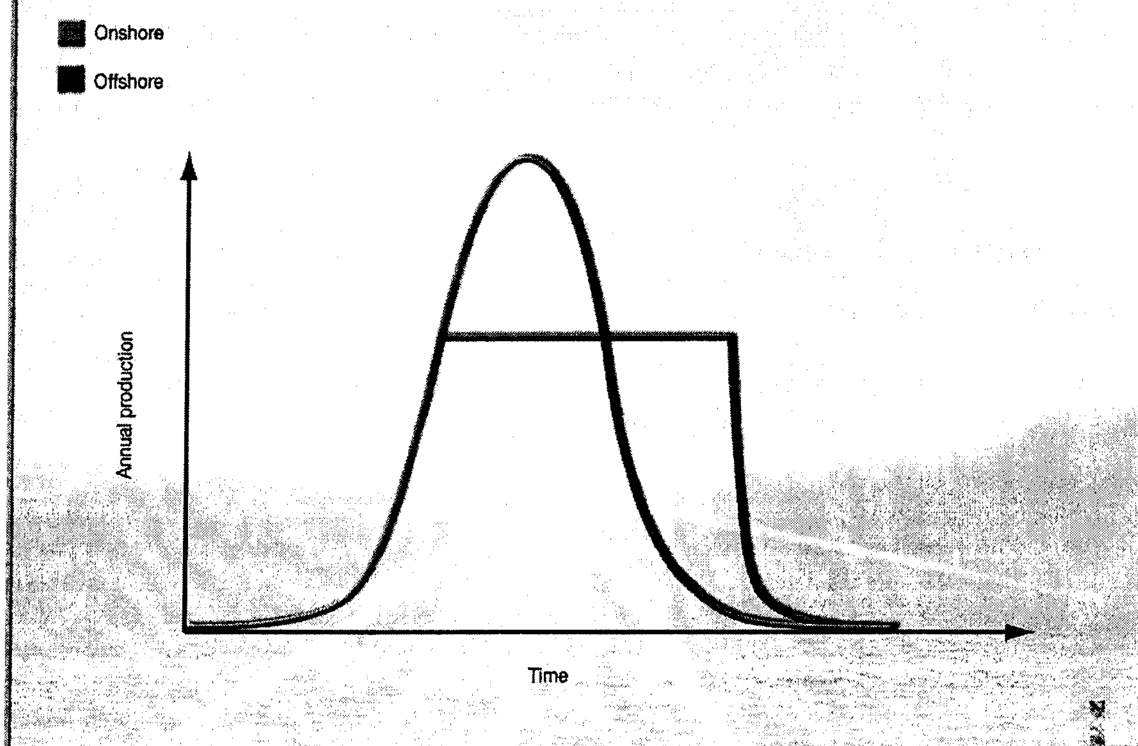
This list illustrates that oil, its availability and price are of eminent importance for the economies of the world.

1.3.3 Production Profiles of Oil Fields

The production of an individual oil field follows a bell curve: increasing until about half of the endowment of oil has been depleted and then dropping at about the same rates (Figure 1-1). When the pressure in the reservoir drops, the extraction of the remaining oil requires increasing efforts. Pressure can be enhanced artificially to a small degree (e.g. through the injection of gas or water) or the viscosity of the oil can be reduced through additives. These measures can influence the downward curve and therewith the production rate only within narrow limits. As long as the production of an oil field is on the up slope side of the bell curve, production rate can be increased by adding new drilling stations. Once the maximum production has been passed, the decrease in production can be slowed down through added technical and financial resources for economic reasons, but the trend in production rate is invariably downward from year to year. [Cambell et al. 2003]

The situation is somewhat different for offshore drilling: While onshore even a production declining by several percent per year can be economically viable for many years, as the original investment exceed the operating costs by far, offshore oil fields are exploited as fast as possible. When production rates fall below a certain limit, the high running costs of offshore oil platforms make their operation unprofitable. As the European oil production is mainly offshore, experts expect a very rapid decline at the end of the production plateau of the large, older oil fields [Cambell et al. 2003].

Fig. 1-1 **IDEALISED PROFILE OF OIL PRODUCTION ONSHORE AND OFFSHORE**



Source: Campbell et al. 2003, modified

Many examples document the typical production profile of oil fields: in 1991 the largest oil field in the western hemisphere since 1970 was found in Cruz Beana in Columbia. The production rate fell from 500,000 Barrel[2] per day at the time of peak production to 200,000 Barrel per day in 2002. In the mid-eighties 500,000 Barrel per day were produced in Forty Field in the North Sea – today production is down to 50,000 Barrels per day. One of the largest fields of the last 40 years, Prudhoe Bay, produced for almost 12 years, till 1989, 1.5 Million Barrel per day. Today the production rate is only 350,000 Barrel per day. The huge Russian Samotlor-Field produced a maximum rate of 3.5 Million Barrels per day at peak times, today the daily production is about 350,000 Barrel. In each of these oil fields production was maintained by introducing gas or water

[2] 1 Barrel = 159 litres

from above into the oil containing layer to maintain the pressure in the oil field. The largest oil field in the world, Ghawar in Saudi-Arabia, at present produces about 60 % of the Saudi Arabian oil, corresponding to about 4.5 Million Barrel per day. Some years ago, the oil gushed from the well through natural pressure. In order to achieve the same production rate now, 7 million Barrel of saltwater are added per day according to geologists – a clear signal for the up coming production decline in the largest oil field of the world.

As most oil fields outside the Middle East are near or beyond their production peak, an increase in production cannot be expected, rather production will drop year by year. The USA, once the most important oil producer of the world, has passed its production maximum 30 years ago and presently produces but 60 % of the rate in the early 70ies. For economical reasons attempts are made to reduce the production decline after the maximum. The European oil production is expected to surpass its peak within few years at the latest.

1.3.4 Availability of Oil

Thus the debate on the availability of oil is not only fed by the significant rise in international oil prices within the last years. However, when following the oil discussion, care must be taken as the term "availability" is used in different meanings:

- Availability in view of reserves, oil that is basically there and extractible;
- Availability in view of satisfying increasing demand measured against production rates per day;
- Availability with respect to safe access to production sites and transport routes and
- Availability in view of the development of prices.

The term "Peak Oil" designates the point in time when the maximum global production rate is reached. After "Peak Oil" the global production rate decreases, even if higher production costs are accepted. Thus "Peak Oil" does not mark the exhaustion of oil reserves, it only marks the time after which - if demand stays constant or increases - reduced production rates cause deterioration of availability and consequently rising prices.

"The essential aspect is that from the moment when an oil field has passed its production maximum, the exact amount of reserves is no longer significant for the future production costs. Whatever the total amount proves to be at the end of production (compared to the initial estimates), the production rates will always drop. [....] Decisive for structural changes in the energy supply is not the (static or dynamic) reach of the reserves, that is "how long is there oil at the given production rate?", but the question: from what point in time can the oil production no longer be increased for geological, technical and economic reasons but only drops in tendency?" [Campell et al. 2003]. This fact makes the following debate on "Peak Oil" easier, as the numbers given for the size of the oil reserves differ widely and have also been subject to significant corrections, indications that large uncertainties are involved. By comparison annual production rates are much better known. In hindsight the point of maximum production is easy to determine: for most oil fields it lies in the past.

1.3.5 When Will "Peak Oil" be Reached?

World wide oil production has reached its highest level so far. "*We have extracted half of the available oil, and we know 90 % of all endowments. We produce 22 Gb per year, but we only find 6 Gb per year. Therefore we can say that for every 4 Barrel we consume we only find one new one. The present rate of exhaustion of the oil fields lies near 2 % per year.*" [Campbell 2000]

In the 10 years from 1990 to 2000 42 billion barrel of new oil reserves were discovered. In the same time the annual consumption was 250 billion barrels. In the last two decennials only three giant oil fields with more than a billion barrels were discovered, in Norway, Columbia and Brazil. From each field no more than 20,000 barrels are produced daily.

The hope of finding new large reserves of conventional oil is small among experts, as the development of oil necessitates certain natural preconditions making oil a limited resource. The peak of new discoveries occurred in the mid 1960ies; large fields have not been found since the early 90ies. [Petroconsultants 1995]

Thus the known reserves and their regional distribution will increasingly determine the course of production in the coming years: 90 % of the present oil production come from oil fields that are older than 20 years and 70 % from fields older than 30 years. According to the recently published report on "The worlds largest oil fields" compiled by the Colorado School of Mines, "*the 120 largest oil fields of the world produce 33 Million barrel daily, that is almost 50 % of the worlds enormous need. The 14 largest produce over 20 %, their average age is about 43.5 years*" [Simmons 2002].

According to competent estimates of internationally renowned geologists, such as the French Petroleum Institute, the Colorado School of Mines, the Uppsala University and Petroconsultants in Geneva, the effects of the diminishing oil reserves or oil production will be dramatically noticeable by the end of this decennium or even earlier.

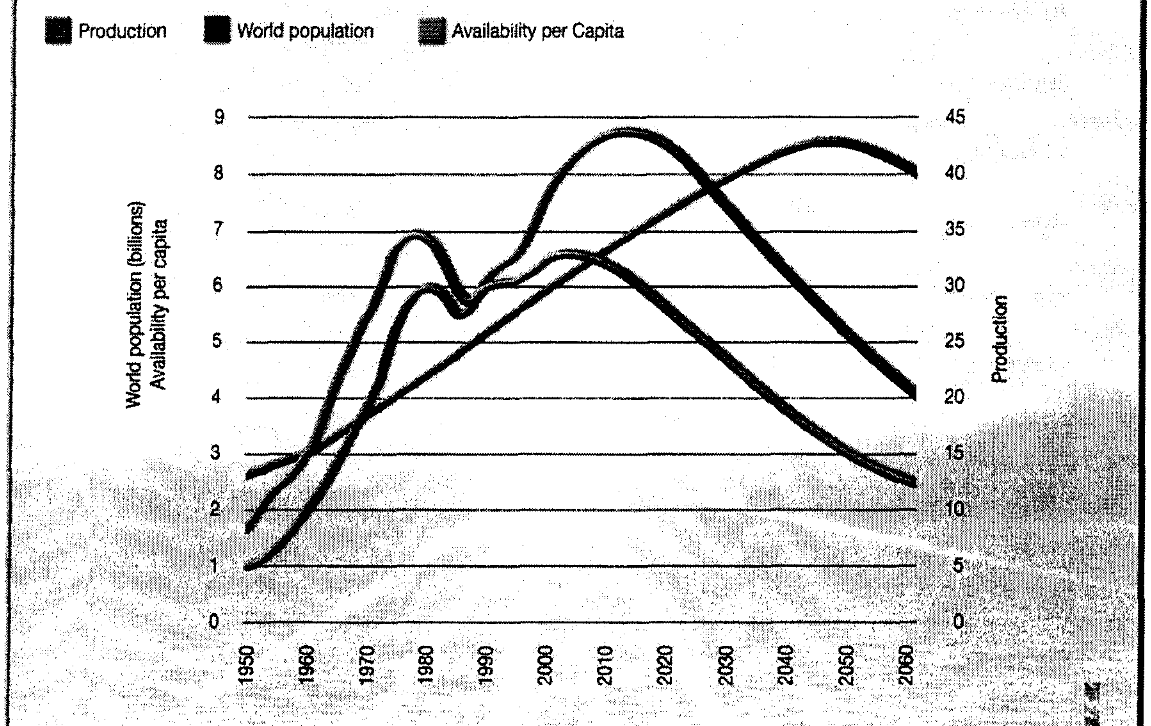
Interestingly, differing opinions are generally voiced by economists, such as for example the chief economist of BP, Peter Davies, who believe that the market will regulate the availability of oil: oil prices will rise with shortages and make less easily accessible fields (e.g. unconventional reserves) profitable, thus making more oil available. This might be correct in principle, but it overlooks the fact that the decisive quantity is production rate, that is production per day or year, not the produced amount, and the achievable production rates for most unconventional fields are much lower than for conventional oil fields.

Pessimists [see e.g. Savinar 2006] believe "Peak Oil" to be the turning point in the history of the industrialised world, as it is dependant on cheap oil in all fields. This is true amongst others for industrialised agriculture that could only reach present production rates by using fossil fuel (coal, oil) and derivatives of oil (fertilizers and pesticides). "Peak Oil" is of central importance, because it must be expected that upon reaching it, prices will rise out of proportion and a world wide oil crisis will ensue. Demand will no longer primarily determine the price on the market, but the increasingly sparse supply (sellers market).

Of those experts concerned regarding "Peak Oil", some believe that "Peak Oil" outside of the OPEC region was passed in the year 2000, others expect it around 2010 [e.g. Campbell et al. 2003, Simmons 2002]. In any case the passing of "Peak Oil" has the consequence that OPEC will again grow in importance. OPEC members could determine production rates and thus also the price and thereby put growing political pressure on the industrialised nations. Especially Saudi Arabia, Iraq and Iran with their large oil reserves will gain in geopolitical importance.

Fig. 1-2 **OIL PRODUCTION RATES AND AVAILABILITY PER CAPITA**

Production rates so far and calculated future development of oil production, world population and oil per capita



Source: After Laherrere 2004 from Kromp-Kolb und Formayer 2005

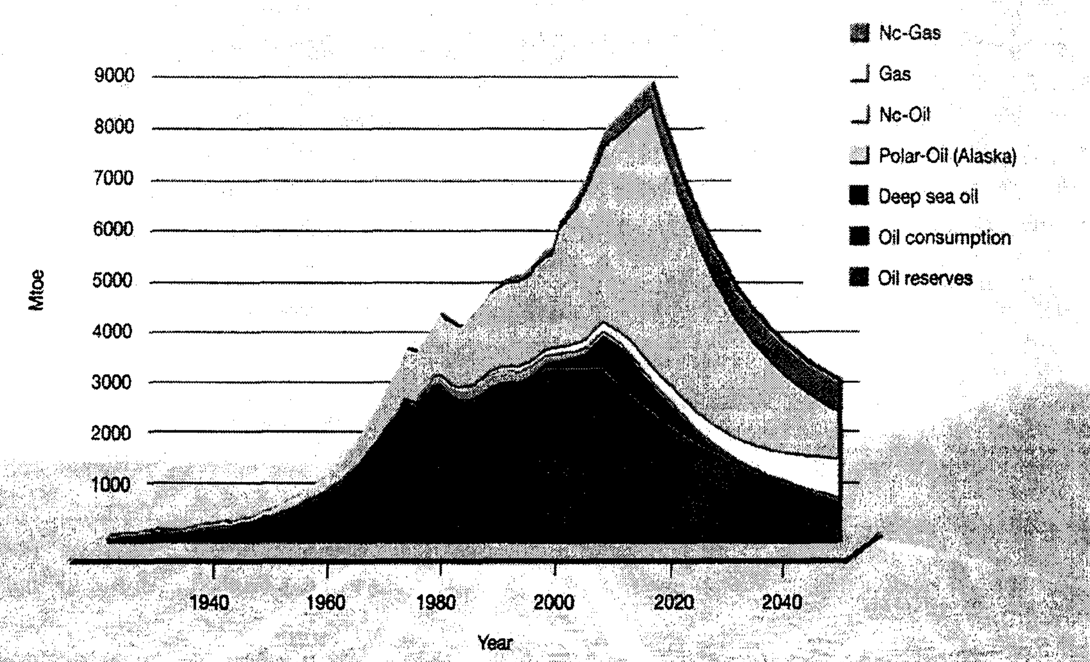
1.3.6 Gas

Gas is easier to extract than oil and the production rate responds to the market more easily than that of oil. The production rate is often constant over many years. Frequently, however, the drop at the end occurs much more rapidly than for oil.

The availability of gas has already notably dropped in some regions of the world. The US gas production has more or less reached its maximum and a supply crisis could occur soon. In Europe the situation will be similar in a few years. If consumption grows in agreement with the infrastructure being built world wide for the distribution of gas, the maximum production could occur around the year 2020 or even earlier [Campbell et al. 2003].

Fig. 1-3 POTENTIAL PRODUCTION OF CONVENTIONAL OIL AND GAS UNTIL 2050

Potential production of conventional oil and gas till 2050, as well as possible contributions by non-conventional energy reserves



Quoted from: Jörg Schindler, Werner Zittel (LB-Systemtechnik GmbH): „Fossile Energiereserven (nur Erdöl und Erdgas) und mögliche Versorgungsengpässe aus Europäischer Perspektive", Ottobrunn 2000. This study was commissioned by the German Bundestag, Committee on Education, Technology and Assessment of Consequences of Technology

1.4 Conclusions

The necessity to protect the climate as well as the foreseeable shortage of oil and gas call for a search for new ways to cover energy needs.

On the one side the increase of energy efficiency and the implementation of renewable energy sources is demanded, on the other increased use of nuclear technologies is being brought into the discussion. This includes nuclear power plants for electricity production as well as for the production of hydrogen. Hydrogen, like electricity, is but an energy carrier, not an energy source, and must therefore be produced; a process requiring energy input.

When looking for a long term, future oriented solution, the answer to climate change and the scarcity of oil and gas must be sustainable – ecologically, economically and socially. The question whether nuclear technologies can meet this criterion, that is contribute significantly and in a sustainable manner, is treated in the following 11 expertises in this volume.

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2 Environmental Pollution Caused by the "Normal Operation" Nuclear Fuel Cycle

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September 2006

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2 Environmental Pollution Caused by the "Normal Operation" Nuclear Fuel Cycle

2.1 Introduction

In order to operate nuclear power plants an extensive system of technical plants and installations is required – starting from uranium mining up to the final disposal of radioactive waste.

Every step of this system is causing environmental pollution, even in case of normal operation without accidents. In some nuclear installations, as frequent events and malfunctions in spent fuel reprocessing plants demonstrate, there is not always a clear separation between normal operation and accidental events.

The environmental effects of radioactive waste management are discussed within a separate paper. Here, the seldom-evaluated sections, fuel supply, particularly uranium mining and the emissions from nuclear power plants during normal operation, will be discussed.

2.2 The Neglected Problem – Uranium Mining

Uranium is an element found in nature in form of different minerals. This does not mean that uranium is not hazardous. During mining, uranium is removed from geological deposits that usually are geochemically stable. The ore is crushed and the uranium is extracted by chemical methods.

Residual uranium and all the separated decay products are left at the site and stored on the surface in form of dumps or as mud in simple basins. The waste products of uranium mining contain hazardous substances like the uranium decay product thorium-230 with a half-life of 77,000 years – this is about three times the half-life of plutonium-239. Thorium decays to radium and gaseous radon.

The isolation periods required for final disposal of these wastes are comparable to those of wastes from the operation of nuclear power plants. But in this case, geological storage is not taken into consideration due to the large amount of material.

Depending on the uranium content of the ore, for every ton of LWR fuel thousands to tens of thousand of tons of ore have to be mined. The amounts of radioactive residuals remaining in the mining sites are respectively large. For example, in corresponding regions in New Mexico (USA) and Wismut (former GDR), more than 100 million tons of radioactive waste from uranium mining are deposited on the surface.

The Wismut region is so heavily contaminated that the German Radiological Protection Ordinance (Deutsche Strahlenschutzverordnung) cannot be applied. The uranium mining in Eastern Germany has left about 8000 dumps and mud ponds. Rainwater is washing out uranium, radium and other toxic substances that reach the groundwater. In case of slagheap sliding, radioactive dust is released into the atmosphere. Uranium can enter into many compounds that are chemically toxic dependent on their solubility.

The redevelopment of this region is an enormous and costly undertaking, which requires several decades. In 1990, the German Federal Government took over responsibility for this redevelopment project. By the end of 2004, the state-owned enterprise Wismut GmbH had spent about 4.4 billion Euros. More than two thirds of the reclamation activities have already been completed. However, the work still has to go on for many years: It is expected that it will be completed by 2015. After that, long-term measures like treatment of waste waters and monitoring of the environment will still be necessary [BMVBW 2005].

The situation in other uranium mining areas is comparable to that of the Wismut region before redevelopment. Since many of these sites are located in the Third World or in those parts of industrial countries where aborigines live, this fact is less publicized and costly redevelopment usually does not take place.

2.3 Normal Operation of Nuclear Power Plants

2.3.1 Radiation Effect on Human Beings

The increasing radioactive contamination of the biosphere due to radioactive emissions from normal operation of nuclear installations and accidents causes an increase of human radiation exposure. Since radiation always has long-term consequences any increase of radiation exposure is fundamentally a problem.

The following discussion focuses on human beings, since they belong to the most radiation sensitive organisms. It should not be forgotten, however, that, depending on circumstances, other creatures can also be severely damaged by radiation.

The effect of ionizing radiation on living cells is comparable to a shower of tiny projectiles that change bio-molecules and cell structures whenever they strike the tissue. The knowledge on radio-biological processes was promoted by the so called "Trefferprinzip" (hit principle) which shows the discontinuous nature of interaction between ionizing radiation and matter [Timofeeff-Ressovsky und Zimmer 1947]. The extent of radiation damage in the cell is mainly dependent on the absorbed dose (number of strikes) and on which structures or which bio-molecules were changed (location of the strikes). There also exists indirect radiation damage caused by radiochemically formed cell poisons like hydrogen peroxide or radicals. The whole-body-irradiation with doses of several hundreds rem (or several Sieverts, the new unit for equivalent doses) damages sensitive organ systems such as the epithelium of the intestine or the red bone-marrow so heavily that due to the failure of cells, death is to be expected after several days to weeks. A lethal radiation dose transfers less energy to the body than a cup of tea (1 rad = $2{,}388 * 10^{-6}$ cal/g. A lethal dose of 1000 rad (10 Gray) is - for a person weighing 70 kg - equivalent to a transferred energy of $1000 * 70000 * 2{,}388 * 10^{-6} = 167$ cal. This warms the body by 0,0024°C). High doses cause the acute radiation disease with typical symptoms that cannot appear below certain threshold dose values.

The damage of the cell's genetic material can cause severe consequences: The desoxyribonucleic acid (DNA) of the cell nucleus containing the species-characteristic structure of genetic information can be changed chemically by a single ionizing event. This can be manifested as "misprint" in the genetic information during the following DNA biosynthesis (which precedes any cell division) because the structure of the changed molecule works as a matrix for the new one. In case of low-dose irradiation with ionizing radiation the organism does not show any symptoms of the acute radiation disease. Only few cells are destroyed which is practically negligible for the organism. But radiation damaged cells can survive, transmit the defect and thus "biologically replicate" the defect. The effect appears only after many cell generations in the form of deformities, cancer, leukemia, or genetic diseases, called long-term radiation damage. The temporal distance between irradiation event and appearing damage (latent time) can amount for different cancer forms to many years, in case of genetic changes up to many generations.

Paracelsus´ well known axiom "only the dose causes the poison" is loosing it's validity for low level ionizing radiation. Based on state-of-the-art experiments, theoretical considerations and medical statistics on the effect of low-dose irradiation, no dose threshold of ionizing radiation can be assumed with respect to long-term somatic damages (cancer, leukemia). A harmless dose does not exist. This topic is covered by a vast amount of literature e.g. many UNSCEAR Reports or publications by John W. Gofman.[1]

The procedure that changes normal cells into cancer cells or into a pre-form of mutated germ cells can be understood as "one-strike-event". The question "which dose is harmless?" is as senseless as the question "which intensity of gunfire is harmless?". The appearance of strikes is in any case a matter of statistics. In case of low-dose irradiation the radiation is not less effective, the "shower of tiny projectiles" is only less dense. The strikes happen more seldom but the strike probability per projectile is the same. This is the meaning of the linear dose-effect-relation. Dilution of radioactive emissions and distribution of the radiation exposure to a larger number of individuals – for example by high exhaust chimneys in nuclear installations – reduces the individual risk of a long-term radiation damage including disease or death, but the risk group is increased, therefore, the total number of health damages remains equal.

2.3.2 Natural Radiation

The argument for nuclear energy uses very often the fact that mankind has always been exposed to regionally different radiation levels from natural sources. This natural radiation was obviously not harmful and could yield a useful measure for acceptable additional radiation exposure due to nuclear power. Counter arguments reveal that many detailed investigations show a relation between the natural radiation exposure and the increasing appearance of several health damages. Natural radiation is therefore not harmless, it might be the cause of a part of the "spontaneously" appearing cancer, leukemia or genetic diseases. Also, natural radiation is not a useful measure for the justification of additional exposure just because we are not responsible for it.

2.3.3 Cancer in the Near-Surroundings of Nuclear Power Plants and Reprocessing Plants

For many years the question of increased cancer frequency in the neighborhood of nuclear plants has been subject to controversy. There exist numerous references pointing to an increased cancer rate near the reprocessing plants La Hague and Sellafield. Also for the areas around nuclear power plants, the findings increase.

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[1] Gofman (1981) or Weish et al. (1986)

2.3.3.1 Findings in Germany

A study of the Institute for Medical Statistics in Mainz from 1997 showed that the frequency of leukemia for children was significantly increased in the neighborhood of German nuclear power plants [BMU 1998]. A very drastic example is the NPP Krümmel where in the adjacent village 17 cases of leukemia of children and juveniles have been registered since 1990.

Such a coincidence constitutes an important indication. It does not definitely prove, however, that there is a causal link between nuclear plant and illness. The radiation exposure derived from official emission and activity surveillance data are by far too low to explain these numbers. But it cannot be excluded that radioactive aerosols escaped unnoticed from the chimney, since the surveillance of the exhaust stream does not reliably record large particles. This shortcoming could basically also exist in other nuclear power plants.

In the same area, there is a large nuclear research center (GKSS) which could also be the source of unmonitored radioactive emissions, causing leukemia.

Comprehensive investigations, which were commissioned by the state governments of Lower Saxony and Schleswig-Holstein, could not definitely resolve the question whether there is a causal link between the emissions from Krümmel and/or GKSS, and the cancer cases in the region [Strahlentelex 2003]. In the last years, the debate focuses more on the research center and, in particular, on an accident which, some experts report, could have taken place there in 1986. Meanwhile, new cases of leukemia keep occurring. The last one of the 17 cases mentioned above was reported in February 2006 [Strahlentelex 2006].

Recently, the German Federal Office for Radiation Protection confirmed results of the Environment Institute (Umweltinstitut) Munich, that had found that an increase in the number of children's cancer cases in the areas around nuclear power plants in Bavaria. For the period from 1983 to 1998, the number of children with cancer in the counties with nuclear power plants was about 20 % higher than average. The Federal Office for Radiation Protection has commissioned investigations of the issue of a possible accumulation of cancer cases on the federal level, in the framework of a comprehensive case-control-study, in 2002. The study is to be concluded in the second half of 2006 [Grosche et al. 2002; Krebsregister 2006; Umweltinstitut 2006].

2.3.3.2 Findings in Other Countries

In the United States, a significant reduction of infant mortality has been reported in 2001 from the vicinity of five nuclear reactors, after they had been shut down [Strahlentelex 2002]. An investigation of children's cancer rates in the surroundings (48 km radius) of 14 sites with 24 reactors showed an increase by 12.4 % compared to the average. The authors of this study also emphasize the need for further investigations. They point out, however, that their results nevertheless already constitute "strong evidence" [Mangano et al. 2002].

In the midst of the 90s increased frequencies of leukemia around nuclear power plants were reported in Japan. In the early 90s an increased number of Down Syndrome cases around the Canadian NPP Pickering (Ontario) was observed, and some years before, an increased appearance of cancer in children and juveniles near the Scottish NPP Dounreay was noted[2].

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[2] Regarding the situation in Great Britain, see also: Busby (1995)

A recent study of cancer in the vicinity of Trawsfynydd nuclear power station in Wales, which is shut down since 1993 but not yet fully decommissioned, shows a significant increase of female breast cancer, male prostate cancer, leukemia and other cancers [Busby 2006].

2.3.3.3 Cancer Cases in the Vicinity of Sellafield and La Hague

A study commissioned by the European Parliament concluded in 2001 that there is definitely an increase in children's cancer cases in the surroundings of the British reprocessing plant Sellafield, particularly in the village of Seascale. So far, investigation could not clarify the cause of this increase. In particular, it remains open whether there is a link to the nuclear plant or not. Further research is regarded as required [Schneider et al. 2001].

In early 2004, new observations of increased cancer incidence in the neighborhood of Sellafield have been published. They concern the coastal city Caernarfon and its surroundings, located on the Irish Sea, south-west of Liverpool. The leukemia rate found in this region is even higher than that in Seascale [Strahlentelex 2004].

In the surroundings of the French reprocessing plant La Hague (region Beaumont-Hague), an increase of leukemia cases has been observed in the mid-nineties for the age group of 0 to 24 years. An investigation of possible causes revealed a positive correlation of the likelihood of getting leukemia with frequent visits to local beaches (by the children concerned or by their mothers, during pregnancy), as well as with the consumption of fish and mussels from the region. 1997, the authors of this study concluded that there is convincing evidence for radiation being the cause of the increase in leukemia incidences [Pobel et al. 1997].

A further study commissioned by the French government [GRNC 1991] did not confirm those findings. The meaningfulness of this study, however, was very limited, since a number of important pathways contributing to radiation exposure had not been taken into account. In mid-2001 a new epidemiological study was published, which had been financed by several state institutions (among them the Direction Générale de la Santé). It supported the results from 1997. Further investigations are called for.[3] In the last years, however, no new reports have been published on this issue. Open questions remain.

The listing of such examples could be continued. All these facts indicate that the radioactive emissions during normal operation of nuclear power plants without accidental events can cause fatalities, even if the valid emission limits are observed.

The reason could be that low-dose radiation effects are systematically underestimated, that the emissions are not completely and reliably detected, or a combination of both. No clear proof is yet available.

2.3.4 Long-Term Consequences

While cancer or leukemia (somatic radiation damage) dies with the individual, genetic defects can accumulate within the human population. Especially within the civilization milieu the genetic burden is increasing. An organism affected from mutated germ cells transfers the genetic damage in all cells of it's body and transfers it to the next generation (provided that the genetic damage

[3] For a more detailed account of the events described briefly in this paragraph, see Schneider et al. (2001), Chapter 6.5.2.3 and 6.5.2.4

is not fatal in utero or before the age of reproduction). The symptoms of such genetic diseases can be mitigated or oppressed but curing them is certainly not possible.

Radiobiological research has identified mechanisms that can repair DNA defects. Occasionally, there appear arguments that based on these repair mechanisms low-dose irradiation is genetically unobjectionable. This thesis is untenable because of the following arguments:

- The repair mechanisms do not work with 100 % efficiency. A certain amount of un-repaired genetic defects remains. This fact is not only verified by experiments[4], it follows from the existence of a spontaneous mutation rate and from the existence of genetic diseases.

- In a variety of radio-genetic experiments it was proved that the number of (unrepaired) mutations is proportional to the radiation dose without threshold value.[5] Moreover, the DNA repair is not necessarily faultless. One of the known repair mechanisms that reconnects DNA string ruptures, is therefore called "error prone" [Calkins 1977]. Repair mechanisms cause in some cases the survival and division potential of cells that would have been eliminated from the germ route due to a DNA defect, thus they enhance the mutation rate.

Due to the biochemical and molecular-biological similarity of organisms, many radio-genetic relations are known from numerous investigations on microorganisms, plants and animals. A quantitative estimation of the mutation triggering effect of radiation for man is difficult or impossible because of the following reasons:

- Striking dominant[6] genetic diseases are relatively seldom. They are only the "tip of the iceberg".

- Far more frequent are recessive mutations that are covered by the genetic disposition of the other parent. Recessive mutations appear if defective genes of both parents are transferred to the descendent[7]. Recessive mutations can be identified in cross-breeding experiments with short-lived organisms, with brief intervals between generations. The proof for human beings is only possible in exceptional cases.

- Therefore most genetic defects remain undiscovered over many generations, before they appear homocygote.

- The long time period of a human generation renders the observations more difficult.

- Since most diseases have genetic components an increased mutation rate will not only increase rare genetic diseases, but also increase many "normal" diseases.

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4 See e.g. Timofeeff-Ressovsky, N. V., Ivanov, V. I., Korogodin, V. J. (1972)

5 This effect was discovered by Hermann Joseph Muller who received the Nobel Prize for this discovery; Muller, H. J. (1927)

6 Dominant genetic dispositions are those that appear even in case they are only transferred by one of the parents. They cover the genetic heritage of the other parent which is called recessive.

7 Medical research has explained the genetic nature of many diseases of metabolism. A good example is the sickle cell anemia, the first genetic disease with detailed research on it's biochemical cause. The beta-polypeptide chain of hemoglobin A, that is composed of a sequence of 146 amino acids, contains in position 6 valine instead of glutamine acid. A minimum "misprint" in the genetic information, a single "faulty character", can cause a severe incurable disease if both parents transfer the same genetic defect to their children.

- While a radiation-induced cancer concerns "only" a single individual – and this might be tragic – a single radiation-induced mutation can imply incurable diseases or deformity for many persons of future human generations.

- In a growing population esp. genetic defects that do not reduce the reproduction rate exhibit negative effects in a long-term because they are not eliminated like genetic lethal factors.

Due to this fact geneticists have warned already some time ago of an increasing human radiation exposure.

"Genetiker werden oft gefragt, welche Strahlendosis toleriert werden könnte. Die Antworten sind unterschiedlich und werden meist nur widerstrebend gegeben, denn es gibt auf diese Frage keine Antwort. Abgesehen von der Tatsache, daß das heute vorliegende Versuchsmaterial zwar eindeutig Erzeugung schädlicher Mutationen durch Strahlung beweist, aber für quantitative Aussagen den Menschen betreffend noch recht unvollkommen ist, müßte für eine solche Antwort festgelegt sein, ob wir eine Verdopplung, Verzehnfachung oder Verhundertfachung der heute durch Spontanmutationen bedingten Fehlgeburten, Mißbildungen und Erbkrankheiten für "tragbar" halten. Entscheidend in unserer Verantwortung für spätere Generationen ist die Tatsache, daß erst nach genügender Verbreitung der rezessiven Defekte durch weitere Fortpflanzung der heutigen Menschheit die Katastrophe über unsere Enkel und Urenkel hereinbrechen kann, auch wenn wir heute den Eindruck einer normalen Situation haben." [Bresch1970]

(Genetics scientists are often asked which radiation dose could be tolerated. The answers are different and are mostly given reluctantly, since there is no answer to this question. Besides the fact that the present experimental results show definitely the radiation-induced production of harmful mutations, for quantitative statements concerning human beings these results are still rather incomplete. For such an answer a commitment would be necessary that we consider a double, tenfold or hundred-fold number of today's spontaneous mutation induced miscarriages, deformities and genetic diseases as "acceptable". In our responsibility for future generations the fact is, that only after sufficient distribution of recessive defects by further reproduction of today's mankind the catastrophe might appear for our grand or great-grand children, even in case we have today the impression of a normal situation.)

Unfortunately, although there definitely is a relationship between low-dose irradiation and health hazards, it is very complex and cannot be proven in an individual case.

Regarding both cancer and genetic defects, it remains complex and difficult to establish causal links between the "normal operation" of nuclear installations and cases of illness. It can be stated in summary, however, that the evidence for such a link has become increasingly clearer in the course of the years.

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3 Nuclear Safety

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January 2007

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3 Nuclear Safety

3.1 Motivation

The accident at the Chernobyl reactor in 1986 demonstrated that the consequences (economical, environmental, health effects, etc.) can be extremely serious and can affect large areas over long periods of time. The expenditures e.g. of Belarus to mitigate the effects of the Chernobyl accident surpassed 10 % of the state budget even 10 years after the accident [Rolevich et al. 1996].

The transboundary character of the consequences of severe reactor accidents has been acknowledged by the Director General of the IAEA [ElBaradei, 1999]: "*Nuclear accidents do not respect national borders, a fact that was brought to the attention of the international community after the Chernobyl accident.*"

The frequency of severe reactor accidents with large off-site releases of radioactivity for a single reactor is presently considered to range in the order of 1 in 100,000 (or 10^{-5}) and 1 in 10.000,000 years (or 10^{-7}) years, dependent on the reactor type, the maintenance, site characteristics, etc.. Just a few years ago, the numbers ranged down to 10^{-3} and 10^{-4}. None of these numbers includes all possible contributors, in particular they do not take account of deliberate attacks. There is general consensus that it is impossible to include terrorist and sabotage attacks in probabilistic risk analyses, since there is no basis for meaningful quantitative estimation of their probability. The same, of course, applies to acts of war.

In view of the consequences of severe reactor accidents with large off-site releases of radioactivity any evaluation of nuclear risk must consider the whole population of some 440 NPPs in operation world-wide, an even larger population in case of a marked nuclear renaissance.

Thus a relatively low probability of occurrence, but catastrophic consequences describe the risk of severe accidents imposed by nuclear power plants (NPPs). According to the systematic categorization of risk types by social scientists [Renn et al. 1998] this corresponds to the risk category "Damocles" [WBGU 1998]. It should be noted here that other nuclear facilities connected with nuclear power such as reprocessing plants and radioactive waste storage facilities are subjected to the same risk type of severe accidents.

Manifold risks – not treated in this report – encompass the whole civil nuclear fuel cycle of commercial power plants as well as research and military reactors (mining, milling, conversion, enrichment, reprocessing, radioactive waste management, or spent fuel management). Significant risks have accompanied the nuclear option from the first mining of uranium and will continue to do so to – eventually – the phase-out of nuclear energy. But even after that the risks involved in nuclear waste disposal will remain as a long-term commitment for timespans of geological scales. The military uses of nuclear power involve additional aspects such as safeguards and proliferation issues affecting civil nuclear facilities. Some of these issues are addressed in other papers in this volume. The purpose of this report is to provide an overview of the current status of the safety of commercial nuclear power plants only.

3.2 Commercial Nuclear Power Plant Designs and Main Generic Severe Accident Vulnerabilities

3.2.1 Overview

As of April 2006, there were 443 power reactors in operation worldwide, and 27 additional units under construction (IAEA Power Reactor Information System, PRIS, data). Collectively, the 443 operating reactors had a net electrical capacity of 370 GW, and produced about 16 % of the total electricity generation worldwide. There are eight countries for which nuclear power provides 40 % or more of total electricity generation; all eight of these countries are in Europe (Belgium, Bulgaria, France, Lithuania, Slovak Republic, Sweden, Switzerland and Ukraine). Of the sixteen countries that get more than 25 % of their electricity from nuclear power plants, thirteen are in Europe.

Currently operating power reactors in Europe fall into six broad types[7]:

- Pressurized water reactors (PWR and WWER);
- Boiling water reactors (BWR);
- Boiling light water cooled, graphite moderated, vertical pressure tube reactors (RBMK);
- Pressurized heavy water cooled and moderated, horizontal pressure tube reactors (PHWR);
- Gas-cooled reactors (MAGNOX & AGR); and
- Liquid-sodium cooled fast breeder reactors.

A sequence of "Generations" reflects the evolution of reactor designs.

Generation I: Some earlier designs falling in Generation I are still in operation, but most are intended to be shut down in the relatively near future. The first generation of NPP were experimental low power reactors to provide the experience needed to build the first series of commercial power reactors of the following generation.

Generation II: With some exceptions, most of the currently operating nuclear power plants are properly classified as Generation II, but exhibiting different levels of safety. The accidents at the NPP Three Mile Island (TMI-2) and at the NPP Chernobyl (Chernobyl-4) – Generation II reactors - emphasized the importance of safety.

Generation III: Generation II reactor concepts were modified to address a large number of foreseeable accidents passively and reduce core damage frequency (CDF) to values as low as $1.7\ 10^{-7}$ (AP-600, see [NRC-1]). Four Generation III units are in operation in Japan; all are Advanced Boiling Water Reactors (ABWR). A Generation III reactor (EPR) is under construction at the Olkiluoto site in Finland, and an EPR unit is planned for the Flamanville site in France.

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[7] These 204 operating units comprise 92 PWR, 56 WWER, 19 BWR, 12 RBMK, 1 PWHR, 22 gas-cooled reactors and 2 fast breeder reactors.

Generation III+: Liberalization of the electricity market and the decreasing governmental support for the nuclear industry forced a further redesign – NPP now have to be competitive on the market, and the designs were worked over to reduce capital costs (the Generation III+). It is claimed that fifty years of experience, best practices and engineering knowledge of light water reactors are reflected in the Generation III+ plant designs. Initiated by a generous support package from the US government, plans to construct more than a dozen Generation III and III+ reactors in the United States have been announced in recent months.

Generation IV: designs are under development internationally; construction of a demonstration unit of one Generation IV design (the PBMR modular gas-cooled reactor) is planned in the near future in South Africa.

Table 3-1 illustrates the different reactor types (with examples) and their corresponding "generation".

Tab. 3-1 **REACTOR TYPES AND GENERATIONS**

Generation	Short Description	Examples
I	Early prototype reactors; mostly built before or during the development of safety standards.	• Early Siemens BWR (Gundremmingen A) • BWR Siemens 69 (Isar 1) • WWER-440/230 (Novovoronezh 1, Bohunice V1, Kozloduy 1-4) • MAGNOX Gas-Cooled Reactor (Calder Hall, Chapelcross, Latina) • Early RBMK-1000 (Leningrad 1 & 2) • UNGG (French, all shutdown)
II	Commercial power reactors; generally designed to formal nuclear safety standards, with most incorporating the defense-in-depth concept and containment; not designed for severe accidents.	• AGR (Hinckley Point B) • BWRs (Leibstadt, Olkiluoto, Gundremmingen B & C) • CANDU (Cernavoda) • French N4 (Chooz & Civaux) • German Konvoi (Emsland, Isar 2, Neckar 2) • Westinghouse PWR (Beznau, Krško & Asco) • WWER-440/213 (Bohunice V2, Dukovany, Paks) • WWER-1000/320 (Temelin, Kozloduy 5 & 6) • Later RBMK-1000 (Chernobyl 3 & 4) • RBMK-1500 (Ignalina 1 & 2) • Fast breeder reactors (FBR) see section 3.2.2.6
III	Advanced reactors with improved safety; designed explicitly for severe accidents.	• Advanced BWRs (ABWR, SWR-1000; 4 Japanese ABWR units) • Advanced CANDU (ACR-700) • Advanced PWRs (AP600, EPR, WWER-1000/392)
III+	Generation III reactors with improved economics.	• Advanced CANDU (ACR-1000) • Advanced PWR (AP1000) • Advanced BWR (ESBWR)
IV	Advanced reactors with improved economics, enhanced safety, improved proliferation resistance, and reduced radioactive waste generation.	• Fast Reactors (GFR, LFR, MSR*, SFR, SCWR closed cycle) • Thermal Reactors (MSR**, VHTR based on PBMR or GT-MHR, SCWR open cycle)

- MSR* with metallic-clad fuel
- MSR** with fuel dissolved in salt

The bulk of the presently operating commercial nuclear power plants being of Generation II, their safety features dominate nuclear safety at present.

Generation III plants are still very few. If the contribution of nuclear energy to overall energy production is to increase in future, nuclear risk in the longer term will be determined by the safety features of Generation III or III+ and – more likely – Generation IV plants (see section 3.2.3).

3.2.2 Main Generic Severe Accident Vulnerabilities of Presently Operating Nuclear Power Plant Types (Generations I and II)

3.2.2.1 PWR & WWER

PWR and WWER rely on pressurized light water for cooling and neutron moderation. With the exception of the WWER-440/230 and WWER-440/213 units, PWR have full containments. The WWER-440/230 and 440/213 units were originally supplied with large, low pressure confinements either with pressure relief valves (230) or with bubbler-condenser pressure suppression systems (213). Containements are the last physical barrier of a multi-step "defense-in-depth" concept to prevent large releases of radioactivity to the environment.

Broadly speaking, PWR NPPs can be vulnerable to containment bypass accidents involving steam generator tube rupture, or containment/confinement failure due to "interfacing LOCAs", "direct containment heating" or hydrogen combustion (particularly hydrogen detonation).

Many PWRs in Europe have been backfit with filtered venting systems as a means of avoiding containment failure in severe accidents, and as a means of reducing the source term from severe accidents. In addition, many PWRs in Europe have been backfit with supplemental "bunkered" systems to perform some safety functions in case the originally provided safety systems fail.

Containments and confinements are generally not designed to withstand rupture of the reactor pressure vessel (RPV). Therefore rupture of the RPV (itself an inner barrier of utmost importance) must be excluded through appropriate precautionary measures, such as careful RPV design and material selection as well as extensive pre- and inservice testing including PTS analyses and sampling. Radiation-induced embrittlement under load of pressurized thermal shock (PTS) poses a severe vulnerability (see also section 3.7.1).

3.2.2.2 BWR

BWR are direct cycle reactors where boiling water from the primary system produces steam which is directed to the turbine for power production. BWR have full containment, using pressure suppression systems to reduce pressure caused by steam release inside containment.

Broadly speaking, BWR NPPs can be vulnerable to containment failures caused by hydrogen combustion or overpressure due to long-term loss of containment heat removal. Severe accidents can also be caused by direct contact of core debris with the containment wall following reactor pressure vessel (RPV) failure, resulting in a large early release of radioactive material to the environment via the reactor building (see also 3.2.2.1 above, RPV rupture). Most of the European BWRs have been backfit with filtered venting systems or with supplemental bunkered systems.

3.2.2.3 RBMK

RBMK are boiling light water reactors with the cores arranged in vertical pressure tubes and moderated by graphite. (IAEA's PRIS database designates these reactors as LWGR, light water-cooled graphite-moderated.) The reactors are thus quite large in dimensions compared with PWR and BWR. RBMK lack containments in any conventional sense; some of the units have pressure suppression systems located under the core area which are capable of dealing with a small number of simultaneous pressure tube failures (out of about 1600 tubes total) [IAEA 1999].

The principal vulnerability of RBMK (notwithstanding the changes made in the aftermath of the Chernobyl accident) is that any accident involving large scale core damage is likely to proceed to a large release accident due to the lack of containment and the limited capacity of the pressure suppression system (where it is present) to mitigate pressure tube failures.

3.2.2.4 PWHR

The PHWR of the CANDU® type is cooled and moderated by heavy water (deuterium). The reactors use natural uranium fuel and are refuelled online by special machines. The CANDU design at the Cernavoda plant has a prestressed concrete containment with a passively actuated spray system (typically referred to as a dousing system) for pressure suppression.

CANDU reactors have relatively slow severe accident progression (compared with PWR) due to the presence of the moderator tank (calandria) which surrounds the fuel channels. The principal faster moving scenarios involve complete loss of heat removal, and transients without scram in which the positive reactivity of the core can result in core disruption and early containment failure [IAEA 2002].

3.2.2.5 Gas-Cooled Reactors

MAGNOX reactors are natural uranium metal fuelled reactors cooled by carbon dioxide and moderated by graphite. Six MAGNOX stations were shut down for decommissioning between 1988 and 2004. The remaining four operating MAGNOX stations have planned shutdown dates ranging from 2006 to 2010 [HSE 2004].

AGR, the second design of gas-cooled reactors operating in Europe, consist of a pre-stressed concrete pressure vessel (with a steel liner) which encloses enriched uranium fuel in stainless steel clad pins. The reactors are graphite moderated and cooled by high-pressure carbon dioxide gas. The reactors are refuelled online.

Few details about severe accident behaviour and vulnerabilities are available for MAGNOX and AGR facilities. In general, the use of gas as a coolant means that there is no phase change under accident conditions as there is with water cooled reactors. In addition, the large mass of graphite in the cores (more than 1000 metric tonnes) gives a very large thermal inertia and a correspondingly very slow temperature increase profile under accident conditions. The principal severe accident vulnerability would seem to be scenarios in which a sufficiently large opening is created by an external event, allowing the graphite moderator to burn.

3.2.2.6 Fast Reactors

There are only two fast reactors in operation now in Europe (Phénix, France and BN-600, Russian Federation), and one is being used only on an experimental basis, with electrical generation being incidental to the experimental programme.

The history to date of commercial fast breeder reactors has been rather poor, with only one of seven such reactors attaining anything remotely approaching commercial viability.

The main severe accident vulnerability of fast reactors appears to be the so-called "hypothetical core disruptive accident" (HCDA), resulting in destruction of the core in a reactivity excursion.

3.2.3 General Considerations on the Safety of Generation III and IV Plants (Advanced Reactors)

The few Generation III units which have begun operation and the few more under construction or planned for construction in the next decade are listed in Table 3-1. Whether Generation IV plant will ever become commercial in any relevant number or, on the contrary, Generation III plants might be skipped over and the significant increase of future nuclear energy will be delivered by Generation IV is controversial. The argument against Generation III is that the reasonably accessible resources of U^{235} needed to drive this generation of reactors are limited (for a time span on the order of few decades depending on assumptions (for details see Zittel et al. 2006 or Sholly, St. "Nuclear Generated Hydrogen Economy - A Sustainable Option?" in this volume)). If NPPs are to play a significant role in filling the gap that fossil fuels are likely to leave, sufficiently abundant fissile isotopes must be used. This implies a variety of still very hypothetic reactor designs based on the use of Pu^{239} and U^{233} by breeding U^{238} and Th^{232}. Practically all of these are Pu driven fast reactors except a thermal breeder type Thorium fuel based reactor. Very optimistic estimates expect deployment of the first of these reactors to be possible by 2015-2025 [DOE-1] (see also Weimann et al. "Timeliness of the Nuclear Energy Option" in this volume).

Safety problems in Generation IV reactors differ widely from those known for the earlier generations. However, it is very difficult to assess their safety at the present time, as they are only in the design phase, and studies addressing safety aspects are still limited.

In the discussion of Generation III, III+, and IV designs one often runs across the phrase "inherently safe". Inherently safe designs are intended to accomplish all safety functions (reactor shutdown, emergency coolant injection, decay heat removal, containment cooling) passively, without active systems and without operator intervention (except after long delay times, ranging from three days to a week or more). Furthermore, "inherently safe" refers only to accidents within the design basis. Compared to Generation I and II plants Generation III plants are designed with a more substantial external hazards design basis (e.g. higher seismic design base, reduced fire and internal flooding risks, higher aircraft crash resistance). Without underestimating the importance of these quantitatively increased safety levels, the new quality of "inherently safe" in the true sense of the word is still not reached, even without considering deliberate acts of safety impairment.

As already mentioned, all Generation IV designs (Table 3-1) are in the phase of planning, and not yet final. For this reason, estimating the actual safety levels is very difficult. However, fast reactors suffer a handful of drawbacks, which make them expensive to build and hard to operate. Some issues:

Small average lifetime of prompt neutrons: Compared to thermal reactors it is difficult for fast reactors to maintain control and prevent "prompt criticality" immediately resulting in an immense power surge, capable of destroying large parts of the reactor core within seconds.

Adverse properties of primary system coolants: The primary system coolants of fast reactors behave neutron poisoning (sodium, lead) or neutral at best (helium). Therefore, other than LWR, fast reactors do certainly not reduce and might even increase reactivity in case of LOCA (positive void coefficient). Calculations assuming reactivity excursion of possible channel type commercial FBR with sodium reveal core destruction to 80 % within 2 seconds [Tobita et al. 2006]. In addition, as opposed to LWR, the once destroyed (molten) core does not loose its reactivity in absence of the primary system coolant, since fast reactors do not need a moderator. The molten core likely will stay critical and continue to produce energy.

What can be seen here is the difference in safety standards that has to be adopted for LWR and FR. While the Generation III+ reactors are intended to be capable of withstanding any accident without operator intervention at least for three days without core damage, a FR may end up a few seconds after the beginning of an accident with 80 % of the core melted and ejected. This seems to be a rather daring generalization , but it is based on two intrinsic principles which can be found in all Generation IV fast reactor designs: first, once the fraction of delayed neutrons diminishes, the progression of a power and reactivity excursion is much faster than the one for a thermal reactor. And second, the beneficial effect of the moderator, which automatically renders the reactor sub critical once evaporated, is missing. No extensive analysis of initial events leading to reactivity excursions has been done, since very few organizations have the tools to do so. But it would not be a surprise if more initiating events leading to reactivity excursion like the one mentioned in [Tobita et al. 2006] could be found.

Activation of the primary coolant is an issue for metal cooled fast reactors. The half-life of Na^{22} with 2.6 years is comparably long, and large activities are expected. Shorter lived isotopes emit radiation at higher energies, are a safety hazard, and emphasize the need to take extra care in the design of the plants [Guerrini et al. 1999]. Lead or lead-bismuth-eutectics as coolant show similar activation chains.

Reaction of sodium with water and air is another topic relevant for the safety of the SFR [Guerrini et al. 1999]. Should there be a secondary to tertiary leak, a fire is to be expected. In the opinion of some, this issue is an obstacle in the deployment of fast reactors, especially together with the fact that large activity of the primary system coolant can be expected. Evgeny Adamov, who is very much in favour of the deployment of fast reactors, stated (regarding the Russian development of fast reactors) "... in the sodium coolant we have around 50 million Curies of radioactivity, so we do not need a fuel melt to have the same accident as at Chernobyl, only a fire ... " [Adamov 1999].

Regarding the GFR it can be said that helium has a small heat capacity, and a LOCA in this gas cooled reactor might mean that heat removal from the core is lost at the same instant.

From a point of safety, the supercritical reactor is sometimes rated highest of Generation IV fast reactors due to its similarity to the "proven" LWR design.

It has to be noted that all fast reactors lead to a so-called Plutonium economy with all the attached adverse effects [Broda 1973]. From the aspect of safety and security the Thorium-originated alternative - due to the adverse radiotoxic properties of U^{233} and accompanying isotopes - would be comparable to the Pu^{239} based alternative.

Thus, while the thermal LWR is a proven technology, the fast reactor is largely virgin soil. For LWR an operational experience of more than 10,000 reactor years exists. The design has undergone an evolutionary development, reactors are designed to cover a large range of accidents already in the design basis, safety systems are kept as simple as possible, and are designed to intervene passively, thereby increasing reliability and reducing costs. A whole arsenal of computational tools exists, each of them very well validated by a vast number of separate and integral tests. The users are well aware what their codes can and cannot do. There is a certain independence of regulatory authorities from industry, since enough codes are available to check and cross-check claims on safety margins. Even independent bodies like universities can assess claims on safety of the plant designs. Inspite of these assets the safety levels reached are controversial.

For fast reactors the situation is completely different. A generous calculation[2] gives some 120 reactor years of operational experience. The experience with the existing reactors does not give rise to the hope that the deployment of fast reactors will be without friction. The materials used for fast reactors are different, the safety concepts will be different. In addition, fast reactors are more difficult to operate due to the intrinsic mechanisms mentioned. Of the total budget for the development of Generation IV reactors the part dedicated to safety research is small. It cannot be expected that the same knowledge and the same awareness on safety about the fast reactors will be present at their planned deployment as it is now for the LWR. Only very few codes exist to estimate the impact of initiating events on fast reactors, and the extensive validation matrices for such codes do not yet exist. Since the declining resources for LWR might push the early deployment of fast reactors, a huge financial effort to raise the standards of the safety analysis tools to the same level as they are for LWR would be needed, but there are no indications that this will happen.

The above mentioned problems are in striking contradiction to the most important design goals for the Generation IV reactors: inherent safety, proliferation resistance, economic performance and absence of long-lived high-level radwaste. Considerable doubts are voiced on the feasibility of meeting these goals: "*We have not found and, based on current knowledge, do not believe it is realistic to expect that there are new reactor and fuel cycle technologies that simultaneously overcome the problems of cost, safety, waste, and proliferation*" [MIT 2003, op. cit., p. 76].

3.2.4 Preliminary Conclusion

This overview of generic severe accident vulnerabilities of the most frequent reactor types and all generations shows that all have vulnerabilities that can lead to severe accidents and possibly large releases of radioactivity despite the efforts to eliminate such vulnerabilities and the undoubted improvements that have been achieved.

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[2] Based on operating data from PRIS and the Nuclear News World List of Nuclear Power Plants, March 2001, with additional information from general sources.

3.3 Hazards

3.3.1 Internal Event Hazard

Some types of events and failures at nuclear power plants are referred to under the broad heading of "internal event hazards". Many types of internal events are common across a number of reactor types, while others are more-or-less specific to particular designs. Some internal event hazards are of the nature of technical system failures. Some types of accident initiators leading to situations where safety systems are required to respond include a loss of feedwater, various sizes of pipe breaks (leading to a loss of coolant accident or LOCA), loss of offsite power and a loss of service water.

Typical types of internal events studied in probabilistic safety assessments (see section 3.5) include the following

- Loss of coolant accidents (LOCA) with failure of emergency core cooling systems (ECCS) or residual heat removal systems.
- Transients involving a loss of feedwater or a loss of heat removal (including loss of essential service water).
- Loss of offsite power with failure of emergency diesel generators (resulting in so-called "station blackout").
- Transient events accompanied by a failure of automatic shutdown, so-called anticipated transient without scram (ATWS).
- Internal plant flooding caused by the rupture of a cooling water system pipe (from a system such as essential service water or the circulating water system), or actuation of a water-based fire suppression system.

Many of the most serious system failures in response to internal initiating events are due to single factors which affect multiple trains of the same system – a so-called "common mode" or "common cause" failure. An example of such a failure would be a single team of personnel which performs lubrication on all three pumps of a system, and systematically applies the wrong type of lubricant to the pump bearings. Then, when the system is called upon to operate, the bearings seize and all three trains of the system fail due to a common cause.

Operator actions in responding to initiating events can also cause system "failure". For example, premature operator termination of high pressure injection during the Three Mile Island Unit 2 accident led to core damage. Since the Three Mile Island accident, nuclear power plants around the world have switched from event-oriented emergency operating procedures (EOP) to symptom oriented EOP. The latter type of EOP does not require the operators to diagnose the accident during the relatively high stress period of accident response – instead the operators are directed to treat accident symptoms. In this way, it is commonly considered that the likelihood of operator error leading to system failure has been reduced. On the other hand, there is at least one case of operators failing to take action which prevented a severe accident[3].

A more pervasive and potentially more severe type of human interaction which can lead to or exacerbate internal event hazards involve weaknesses in the so-called "safety culture" of a nuclear power plant. Safety culture is defined as "*that assembly of characteristics and attitudes in organizations and individuals which establishes that, as an overriding priority, nuclear plant safety issues receive the attention warranted by their significance*" [INSAG 1991]. Safety culture issues are widely considered to have played a significant role in the Chernobyl Unit 4 accident. Another example of safety culture problems was provided by the discovery of operators sleeping on duty at the Peach Bottom nuclear power station in the United States in 1987 [NRC 1987]. The US NRC ordered a shutdown of the plant and imposed a more than million dollar civil penalty (at the time, this was the largest civil penalty ever). The plant remained shutdown for two years.

3.3.2 External Event Hazards

External events are considered to be hazards which do not originate in the design of the plant equipment[4]. External event hazards are considered to arise from natural phenomena hazards and man-made phenomena hazards; they are numerous and very divers (Table 3-2). In general, the hazard posed by external events is that they can cause common-cause failures of numerous systems.

External hazards that occur at the specific site should be taken into account by the design and are treated during the licensing procedure. However, external hazards can undergo changes in reality or in assessment during the operative phase of NPPs. Thus e.g. changes in flood extent or frequencies due to climate change, as extensively experienced presently, new evaluations of the seismic hazard due to improved methods of assessment or the development of commercial airplanes of increasing size, weight and speed should induce reassessments of the safety of NPPs vis-à-vis external hazards. The specific examples given here are addressed in more detail further on.

[3] The failure of operators to reset the scram in the case of the Browns Ferry fire in 1974; had the scram been reset, the control rod drive hydraulic system - which was the only system adding water to keep the core covered - would have cut its flow rate in half and the core would have been damaged due to insufficient makeup.

[4] Even though fires starting within the plant might be considered to be an "internal" event, they are generally treated as an external event.

Tab. 3-2 EXTERNAL HAZARDS

External hazards that need to be considered in the design, the licensing and the operation of nuclear plants

Natural Phenomena Hazards	Man-Made Hazards	Deliberate Acts
Asteroid Impact	Aerial Tramway Failure	Computer Vulnerability (Viruses, Hacking, Y2K)
Avalanche	Aircraft Crash	Criminal Acts Murder
Biodiversity changes	Air Pollution	Fallout from Distant Nuclear Weapon Use
Cave Collapse	Air Traffic Control System Failure or Strike	Riot
Climate Change	Boat or Ship Sinking	Terrorism
Comet Impact	Bridge Collapse	Assassination
Drought	Building Structural Collapse	Contamination of Food, Medicine, etc.
Dust Storm	Chemical Release	Contamination of Drinking Water
Earthquake	Criticality in Nuclear Facility	Hijacking
Earth Axis Rotation Aberration	Dam Failure	Hostage Situation
El Niño	Explosion	Mail Bombs
Epidemic	Fire	Military-Style Assault
Bacterial	Geomagnetic Storms	Snipers
Viral	Military Weapon Accident	Vehicle Bomb
Extreme Cold Temperature	Nuclear Power Plant Accident	Weapons of Mass Destruction
Extreme High Temperature	Nuclear Weapon Accident	Biological Weapons
Famine	Oil Spill	Chemical Weapons
Flooding	Ozone Depletion	Nuclear Weapons
Forest Fire	Pipeline Failure	Warfare (Conventional)
Geomagnetic Storms	Power Failure	Aircraft Attack
Hail	Refinery Accident	Artillery and Tanks
Hurricane	Soil Contamination	Infantry Assault
Landslide	Spacecraft Re-entry (Uncontrolled)	Landmines
Lightning Strike	Traffic Accident	Missiles and Rockets
Meteorite Impact	Train Collision or Derailment	Warfare (Weapons of Mass Destruction)
Perma frost thawing	Transportation Strike	Biological Weapons
Sandstorm	Tunnel Accidents	Bacteriological Agents
Sea level rise	Collapse	Viral Agents
Seiche	Fire	Chemical Weapons
Sinkholes	Flooding	Electromagnetic Pulse
Sleet	Water Pollution	Nuclear Weapons
Slope Failure		
Snow		
Solar Flare/Sunspot Activity		
Subsidence		
Tornado		
Tsunami		
Volcanic Activity		
Wildfire		

3.3.2.1 External Natural Phenomena Hazards

There are a variety of external natural phenomena hazards (see Table 3-2) that could initiate a sequence of events resulting in a nuclear power plant accident. In many cases, when a probabilistic safety assessment (PSA) is performed for a nuclear power plant, external events (including natural phenomena hazards) are considered as part of the analysis.

3.3.2.2 External Man-Made Phenomena Hazards

Just as natural phenomena hazards can pose a risk of a nuclear power plant accident, so can man-made hazards (see Table 3-2). Many of these are very site specific e.g. in consequence of nearby hazardous installations and they may change over time, as the infrastructure near and the environment of the NPP change.

3.3.3 Adversary Actions

Another category of potential initiators of accidents at nuclear power plants is the broad category of "adversary actions". The internal and external event initiators discussed above are assumed to be random events that occur at a more or less predictable rate. Adversary actions are different – they are deliberate acts directed against nuclear facilities with the aim of causing damage to the facility, economic losses (e.g., by causing a prolonged shutdown), energy shortages, or with the aim of causing a release of radioactivity to the environment.

Four categories of adversary actions can be distinguished, in roughly escalating order of severity (each discussed briefly below): vandalism, sabotage, terrorism and acts of warfare.

The history of the commercial nuclear power program has had numerous examples of acts of vandalism directed against nuclear power plants. Most countries do not discuss such actions publicly. The United States published the Safeguards Summary Event List (SSEL) which detailed (within limits) these events, possibly only up to the year 2000.

Such acts range from the harmless to the unexpectedly hazardous. There is always the danger in acts of vandalism that an act will be committed that, not clearly recognized by the perpetrator, nonetheless poses a risk of initiating a sequence of events that could end in an accident.

Acts of sabotage are typically performed by two types of perpetrators. First, there are acts of sabotage performed by persons with authorized access to nuclear facilities. Second, there are acts of sabotage perpetrated by persons who penetrate plant security provisions with the aim of causing damage to the plant. Whether intended or not, these more serious acts – which are deliberately intended to cause facility damage – could in some circumstances initiate a sequence of events resulting in an accident.

Without getting too specific, there are events on record at nuclear power plants in which: (a) valves have been closed to prevent safety system actuation; (b) foreign substances have been introduced into plant equipment in an apparent attempt to cause component or system failure in the event of actuation in response to an initiating event; and (c) fuel supplies for emergency generating systems have been tampered with in an apparent attempt to cause failure in the event of loss of offsite power. These sabotage attempts were apparently perpetrated by individuals with authorized access to the facilities – acts of so-called "insider" sabotage. There is also at least one incident on record in which individuals were apparently trying to cause a loss of offsite power to a nuclear power station. This is an example of "outsider" sabotage.

Since the terrorist attacks in the US in September 2001, and subsequent terrorist actions elsewhere in the world, there is obviously a concern that terrorist attacks could be directed against nuclear facilities. The possibility that aircraft could be hijacked and deliberately crashed into nuclear power plants has, following the September 2001 attacks on the former World Trade Center in New York and on the Pentagon in Virginia, received a great deal of attention, as has the potential for terrorist attacks against nuclear facilities in general [EPRI 2002; POST 2004; SKI 2003]. The German environment ministry (BMU) has had a study performed by the German nuclear safety expert group GRS concerning aircraft crash at nuclear power plants (the study is formally classified, but it has been widely discussed in the media nevertheless). However, there is little evidence that the largest civil aircraft in operation or going into commercial service soon have been considered in these assessments. Broadly speaking, the largest of these, the Airbus A380 has about the double to 4-fold take-off weight[5] in comparison to the aircraft that were used in the September 2001 terrorist attacks.

There are examples in the historical record of bombing attacks on a nuclear power plant construction site (Bushehr in Iran was attacked several times during the Iran-Iraq war). In addition, during the various conflicts which erupted in the wake of the breakup of Yugoslavia, military aircraft overflew the Krško nuclear power plant in Slovenia. (Nuclear facilities other than nuclear power plants have been destroyed in military attacks carried out by Israel and the United States.) For more examples see Hirsch, H. "Terrorism and War" in this volume.

Nuclear power plants are not designed for protection against military attacks. It is assumed that the military of the nation in which the power plant is located will provide protection against such threats. In the US nuclear legislation, there is even a prohibition against considering military attacks in licensing proceedings for nuclear power plants.

The consequences of military or terrorist attacks for NPPs could be extremely large radioactive releases into the environment.

[5] http://www.airbus.com

3.4 Commercial Nuclear Power Plant Accidents and Selected "Near Misses"

3.4.1 Severe Accidents in Commercial NPPs

There have been two severe accidents in commercial nuclear power plants. The Three Mile Island Unit 2 reactor (a PWR supplied by Babcock & Wilcox, now owned by Framatome ANP) in the United States suffered a partial core melt accident in March 1979 due to a loss of feedwater with a stuck-open relief valve and operator action to terminate emergency core cooling system operation. In this case, core debris was retained inside the reactor as a result of late re-initiation of forced cooling, and the containment survived a hydrogen combustion event, preventing a large release of radioactivity to the environment.

In April 1986, the Chernobyl Unit 4 reactor (an RBMK facility) exploded in a reactivity-initiated explosion [Steinberg et al. 1991], causing a large release of radioactivity to the environment and permanent evacuation of a 30-kilometer radius around the plant. The last of four reactors at the Chernobyl plant (Unit 3) was shut down in December 2000.

3.4.2 Chronology of Recent Incidents

Some types of events at operating nuclear power plants, while they do not result in an accident *per se*, are sufficiently close in circumstances that they are considered to be "precursors" of a severe accident. A more colloquial expression for a precursor – especially one in which the conditional probability of core damage was quite high – is a so-called "near miss". A chronology of selected events is given in Table 3-3.

Tab. 3-3 **CHRONOLOGY OF EVENTS, "NEAR MISSES" AND CLEAR INDICATIONS OF DEFICITS IN SAFETY CULTURE**

Year	NPP/Country	Accident/Event/...	INES
1958	Calder Hall / UK	Turbine failure	not included
1974	Shippinport / USA	Turbine failure	
1975	Browns Ferry / USA	Fire	not included
1979	Barsebäck / SWE	Turbine failure	not included
1980	Yankee Rowe / USA	Turbine failure	not included
1982	Metzamor / Armenia	Fire	not included
1983	Salem / USA	Anticipated Transient Without Scram (ATWS)	not included
1985	Maanshan / Taiwan	Turbine failure	not included
1989	Vandellos I / Spain	Turbine failure/ Fire	3
1989	Ignalina II / LIT	Fire	not included
1991	Salem Unit 2 / USA	Turbine failure	not included
1991	Chernobyl II / UKR	Turbine failure/ Fire	2
1993	Narora / India	Turbine failure/Fire	not included
1995	Leibstadt/ CH	hydrogen deflagration in an auxiliary steam generator	not included
1999	Blayais / FRA	Flooding/loss of offsite power	2
1999	Sellafield / UK	data falsification	not included
2001	Sizewell-B / UK	reactor pressure vessel head seal leakage	not included
2001	Cattenom-3 / FRA	Fuel damage	not included
2001	Hamaoka /Japan	double-ended steam line break	not included
2001	Philippsburg / GER	Incorrect boron concentration	2
2002	Brunsbüttel / GER	pipe failure	1
2002	Davis-Besse / USA	RPV head Corrosion	3
2002	TEPCO / Japan	data falsification	1
2003	Paks 3 / HUN	extensive ex-core fuel damage during cleaning	3
2003	Kozloduy 3 / BG	Loss of coolant accident (LOCA)	1
2004	Vandellos 2 /SPA	Service Water System pipe break and loss of wall thickness due to corrosion	2
2004	Temelin/CZ	Spill of contaminated coolant	
2004	Sellafield THORP/ UK	Leaks in the heat exchanger tubes	not included
2005	Sellafield THORP/UK	Pipe failure in feed clarification cell	not included
2006	Kozloduy 5 / BG	ATWS / Mechanical Scram Failure	2
2006	Forsmark-1 /SWE	Two emergency dieselgnerators did not start when the unit was disconnected from the ordinary off site grid	2
2006	Forsmark-2 / SWE	INES-rating due to earlier event at Forsmark 1	2

As can be seen, a number of serious incidents occurred over the past years, such as reactor pressure vessel head seal leakage at Sizewell-B (UK), incorrect boron concentration at Philippsburg (Germany), unprecedented fuel damage at Cattenom-3 (France), a pipe break in the reactor head spray system at Brunsbuettel (Germany), reactor pressure vessel head corrosion at Davis-Besse (US), extensive ex-core fuel damage at Paks Unit 3 (Hungary), data falsification at both Sellafield (UK) and TEPCO (Japan) and break of primary pipe in Kozloduy (Bulgaria).

Events, even without impact on the environment, can result in severe financial consequences due to plant damages, stand stills and fines. The costs at Philippsburg, Paks and Davis-Besse alone, including replacement power, stand at more than 570 million € (U.S. $ 667 million) to October 2003. Besides the financial disaster, the ensuing external reviews often show that a lot is wrong with the utility's safety organization as well.

One of the latest in the series is the incident at Forsmark, Sweden, where of the 4 emergency power diesels only 2 functioned when needed. As a result, Forsmark and 4 other reactors were temporarily shut down. At the end of 2006 there was no conclusive understanding why two diesel generators functioned and two did not. The incident demonstrated that the redundancy deemed sufficient was by no means satisfactory. In more general terms, calculated probabilities of failure – as e.g. for PSAs – apparently do not show the complete picture. Surprises can never be excluded. The investigations following the incident also revealed deficits in the safety culture at NPP Forsmark deemed sufficiently important by the regulatory body to warrant a law suit.

3.4.3 Lessons Learned or to be Learned

Prior to the Three Mile Island Unit 2 accident in 1979, it was quite typical for nuclear safety experts to assert that the likelihood of a severe accident in a commercial power reactor was of the order of one in a million per year (10^{-6}/a), notwithstanding the fact that the pioneering probabilistic safety assessment of its time (WASH-1400) estimated a likelihood far higher (one in 17,000 per year, or about 6×10^{-5}/a).

The occurrence of the TMI-2 accident after less than 1,000 reactor-years of operating experience with commercial power reactors was a wakeup call for the nuclear industry. Numerous improvements in human factors aspects of power plant operation, procedures, training, and to a lesser extent changes in plant design were accomplished in the decade that followed.

More specific to the European situation however, the Chernobyl accident in 1986 - resulting in a large release accident that spread contamination widely in Europe - caused a significant re-examination of nuclear safety and a recognition in most quarters that heavily populated Europe could ill-afford a large release accident. Thus notable safety improvements were made at European NPPs in the era since the TMI-2 and Chernobyl 4 accidents.

There has also been more extensive use of operating experience analysis and feedback, encouraged by the World Association of Nuclear Operators (WANO), the IAEA, and others. In addition, WANO and the IAEA have performed a variety of types of peer reviews (e.g. design, operations, radioactive waste management, regulatory oversight, safety culture, accident management, radiation protection, etc.).

But since then a number of incidents again showed shortcomings in the safety documentation, design of the systems and safety culture. Even the leaders of the nuclear industry came to the conclusion that complacency, overconfidence, self-satisfaction and negligence, shown in a number of incidents, threaten the whole nuclear industry.

An accident or significant safety incident will cripple the nuclear industry, IAEA Director General Mohamed El Baradei said in a video presentation at the American Nuclear Society meeting in New Orleans in November 2003. "*We cannot afford another accident*," he added. El Baradei said there is still a lot of work that needs to be done in the area of safety, particularly in the area of applying safety standards and safety culture uniformly across the industry.

The world nuclear power industry is in danger, threatened by the negligence and complacency that led to multiple "severe incidents" at nuclear plants in Europe, the U.S. and Japan over just the last few years, utility executives were warned at the biennial general meeting of the WANO held in Berlin, on 13-14 October 2003. The warnings were launched by senior WANO officials, but the message was brought home even more forcefully by those whose organizations had not heeded earlier signs and, in many cases, are still suffering the financial, social, and political consequences. WANO Chairman Hajimu Maeda warned that "*a terrible disease*" threatens nuclear operating organizations from within. It begins, he said, with "*loss of motivation to learn from others...overconfidence...(and) negligence in cultivating a safety culture due to severe pressure to reduce costs following the deregulation of the power market*." Those troubles, if ignored, "*are like a terrible disease that originates within the organization*" and can, if not detected, lead to "*a major accident*" that will "*destroy the whole organization. We must avoid the pitfalls of self-satisfaction which threaten us*".

"*Even a minor accident could be a disaster*," echoed Bruno Lescoeur, executive vice president, generation & trading, of Eléctricité de France, "*because it could question the acceptability of nuclear energy in France, and perhaps in the world.*"

Armen Abagyan of Rosenergoatom said at the same time that lack of attention to operational events – he cited events in Russia, France, and the U.S. – "*may lead to a new burst of antinuclear opposition and adversely affect both Russian and the world nuclear industry.*"

Yet, the series of incidents that occurred and the deficits in safety culture that surfaced after these warnings show that they have not or not sufficiently been heeded. In fact, Brychanov, director of the Chernobyl NPP at the time of the accident, said in 2006 in an interview at the occasion of the 20th anniversary of the accident: "*Chernobyl has not taught anything to anyone*".

3.5 PSA, their Results and Implications

Probabilistic safety assessments (PSA) are by now nearly universally performed to identify the sequences of events which contribute most to the likelihood of a severe accident and in the case of Level 2 analyses, to the likelihood of a large release of radioactivity to the environment. Two measures of interest are the core damage frequency (CDF) and the large release frequency (LRF). The CDF provides an indication of how successful the design is in avoiding accidents. The LRF provides an indication of how successful the design is in mitigating accidents that nonetheless occur.

A state-of-the-art PSA in 2006 includes the following aspects:

- Internal events analysis at full power and at shutdown conditions (including refuelling and other types of outage evolutions).

- External events analysis at full power and at shutdown conditions, including both natural phenomena hazards and man-made hazards.
- Full analysis, on a best estimate basis, of the structural capability of the containment and of the effects of accident progression on containment integrity (Level 2 PSA).
- Uncertainty and sensitivity analysis.

The state-of-the-art PSA is maintained as a "living PSA" – that is, as changes are made to the plant design and to plant procedures (and as additional operating experience is gained), the changes are regularly reflected in revisions to the PSA.

Yet it should be understood that PSAs are never formally "complete": it is questionable whether state-of-the-art safety and risk research can cover all possible initiating events for NPP accidents [Sholly et al. 2000]; there are uncertainties in the results even for the accident contributors that are included in the PSA models; some sources of uncertainty have broad numerical bands that can make comparisons based on mean values difficult; some types of accident contributors are difficult to model probabilistically, and are usually excluded from safety and risk assessments, e.g.:

- independence of the nuclear regulatory authority and technical support organizations,
- influence of safety culture,
- adequacy of funding available for research into operating and safety issues,
- sufficient numbers of qualified staff in the whole nuclear infrastructure,
- economic stability of the energy economy sector,
- sabotage and terrorism, etc..

Aside from these theoretical weaknesses of PSAs, in practice very few state-of-the-art PSAs exist. Most PSAs do not cover the full range of aspects listed above.

PSA results of European NPPs – where available – are summarized in Table 3-4 below. At least Level 1 PSAs and, in Europe, very often Level 2 PSAs, have been performed of nearly all NPPs. In some cases, there are scope limitations (i.e., not all of the PSAs include external events and of those that do, often seismic events are not included for reasons which are seldom articulated). In the case of PSAs on the French NPPs, the PSAs are performed only on classes of plants, the argument being that the plants are so similar that a somewhat generic PSA can adequately represent all of the units in a class[6].

The point in the following table is not the plant-to-plant .comparison – such comparisons are difficult and fraught with uncertainty due to differences in methods, data, scope, assumptions, etc. The point of showing these results is to give an impression of the range of results that are seen for European NPPs.

[6] It is difficult to follow this argument, since even if the plants, their procedures, their operators (and their training), and their management were absolutely identical (and, of course, they are not), the external event hazards faced by the units vary from site to site.

Tab. 3-4 **PSA RESULTS FOR OPERATING NPPs**

NPPs	CDF [10^{-6}/a]	LRF [10^{-6}/a]	Comment on PSA	Source
PWR[1]				
Almaraz	5.9			CSN 2004
Ascó	22			CSN 2004
Beznau (2002)	7.9	0.26		HSK 2004
Borssele	4.5	0.03		ECN 2005
Gösgen-Däniken (1999)	18	0.31		HSK 1999
José Cabrera	22			CSN 2004
Santa María de Garoña	10			CSN 2004
Trillo	3.3			CSN 2004
Vandellós II	35			CSN 2004
WWER[2]				
Bohunice V1	27	21	internal & external events; following completion of upgrade & reconstruction programme, 2003	Gabko & Kovâcs 2004
Bohunice V1	54.3		shutdown PSA, 2003	Slovak 2004
Bohunice V2	11		internal events, full power, 2003	Slovak 2004
Bohunice V2	58		internal events, shutdown PSA, 2003	Slovak 2004
Kozloduy 3 & 4	16		internal & external events	Bulgaria 2004
Loviisa	170	5	internal & external events, shutdown events	STUK 2004
Mochovce	3.8		internal & external events, 2001	Slovak 2004
Mochovce	170		shutdown PSA, 2002	Slovak 2004
Paks	33 to 44		internal events, fire & flooding, shutdown events	HAEA 2004
Paks	290		seismic, average of four units	HAEA 2004
BWR				
Cofrentes (BWR/6, Mark III).	1.2			CSN 2004
Leibstadt	8.1	0.10	internal & external events, 1996	HSK 1996
Mühleberg (2002)	7.90	0.014		HSK 2002
Olkiluoto (ASEA-Atom BWR)	17	6		STUK 2004
PHWR				
Cernavoda Unit 1	14		internal events PSA	Romania 2004
Gas Cooled Reactors[3]				
Latina (MAGNOX) 1987	27		internal events PSA; core damage frequency for „unconfined events" (presumably involving failure of the vessel with core damage)	Volterra 1988
RBMK				
Ignalina	30		internal events and limited to Level 1 scope (no consideration of accident progression)	Uspuras 1999
Ignalina (Brand)	1000[4]			STUK 2000

[1] PWR PSA results indicate a range of CDFs covering three orders of magnitude. These results cover a wide range of PWR designs from Framatome, Siemens, and Westinghouse, and the PSA vintages span the era from 1995-2003. In many cases, the results reported consider only internal events.

[2] PSA results for WWERs span a wide range, but it must be recognized that there are three different basic designs (WWER-440/230, WWER-440/213, and WWER-1000), plus the unique Loviisa design (which includes a WWER-440 reactor with safety systems designed by Siemens, housed in an ice condenser containment). In addition, in some cases the designs of the units have evolved rapidly over the past 10 years. Some of the PSA studies include only internal events.

[3] PSAs are performed for AGRs as part of their Periodic Safety Reviews (PSRs) [Magne & Shepherd 2003], however no published summaries of results of these PSAs have been identified.

[4] It is to be expected that this high CDF value for Ignalina Block 2 in 2000 – a number that was entirely due to fire hazards – has been brought down by safety measures meanwhile.

Available probabilistic safety assessments (PSA) indicate that Generation III and III+ designs have mean core damage frequencies that are a factor of 5 to 10 below the best Generation II designs and mean large release frequencies that are a factor of 10 to 100 below the best Generation II designs. However, as there is little or no operational experience with Generation III and III+, in most cases the PSA studies are design PSA studies with assumed site parameters which are asserted by the manufacturers to be enveloping of most site conditions.

Tab. 3-5 **PSA RESULTS FOR ADVANCED DESIGN REACTORS**

Advanced Reactor Designs*	CDF [10-6/a]	PSA	Source
ABWR (Generation III)	0.16		IRR 2004
ABWR II (Generation III+)	0.045	internal events only	IRR 2004
AP1000 (Generation III+)	0.51		IRR 2004
WWER-1000/392 (Tianwan design, Generation III)	5.4		IRR 2004
WWER-1500/448 (Generation III+)	0.048		

* Advanced reactor designs range from Generation III and Generation III+ designs which are being or are soon expected to be deployed (e.g., ABWR, AP1000, EPR, and ESBWR) to more advanced Generation IV concepts that in most cases are not expected to be deployed until 2020 or thereafter (a possible ex-ception being a demonstration PBMR reactor expected to be built by South Africa).

The PSA results for the Generation III and III+ designs reflect a combination of explicit consideration of severe accident prevention and mitigation in the design process, optimisation of system and structural design, and the traditional safety factors incorporated in nuclear power plant design. Generation III and III+ designs also tend to incorporate some "passive" designs to perform some important safety functions.

There is a "tension" between risk and cost considerations in all nuclear power plant designs. Regardless of where the line is drawn between design basis and beyond design basis accidents, there are always some extreme events that have the capability to damage the reactor core and containment and cause a release of radioactive materials to the environment. The measure of safety or risk then becomes an understanding of what it takes before such an event can occur.

3.6 *Safety Standards*

3.6.1 Early Evolvement of Safety Standards

Since the first commercial NPPs went into operation in the 1950s and 1960s safety codes and safety standards were continually raised, due to accidents such as Three Mile Island 2 (USA 1979), Chernobyl (USSR 1986), or severe incidents (e.g. a fire in the US reactor Browns Ferry), increasing operational experience, advanced methods in safety research and last but not least an increasingly critical approach of the public towards nuclear industry.

The rising safety standards often led to safety improvement programs for NPPs of older design, but these upgrading programs (backfits) could not always remove what appeared to be design flaws from a state-of-the-art safety standards perspective. According to Govaerts et al. [Govaerts et al. 1998]: "*Back in the late fifties and in the sixties, the plants were usually designed in a very conservative way, with margins to cover insufficient knowledge of material resistance, of thermal hydraulic aspects, of long term behaviour of structures, systems and components. The accident conditions taken into account in the design basis were much less drastic than in present designs (e.g. breaks of small diameter pipes only, no man made or natural hazards,...), not many systems were considered as safety related, with accompanying redundancy and physical separation requirements.*

When reassessing the safety of these plants the first obstacle is to know accurately the status of the plant. Original design data may be missing, the equipment qualification is incomplete or unknown, information can no longer be obtained from the original supplier. Moreover in some countries it seems there are no detailed requirements for keeping up to date the safety analysis documentary support when modifications are made during operation of the plant."

IAEA International Nuclear Safety Advisory Group Report INSAG-8 [INSAG-8, 1995] expects standards to continue to rise:

"*1. Safety standards for nuclear power plants have undergone evolution and development since the first plants were designed in the 1950s. Many changes have occurred as the nuclear industry has matured and changes will continue to occur, as a result of increased knowledge and experience in both design and operation, and owing to a raising of the objectives for safety and reliability.*

2. Most plants have a design life of 30 to 40 years or more, and it is inevitable that all plants will eventually be overtaken by the developing technologies and standards."

3.6.2 Present Safety Standards, Goals and Targets

The International Nuclear Safety Advisory Group (INSAG), which was established after the Chernobyl accident, defined minimum safety targets for currently operating NPPs and future NPPs. These safety targets are basically as follows [INSAG-3, 1988]:

- For existing NPPs, a core damage frequency (CDF) of less than 10^{-4}/a, and a large release frequency (LRF) of less than 10^{-5}/a.

- For future NPPs, a CDF of less than 10^{-5}/a and an LRF of less than 10^{-6}/a.

These values were not changed during the first revision of INSAG-3 in 1999 [INSAG-12, 1999].

Some countries have defined safety targets for their nuclear power plants or specified those established by the IAEA to greater detail. Thus Sweden, e.g. has no explicit regulatory requirement regarding maximum core damage frequency, but the utilities have established probabilistic safety objectives for their internal use. Safety measures shall be prioritised if CDF exceeds 10^{-5}/a with a high confidence, or probability of a release of more than 0.1 % of the core inventory, excluding noble gases, is higher than 10^{-7}/a [Swedish CNS 1998]. Stricter safety targets have also been established in the Netherlands, which requires a LRF of less than 10^{-6}/a.

General Provisions on the Safety Assurance of Nuclear Power Plants [OPB-88] were introduced in Russia since 1990 and are applicable to all projects which had not been commissioned before the introduction of OPB-88. These targets are more stringent by an order of magnitude than those established by INSAG 3: *"In order to exclude a required evacuation of the public in the vicinity of NPPs, it should be a goal not to exceed an accidental frequency of 10^{-7}/reactor and year for large releases of radioactivity"* [OPB-88, chapter 1.2.17].

In the last years the European Commission issued a proposal for adoption of common European safety standards and a revision [EC 2003/2004]. In spite of considerable efforts no acceptance by member states was reached (see relevant passages in Rotter, M. "Sustainability and the Production of Electricity by Nuclear Power Stations - The Legal Dimension" in this volume).

3.6.3 Compliance with Safety Targets and Standards

Not all NPPs meet the minimal IAEA safety targets for plants in operation as the following examples show. The US Nuclear Regulatory Commission in its Generic Letter (GL) 88-20, in November 1988, requested all licensees to perform an Individual Plant Examination (IPE) to identify any plant-specific vulnerabilities to severe accidents and to report the results. The following results were compiled on basis of an IPE database of the NRC from April 1997 [NRC, 1997]:

No. of plants in database	91	100 %
No. of plants at or above INSAG-3 safety goal for the CDF (10^{-4}/a)	12	13 %
No. of plants at or above INSAG-3 safety goal for large releases (10^{-5}/a)	24	26 %

This means that in that period about one fourth of the NPPs included in the statistics did not meet the INSAG goals for large releases and more than one tenth did not meet those for Core Damage Frequency. Unfortunately no recent update of these figures is available.

The Western European Nuclear Regulators Association (WENRA) in the course of its initiative to harmonize safety approaches in Europe published aggregated national assessments[7] of compliance with the WENRA Safety Reference Levels. This permits some conclusions concerning IAEA (non-quantitative) Safety Standards:

- There are several European countries where the formal legal requirements for nuclear safety do not conform to IAEA Safety Standards.
- There are a few European countries where IAEA Safety Standards are not completely implemented in all operating nuclear power plants.

These conclusions are noteworthy, given the seemingly universal consensus that IAEA Safety Standards, in principle, have to be adhered to in every country. Even apart from this, the WENRA effort made clear that there is a need for safety improvements in the NPPs of the European Union.

[7] The assessments are self assessments by the individual national regulatory bodies and are partially surprisingly optimistic.

Soviet design reactors are considered to have specific safety problems and there is general agreement in the West, that the safety levels of some of the soviet design reactors need to be raised urgently.

The IAEA developed specific extra-budgetary programs to improve the safety of nuclear facilities in Eastern European countries with Soviet designed NPPs (WWER and RBMK reactors) [IAEA 1999]: "*The objective of the Programme is to strengthen nuclear safety in countries of the region, and in particular to enhance the technical capabilities of regulatory authorities and supporting technical organizations, the nuclear safety infrastructure and human resources development*" because "*Despite the improvements in safety already achieved, much remains to be done at individual NPPs, particularly at the WWER and RBMK plants of the first generation.*"

The United States General Accounting Offices (GAO) in its Report on the Safety of Soviet Designed Reactors states that: "*Soviet-designed reactors in general exhibit deficiencies, including insufficient protection against fire, poor-quality materials and construction, and inadequate separation and redundancy of safety systems. Furthermore, many of these reactors are located in countries such as Russia and Ukraine that do not have fully independent or effective nuclear regulatory organizations that oversee plant safety. Of greatest concern are 25 of the 59 reactors that western safety experts generally agree fall well below accepted international safety standards and cannot be economically upgraded*" [GAO 2000].

The European Commission concluded in 1993: "*Although it is clear that Soviet-designed nuclear installations generally pose safety problems, the situation varies according to reactor types and to the way they are operated, as well as the countries concerned:*

- *WWER-230 and RBMK reactors show fundamental design deficiencies which cannot be fully overcome, whereas WWER-213 and WWER-320 reactors can be substantially upgraded, notwithstanding the questionable design of some plant components;*

- *the regulatory, technological, engineering and industrial environment varies from one country to the other.*"[EC 1993]

The importance of socio-political and socio-economic factors was stressed in the follow-up of the Three Mile Island accident analysis [Kemeny 1979] as well as the Chernobyl accident analysis [Steinberg et al. 1991].

3.7 Factors Influencing Future Safety Status of Nuclear Power Plants: Emerging Issues

This section of the report briefly discusses some "emergent" issues, the nature and importance of which are still evolving.

3.7.1 Aging of Nuclear Power Plants

Aging leads to increase in risk of failure of individual components or the system as a whole. Aging of materials is an inevitable degradation phenomenon caused by various kinds of loads during usage. Mechanical properties (e.g. strength, toughness, elasticity) of very different materials such as vessel steel, fuel claddings or even reinforced concrete can be affected. Degradation by aging affects also electrical, electronic, opto-electronic and magnetic properties e.g. of parts in electronic devices. The loads to the materials can be of mechanical, thermal, chemical or radiological nature. If simultaneously applied, loads of different nature can result in synergistic enhancement of their deteriorating effects. Steel embrittlement in the core belt region subjected to simultaneous loads by neutron irradiation, chemical attack (e.g. corrosion by hydrogen diffusion) and fatigue by (alternating) mechanical stresses is an important example of aging. With aging progressing in time, an additional thermo-mechanical load transient (thermal shock) e.g. under emergency operation conditions could result in rupture of the aged steel component.

Although plants that were commissioned in the 1970s and 1980s were generally designed for operating lifetimes of 30-40 years [INSAG-14 1999], many of the earlier plants were not operated more than 20 or 25 years. The others are now entering the stage of systematically increasing risk.

Due to the difficulties and investments involved in licensing new power plants, some operating organizations are now investigating the possibility of extending the operating lifetimes of some plants up to 45, 50 or even 60 years. But, as the IAEA points out, this can involve additional risk: "*Nuclear Power plant ageing can, if not correctly managed, result in the operating safety level falling below the reference safety level set at the design and construction stages of the plant and accepted by the regulator prior to plant operation.*" [INSAG-14 1999]

3.7.2 Decreasing Know How and Infrastructure Capacities

The original hopes connected with nuclear power as the unlimited energy source led to a boom in the nuclear industry, which attracted a large number of qualified scientists, engineers and technicians. The drastic decline of the number of nuclear power plants ordered and built in western countries over the past decades has led to a change of the situation: there is a lack of trained personnel, a decline of technical support organizations, an increasing shortage of nuclear grade spare parts, etc. "*Underlying the operation of nuclear power plants are the host activities – collectively called – infrastructure – in design, construction, regulation, education and research. While all of these activities help ensure safe and economic production of electricity, they have been declining in many of the OECD countries.*" [NEA 1996]

Nuclear industry is experiencing the problems every declining industry experiences, but in the case of nuclear, this implies increased risk at a time when aging of the plants would require additional precautionary measures.

3.7.3 Liberalization of the Electricity Market / Reduction of Saftey Margins

The liberalization of the electricity market has led to increased competition and will continue to do so, as customers learn to act in a deregulated market. There is some fear, that in consequence safety maintenance and upgrading might be jeopardized: "*As the most important safety concern, the regulatory authorities report that there are indications of work overload of the NPP organizations, and keen competition to get qualified specialists, at the same time as the economical competition becomes harder on the deregulated electricity market*" [Swedish CNS 1998]. Practical examples demonstrating consequences of the pressure on costs are reductions in staff (in Grohnde, Germany, e.g. staff was reduced from 340 to 300 between 1990 and 2004, the reduction involving 90 % technicians, and general revisions of turbines are now scheduled every 12 years rather than 6 years, thus doubling the inspection interval [Bruns 2004].

Another worrying example is the downgrading, of IAEA guidelines as well as national standards and regulations. Thus, the new IAEA guidelines for WWER-PTS analysis (see section 3.2.2.1) have reduced the safety margin in the structural integrity assessment compared to the previous guidelines significantly. This new version [IAEA 2006] was developed in parallel with the licensing procedure of the Temelin NPP, and they were immediately incorporated into the Czech legislation. At the time of start-up the former IAEA guidelines [IAEA 1997] were part of the Czech legislation. The demonstration of structural integrity of the Temelin RPV throughout the projected lifetime would not have been possible using the 1997 IAEA guidelines [Batishchev 2005, Austrian Expert Team 2001].

In other cases, standards and regulations are overruled by so-called "expert judgement"[8], a delecate procedure in view of the small pool of nuclear experts, the majority of which are tied in with the nuclear industry.

In Germany a working group of the German Ministry of Economy and Technology pointed out the necessity of studying the effects of changes in managerial and organizational structures in the energy markets due to mergers of utilities especially on the safety of nuclear power plants and their safety culture [BMWi Arbeitsgruppe 2000).

While it is questionable whether the serious nuclear incidents that occurred over the past few years can already be attributed to the cost reduction efforts in view of market liberalization, they clearly indicate that more efforts must be put into safety culture and safety measures. It is difficult to see this happening in the present economic constraints (see also Frogatt, H. "Nuclear Energy – The Economic Perspective" in this volume).

The nuclear industry has seen remarkable consolidation in the past decade and a half. There are fewer and larger organizations operating nuclear power plants worldwide. Many of these organizations are reporting record profits year after year. And yet these same organizations are complaining about the lack of nuclear-related graduates and a reduction in research and development.

The following passage, written in March 2006 by the Chairman of INSAG (and formerly Chairman of the US Nuclear Regulatory Commission), is illustrative [Meserve 2006]:

[8] See e.g. IAEA Experts Meeting 1998 in combination with Hofer et al. 2001.

The nuclear slowdown of the past two decades has resulted in a smaller cadre of highly qualified experts, fewer graduates in nuclear engineering, and less global financing for safety research than 20 years ago. Moreover, nuclear skills in the operators' organizations and in regulatory authorities may, in some cases, be getting thin. This concern is heightened by the trend in some enterprises with operational responsibility for nuclear reactors to rely increasingly on managers with financial experience, at the expense of those with nuclear experience. A focused effort to rebuild the nuclear infrastructure should be a high priority, but progress has been slow.

The same industry that does recognize that "*an accident anywhere is an accident everywhere*" does not seem to recognize that in a free market, in many cases governments have stopped subsidizing the nuclear industry. (There are, of course, exceptions.) Paradoxically, there continue to be calls for governments to provide funding for programs that are so obviously in the industry's own best that is inexplicable why the industry is not already funding the programs itself. For example, a 2003 MIT study (MIT 2003) recommended that the US Department of Energy provide $ 50 million (about € 42 million) per year for five years to fund a global uranium ore resource assessment. Such an assessment is perhaps needed (especially if the industry hopes to expand in the coming decades) but it is there is no reason why it should be the government's responsibility to fund it. If the nuclear industry - which is a mature industry providing 16 % of the world's electricity - cannot sufficiently perceive its own self-interest in understanding what its fuel resource base is, why should governments save that industry from its own short-sightedness? A free market will correct such errors in its own harsh way typical of such markets.

3.7.4 Knowledge Management

As nuclear power plants (and their workforces) age and the end of operating lives of the power plants comes into clearer view, it is to be expected that there will be departures of experienced personnel from the industry as staff retires or takes up opportunities in other companies as the competition for experienced staff gets stiffer. Under such conditions, organizations operating nuclear power plants have a need to practice knowledge management - that is, to ensure that under all conditions the knowledge required to safely operate nuclear power plants (including maintaining the plants, upgrading their safety, managing their spent fuel and radioactive wastes, and ultimately decommissioning the plants) stays in the company.

Knowledge management is an important consideration for nuclear regulatory authorities, technical support organizations, and vendors as well as operating utilities. (The nuclear power industry is by no means unique in the knowledge management problems it is facing. Similar considerations also pertain to other industries and functions, such as maintaining the safety and reliability of nuclear weapons and space transportation systems.) Knowledge management will be an increasing important factor for countries that have decided to end their involvement with commercial nuclear power plants.

The IAEA nuclear safety review issued in 2005 (for the situation in the year 2004) succinctly states the issue [IAEA 2005b]: *It is generally agreed that existing safety knowledge has not been fully elicited and analysed to extract and share the lessons learned and embed them in the knowledge and behaviour of nuclear organizations. In his concluding remarks, the chair of a nuclear knowledge management conference in Saclay, France in September 2004 stated that "knowledge management is at the heart of safety culture and that the development of individuals is central to the process of knowledge management. ... A key challenge is to manage not only explicit knowledge, such as databases, documents and processes, but also tacit knowledge, such as personal knowledge, skills and aptitudes. For long term viability, it is essential to foster a corporate culture where sharing safety knowledge is a priority."*

3.7.5 Seismic Hazard

Many nuclear power stations are subjected to a higher earthquake hazard than previously assessed. On the one hand earthquake hazard was either neglected or strong earthquakes were assumed to be very unlikely to occur, at least during the lifetime of a plant. Although the reactor building itself may have been dimensioned to withstand earthquakes, the vulnerability of auxiliary components such as tanks, power lines, etc. was neglected and can lead to catastrophic consequences.

On the other hand new scientific methods, developed during the last 20 years, and taken account of in the recommendations of IAEA are not yet applied in practice by all member states. Possibly high costs for scientific investigations and even higher costs for the following upgrading of a plant did not favour the implementation of the new procedures. Formerly the presumed largest or any strong earthquake in the near or far region, at or near a given fault was selected and a diminuation of the intensity with distance between the epicentre (or the fault) and the plant was calculated. By adding a value of 0.5 or 1 to the thus calculated intensity a value for the safe shutdown earthquake (SSE) was determined. But it is obvious that the strongest known historical earthquake may not be the strongest possible along a given fault that could affect the plant. It is impossible to determine a maximum credible earthquake (MCE) from historical data that rarely exceeds 500 years.

However, the existence of such rare strong earthquakes in the past may be proven by the application of modern seismotectonic methods (paleoseismology, neotectonics, geomorphology). Thus the recurrence rate of rare large events needs to be sought from geological and palaeoseismological evidence, which may give information about events underrepresented in the historical catalogue. Earthquakes of very high intensity but very low probability could be found in the archives of the sediments and their age, date and size can be calculated. These results should then be considered in the siting procedure of new as well as during a seismic evaluation of existing nuclear power plants. Paleoseismological methods (geomorphological and neotectonic studies, trenching, dating the age of the youngest movements of faults) and the consideration of long recurrence intervals of strong earthquakes were recommended in the IAEA's safety guide S1, 1st revision,1991 and NS-G-3.3, 2002.

3.7.6 Climate Change

As can be seen from the geographical distribution of nuclear power plants between about 35° southern and 70° northern latitude, nuclear power plants were built and operated in many different climates. Thus it is not to be expected that the present climate change would make the production of nuclear energy in power plants impossible. However, many of the external hazards that could pose a threat to nuclear plants (Table 3-2) are directly or indirectly weather or climate dependant. This is true for natural hazards, their extent, intensity or frequency of occurrence, but also for man-made hazards, that frequently are connected to failures in plants or systems of neighbouring non-nuclear plants. In a wider sense, war and terrorism, and thus deliberate acts could be traced back to problems partially rooted in climate change or inadequate national and international mitigation and adaptation measures. As the design and the safety measures of every nuclear plant were licensed based on specific assumptions regarding external hazards, it must be ascertained that the safety standards can be maintained throughout the life time of each plant in spite of observed climate change and that expected in the near future.

Extreme heat can lead to exceedance of temperature limits inside nuclear power plants in place to protect the instruments that control the reactor and also to contain the potentially serious hazards in the event of a malfunction [Schwartz 2003]. Heat also can reduce the efficiency of the final heat sink and thus the yield of thermal power plants.

Increase in heavy precipitation events and in frequency and length of draughts have been observed simultaneously and are expected to continue as the climate changes. Draught is frequently associated with low water levels in rivers and streams. In the record summer of 2003 several power plants in Europe, including nuclear power plants, had to be shut down: the extremely hot weather and lack of rainfall had severely reduced supplies of river water with temperatures low enough to provide sufficient cooling [Schwartz 2003]. The increase of heavy precipitation events will probably result in more floods, unless re-naturalisation of rivers and banks lead to improved retention potentials. The authorities in France reacted after the 2000 flooding of the nuclear power plant Le Blayais, by requesting an update of the risk assessment for floods before the plant was allowed to start up again [NE 2000].

In specific circumstances extreme snowfall, hail and sleet could become relevant. Landslides e.g. are frequently a consequence such events. Root causes are frequently methods of soil cultivation, construction work or, in alpine areas, thawing of permafrost. In 2002 for instance, a huge landslide nearly 400,000 m^3 in size blocked a river, posing a threat of flooding a radioactive waste disposal site near Maylisu in the south of Kyrgyzstan [NE 2002].

The geographical pattern of occurrence of tropical storms (Hurricanes), storms and tornados, as well as their frequency and intensity are changing. This might make adaptations necessary in some nuclear power plants. In the 1998 hit of the Nuclear Power Plant Davis-Besse by a tornado the control room grew dark for a brief period, except for instruments and emergency lighting, and the plant shut down automatically. As telecommunication lines had been severed by the tornado, information exchange was severely hampered. The emergency situation lasted about 40 hours [NE 1998].

The scenarios for sea level rise have changed significantly during the last months. Rises of more than 1 m within the next 100 years now no longer seem impossible. This will be of importance for some nuclear power plants situated on the coast.

3.7.7 Increasing Social and Political Instability

World developments such as rapid increase of the world population under diminishing natural resources and the increasing inability of the human society to establish a fairer distribution of resources and welfare are likely to increase the risk of "adverse actions", especially of terrorism and acts of warfare [Bouthoul 1972, Heinsohn 2003].

Any installation with high potential for catastrophe (e.g. large volumes of dammed up water, high concentrations of toxic material and energy at the same spot) must be considered attractive targets and can in fact not reliably be safeguarded. This is especially true of nuclear power plants - already vulnerable to various other internal and external hazards as pointed out above. Vulnerability against deliberate attacks holds true even for the most advanced future "inherently safe" plants.

3.8 Summary and Conclusion

The accident at the Chernobyl reactor in 1986 demonstrated in the most dramatic way yet that in spite of the very low probability of severe accidents occurring in nuclear power plants, they do occur and their consequences (economical, environmental, health effects, etc.) can be extremely serious and can affect large areas over long periods of time. With 443 power reactors in operation worldwide and projections of large increases in nuclear power production – whatever the chances of realisation – nuclear safety is and obviously will continue to be an issue.

Nuclear safety problems are not limited to commercial nuclear power generation. Manifold risks – not treated in this report – encompass the whole fuel cycle from the first mining of uranium to – eventually – the phase-out of nuclear energy. But even after that the risks involved in nuclear waste disposal will remain as a long-term commitment for timespans of geological scales.

A sequence of reactor "generations" reflects an evolution of reactor designs featuring a variety of basic approaches to energy production as well as to reactor safety. The bulk of the presently operating commercial nuclear power plants are of Generation II, and their safety features determine nuclear safety at present. Generation III plants are still very few, and Generation IV is only in the process of being developed. If the contribution of nuclear energy to overall energy production is to increase in future in an environment of growing energy demand, nuclear risk will be determined by the safety features of Generation III or III+ and in the long run – due to the foreseeable limits of availability of fissile uranium – Generation IV plants.

For the coming generation of reactors (Generation III) concepts were modified to address a large number of foreseeable accidents passively ("inherent safety") and reduce core damage frequency. However, the "inherent safety" has not been proven for any reactor so far, and applies only to design base accidents, not to external dangers and certainly not to acts of war or terrorism. Liberalization of the electricity market and the decreasing governmental support for the nuclear industry forced a further redesign to reduce capital costs (Generation III+).

The declared aims of Generation IV – fast reactors – are to be "inherently safe", proliferation resistant, economic and free of long lived high radioactive waste. Fast reactors suffer from a handful of drawbacks, which make them expensive to build and hard to operate. Considerable doubts are voiced on the feasibility of meeting these goals simultaneously. Safety problems in generation IV reactors differ widely from those known for the earlier generations. However, it is very difficult to assess their safety at the present time, as they are only in the design phase, and studies addressing safety aspects are still limited.

An overview of generic severe accident vulnerabilities of the most frequent reactor types and the four generations shows that all have vulnerabilities that can lead to severe accidents with large releases of radioactivity despite the efforts to eliminate such vulnerabilities and the undoubted improvements that have been achieved.

There is a "tension" between safety and cost considerations in nuclear power plant design and operation. Safety codes and standards have been continuously raised but up grading of existing plants frequently do not keep up with this development. The US NRC found in 1997 that the about one fourth of NPPs assessed did not comply with INSAG goals for Large Release Frequencies and one tenth with those for Core Damage Frequency. More recently WENRA found that - contrary to the seemingly universal consensus – not all IAEA Safety Standards are adhered to in all European countries.

This, together with the nuclear accidents at Three Mile Island and Chernobyl, a series of incidents, "near misses", cases of flagrant deficits in safety culture, etc., demonstrates that the safety problem is not resolved by far. Emergent issues aggravate the situation.

- Aging of materials and components leads to a growing risk of accidents.

- Extending lifetimes of nuclear power plants aggravates the aging problem and enhances inherent risks.

- In consequence of its stagnation the nuclear industry suffers from lack of trained personnel, decline of technical support organizations, increasing shortage of nuclear grade spare parts, etc.; necessities the plants have enhanced demand for due to aging.

- Liberalization of the electricity market has led to increased competition and enhanced pressure on costs. There is some fear that in consequence investements in safety coul d be reduced. Practical examples demonstrating consequences of the pressure on costs are reductions in technical staff and increasing of inspection intervals.

- Downgradings of IAEA guidelines as well as national standards and regulations can be seen from the example of WWER-pressurized thermal shock analysis, comparing the safety margins of former 1997 with new 2006 IAEA guidelines that were incorporated into the Czech legislation in parallel. It was only possible through this "update" to demonstrate the structural integrity of the Temelin reactor pressure vessel throughout the projected lifetime. In other cases, standards and regulations are overruled by so-called "expert judgement", a delicate procedure in view of the small pool of nuclear experts, the majority of which are tied in with the nuclear industry.

- Many nuclear power stations are subjected to a higher earthquake hazard than previously assessed. New scientific detection methods taken account of in the recommendations of IAEA are not yet required in practice by all regulatory bodies.

- The specific assumptions regarding weather influenced external hazards must be reassessed in view of observed and expected climate change.

- One likely consequence of an increasing world population facing diminishing natural resources and their increasingly unequal distribution is increasing social and political instability. Nuclear power plants represent particularly attractive targets for sabotage and in armed conflicts and can in fact not be reliably safeguarded. This could become a serious problem as the number of clashes – increasingly on the territory of industrialized states – grows.

Catastrophes are inherent in complex and coupled systems and therefore unavoidable [Perrow 1999], although the likelihood of their occurrence can be reduced. Nuclear power production necessitates very complex and coupled systems involving the implementation of sophisticated safety concepts such as redundant and divers defence in depth. The latter constitutes a factor of increased vulnerability in itself [e.g. Sagan 2004]. But safety measures are imperative, as the enormous energies concentrated in a very small volume together with highly dangerous materials in amounts sufficient to contaminate large areas with persistent deadly radioactive pollutants in principle cannot be contained sufficiently safely nor can handling be made proof against the human factor. By impelling physical laws the causal chains triggering accidents can never be fully eliminated by safety provisions of material containments and technical structures, nor can the evolutionary biological constraints of human nature be overcome by administrative, legal or psychological security measures.

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4 Radioactive Waste

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September 2006

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4 Radioactive Waste

4.1 Introduction

Radioactive waste from civil use of nuclear power represents a long-term hazard. Radiotoxicity is especially due to nuclides that do not exist in nature or appear only in trace amounts (for example plutonium isotopes, neptunium-237).

The amount of radioactive waste is continuously increasing. Nuclear power plants around the world produce about 10,000 tons of spent fuel per year.

Aside from that, the civil use of nuclear power generates many other streams of radioactive wastes. The spent fuel elements contain the highest amount of radio nuclides, but other radioactive wastes can also be problematic.

The largest total quantity of radioactive wastes is produced during uranium mining and in the first steps of processing. At Wismut in the former DDR about 95,000 tons of uranium concentrate (Yellow Cake) were produced until 1989 from some 124 million tons of ore [Lowson and Browon 1995]. This is equivalent to 1,300 tons of ore per ton of uranium concentrate, or about 10,000 tons of ore per ton of LWR fuel.

Further radioactive wastes are produced during enrichment, fuel element manufacture, as secondary waste during the NPP operation, in relatively small amounts during the fuel storage and in large amounts during spent fuel reprocessing. Radioactive wastes that originate during nuclear power related research and development should also be mentioned (for example from the operation of material test reactors or test facilities for waste processing).

Since the largest amount of the total radiotoxicity of radioactive wastes results from spent fuels, these will be the main consideration of the following.

4.2 Transport, Intermediate Storage and Reprocessing

Transport of radioactive wastes, especially spent fuel elements, is potentially hazardous.

The containers used are built to be very resistant to accident conditions but they are not completely safe. Severe accidents during the transport on rail, road or ships can lead to leakage, especially during long fires or due to severe mechanical impacts. Furthermore, the containers are vulnerable to terrorist attacks (for example with armor-piercing weapons). Significant radioactive releases can result in these cases. In case of unfavorable weather conditions, such releases could make it necessary to relocate the population within a radius of more than 5 km from the accident site [Deppe et al. 1992].

Further possible hazards result from radioactive contamination of the outside of transport casks or of transport vehicles that can get detached and then lead to radioactive pollution of persons due to inhalation, ingestion or skin contact. The risk factor due to direct radiation from the cask should not be neglected either.

The intermediate storage of radioactive wastes includes potential safety hazards as well.

During the storage of spent fuel with forced cooling, especially in water pools, loss of cooling or loss of water inventory can result in severe radioactive releases due to the large Cs-137 inventory of a spent fuel pool (can be many cores worth of Cesium). At many nuclear power plant sites, the spent fuel pools are less protected against external events (including terror attacks) than the reactor, since they are located outside the reactor building, or in a part of this building encloses by thinner walls than the reactor itself. This applies to most U.S. NPPs, but also to several NPPs in the EU.

In case of the dry spent fuel storage installations with natural ventilation that are increasingly favored, external impacts (especially fires) can trigger severe accidents. The storage in modified transport casks is connected with the additional problem of guaranteeing the tightness of the casks and the future handling of the stored fuel over long periods of time.

The reprocessing of spent fuel elements implies the separation of most of the uranium and plutonium, but also the distribution of the remaining nuclides within a large waste volume. In Sellafield or La Hague one ton of spent fuel with a volume of about ½ m^3 leads to about 10 m^3 of radioactive waste [COGEMA and BNFL 1990].

Reprocessing processes have a significant hazard potential in the event of an accident, particularly with respect to storage of liquid high level waste in tanks. Even during normal operation significant radioactive emissions are produced. Therefore the OSPAR Commission stated in June 2000:

"...that nuclear reprocessing facilities in the North-East Atlantic area are the dominant sources of discharges, emissions and losses of radioactive substances and that implementing the non-reprocessing option for spent nuclear fuel would, therefore, produce substantial reductions of discharges, emissions and losses of radioactive substances into the North-East Atlantic..."

The Commission called for a review of the existing emissions from reprocessing plants with the aim of ending reprocessing and taking other measures to minimize the risk of accidents involving the existing inventories of high level waste produced by reprocessing to date [OSPAR Commission 2000].

The overall radioactive emissions from the La Hague and Sellafield reprocessing plants are to be reduced to *"close to zero"* by the year 2020. The 15 countries which are cooperating in the framework of OSPAR, including France and Great Britain, agreed on the details of the further action in June 2003. To achieve consensus, far-reaching compromises were required. The reductions of the emissions will be implemented very slowly, and exceptions are granted for certain nuclides, to provide the plant operators with more flexibility. Considering this, it appears questionable whether the goal of *"close to zero"* will actually be reached by 2020 [Nuclear Fuel 2003].

4.3 Final Disposal of Radioactive Wastes

4.3.1 The Hazardous Potential of Wastes

Radioactive wastes from the civil use of nuclear power exhibit a considerable long-term hazard potential that cannot be neglected for millions of years, which is unique within the industrial society.

It has to be pointed out that this statement is exclusively bound to the commercial use of nuclear energy. This is not necessarily true for radioactive wastes from the use of radioactive materials in medicine, research and industry.

Several numbers can prove this unique long-term hazard, considering the amount of 400,000 tons of spent nuclear fuel, corresponding to 40 times the actual global production per year of about 10,000 t [Fukada et al. 2003] (for nuclear power plants usually a total operation time of about 40 years is assumed).

In order to illustrate the hazard, the amount of water will be determined that would be required to dilute this amount of waste so that this water could be used as drinking-water fulfilling the corresponding limits (observing the limits does not mean that no health hazards are possible).

Basis for the determination of the water amount is the Euratom Directive 96/29. National regulations in force in the EU countries are partly more stringent than this Directive. For example, if the calculation were based on the German Radiation Protection Ordinance, significantly greater amounts of water would result.

The calculations are performed for the time period after disposal of 1000 and 1 million years, respectively. For simplification only the respectively dominant radio nuclides are considered, the real radiotoxicity will therefore be higher than the given values for this reason alone.

Tab. 4-1 **REQUIRED DILUTION VOLUME FOR SELECTED NUCLIDES IN SPENT FUEL**

Time	**Nuclide**	**Dilution volume (Euratom)**
after 1,000 yrs	Plutonium (alpha)	3 Mio km³
after 1 Million yrs	Neptunium-237	1,500 km³

For comparison: The total volume of groundwater on earth is estimated to be about 4 millions km³. The Atlantic Ocean contains about 350 millions km³, the Baltic Sea about 23,000 km³.

It is also of interest to compare with chemotoxic wastes. For simplification only cadmium, one of the most toxic heavy metals, is considered. In order to dilute the same amount (400,000 tons) of cadmium to the limits according to the German drinking-water regulation an amount of about 80,000 km³ would be necessary.

These results show roughly, that for tens of thousands of years the toxicity of radioactive wastes is by far higher than that of chemotoxic wastes, and is therefore a unique problem. For periods of hundreds of thousands to a million of years the radioactive waste repository and the heavy metal deposit are increasingly similar with respect to their toxicity. This is also true for the nature of the deposited wastes (long-term dominance of uranium and other also chemotoxic metals; moreover, in a final repository non-radioactive heavy metals like lead which is being used as shielding material in waste containers can be present).

This consideration shows that also the final disposal of pure chemotoxic wastes is very problematic, thus the amount of these wastes should be reduced significantly.

4.3.2 Options for the Final Disposal and their Evaluation

In principle, three different options for final disposal are possible (final disposal is defined as the deposition of wastes into a repository without temporal limitation):

- Storage in deep geological repositories with temporally restricted control and correction possibilities (about 100 years). A variation would be a deep geological repository with the principal option of long term retrievability.

- Surface or near-surface disposal with temporally unlimited control and correction possibilities (retrievability).

- Partitioning and transmutation of long-living radio nuclides with limitation of the hazardous time period to max. 1,000 years; storage for this time period.

Several "exotic" variations can be either assigned to the named options, like the disposal in the ocean ground, in the arctic ice or in very deep bore holes (geological repositories), or should be considered as far-fetched like the plans to launch radioactive waste into space.

4.3.2.1 Geological Final Disposal

Geologic disposal is the option favored worldwide and also has first priority in most EU-countries.

The main problem with this option is the fact that a reliable safety assessment is not possible for the required time periods (millions of years). Natural sciences are reaching their limits in their ability to make safety predictions.

On this point there is an extended agreement between all participating scientists.

"Wegen der langen zu betrachtenden Zeiträume kann weder die Richtigkeit der Beweisführung belegt noch eine Fehleinschätzung korrigiert werden."
[Niedersächsisches Umweltministerium 1993]

(Due to the long time periods that have to be considered neither can the correctness be proven nor can a mistake be corrected.)

"Wenn auch die für die Sicherheitsanalyse bedeutsamen Ereignisabläufe noch nicht alle im Detail aufgeklärt und verstanden, die Eingangsdaten für Modellrechnungen mit Unsicherheiten behaftet

und folglich auch die zum Einsatz gelangenden Modelle noch nicht vollständig entwickelt sind, so herrscht international doch Einigkeit darüber, daß der Nachweis der Sicherheit eines Endlagers über einen Zeitraum bis zu 10,000 Jahren auf analytische Weise erbracht werden kann." [FZK 1998]

(Although the safety assessment relevant event procedures are not explained and understood in detail, the input data for the modeling simulations include uncertainties and the used models are not yet fully developed, there exists an international agreement that the safety assessment of a final disposal can be performed analytically for a time period up to 10,000 years.)

"Allerdings setzt sich zunehmend die Erkenntnis durch, dass eine Modellvalidierung [beim Nachweis der Langzeitsicherheit] im strengen Sinn nicht durchführbar ist." [FZK 1998]

(Nevertheless it is increasingly recognized that a model validation [for the assessment of long-term safety] cannot be performed in a stringent way.)

"In the context of geological disposal, because of the long timescales involved, it is not possible to demonstrate safety directly and recourse must be made to other, less direct, evidence." [Pather 2005]

Difficulties already exist in finding an appropriate criterion for long-term safety. It can be questioned whether the maximum individual dose for people due to the releases from final disposals are useful as only or central criterion for safety. Additional requirements to protect the living environment and the environmental media have been discussed [Endlagerhearing 1993]. However, this aspect generally received relatively little attention in the last years. The latest IAEA Safety Requirements for geologic disposal do discuss the protection of the environment as well as the protection of human health, but only in rather marginal manner [IAEA 2006].

There are demands to discuss the use of doses as criterion in a more rational way and to define additional long-term safety indicators.

"....radiation doses are not assessable with any certainty for periods of time longer than a few hundred years ... we appear to be unable to find a suitable indicator to demonstrate the long-term safety of waste disposal... " [Gonzalez 1998]

Moreover, many unsolved problems exist that render the predictions even more difficult, for example, with respect to the development of gases in a geological repository, and concerning the effect of colloids in the groundwater for the transport of nuclides:

"Die Beherrschbarkeit der Gasbildung in dichtem Salzgestein in Folge von Korrosion und Zersetzung der Abfälle stellt ein besonderes Problem dar." [Erklärung der deutschen Bundesregierung 2000]

(The control of gas development in dense salt deposits due to corrosion and decomposition of the wastes is a specific problem.)

"Although the three projects [EU-Projekte HUMICS, CARESS and TRANCOM] have significantly improved our understanding of colloid facilitated radio nuclide transport, further research is required if long-term predictions of the performance of a waste repository are to be made." [Warwick et al. 1999]

In 2004, a report on the safety of geologic disposal in Switzerland was published by the OECD's Nuclear Energy Agency (NEA). This report clearly shows that there is still a large number of open problems [OECD NEA 2004]. Further work is recommended in order to reduce the existing uncertainties. Need for clarification is seen, for example, regarding the behavior of the backfill material which is to be used in Switzerland (Bentonite) and the interaction of this material with other components in the repository. There are also questions regarding geochemical retention, the validity of the use of natural analogues and diffusion processes in clay – in short, regarding many issues of significance for the safety of final disposal. Furthermore, it is emphasized that the dose rates determined by modeling are merely indicators; they cannot be regarded as long-term prognoses. A review of the Swiss disposal plans by Austrian experts agreed with most of the findings of the NEA. This review also came to the conclusion that further vital questions like the possible effects of erosion by meltwater in a future ice age and the homogeneity of the clay formation envisaged as host rock also require clarification [Hirsch et al. 2005]. The work performed in Switzerland so far has been accepted as proof of feasibility of final disposal ("Entsorgungsnachweis") in mid-2006, by the Swiss government [BFE 2006]. The open questions, however, remain.

At the international conference on final disposal DisTec in April 2004, unsolved problems were also reported from other countries, for example Belgium, France and Germany [DisTec 2004]. It became clear that a comprehensive data base for the modeling of the reactions occurring in a repository in salt (which is one of the media most favored for final disposal) does not yet exist.

In an IAEA technical report on geologic disposal which was published a few years ago, 13 subject areas are listed in the summary where there are still deficits and further work is considered necessary in order to enlarge the scientific and technological basis for final disposal [IAEA 2003]. This concerns basic issues like methods for the evaluation of site data, how to deal with lack of knowledge and uncertainties when assessing a site, mechanisms of radiolysis around canisters with spent fuel as well as questions of gas transport in geologic media.

In view of these problems and open questions it is not astonishing that world wide no final disposal exist for high-level, heat generating wastes from the civil use of nuclear power.

4.3.2.2 Retrievability in Geological Repositories

The existing uncertainties for geological final disposal and the lack of control and possibilities for correction measures are increasingly seen as disadvantages of the "classic" final repository. Therefore, more and more countries are studying the option of retrievability.

Between 1985 and 1999 almost all EU countries, including Switzerland, with Nuclear Programs, began an active engagement in retrievability [Vrijen 1999].

Nevertheless there is a demand to intensify the respective investigations: *"Why isn't the option of retrievable disposal explored more carefully?"* [Gonzalez 1998]

During the last years, the trend towards retrievability appears to have become more noticeable. In one EU member state, the Netherlands, it is obligatory that radioactive wastes – if they are geologically disposed at all – are retrievable. The period of time for which this is considered as feasible is seen as *"restricted to a maximum of a couple of hundred years"*, however [JC/NL 2006].

In France, reversibility (which is a concept similar to retrievability, but further-reaching) is also considered important. The French waste disposal agency ANDRA estimates the duration of reversibility at 200 - 300 years [JC/FRA 2006]. In the new French waste bill which was passed in June 2006, reversibility is specified for a minimum of 100 years [Nuclear Fuel 2006b].

The specific applicability and usefulness of retrievability in geological final disposal with the aim of increased safety, however, is rather limited.

Retrieval of waste from a geologic repository that is typically in a depth of several hundred to thousand meters, is principally always possible as long as the location is known and the required expenses are accepted.

The problem results from the fact that in a refilled final disposal mine no information exists on the state of the repository and its environment. It is therefore not possible to retrieve wastes in a controlled way and in time in case of unexpected events that impair the safety.

A retrieval in case of detected radio nuclides in the near-surface groundwater, indicating that radio nuclide migration has already taken place over hundreds or thousands of years, will not be helpful.

Moreover, every attempt at retrieval will be aggravated due to the fact that no information on the conditions in the repository is available.

Measures like piping in the waste containing bore holes or the coloring of the refill material in order to facilitate the re-discovering are not expensive and will not negatively affect the safety of the repository, but do not change the lack of information on the state of the repository. Sensors to control temperature, strain, humidity, etc. in the area of the repository are limited with respect to their lifetime, so that no reliable information can be expected not even for several hundreds of years.

Another possibility would be to leave the repository mine or parts of it open to allow the access to the waste. But this would yield additional risks such as an increased hazard of flooding, possible stability problems of the geological deposit, or the risk that the mine will be surrendered without appropriate refill.

"Such implications could increase uncertainty in the initial conditions for the safety assessment by the long-term period." [Vrijen 1999]

In case of surface or near-surface disposal the retrievability is given over long time periods. This option is fundamentally different from the geological final disposal and will be evaluated separately.

4.3.2.3 Controlled Surface or Near-Surface Disposal

The controlled storage of radioactive wastes as final disposal, i.e. with unlimited time horizon (in contrast to the temporally limited intermediate storage) is a concept of only minor interest within the "nuclear community".

In France, long-term surface disposal was selected as one of several options to be investigated in the waste bill of 1991 [Damveld & van den Berg 2000]. The new waste bill of 2006 stipulates that a long-term storage facility for long-lived high level waste is to be constructed by 2015. A geologic repository is to be operational in the same year [Nuclear Fuel 2006b]. Deep geologic disposal is the preferred option in France; the parallel development of long-term controlled storage clearly shows, however, that a back-up strategy is regarded as necessary.

In the Netherlands a governmental resolution from May 1993 states that, the final disposal of radioactive wastes has to be performed according to the principles of "isolation, management and control" [Damveld & van den Berg 2000]. Therefore, as mentioned above, retrievability is obligatory in case of geologic disposal. At the moment, however, only controlled storage at the surface is actually planned. The waste is to be stored in buildings, at first for a time period of at least 100 years [JC/NL 2006].

A number of non-governmental organizations (NGOs), environmental groups and university scientists in Western Europe and the USA call for controlled long-term disposal, in combination with appropriate institutionalised long-term monitoring ("Nuclear Guardianship"; [Macy 2005]; [Kromp and Lahodynsky 2006]). In these considerations disposal is not limited to buildings on the surface. Different concepts for underground, but near the surface storage, are thinkable, to enhance protection against unwarranted access and natural disasters.

However, controlled disposal over the required time periods can also not be considered as a realistic perspective. While natural sciences reach their predictive limits in the case of the geological final disposal, the impossibility of predicting social developments over hundreds, much less millions of years makes unlimited controlled disposal questionable.

Significant radioactive releases within short periods of time can occur in all modes of final repositories, including geological repositories. The likelihood of such releases, however, is much larger for surface or near surface disposal, as the total radioactive inventory is already within or very near the biosphere.

4.3.2.4 Partition and Transmutation

This option, as well as the retrievability, has been discussed more frequently within the last few years.

Currently, the problems in connection with their industrial implementation are not foreseeable in detail. It is more than likely, however, that the problems to be expected will include accident potential, pollution caused by reprocessing, proliferation vulnerabilities and massive costs [National Academy of Science 1996].

Practically the complete partitioning of all long-lived nuclides would be required in order to secure that the remaining wastes need a safe storage only for short time periods. At present, separation levels of about 99 % are reached in reprocessing plants. Much better separation would have to be achieved in order to avoid long isolation times of the remaining wastes.

A technology of "super-reprocessing" would have to be developed (partition of all actinides and long-living isotopes with an efficiency of 99.99 % and more), that would have to be performed without environmental pollution (in contrast to today's reprocessing practice) and without catastrophic potential.

Moreover, the specific transmutation methods - based on neutron sources or special reactors – exist today only in laboratories.

Generally it is expected, that appropriate methods for reprocessing and transmutation will – if at all – be available only after several decades [Kacsóh 1999]. This means that this option cannot be considered as a solution for the already existing waste or the radioactive waste produced in the near future.

This is in agreement with expert estimations at the conference 'Euradwaste 1999' of the European Commission on partition and transmutation:

"It will require a few decades to install partitioning facilities capable of separating the most hazardous radionuclides from conventional reprocessing waste streams and to gradually introduce in an industrial power production reactor park fast neutron reactors or accelerator driven systems to transmute these radionuclides.

Once the installations for partition and transmutation have been introduced, the balances between the production and destruction of plutonium and of the hazardous radioanuclides will only be reached after several decades due to the long time span of the nuclear fuel cycle.

It is therefore necessary, and whatever the scenario, to have operational geological repositories to safely dispose of existing and future conditioned high level and medium level nuclear waste, which cannot be transmuted." [COGEMA and BNFL 1999]

The experts of the podium discussion pointed out that the implementation of partitioning and transmutation is only an option if nuclear power will be used over long periods of time.

It was also pointed out that the feasibility of this option is, from today's view, basically questionable and thus it is not clear whether the efforts for the development over the last decades and the billions of Euros spent will ever be proven worthwhile.

"Solange jedoch nur Laborexperimente zur Machbarkeit der Transmutation durchgeführt werden – und hier steht die Forschung momentan –, kann das große theoretischen Potential dieser Technik nur mit gesunder Skepsis betrachtet werden." [Kacsóh 1999]

(As long as only laboratory experiments are performed with respect to the feasibility of transmutation – and this is the actual state of research – the theoretical potential of this technology can only be considered with sound skepticism.)

A representative of the OECD's Nuclear Energy Agency, at the DisTec 2004 conference, has recently confirmed this assessment. This representative pointed out that there are still open questions; he also emphasized that even after transmutation, a final repository would be needed, although for smaller quantities of waste [Shimomura 2004].

4.4 Recent International Developments and Trends

Steps backward and problems, in many countries, characterize the international development of the last years.

In Germany, the final disposal projects have reached a standstill. The former (red/green) Federal Government initiated the development of a new procedure for site selection with public participation, which is to start without any advance decisions or assumptions, from a "white map" (a blank map of all of Germany), so to speak. At the same time, the old repository projects of Gorleben and Konrad were not given up, in spite of them being both politically controversial and scientifically questionable. The newly developed site selection procedure was effectively blocked by this lack of consistency, as well as by resistance from the waste producers' prospective (NPP operators), right from the beginning.

The Federal Minister for the Environment under the former government was considering a new legal regulation, which would transfer responsibility for final disposal from the Federal Government to a corporation founded by the NPP operators. The former government, however, could not get the site selection procedures for final disposal out of their deadlock [Nies 2004]. Since the change of Federal Government in Germany in 2005, increasing pressure is building up to disregard the new procedure for site selection altogether and go back to the Gorleben and Konrad projects as only options. The concept of the present Minister for the Environment so far, on the other hand, has been to initiate a new site selection process and compare new sites to the Gorleben and Konrad sites. To date (September 2006), the issue is unresolved.

In the United States, scientific doubt concerning the final disposal project Yucca Mountain is persisting. In the last years, it has been questioned whether the quality control regarding the scientific work performed during site investigation was adequate. Problems which have not been sufficiently explored include, for example, the possibility of groundwater intrusion and the effects of earthquakes.

Furthermore, there has been a far-reaching change in the basic premises for the project. In July 2004, the U.S. Appeals Court (Washington) rescinded the isolation period of 10,000 years, which has so far been required for Yucca Mountain. Corresponding to a recommendation of the U.S. National Academy of Sciences, the Court demanded a longer isolation period (up to 1 million years). [Platts 2004]. Consequently, the U.S. Environmental Protection Agency and Nuclear Regulatory Commission both have proposed changes in the safety standards. According to these proposals, the period to be considered in safety analyses is to extend to the time of peak dose, but for no more than 1.000,000 years. For the first 10,000 years, the individual protection standard shall be 0,15 mSv/year. For the remainder of the period under consideration, it is to be 3.5 mSv/year [NWTRB 2006]. The latter number is significantly higher than the value set in IAEA Safety Requirements – 0.3 mSv/year [IAEA 2006].

In the last report of the U.S. Nuclear Waste Technical Review Board, it is also pointed out that additional work is needed concerning the capability of natural barriers to isolate radio nuclides; work concerning processes and phenomena that could significantly affect the rate of radio nuclide transport. Although seven performance assessments have already been carried out, there is still lack of fundamental understanding. This is to be bridged by conservative approaches. However, the degree of conservatism is often difficult to assess [NWTRB 2006]. The license application for Yucca Mountain is now being prepared; but many open questions remain.

In many countries, among them Japan, site selection for a final repository is impeded not only by scientific problems, but also by lack of acceptance by the populace. In Finland, which is sometimes mentioned a positive example for progress regarding final disposal, site selection could be carried through only because a site in the immediate neighbourhood of a nuclear power plant was chosen. In the region concerned, intense public relations work for the nuclear installations had been ongoing for decades [Ryhänen 2004].

On June 18, 2001, the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management has entered into play. Without doubt, this constitutes a step forward in the international development. This convention is the first instrument which regulates aspects of final disposal in an international context and establishes basic principles regarding the legal and regulatory framework as well as safety.

Significant problems remain in connection with this convention. At the time of the First Review Conference in November 2003, important countries like, for example, Russia or China had not yet consented to the agreement. Furthermore, an IAEA representative criticised the reports and the discussion at the First Review Conference in November 2003 for not being altogether satisfactory. Reporting was not always characterized by the frankness which is to be desired [Metcalf 2004].

At the time of the Second Review Conference in May 2006, positive developments were to be noted. There was progress in the scope of membership and the quality of national reports was improved, according to participants. The Joint Convention now includes all major nuclear power producing countries except India. However, no consensus on waste safety standards could be reached at the Conference. Regarding this crucial issue, "tooth-and-nail" fighting was reported. Whereas many countries are following IAEA recommendations, others, most notably the US, refused the establishment of IAEA documents as standard or benchmark [Nuclear Fuel 2006a].

An important finding of the Second Review Conference was that siting of disposal facilities, in particular geological repositories, is very difficult world-wide, and there is little progress [JC 2006].

4.5 Conclusion

Even the first steps of radioactive waste management – transport, intermediate storage, reprocessing – generate significant environmental pollution and include accident risks.

The most severe and unique problems appear during final disposal.

From today's point of view none of the options for final disposal fulfills the requirements of safety and social compatibility.

- In case of transmutation there are open questions concerning the safety of the required partitioning procedures, as well as the operation of the reactor or accelerator systems. There are additional doubts with respect to the basic feasibility and the costs.

- For the two other options (geological repositories and temporally unlimited controlled surface disposal), due to the long time periods that would have to be covered by safety assessments it is hardly conceivable that sufficient safety can be guaranteed.

- In case of the disposal in geological repositories the natural sciences reach their predictive limits, considering that analyses are required to cover many thousands, and even millions of years. In case of unlimited controlled surface or near-surface disposal, on the other hand, the predictive limits with respect to social development will already be reached within a short period of time. Thus the further production of high-level radioactive wastes is not acceptable and should be stopped as soon as possible.

In the long-term there is a convergence of the problems of radioactive wastes and chemotoxic heavy metals. In both cases the hazardous potential is high even after millions of years. This means that the final disposal of chemotoxic wastes is also very problematic and the amounts generated have to be reduced significantly.

For the already existing radioactive wastes the solution with the smallest disadvantages has to be found within a social consensus. Nuclear phase out favors the minimization of disadvantages. The limitation of the produced waste streams possibly allows options that would not be possible for continuously increasing waste volumes (for example geological disposal in few mines that could be selected regionally according to the most favorable geological conditions, but have limited capacity; or concepts that could not be financed for larger amounts of waste).

The limitation of waste amounts would also reduce the temporal pressure, since the waste volumes that have to be transported and intermediately stored are smaller and thus the risks of intermediate storage and transport are reduced.

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5 Terrorism and War*

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With contributions by Oda Becker
September 2006

Editors comment:

An assessment of the nuclear option would be incomplete without consideration of possible effects of terrorism and war. A comprehensive paper on this topic was prepared and submitted to the Austrian government. However, many things are known or should be discussed in this context, that prudence forbids to publish. For the purposes of the published edition of the assessment, such sensitive passages were deleted and a shortened version of the comprehensive paper was produced. Even so, the relevance of terrorism and war for the nuclear option remains obvious.

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5 Terrorism and War*

5.1 Introduction

In the course of the 20th century, numerous deliberate acts of terrorism have occurred. Long before September 11th 2001, terrorist groups demonstrated their determination and ability to attack exposed targets. The suicide attack by Hezbollah against U.S. barracks in Beirut, which took place October 23, 1983 can serve as an example. A highly developed car bomb exploded, destroying the building and killing 241 soldiers. Another suicide car bomb attack with a high number of casualties occurred in Colombo, Sri Lanka, on June 21, 1991 when the Liberation Tigers of Tamil Eelam killed 51 people. The list goes on.

Considering the present global situation, the terrorist threat appears to be particularly great in the early 21st century. This overall situation, which is determined by economic, military, ideological and political factors, will not be discussed and evaluated here. It is important, however, to take note of the following fact: Although, at the moment, general attention is focussed on the threat from a certain direction (Islamic fundamentalism), there are, worldwide, many different ideological positions and organisations from which potential terrorists could be recruited. For example, the bombing of a building of the U.S. federal government in Oklahoma on April 19, 1995, which killed 169 people and injured more than 500, was committed by right wing American extremists [Thompson 1995]. The bombing attacks by ETA in Spain in the last years can serve as another example for the diversity of the terrorist threat.

There are numerous potential targets for terrorist attacks. Industrial installations, office buildings in city centers or sports stadiums filled with spectators can appear "attractive", if a terrorist group plans to kill as many human beings as possible in one attack. A nuclear power plant, on the other hand, could be selected as target for one of the following reasons, or a combination of those reasons:

- Because of the symbolic character – nuclear power can be seen as the epitome of technological development, as typically "high-tech". Furthermore, it is a technology of an ambiguous civilian/military nature. Many people therefore regard it as potentially very hazardous. Therefore, attacks against nuclear power plants can have a particularly strong psychological impact.

- Because of the long-term effects – an attack can lead to far-reaching radioactive contamination with long-lived radio-nuclides. The region which is being attacked will bear the mark of destruction for a long time. Furthermore, there will be economic damage for decades.

- Because of the immediate effects on the electricity generation in the region – nuclear power plants are, wherever they are operated, important components of the electricity supply system. They feed into the grid with a high capacity. The sudden shutdown of such a large plant can lead to a collapse of the electricity grid.

- Because of the longer-term effects on electricity generation, not only in the affected region, but also in other regions (possibly even in all countries where nuclear power plants are operated) – a successful attack against a nuclear power plant in one country is also an attack against all

* Short version of a more comprehensive report to the Austrian government

nuclear power plants in the world [Braun et al. 2002]. After such an attack has demonstrated the vulnerability of an NPP, it is possible that other NPPs will be shut down in the country affected, but also in other countries. This leads to world-wide attention.

If nuclear plants other than NPPs or nuclear transports are attacked, there is no direct consequence for electricity production. However, the symbolic character as well as the possibility of long-term land contamination also applies in this case.

Terror attacks against nuclear plants can be performed through large variety of means. It is not possible to list all conceivable scenarios since it is absolutely impossible to anticipate all products of human fantasy.

In principle, attacks can vary with respect to the means being used, the concrete target, the organisation, number and effort of the attackers as well as other factors. For each of those variables, there are many possibilities of implementation. Even the attempt to completely list what is foreseeable would, therefore, lead to a matrix with a large number of different scenarios.

Terror attacks against nuclear plants are no hypothetical risk. In the past, a number of such attacks have already taken place. Luckily, they have not, so far, led to a catastrophic radioactive release.

For example, in February 1993, a man forced his station wagon through the main gate into the turbine building of Three Mile Island 1 NPP in the United States [Thompson 1995, USNRC 1993]. In November 1994, there was a bomb threat at Ignalina NPP, Lithuania. Fortunately, the deadline passed without an explosion and no bomb was found in the power plant [Nucleonics Week 1994]. In December 1995, the U.S. government warned the Russian Federation and other members of the Commonwealth of Independent States of the possibility of terrorist attacks by Chechnyan commandoes against power reactors on their territory. This warning was based on a psychological profile of Chechnyan leader Dzhokar Dudayev [Nucleonics Week 1995].

Acts of war against nuclear installations constitute another danger deserving special attention in the present global situation – in spite of the fact that the 1st Protocol to the Geneva Conventions forbids attacks against nuclear plants. Since the fall of the Iron Curtain, there is an increasing tendency towards "small", regionally restricted wars of long duration. Those wars are connected occasionally with the falling apart of a large state; or with efforts of groups in a population to achieve independence from such a large state [Münkler 2003]. The reasons for terror attacks listed above could, in such a war, motivate one of the conflict parties to attack a nuclear plant.

Wars of intervention constitute another form of conflict. They can occur as a consequence of a regional war of long duration, as mentioned above. In the course of such wars, western countries attack a state from which emanates a real or alleged threat. The political goals and interests of the attacking states usually play an important role in such cases. If there are nuclear plants in the attacked country, there is the hazard that they will be damaged unintentionally during the fighting. Furthermore, an intervening power might attack power plants in order to paralyse electricity supply in the attacked country. If there were efforts to avoid radioactive releases; such attacks probably would concentrate on the conventional parts of an NPP (turbine hall, transformer station). Because of the compact layout of the individual parts of a nuclear power plant, however, safety relevant parts of the installation might nevertheless be damaged. Furthermore, it must be considered, that damages to the conventional part of the plant would lead to radioactive releases, for example through failure of cooling systems or of the connection to the grid. Also, in times of war, the electrical supply system might collapse without direct attacks against power plants. In combination with further destruction of infrastructure, this, too, could in the end, lead to incidents or accidents in nuclear power plants, with consequences for the surroundings.

It is also conceivable that nuclear plants, which serve military purposes or are feared to serve such purposes, will be deliberately destroyed. In this case, the release of radioactive materials might not be intended by the attacker, but the attacker will accept the risk. The Israeli air raid of June 7, 1981, destroying the Iraqi research reactor at Tuwaitha, can serve as an example for such attacks. The reactor was not yet in operation, and no radioactive release took place. Nevertheless, this attack demonstrates that such considerations are by no means purely theoretical [Thompson 1995].

Threats through acts of war cannot be excluded in any region, not even in Europe. During the Balkan conflicts in the early 90s, the Slovenian nuclear power plant Krško was endangered several times. In June 1991, three fighter bombers of the Yugoslavian air force flew over the plant. There was no attack; however, this act clearly constituted a warning. In September 1991, war again approached the Slovenian border. There was fighting in the surroundings of Zagreb, which could easily have spread to Slovenian territory [Hirsch et al. 1997].

In case of a military conflict, terror attacks might occur in combination with acts of war.

This danger is particularly high in case of an asymmetric war – in case an enemy attacks a much weaker country, for example during a war of intervention. Scruples about actions mostly directed against the enemy's civilian population might be drastically reduced if the attacked country has no other options of hitting back at an all-powerful enemy, and/or has already suffered severe civilian losses itself.

The special case of the use of weapons of mass destruction, particularly of nuclear weapons, against nuclear power plants (through terrorist or military attack) will not be discussed here.

5.2 Targets and their Vulnerability

Of all commercial nuclear plants, nuclear power plants are probably the most "attractive" targets for terrorist or military attacks. They are most numerous of all nuclear plants, contain a considerable radioactive inventory and are, as already pointed out, important components of the electricity supply system. Furthermore, they are large buildings with a typical structure, well visible even over large distances. Therefore, this contribution focuses on nuclear power plants as possible targets of attacks.

The nuclear power plant area consists of several tens of thousands of square meters. The core piece of the buildings in this area is the reactor building, which, as the name indicates, contains the reactor with the highly radioactive nuclear fuel (in the order of magnitude of 100 tonnes), as well as important cooling and safety installations.

It is likely that the reactor building would be the primary target in case of an attack. If the reactor is in operation when the attack occurs, and the cooling is interrupted, a core melt can result within a very short time (about 1 hour). Even if the reactor is shut down, the decay heat is still considerable, and the fuel will also melt – although somewhat slower.

In case of destruction of the reactor building with failure of the cooling systems, a core melt accident of the most hazardous category results: rapid melting with open containment. The resulting radioactive releases will be particularly high and occur particularly early.

The spent fuel storage pool is another vulnerable component with considerable radioactive inventory. In some plants, it can contain more fuel (and thus more long-lived radioactive substances) than the reactor itself. In some nuclear power plants, this pool is located inside the containment and is protected against external impacts by a concrete hull (for example in German pressurized water reactors). In many cases, however, the pool is installed in a separate building with less protection.

Apart from the reactor building and, if applicable, the building with the spent fuel pool, there are further buildings and installation of varying safety significance. So far, not all nuclear power plants have been specially designed against external, human-made impacts (for example aircraft crashes). In the case of those that have been, an impact in one spot only has been assumed (corresponding, for example, to the crash of a small military aircraft, and not a large commercial airliner). Spatial separation of safety relevant installations was the most important counter measure. This should guarantee that only one installation vital for safety could be destroyed by an impact – a situation where recovery is possible.

For example, in case of failure of the auxiliary power supply via the corresponding transformer, the emergency power supply with diesel generators can be activated. If the control room is destroyed, the emergency feed building or the emergency standby building should be able to guarantee the safety functions which are absolutely necessary (i.e. cooling of the reactor).

Even if the reactor building remains intact in the case of an attack, the situation is still likely to get out of control, if more than one safety relevant installation of the plant is destroyed. This can happen even in case of spatial separation of important components.

Apart from nuclear power plants, all those nuclear plants containing large radioactive inventories could be "interesting" targets for attacks leading to large-scale radioactive contamination. An important example is intermediate storage facilities, which can be co-located with other nuclear plants (in particular, NPPs or nuclear reprocessing plants).

An analysis of the relative probabilities of attacks against nuclear power plants on the one hand and other nuclear plants on the other, cannot be performed here. Only the technical hazard potential will be discussed.

At the site of reprocessing plants highly active liquid waste and other radiologically important and long-lived waste is stored in quantities much larger than the amounts in the core of a large pressurized water reactor [Thompson 2003]. Reactor intermediate storage facilities for spent fuel in combined transport and storage casks, can have capacities of more than 1,500 t. The potential for large releases from those facilities, although smaller than for storage pools, is still considerable [Meister et al. 2002].

In the sector of nuclear fuel supply, stores of uranium hexafluoride are particularly in danger. In order to be enriched, uranium has to be converted into this chemical form. The depleted uranium which is also produced during enrichment, is not required for fuel production, but is stored for possible later use – usually as hexafluoride.

Uranium hexafluoride is a volatile substance. If it is released, it reacts with the humidity of the air, resulting among others in highly toxic hydrofluoric acid (HF).

At present, in the USA, about 57,000 steel containers with almost 700,000 t of depleted uranium hexafluoride are stored at three different sites[1].

A further potential target for terrorists is the transport of radioactive substances. Most important are the following:

- Spent fuel elements and highly active wastes from reprocessing (high specific inventory of radioactive substances)

- Plutonium (high radiotoxicity, particularly if released as aerosol)

- Uranium hexafluoride (high chemical toxicity of released substances, resulting in immediate damaging effects (lung damage))

Since the amounts transported, at most, are about several tonnes, the expected releases will be smaller than those which result from attack on a storage facility – even if the transport containers are severely damaged. On the other hand, the place where the release occurs cannot be foreseen, as attacks can occur, in principle, everywhere along the transport routes (for example, during handling at seaports; during rail transport through large cities). Thus, releases can take place in urban areas, leading to severe damage to many people, even if the area affected is comparatively small.

5.3 *Possible Attack Scenarios*

Since September 11, 2001, the public debate tends to concentrate on suicide attacks with a commercial airliner. In fact, the threat is much more diverse and complex.

In the following, various possibilities for terror attacks are listed as examples. Almost all of them could also take place in times of war, committed by commando troops or a fifth column. Some of the scenarios could be implemented, with minor changes, in the course of military operations.

Scenarios for fixed nuclear installations (nuclear power plants and others) could include [Hirsch et al. 2005]:

- Attack from the air

- Firing on plant from a distance

- Intrusion of attackers onto plant area

- Attacks involving insiders

- Attacks against installations located outside the plant perimeter

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[1] http: //web.ead.anl.gov/uranium/faq/storage/faq16.cfm; seen on September 15, 2006

Furthermore, transports of radioactive materials, particularly with high inventory, high radio-toxicity and/or chemical toxicity, could be the target of an attack.

Not all nuclear plants and nuclear transports are vulnerable to the same extent. Most attack options listed here can lead, in the worst case, to very severe releases. Some will have rather limited effects. Different parts of a plant can be varyingly vulnerable to different modes of attack.

5.4 Consequences of Terror or Military Attacks on Nuclear Facilities

From the long list of possible scenarios, three will be discussed in more detail here – shelling of a nuclear power plant, bombing of an intermediate storage facility for spent fuel and attack on a uranium hexafluoride transport. These examples are intended to illustrate the great variety of conceivable targets and scenarios.

5.4.1 Shelling of a Nuclear Power Plant

Attacking a nuclear power plant can lead to a reactor accident of the most severe category: Core meltdown with early containment failure.

A possible scenario would be shelling with a 15.5 cm-howitzer, transported by road, as part of military operations or as terrorist attack. Almost every army of the world today possess such weapons; it is conceivable that terrorists are also able to acquire them.

If high-explosive shells are used, which belong to the standard munitions for howitzers, the reactor building will be destroyed. Severe damage will occur inside. A large part of the plant personnel will be killed or injured. At the site area, shots which are slightly off-target will create further devastation. It is extremely difficult to implement effective and rapid counter measures.

Within a few hours, core meltdown will occur, with severe releases of radioactivity. The amount released to the atmosphere can be 50 – 90 % of the radioactive inventory of volatile nuclides like iodine and cesium, plus a few percents of further nuclides like strontium-90. In case of a nuclear power plant with 1000 MW electric power, this corresponds, among others, to several 100,000 Tera-Becquerel (TBq) of Cs-137. (During the Chernobyl accident, about 85,000 TBq Cs-137 were released [OECD NEA 1996].)

According to the assessment of L. Hahn, chairman of the German Reactor Safety Commission (Reaktor-Sicherheitskommission, RSK) at that time, the consequences would amount to a national catastrophe [Hahn 1999]: Up to 10,000 km^2 would have to be evacuated in a short amount of time. There could be up to 15,000 acute radiation deaths and up to 1 million cancer deaths, as well as uncounted cases of genetic damage. An area of up to 100,000 km^2 could be contaminated in the long term to a degree such as to necessitate the relocation of the population. This is an area larger than Portugal. The economic damage has been estimated at about 6 trillion Euros.

For many reactors, the probability of destruction or severe damage of the spent fuel pool is high. In this case, releases can be several times those given above, with correspondingly more severe consequences.

5.4.2 Bombing of an Intermediate Storage Facility

An attack of this kind is conceivable, primarily as an act of war. However, it also cannot be excluded that a terrorist organisation kidnaps an armed military plane or recruits the pilot of an air force to perform an attack of this kind – be it through bribery, blackmail or ideological conviction.

For the example considered here, it is assumed that the spent fuel in the facility is stored in casks. This storage concept is increasingly used in Germany as well as in some of the new EU member states. It is less vulnerable to attacks than pool storage, which is still the favoured concept worldwide (for example, there are storage pools with very large capacity at La Hague, France).

For the attack, a bomb of the type BLU-109 (908 kg) could be employed. This bomb is widely used by air forces.

If the bomb is well aimed, it will pass through the roof of the storage building and hit a spent fuel cask. The cask will be severely damaged; air can flow into in its interior. The material of the fuel element hulls (an alloy, based on zirconium) will be, to some extent, fragmented and will start burning. From one cask of the German type CASTOR V/19, about 10,000 TBq Cs-137 could be released. If several casks are destroyed or severely damaged, the release would be higher.

A release of this order of magnitude could necessitate long-term relocation of the population in distances up to 10 km. Even further away, there will be significant radioactive ground contamination which requires drastic restrictions in agricultural use. There would possibly be no acute radiation deaths. The number of resulting cancer cases would depend on population density and on the timeliness and efficiency of emergency measures.

5.4.3 Attack of an Uranium Hexafluoride Transport

Uranium hexafluoride is transported in containers of the type 48"Y, if it is material yet to be enriched or depleted uranium. These steel containers have a wall thickness of merely 16 mm; they can be loaded with up to 12.5 t UF_6. On a truck one container can be transported, in case of rail transport, there are up to three on a wagon [URENCO 2001]. A tanker with petrol or liquid gas could be used as a "weapon" to attack a road transport of uranium hexafluoride. After a violent collision with the uranium hexafluoride transport, the tanker will be severely damaged. At the site of the accident, a hot fire lasting several hours would result.

A container of the type 48"Y fails after about 50 minutes in a fire with a flame temperature of 800 °C. Failure will occur earlier in case of higher flame temperatures (1000 °C and more could in fact be reached). The steel cylinder would burst. Part of the UF_6 would be ejected high in the air, the remainder would be thrown piecewise in the nearer surroundings. Chemical reaction with the humidity of the air produces, among others, HF (hydrofluoric acid). HF is a very effective respiratory as well as contact poison.

In the immediate vicinity of the site of the accident (up to about 100 m distance), there is acute mortal danger. In a distance of up to 500 m, people could suffer severe poisoning and burning from HF. In case of longer exposure times, there is mortal danger also in this region. Even in distances of more than 1 km, there is the risk for health damage for sensitive people [Albrecht et al. 1988].

The short-term consequences of such an attack, regarding health effects and deaths caused by HF, can be drastic – in particular, if the attack takes place in a densely populated region. It is possible that thousands of people would be killed or injured. Additional effects would result from uranium contamination. Uranium is a metal of relatively low specific activity, but considerable chemical toxicity. If it is the product of reprocessing, it could contain further toxic radio-nuclides.

If the attack takes place in a rural area, there would be severe damage to plant and animal life.

5.5 Protective and Countermeasures and their Limits

Several measures are conceivable which could possibly provide a certain degree of protection for nuclear plants against acts of war and terror attacks. Regarding terror attacks, such measures are at present under examination by NPP operators and supervisory authorities. Some have already been implemented or are at least in a concrete planning stage.

The most important options are the following, which are, to some extent, also subject of public debate:

1. Preventive shut-down of nuclear power plants

2. Structural backfitting against deliberate aircraft crash and other hazards

3. Covering buildings with a smoke screen as protection against deliberate aircraft crashes

4. Additional personnel (and equipment) at the site, for the mitigation of the consequences of an attack

5. Strengthening the guard force

6. Implementing additional measures for accident management

Issues 2 to 5 can be relevant for all kinds of nuclear plants.

The protective measures mentioned in most cases do not correspond directly with a particular mode of attack; generally, their potential effects are directed against several kinds of attacks.

Potentially, all measures mentioned can also increase protection against acts of war. Smokescreens e.g. could be effective against military air raids as well as against suicide attacks with airliners. However, most will be of little use against a military attack, supported by heavy weapons.

In connection with terror attacks, further measures are also under consideration, which belong to the military, police or administrative sector.

5.5.1 Preventive Shut-Down

Preventive shut-down of a nuclear power plant in case of a threat can increase safety margins against all types of attacks. In particular, it can increase the time span available for counter measures after the attack.

However, the thermal power of the fuel elements (decay heat) decreases rather slowly in the shut-down reactor. In order to achieve a significant safety gain, intervention times of about one day should be available (in case the barriers around the fuel remain intact). This would require shutting down of a nuclear power plant (pressurized or boiling water reactor) several months before the attack, at the latest.

If barriers are compromised, in particular, if the reactor pressure vessel and/or the cooling circuit are damaged, even preventive shut-down cannot guarantee appropriate intervention times. Even in this case, however, it will give some slight advantages; core melt will occur somewhat later.

The potential advantages of preventive shut-down are mostly irrelevant if the spent fuel pool is in an exposed position in the reactor building – as is the case in many nuclear power plants.

5.5.2 Structural Backfitting Against Deliberate Aircraft Crash and Other Hazards

In principle, structural backfitting could be a protective measure against attacks of all kind from the air, but also against shelling and the use of explosives. The following options are conceivable:

- Strengthening of buildings against all kinds of impacts
- Protective buildings against air attacks (e.g. towers)
- Obstacles on the ground against car bomb attacks

Strengthening of the structures of nuclear plant buildings, however, is hardly feasible and has not been seriously discussed so far.

The construction of protective buildings around the reactor buildings, on the other hand, has been seriously considered. In Germany, the erection of towers was originally proposed [BMU 2002], as well as the building protective ramparts of reinforced concrete, to block approach paths for aircraft [Financial Times Deutschland 2004]. However, those concepts are not in the focus of public debate any more.

The construction of protective buildings, whatever the concept, would create specific new problems: If the buildings are placed at a greater distance from the reactor building, their height would have to be considerable. In a distance of over 200 m, it would have to reach 200 m and more. Thus, the buildings would be visible from a large distance. They could serve as orientation points in case of other attacks, for example, shelling. If the protective structures were placed close to the reactor building, on the other hand, they would create hindrances for traffic on the site.

The erection of massive reinforced concrete structures leads to another problem. The destruction of such a structure, be it tower or rampart, by aircraft attack leads to the formation of heavy concrete pieces which can create damage to the site.

Thus, such protective structures could be an effective measure, only in case of low buildings – for example nuclear waste or plutonium stores. In this case, no large height would be required.

The situation is different regarding the intrusion of attackers with vehicles on the ground. If such intrusion onto the site is effectively prevented, the options for terrorist are reduced. In particular, the use of car bombs in the vicinity of a nuclear plant can be blocked. Even a military attacker could be hindered by such obstacles. Furthermore, the expenditure for the erection of such barriers can be expected to be small. However, the traffic level is usually high in the surroundings of nuclear plants, and to some extent also on the site itself. This, in practice, creates limits to the implementation of this measure.

Measures like strengthening of the fence which is to prevent the intrusion of attackers, too, can result in a certain improvement of protection at low costs.

5.5.3 Covering Buildings with a Smoke Screen

Concepts for covering nuclear power plants with smokescreens, mainly for the protection against deliberate crash of an aircraft, constitute the central element of the protective concept in Germany, according to an agreement reached by the NPP operators and the German Government. This measure is to be supplemented by jamming the global positioning system (GPS) in the surroundings of the nuclear power plant concerned. It is to be introduced first, as a pilot project, at Grohnde NPP in Lower Saxony [BMU 2005]. In April 2006, however, the assessment of the measure was not yet completed [Deutsche Bundesregierung 2006].

Adaptation of military concepts is envisaged. However, military smokescreens usually are used under completely different circumstances. Military smokescreens are used for example to protect warships against attack by automatic, target-seeking missiles. Under cover of the smokescreen, the ships will withdraw. In case of an attack against a nuclear power plant, the target is not movable. Furthermore, a human pilot who can circle for some time over the target since no immediate counter attack is to be feared would guide the aircraft. Also, it will probably be more difficult to mislead a human pilot than an automated system.

The timely triggering of this measure constitutes a further problem. Europe is densely populated – all nuclear power plants, more or less, are located close to large airports and air traffic routes. Thus, it is possible that a possible attack would not be recognised early enough. Furthermore, even if a smokescreen is successfully created, it would be relatively easy to find the target nevertheless – for example with the aid of flares triggered by accomplices on the ground.

If, in times of peace air attacks at low height, by helicopter or military aircraft occur, the smokescreen system would be completely useless. In this case, the attack would only be recognised as such when it is too late to put the smoke screen in place.

An extensive smokescreen furthermore reduces visibility on the site and thus can hinder the personnel as well as counter measures like fire fighting. If the smokescreen is small, this aspect is less relevant. In this case, buildings on the site will still be visible, helping the orientation of the attacker and thus reducing the protection.

The deliberate triggering of the smokescreen by terrorists (faking of an air attack) can not be excluded. Subsequently, a ground attack could be launched under cover of the smoke.

The accompanying jamming of GPS has been criticised as problematic for the safety of air traffic. Also, it is possible that an airplane can navigate without GPS [Becker et al. 2006].

In times of war, smokescreens probably give better protection as it is more likely that approaching enemies will be recognised in time because of a higher alert level. For the protection of an immovable target, the position of which is well known, however, a smokescreen alone will nevertheless not be sufficient.

5.5.4 Additional Personnel (and Equipment) at the Site

In order to mitigate the consequences of all kinds of attack, experts in various fields are needed on the site. The possibilities and chances for mitigation will no doubt be improved if the number of knowledgeable personnel is increased – be it personnel directly located at the site, or in installations in the vicinity.

This concerns medical personnel, fire fighters and clearance workers, specialists for de-activating explosives, nuclear personnel and health physics experts. The corresponding equipment and materials could also be stored at the site.

5.5.5 Strengthening the Guard Force

In principle, strengthening of the guard force at the site is a suitable measure to improve protection against a terrorist attack on the ground. The task of the guard force consists of repelling the attacks of small groups, as well as in delaying larger attacks at least until police and/or military forces arrive.

Strengthening of the guard force, however, can lead to other risks:

- Members of the guard force could be blackmailed or bribed into supporting attacks.
- Protective installations on the site (in particular, weapons) could be taken over by terrorists.
- In case of private guard services, there is also the issue of sufficient quality control and vetting of guards.

In a recently published report on the U.S.-firm Wackenhut, which is, among others, responsible for security at nearly half the nuclear reactors in the U.S. many shortcomings are listed. This concerns, for example, poorly maintained weapons' inventories, inappropriate storage of explosives, inadequate control over access badges and improperly positioned guards [Service Employees International Union 2004].

Another investigation concludes that guard forces frequently are under-manned, under-equipped, under-trained, under-paid and unsure about the use of deadly force in case of a terrorist attack. Furthermore, in case of a stronger attack, the guard force is to use delaying tactics, while calling for reinforcements from outside. However, a terrorist attack is likely to be "successfully" concluded within three to ten minutes, and will not necessarily be noticed immediately. On the other hand, help from outside the site (for example a SWAT-team) will need one or two hours to reach the nuclear power plant. At best, local police forces could arrive within about twenty minutes [Project on Government Oversight 2002].

The adequacy of exercises testing the security of nuclear power plants is also questioned in the U.S.. It was criticised by NGOs that the same firm which provides guard services at many reactors (Wackenhut, mentioned above) was also training the teams which would act as "attackers" in these exercises [Nucleonics Week 2004].

Problems with ineffective exercises, deficient security equipment, improper access controls and other shortcomings appear to persist in mid-2006 [Nucleonics Week 2006].

In case of military attacks on large units, in particular those equipped with heavy weapons, the guard force is still less likely to be able to mount an effective defence.

5.5.6 Additional Measures of Accident Management

Measures of accident management are available in most nuclear power plants worldwide, to control severe accidents or to at least mitigate the effects of such an accident. In connection with the protection against terrorist attacks, there have been new considerations since September 11, 2001, to further improve accident management. For example, the German technical support organisation GRS claims that the protection of NPPs could be enhanced by accident management methods [BMU 2002].

The corresponding concepts have not yet been published. However, it is questionable to which extent the measures already planned could be expanded further. It is not possible to backfit a significant number of additional diverse installations; there are limits regarding the available space, as well as regarding the increasing complexity of the whole system, which could reduce clarity in case of an emergency.

5.5.7 Remark on Military, Police and Administrative Measures Against Terror Attacks

Concerning military, police, secret services and administration, the following measures, among others, are conceivable:

1. Protection of plants by military (including anti-aircraft defence and control of neighbouring waterways)

2. Measures to prevent hijacking of airplanes, for example improving control of passengers and military airplanes

3. Measures for the early recognition of a skyjacking, for example by improved control of air traffic

4. Measures against a skyjacked plane

5. Intensifying measures for vetting and control of plant employees (including sub-contractors); screening of previous career, constant surveillance – leading to better protection against insiders

The first measure mentioned clearly could also improve protection against acts of war.

Steps for an improvement of the control of flight passengers as well as preparing the possible use of military planes against hijacked airliners have already been taken in Germany [Deutsche Bundesregierung 2004].

It has to be kept in mind that measures like the "militarization" of the energy economy or extensive control of flight passengers as well as intensified vetting and surveillance of plant personnel are limited, in particular in times of peace, in an open and democratic society.

In a remarkable decision, the German Federal Constitutional Court stopped a law, introduced by the German Government, which would have permitted shooting down of a skyjacked plane as a last resort to avoid a sensitive target being hit [FR 2006].

If plants are protected by military units, the protection measures themselves can lead to new risks, just as in the case of private guard services. Military personnel, too, could be recruited by terrorists using bribes or blackmail. Furthermore, military installations at the site could be taken over by terrorists.

Furthermore, some experts fear that increased military protection of nuclear installations will lead to an escalation of violence. The reaction to such protection could be that terrorists will consider the use of weapons of mass destruction [Braun et al. 2002].

Military installations located directly at the plant site alone will be largely useless against certain kinds of attacks, if there is no timely warning – for example in case of an attack with business jets or helicopters. In particular, a helicopter attack can be performed at treetop height unnoticed by radar.

The insider problem is of particular complexity. Generally, at present, qualified personnel for nuclear plants is scarce. Sub-contractors are extensively used, for example for maintenance work during the regular plant stand-stills. This considerably increases the "chances" for terror organisations to recruit insiders. The efficiency of the internal surveillance of the personnel depends on the internal work organisation as well as on the concrete measures which are being used by the employer.

5.6 Conclusions

The threats to nuclear plants form terror attacks and acts of war can be summarized as follows:

- Because of their importance for the electricity supply system, nuclear power plants are "attractive" targets for terrorist as well as for military attacks.

- Various kinds of nuclear plants as well as nuclear transports could become targets of terrorist attacks, because of their symbolic character as well as the severe consequences of radioactive releases.

- All kinds of nuclear plants are vulnerable against terrorist and military attacks.

- An attack on a nuclear power plant can lead to radioactive releases equivalent to several times the release during the accident at the NPP Chernobyl in 1986. Relocation of the population can become necessary for large areas (up to 100,000 km^2). The number of cancer deaths can reach 1 million and more.

- Attacks on other nuclear plants, for example intermediate storage facilities, can also lead to severe releases with catastrophic consequences.

- Transports of various substances being used in large amounts within the nuclear energy system are also vulnerable to terror attacks. For example, an attack against a transport of uranium hexafluoride taking place in an urban area can lead to thousands of deaths and injuries within a short time.

- Protective measures against terror attacks are of very limited use. Furthermore, a number of conceivable measures (for example military protection of plants, increased surveillance and control of all suspect persons) cannot be implemented in an open and democratic society.

- There is no protection against military attacks, in particular if heavy weapons are used.

Thus, nuclear plants are and will remain vulnerable to terrorist and military attacks, no matter what protective measures are being taken. The only effective protection is the phasing out of nuclear power.

An ideal society that has eliminated the root causes of instability, war and terrorism on the global scale could operate nuclear power plants without significant risks of the type described above. Present day society, however, is far from being ideal. Indeed, global development seems to be heading the opposite direction: The gap between rich and poor nations as well as people is widening, the number of clashes is increasing, the dividing line between terrorism and acts of war is becoming blurred, thus international treaties protecting nuclear power plants are losing effectiveness, etc..

A central question to be asked is: Which industrial and energy systems can this kind of society afford from a safety point of view?

Obviously large, centralised installations that are essential for the economy of a society make this society vulnerable. If – as is the case with nuclear plants – societies must not only deal with loss of the services of the installation in case of attack, but also with substantial health and environmental problems, the acceptability of the risk incurred by the operation of such an installation must be questioned. It is not only legitimate to pose this question; in view of recent global developments it is indeed increasingly necessary to give it serious thought. In the energy field alternative solutions are available. The "soft" energy path, with maximum efficiency of energy use and reliance on renewables implies the production of energy in many small decentralized plants. Thus there is little dependence on any one plant. The system as a whole is less vulnerable to attacks than "hard" systems, such as the nuclear option. "Soft", sustainable energy systems are therefore also less attractive targets for attacks. Should, nevertheless, an attack occur the destruction of a renewable energy plant will generally not lead to dramatic consequences for people and for the environment. Thus, such systems could meet sustainability criteria also in the face of terrorist and military attacks, while the nuclear option clearly does not.

Finally, it should be noted that a "soft" energy system which does not include dual-use (civilian/military) technology, which does not present targets which can be "tempting" to terrorists and military attackers, and hence does not give rise to the need for extensive protective measures, could also contribute to the lessening of international and societal tensions.

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6 Emergency Planning

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September 2006

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6.1 Introduction

The reactor of a nuclear power plant contains a large amount of highly toxic radioactive materials. A severe accident can cause the release of a significant part of these materials into the atmosphere.

The emissions of Chernobyl demonstrate this fact: the total inventory of radioactive inert gases was released (6.5 billion GBq [1 Gigabequerel GBq is one billion Becquerel], 50-60 % of the radioactive iodine (1.76 billion GBq), 25-60 % of tellurium-132 (1.15 billion GBq), 20-40 % of radioactive cesium (140 million Gbq), 4-6 % of strontium-90 and about 3,5 % of the inventory of plutonium, one of the most hazardous radioactive substances [OECD NEA 2002].

A PWR melt-down accident in connection with an early containment failure or containment bypass occurring in Western Europe, the United States or another country could release comparable radioactive emissions or even higher. This could arise due to a hydrogen explosion or be caused by a melt ejection from the reactor pressure vessel at high internal pressure. In that case 50-90 % of the radioactive iodine, cesium, tellurium could be released into the environment [Ministerium für Finanzen und Energie des Landes Schleswig-Holstein 1999].

Especially in cases were the release is very high, the radioactive cloud reaches the atmosphere after only few hours. The warning time to take emergency measures can, therefore be very short. This is also true for larger distances. With wind speeds of only 20 km/hour – rather frequent in Europe – the radioactive cloud can travel about 500 km per day and thus cross, for example, Austria completely.

The exposure of the population to radioactive material could cause death from acute radiation diseases after few weeks. In any case millions of human beings could be affected by long-term effects, like cancer or genetic changes (mutations).

Severe accidents with radioactive emissions are not unique to nuclear power plants; large releases can also occur in other nuclear installations, like reprocessing plants or fuel manufacturing plants. The transport of nuclear materials can also cause radioactive releases that in case of an accident could require counter measures even within several km distance [Deppe et al. 1992]. The particular problem with these accidents is the fact that they can occur at any point of the transport route, which very often has a length of several hundreds of kilometers.

These points already prove that nuclear power is neither environmentally sound nor socially compatible.

During the last few years, the situation has become more and more critical, and this trend is likely to continue in the future. The risk of terror attacks and acts of war against nuclear installations is increasing – and with it, the risk of catastrophic radioactive releases with very little warning beforehand. Furthermore, the likelihood of natural catastrophes is increasing, because of the anthropogenic climate change under way. Floods, tornadoes and extreme temperatures also heighten the risk of nuclear accidents.

On the other hand, it should to be pointed out that the discussion here is based on the reactor types which are presently in operation worldwide. The assessment does not concern possible future generations of reactors with qualitative improvements compared to present-day plants.

6.2 Emergency Planning

A variety of different measures is required to be prepared for the case of a nuclear emergency. Expenditures related to these measures have to be covered not only by the countries that operate nuclear power plants, as there may be transboundary effects.

It is generally acknowledged, esp. in countries with nuclear power plants, that the threat of nuclear power plants in neighbouring countries is identical to that of national plants. This is demonstrated by a quotation from the German recommendations for the emergency planning (Deutsche Rahmenempfehlungen für den Katastrophenschutz):

"Bei ausländischen kerntechnischen Anlagen, die sich in der Nähe der deutschen Grenze befinden, müssen die gleichen Maßnahmen zum Schutz der Bevölkerung durchgeführt werden können wie bei deutschen Anlagen." [Länderausschuss für Atomkernenergie 1999].

(It must be possible to take the same measures of protection of the population for foreign nuclear installations near the German border as for German installations.)

A complete presentation of required emergency measures is not possible here, but as an example several topics will be named which show the enormous efforts that have to be taken:

- Preparation of shelters, planning of protection measures outside of these rooms (in apartments, working places, schools, etc.)
- Installation of an early-warning system with sufficient measuring sites, connected to the respective systems of other countries
- Development of a warning and alarm systems for the population, including an information system
- Planning for the distribution and administration of prophylactic stable iodine
- Planning for the decontamination of equipment
- Planning of installations for medical treatment of radiation exposure victims (including possibly contaminated victims)
- Planning of evacuation and other countermeasures: preparation of the legal basis, evaluation of specific plans, education of the public and emergency workers

All of these measures and plans have to be updated continuously taking into account the most recent state of population distribution and structure, the traffic routing, the medical state-of-the-art, technical possibilities etc. The start-up of a new nuclear installation can require extensive supplementary activities and revisions.

Emergency planning is also necessary for countries that do not operate nuclear power plants. It is not a singular expenditure, but requires a continuous effort. It is a kind of infrastructure that has to be maintained and possibly modified and extended – especially in case of a world wide extension of nuclear power.

The financial expenditures are paid by the public, an expense generally not taken into account in the electricity costs from nuclear power plants.

6.3 In Case of Emergency

Even in case of optimum emergency planning, it is doubtful that due to the short pre-warning times the required measures can be realized in time, in the most endangered areas. These are areas that will be reached by the radioactive cloud within several hours, and can enclose several hundreds of square kilometers.

With the incoming information about an accident in a nuclear power plant the first questions arise: At which time are radioactive releases expected? Which emission is to be expected? In which direction is the radioactive cloud going to move?

These predictions can be very difficult and will always include large uncertainties. Nevertheless, decisions are required. In the first place, the public has to be informed. The advantages of spreading information quickly to reduce the radiation exposure in a population in the case of an emergency has to be weighed with the consequences of having an unnecessary alarm that might cause panic within a population.

Immediate decisions on the implementation of measures have to be taken. Should the public be asked to stay in their houses or move into shelters? Is it necessary to start preparations for an evacuation? Shall stable iodine tablets be distributed?

These considerations will take place while the situation within the power plant could be very complicated. The conditions within the reactor building are presumably not exactly known. Measuring devices for monitoring and surveillance of the spreading of radioactive materials might fail or deliver unreliable or contradictory data.

Even a short-term prediction of wind direction and the resulting path of the radioactive cloud is difficult. In France, an extensive emergency system was developed that is supposed to allow the prediction of radiological consequences. Even under such circumstances – that certainly are not at all existing in every country – there are still significant uncertainties:

"...tests performed on some of the French nuclear sites have shown that the prediction [of wind direction] could be done with an uncertainty of + 30° with a confidence level lower than 70 percent on rather complex terrains." [Herviou & Winter 1999]

The identification of a sector with an opening angle of 60° with less than 70 % reliability is not a good basis for the implementation of emergency measures.

The situation is aggravated due to the known fact that radioactivity is not perceptible by human senses. Therefore it is not astonishing that stress, panic, and irrational behavior of people has to be expected – including official personnel and emergency management workers.

Besides these problems it could be very difficult to realize the planned measures in case of emergency, due to the pressure of time and other factors.

This could concern the distribution of iodine tablets since the thyroid gland has to be saturated with iodine in order to block the intake of radioactive iodine. This should happen before or just at the time the radioactive cloud passes inhabited areas.

"Der Schutz ist dann am wirksamsten, wenn die Jodtabletten kurz vor oder praktisch gleichzeitig mit dem Einatmen von radioaktivem Jod eingenommen werden. Aber auch wenige Stunden nach dem Einatmen von radioaktivem Jod wird noch ein gewisser Schutz erzielt. Später als ein Tag nach der Aufnahme des radioaktiven Jods schützt die Einnahme von Jodtabletten nicht mehr; sie ist dann eher schädlich." [Strahlenschutzkommission 2004]

(Protection is most effective, if the iodine tablets are taken immediately before of or at the same time than the inhalation of radioactive iodine. However, some protection is also achieved a few hours after the inhalation of radioactive iodine. More than a day after the uptake of radioactive iodine, taking iodine tablets provides no protection any more; rather, it can be harmful.)

In Germany, the distribution of tablets to households in an area of up to 25 km around the nuclear power plant is supposed to be completed within 2-4 hours, in the endangered regions up to 100 km distance within 12 hours after the decision for the distribution has been taken [Länderausschuss für Atomkernenergie 1999]. It is more than doubtful that this can be realized.

Moreover, in the worst case the radioactive cloud could reach communities within 25 km of the respective nuclear power plant within 3 hours after the accident has been initiated, since core melting and containment failure can occur within two hours. Depending on wind velocity and the path of the cloud, radioactivity can reach places within 100 km after only a few hours.

Taking iodine tablets can actually be harmful to susceptible persons (for example by triggering hyperactivity of the thyroid). Thus, if taken too late, the negative effects of iodine tablets could outweigh the positive ones.

Nevertheless, the quantity of tablets which is stored by the German state (Länder) authorities recently was increased, as a precautionary measure. This decision is likely to have been influenced by the threat of terror attacks. However, in case of such attacks, it is feared that the advance warning time will be very short, and hence, that preconditions are particularly unfavorable for the timely taking of iodine tablets [Strahlentelex 2004].

Sheltering is supposed to protect, in case of emergency, against external exposure to the radiation from the cloud and against inhalation of radioactive pollutants. The best protection will be to stay in cellars. However, even this mode of protection is limited as the air within the shelter will eventually become contaminated. Sheltering is meant to be used until the cloud passes, and is then to be followed by relocation as needed from excessively contaminated areas.

This yields problematic conflicts: It is simultaneously necessary that the population can be reached by broadcasting or public-address systems, which is not always possible in cellars. Moreover, it might be that within the most critical time period many people are on the way to pick up the iodine tablets. Accordingly, the German recommendations state:

"Der Aufenthalt in Gebäuden ist eine einfache und effektive Katastrophenschutzmaßnahme, die jedoch nur über kurze Zeit aufrechterhalten werden kann." [Länderausschuss für Atomkernenergie 1999]

(Staying in buildings is a simple and effective protective measure, however this can only be maintained for a short time)

In case of the feared severe radioactive exposure, evacuation is the strongest protective measure (provided that it can be accomplished before plume arrival). Also in this case the timely action is decisive. The German recommendations state laconically:

"Die Evakuierung ist besonders dann eine wirkungsvolle Maßnahme, wenn sie vor Durchzug der radioaktiven Wolke erfolgt." [Länderausschuss für Atomkernenergie 1999]

(Evacuation is an efficient measure especially if performed before the crossing of the radioactive cloud)

It is not clear how the evacuation shall be realized in time, especially in large cities. The problem of finding citizens in need of help (disabled, old and sick persons) in a city and being able to transport them in an appropriate way is presumably unsolvable. It is also almost impossible to avoid the total collapse of traffic, especially on main roads.

Also, it has to be considered that evacuations, in case they can be performed, will cause additional grave problems for the persons concerned. They will presumably have to live for long time periods in emergency lodgings, with possible psychological stress and social tensions. Working places will be lost; education and schools will be hampered. Whole cities as functioning social units will be destroyed, neighborhoods and even families disrupted.

The fast and efficient implementation of emergency measures is further hindered by the fact that plans and guidelines in different countries are varying, sometimes to a considerable extent. Even inside the European Union, there are significant differences. This point is of great importance, since nuclear accidents generally will have cross-border consequences.

For example, regarding the iodine tablets already mentioned, the radioactive dose above which children are to receive such tablets is different in Belgium, France, Germany and Luxembourg. They vary by a factor of ten. Also, there are differences regarding the zones of distribution. The regulations are different in all those four neighboring countries. It cannot be expected in the short or medium term that they will be harmonized [Feider 2004].

It is not surprising that a German state government, the highest level emergency protection authority in case of an nuclear accident, has summarized:

"Die schleswig-holsteinische Landesregierung ist jedoch der festen Überzeugung, dass die bestmögliche Vorsorge gegen den Unfall eines Atomreaktors darin besteht, diesen Reaktor gar nicht erst zu betreiben. Die Folgen einer nuklearen Katastrophe wären so unermesslich, dass

ein Verzicht auf diese Form der Energiebereitstellung das Ziel staatlichen Handelns sein muss." [Ministerium für Finanzen und Energie des Landes Schleswig-Holstein 1999]

(The government of Schleswig-Holstein is convinced that the best precaution against a nuclear power plant accident is not to operate the power plant. The consequences of a nuclear catastrophe would be so immense that the renunciation of this form of energy production has to be a governmental aim.)

6.4 International Efforts – a Considerable Helplessness Remains

In order to improve decision making and planning of measures in case of a nuclear catastrophe, the system RODOS (Real-time On-line Decision Support system for off-site emergency management in Europe) was developed as a common effort by 20 countries of the European Union, Eastern Europe and the former Soviet Union. This System is to provide information on the present and future radiological situation, information for the evaluation of counter measures as well as methodical support for decision making.

In principle, this approach has the potential to improve emergency management. However, the system is very complex, and its development and introduction are very time-consuming. The project started in 1989. At present, the installation of the RODOS-System is still under way in East European Countries. Until 2004, it has been implemented in Hungary, Poland, the Slovak Republic, Slovenia and Ukraine. Installation in Bulgaria, the Czech Republic, Romania and Russia is still under way [Forschungszentrum Karlsruhe 2003]. An assessment of the strengths and shortcomings of this system will not be possible before the installation is completed and comprehensive tests and exercises have been performed. Even then, it will remain open how it will prove itself in case of a real emergency. Furthermore, the RODOS-System also relies on extensive prognostic models, for example for the meteorological situation. The prediction accuracy of those models is limited. All the information and decision support which RODOS is providing can only be as accurate and reliable as the models on which they are based.

The IAEA, together with six other international organizations, published a new report in the "Safety Standards Series" in November 2002, which determines the requirements for advance planning and reaction in case of a nuclear emergency. This is the first report, in an international framework, of a comprehensive and summarizing character. It is to support the responsible national authorities by better enabling them to see questions of emergency planning in their entirety – on a rather general level [IAEA 2002].

This effort towards harmonizing the requirements for emergency planning can, in principle, only be welcomed. However, the helplessness which, to a large degree, remains in the face of a nuclear catastrophe in spite of all planning and preparation is also mirrored in the wording of this report.

This can be seen, for example, in the requirement that first responders, when saving human life, should ignore signs indicating the presence of radioactive material – and thus, could be exposed to very high doses of radiation. Furthermore, it is stated that precautionary urgent action should be taken before a release of radioactive material occurs or shortly after. It has already been pointed out that this requirement will be very difficult to fulfill in practice – particularly in case of terror attacks or acts of war, but also in a situation in which the plant personnel at first assumes that a release can still be avoided.

The doses received shall be communicated to the workers involved when an intervention has ended; however, the reconstruction of those doses will not always be possible. In addition, the general impossibility to set obligatory dose limits for the first responders becomes manifest. Their dose shall be kept below twice the maximum single year dose limit, unless for life saving actions – in the latter case, a limit of ten times the maximum single year dose applies. However, in certain circumstances, even this limit can be exceeded.

And the list of examples goes on. By no means, is it to be understood as a criticism of the document which was compiled by IAEA and the other international organizations. It is simply not possible to formulate requirements for the case of a nuclear catastrophe which can be reliable fulfilled in all possible situations. Even the use of practical exercises, as were performed in the framework of emergency planning, is limited.

Chapter 5 of the document lays down the requirements for the infrastructure. Again, it becomes clear how substantial the efforts and expenditures are, which have to be performed well in advance. Because of the far-reaching consequences of nuclear accidents, countries without nuclear power plants are also concerned.

All in all, many open problems still remain in mid-2006; even regarding those measures which could, in principle, be implemented to somewhat mitigate the effects of a nuclear catastrophe. An IAEA representative comes to the following conclusions:

"Many member states are currently not adequately prepared to respond to such [radiological] emergency situations. Moreover, without standard procedures and common approaches, protective actions can differ between countries, resulting in confusion and mistrust among the public, interfering with recovery operations and possible leading to severe socioeconomic and political consequences. Many of the lessons from past accidents, including even the Three Mile Island and Chernobyl accidents, have still not been completely incorporated into emergency plans in all States. Furthermore, there is a heightened awareness of the need to strengthen arrangements to respond to emergencies that could arise from criminal or terrorist activities involving nuclear and other radioactive materials." [de Oliveira 2006]

6.5 Experiences: Harrisburg, Chernobyl, Tokai Mura

6.5.1 Three Mile Islands – "Blind Men" Decide

The accident in the NPP Three Mile Islands on March 28, 1979 caused significant emissions of radioactive materials, compared to emissions in normal operation. Fortunately, the containment was not significantly challenged and a catastrophic release of radioactivity was avoided.

The Three Mile Island accident illustrates how in case of a nuclear accident a completely unclear situation can arise.

On March 30 the confusion was culminating. There was no definite information from the plant. While the temperature of the reactor core was increasing several measuring points failed and radioactivity was released. The further development was not predictable (at least as far as the operating crew was concerned). The emergency protection management therefore received the recommendation to consider evacuation [Innenausschuss des Deutschen Bundestages 1979].

On that day the chairmen of the upper nuclear regulation authority NRC Joseph Hendrie stated with respect to himself and the governor of Pennsylvania Richard Thornburgh:

"We were almost completely fumbling in the dark. His knowledge was not existent and mine not sufficient. It was, like a few blind old men stumbling around were making decisions." [May 1989]

The monitoring devices in the off-gas stacks had failed. Radiation monitoring in the surroundings was full of gaps; there were not enough measuring instruments available.

Especially due to the fact that on March 30 a hydrogen explosion was threatening, about 3.500 children and pregnant women were evacuated from the 8 km-radius of the power plant. In total up to 200.000 people voluntarily left the area.

In the next week, the situation gradually cleared up. The closed schools were re-opened and the public was asked to return to their homes. It was not possible, however, to determine the extent of the radioactive releases which had taken place.

The health effects of the accident have only been investigated to a small extent. There are indications for an increase of cancer incidence in the surroundings of the plant, which were discussed controversially. Many questions remain open until today [Mangano 2004].

Since this accident, the emergency planning in the USA was revised and extended, and major shortcomings were eliminated.

Still, for the basic problem, that in case of a nuclear accident the information can be incomplete and confusing and thus for days no reliable basis for the planning of protective measures might be available, no completely satisfying solution will be possible.

6.5.2 Chernobyl – Accident Consequences over Thousands of Kilometers and Many Decades

Seven years after the Three Mile Island accident a catastrophe occurred in a Soviet nuclear power plant. The accident of Chernobyl on April 26, 1986 has dramatically changed the lives of millions of people. Hundred of thousands of square kilometers of soil were contaminated. The officially stated economic losses are in the order of a billion US dollars [Hille et al. 1996].

What are the lessons to be learned for emergency planning?

The early days after the accident were characterized by a very hesitant information policy of the Soviet authorities – with respect to their own public and foreign countries. The community Pripyat in the immediate neighborhood of the nuclear power plant was warned only 36 hours after the accident [UNOCHA 2000]. The radioactive cloud reached many European countries earlier than reliable information on the accident. Indeed, the first hint of trouble outside the Soviet sphere of influence was an increase of radiation monitoring instrumentation at the Forsmark NPP in Sweden.

These problems are, to some extent, avoidable. After the Chernobyl accident two international conventions were agreed on that offer an improved basis for international cooperation with respect to early information in case of accidents and for mutual help [IAEA 1986a,b]. Beyond that many bilateral agreements arose and in many countries improvements were achieved with respect to early-warning systems and the planning of protective measures.

Chernobyl also shows that a considerable part of the consequences of a severe nuclear accident cannot be avoided by any optimized planning. A quarter million people were evacuated, millions still live in heavily contaminated areas. It would be extremely difficult to find living areas for all of them in uncontaminated regions.

New cities had to be built within a short time for the evacuated people. These cities became focal points of social stresses. Economic life does not function without friction – unemployment is high and the cities depend on subsidies.

In the best case, emergency planning can reduce radiation exposure of the public, but is less useful with respect to the social consequences of a large accident.

Moreover, Chernobyl has shown the size of the area that can be affected by a reactor accident. Countermeasures due to contamination were found to be necessary in distances of thousands of kilometers from Chernobyl.

Even in recent years, high values of cesium contamination are found in game meat in Bavaria. Up to 40,000 Bq/kg were measured in the meat of wild pigs in 2004, far above the German limit of 600 Bq/kg [BFS 2006].

In Nordic countries, cesium levels remain high in mushrooms and freshwater fish, frequently showing levels 10 to 20 times the limit of 1,500 Bq/kg. Reindeer meat also was highly contaminated, but is reported to be "mostly within limits" by 2006 [Nucleonics Week 2006]. Possibly restrictions concerning the consumption of food will have to be maintained in Great Britain until 2010 or 2015 [Smith et al. 2000].

Finally the Chernobyl accident demonstrates the long-term consequences of a nuclear catastrophe. This does not only concern the long-term restrictions of food consumption in large distances from the accident site but also the accumulating number of diseases and deaths.

Due to the lack of systematic studies and documentation, especially during the first years after 1986, part of the consequences cannot be recorded in detail anymore. And most of the consequences with respect to lifetime and health of the population will happen in the future.

A comprehensive study of the Chernobyl health effects, compiled by 50 Russian and Ukrainian scientists and published at the occasion of the 20th anniversary comes to the conclusion:

"Complete evaluation of the human health consequences of the Chernobyl accident is therefore likely to remain an almost impossible task, such that the true extent of morbidity and mortality resulting may never be fully appreciated." [Yablakov 2006]

In this study, various estimates of the number of victims of cancer and other illnesses are reported. The highest values go up in the millions. In view of the available evidence, it seems plausible that the number of deaths will be in the six-figure range. Clearly, the countries most severely concerned are Belarus, the Ukraine and Russia. A significant amount of morbidity and mortality also has been caused across other European countries.

Even today the consequences of the accident can still be aggravated if already released radioactive materials are further distributed into the environment, by plant growth or fire in contaminated woods, or if more of the radioactive inventory is released from the site – for example, from the waste trenches which have been hastily dug there, or from the severely damaged reactor building.

In order to be efficient, emergency planning should therefore include long-term considerations (over decades).

6.5.3 Tokai Mura – an Accident in a Densely Populated Area

The criticality accident in the uranium conversion plant of JCO (Japan Nuclear Fuel Conversion Company Ltd.) on September-30 and October-01, 1999 did not have far-reaching consequences. Other countries were not concerned.

But still this accident demonstrates the difficulties of taking timely protective emergency measures in a densely populated region. It also demonstrated that nuclear threats are not unique to nuclear power plants.

The uncontrolled chain reaction in the uranium conversion plant started on September 30 at 10:35. The operation management realized within a few minutes that criticality occurred. Nevertheless the respective authority, the Science and Technology Agency, was not notified until 40 minutes later, and the municipality of Tokai Mura only at 11:34. [Nucleonics Week 1999]

Only four to five hours after the start of criticality were 150 persons within a 150-meter-radius around the plant were evacuated. At about the same time the 310,000 inhabitants within a 10-km surrounding got the information to stay in their houses [Nuclear Fuel 1999].

In the early morning of October 1st, further evacuations were considered. Finally, the authorities did not evacuate because it was raining and panic was expected. At that time the chain reaction was still going. Due to the direct neutron radiation the radiation exposure in 400 meters distance was one milli-Sievert [WISE 1999].

At 6:30 in the morning of October 1st criticality was stopped and the protective measures were cancelled.

Since the ventilation system in the plant was still operating, radioactive iodine was still released. These emissions lasted for at least one week [Nucleonics Week 1999a]. Later on the system was shut down, and leakage through windows of the respective building was reduced.

The accident was characterized by delays in information distribution and by slow implementation of protective measures – and that happened in an industrialized country with a highly developed infrastructure. It is also clear that the continuing iodine release was stopped far too late.

Besides, it cannot be judged whether the protective measures were optimal. The exact radiation exposure in the environment cannot be reconstructed anymore – only rough estimates are possible and they are not very reliable for the short-living iodine isotopes. Therefore it will not be possible to get exact information on the radiological long-term consequences.

Such uncertainties during nuclear accidents can most likely not be completely avoided, even in case of better organization and faster reaction.

6.6 Conclusions

The reactor of a nuclear power plant contains large amounts of radioactive materials. During a severe accident a significant part of these hazardous substances can be released into the atmosphere. This is valid for all reactor types that are presently in commercial use or in concrete planning.

In case of accidents with very severe releases – like terrorist attacks or acts of war leading to the destruction of a reactor building, or internally initiated accidents with early containment failure – the radioactive cloud reaches the atmosphere after a few hours. The warning time for protective measures can be very short. Depending on the wind velocity the cloud can travel several hundreds of kilometers during the first day.

The radioactive exposure of the population due to a severe accident can cause acute radiation diseases. In any case millions of persons could experience long-term consequences like cancer or other diseases, and genetic changes (mutations).

In order to be prepared for an emergency a large variety of protective measures is required. Expenditures for such measures are also necessary for countries that do not operate nuclear power plants or other nuclear facilities due to transboundary effects.

Extensive measures have to be taken, early-warning systems have to be implemented, stockpiling and evacuation plans have to be worked out, installations for decontamination and medical care for the contaminated victims have to be provided, and so on.

This will be a continuous task as long nuclear power plants are operated: The plans and protective measures have to be continuously revised and actualized, even extended in case of a world wide continuation of nuclear power generation.

Even in case of optimum emergency planning it has to be assumed that the implementation of protective measures in the near surroundings of the accidental plant cannot be realized in time, due to the limited warning times. Depending on wind speed the extension of the "near surroundings" can comprise hundred kilometers.

It is doubtful that protective measures like the distribution of iodine tablets and especially the evacuation of the endangered population is possible within appropriate time periods. The evacuation of large cities is certainly impossible within several hours.

Finally, it has to be considered that evacuations, as far as they can be realized, will cause further burden on the concerned persons. They might have to live for long time periods in emergency lodgings, were psychological stress and social tensions have to be expected. Working places will be lost, education and schools might be compromised. Cities as functioning social units will be destroyed; neighborhoods and even families will be disrupted.

In the last few years, there have been international efforts to strengthen emergency planning. The endeavors are aiming, on the one hand, at the development of prognostic methods and other tools for decision support in case of severe releases. On the other hand, basic requirements of general validity are to be established. Without doubt, those international efforts are going in the right direction. However, they cannot provide a sound and reliable solution. A closer look reveals that they, too, only demonstrate the far-reaching helplessness in the face of a nuclear catastrophe.

Three examples from the last three decades show that the basic problems of emergency planning exist even today and are very likely unsolvable.

During the Three Mile Island accident in 1979 the responsible authorities were unable to take adequate decisions for days due to incomplete and confusing information from the plant.

The Chernobyl catastrophe in 1986 showed drastic consequences requiring the resettlement of the population. Moreover it was demonstrated that a severe accident can concern whole continents, even after decades counter measures are still necessary thousands of kilometers away from the incident.

During the criticality accident in Tokai Mura it was remarkable that the responsible management and the authorities reacted very slowly in spite of early information - and that occurred in a modern industrial country with very good infrastructure.

Efficient emergency planning has to consider the large spatial distribution and the long-term character of the consequences. Furthermore, the possibility of incomplete information and hesitation on the part of responsible persons has to be taken into account.

Besides technical and medical aspects, the social, psychological and economic aspects have to be considered – and the fact that a large number of different countries could be concerned and an international exchange and coordination of information is required.

All this is valid not only for countries that operate nuclear power plants but also for those that do not to use nuclear power.

It seems impossible that all the needed requirements can be fulfilled. The challenges seem to be too overwhelming.

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7 Nuclear Proliferation Issues Associated with the Commercial Nuclear Fuel Cycle

Steven Sholly
March 2006

Editors comment:

From the start development of nuclear energy was strongly linked with military interests. The nuclear proliferation debate stood at the beginning of the discussions on commercial use of nuclear energy and has been a part of the debate through-out. The international dispute about the Iranian Nuclear Program is just one recent example of this.

An assessment of the Nuclear Option would therefore be incomplete without consideration of possible misuse of nuclear material for non-peaceful purposes. A comprehensive paper on the possibilities of states that do not have nuclear weapons at present to proliferate from the commercial nuclear fuel cycle was prepared and submitted to the Austrian government. However, many things are known or should be discussed in this context that prudence forbids to publish. For the purposes of the published edition of the assessment, such sensitive passages were deleted and a shortened version of the comprehensive paper was produced. Even this "cleaned" version makes the relevance of proliferation for the nuclear option obvious.

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7.1 Introduction

7.1.1 Purpose

The purpose of this report is to provide a perspective on the potential nuclear weapons proliferation pathways available from a commercial nuclear (fission) power plant fuel cycle, considering all the steps from mining to final waste disposal (including reprocessing and recycling). For the purpose of this document, proliferation is defined as "*the spread of nuclear weapons, nuclear weapons materials, and nuclear weapons technology*" [DOE 1998].

This report does not address, except in passing, proliferation arising from other pathways (such as research reactors, accelerators, fusion power concepts, etc.). Finally, this report also does not address weapons other than nuclear weapons (e.g., radiological dispersal devices, so-called "dirty bombs") [Carafano][1].

7.1.2 Background

As part of the Kyoto Protocol to the UN's Framework Convention on Climate Change, adopted in December 1997, a "*clean development mechanism*" (CDM) has been defined for the purpose of supporting - in developing countries - the development and deployment of energy production facilities that do not release greenhouse gases. Some organisations have advocated the expansion of the CDM to include nuclear power projects although this proposal has not been accepted to date. Certain aspects or characteristics of nuclear power bear on its potential inclusion within the CDM. The purpose of the current report is to address one of these matters - the potential to use the commercial nuclear (fission) fuel cycle to obtain nuclear weapons.

Specifically, this report assesses the proliferation potential of the nuclear fuel cycle for nations which are not already "nuclear weapon states"[2]. This focus arises from the Kyoto Protocol scope, parties to which are nations (rather than subnational or multinational groups). The scope limitation to the commercial nuclear fuel cycle arises from the need to assess whether the commercial nuclear fuel cycle is sustainable. Thus, this report does not look at other aspects of nuclear energy, nor at issues dealing with sabotage, terrorism or military actions which are addressed by other authors.

In addition, this report focuses on horizontal proliferation. Vertical proliferation is possible – that is, "nuclear weapon states" can use the commercial nuclear fuel cycle to produce additional

[1] Readers interested in the subject of radiological dispersal weapons may wish to consult other reports which discuss radiological dispersal devices (RDDs), several of which are easily available (Carafano 2004; Ferguson 2003; Ford 1998).

[2] The phrase "nuclear weapon states" as used in this report does not have the same meaning as that phrase is used in the Nonproliferation Treaty (NPT). The NPT recognizes only five "nuclear weapon states": China (the People's Republic of China, PRC), France, the Russian Federation, the United Kingdom and the United States of America. The NPT definition ignores the very evident possession of nuclear weapons by, for example, India and Pakistan (both of which have conducted multiple nuclear tests).

nuclear weapons, enhance the capabilities of existing nuclear weapons, or maintain the yield strength of existing nuclear weapons. Such a concern is not merely theoretical – the United States of America is using the Watts Bar nuclear power plant (operated by the Tennessee Valley Authority and licensed by the US Nuclear Regulatory Commission) to produce tritium for use in its nuclear weapons program. Such vertical proliferation is not further addressed in this report because the focus of the current report is on the potential for non nuclear weapon states to proliferate from the commercial nuclear fuel cycle.

The commercial nuclear fuel cycle[3] is inherently associated with a risk that nuclear explosive devices or nuclear weapons can be produced if internationally agreed safeguards arrangements are not followed. It can be argued how easy or difficult it is to proliferate from various steps in the nuclear fuel cycle, but a potential for the nuclear fuel cycle to be used to produce nuclear weapons cannot be avoided. The risk of nuclear weapons proliferation among current methods of producing electricity or process heat is unique to the commercial nuclear (fission) power fuel cycle. This risk can be minimized, but it cannot be eliminated.

With the scope of the current report as defined above, the first task is to identify those nations which are already nuclear weapon states. The main attempt to control risk of proliferation from the commercial nuclear fuel cycle on an international level is the Treaty on the Non-Proliferation of Nuclear Weapons, most often referred to as the "Nonproliferation Treaty" or simply the NPT [IAEA 1970]. The NPT entered into force on 5 March 1970, and includes as signatories nearly all of the nations on earth. The four nations not belonging (or no longer belonging) to the NPT are (note that all four are identified as "nuclear weapon states" below):

- India
- Israel
- North Korea (DPRK)
- Pakistan

Secondarily, there are a variety of multi-lateral arrangements by which transfers of so-called "dual use" equipment (i.e., equipment with legitimate uses apart from nuclear weapons production) are controlled. These multi-lateral dual use arrangements include the following:

- The Nuclear Suppliers Group (NSG), http: //www.nsg-online.org/.
- The Zangger Committee, http: //www.zanggercommittee.org/Zangger/default.htm.

[3] The nuclear fuel cycle comprises the following steps:
- Mining and milling of uranium ore, and its conversion to yellowcake.
- Production of either natural uranium metal or uranium hexafluoride (UF6) as a prelude to enrichment.
- Enrichment of the uranium-235 fraction from the natural state (0.7 % U-235) to 3 %-5 %.
- Production of nuclear fuel and its "burnup" in a power reactor.
- Removal of "spent" fuel from the reactor and cooling in a spent fuel storage facility.
- Transport of the spent fuel to a reprocessing facility (if used) for separation of plutonium for recycling in mixed oxide (MOX) fuel, and vitrification of the resulting high level waste.
- Preparation of spent fuel and/or vitrified waste for disposal.
- Disposal of the spent fuel and/or vitrified waste in a geological repository.
- Preparation of spent fuel and/or vitrified waste for disposal.

There are also a variety of additional bilateral and multilateral arrangements and agreements by which proliferation of nuclear weapons is sought to be controlled. These arrangements are widely described and need not be enumerated here [Federation of American Scientists][4].

For the purposes of this report, "nuclear weapon states" are identified based on the following four criteria:

1. The state is known to have nuclear weapons by virtue of its own admission and by the conduct of one or more nuclear tests.

2. The state has publicly declared that it has nuclear weapons, and this claim is widely acknowledged to be correct despite the absence of a nuclear test.

3. The state is strongly suspected of having nuclear weapons, and this suspicion is widely held to be correct notwithstanding the silence or contrary statements of the government.

4. The state previously had nuclear weapons, but has since decommissioned these weapons (the decommissioning having been verified).

Based on these criteria, there are ten nuclear weapon states:

- China (criterion 1; also an NPT Nuclear Weapon State).
- France (criterion 1; also an NPT Nuclear Weapon State).
- India (criterion 1).
- Israel[5] (criterion 3).
- North Korea (DPRK)[6] (criterion 2)[7].
- Pakistan (criterion 1).
- Russian Federation (criterion 1; also an NPT Nuclear Weapon State).

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[4] See, for example:
- Federation of American Scientists on "Arms Control Agreements" [http: //www.fas.org/nuke/control/index.html]
- Arms Control Association's Web page on "Treaties" [http: //www.armscontrol.org/treaties]
- Center for Nonproliferation Studies, http: //cns.miis.edu/pubs/inven/index.htm, Monterey Institute of International Studies.

[5] Israel refuses to comment concerning speculation that it has a large number of nuclear weapons. Nonetheless, Israel is widely suspected of having 75-200 (or more) nuclear weapons of various types (Cirincione 2003; Farr 1999; Hersh 1993; Norris 2002; Sublette 2001; UIC 2004; WP 1996).

[6] North Korea claims to have nuclear weapons. Although this has not been independently verified, and North Korea has not conducted a nuclear test, there is no substantial reason to suspect that their claim is not correct. The US Central Intelligence Agency has concluded that North Korea has a small number of nuclear weapons (Niksch 2003, Shea 2004).

[7] Editor's Note: North Korea conducted an underground nuclear test on 09 October 2006.

- South Africa[8] (criterion 4).
- United Kingdom of Great Britain and Northern Ireland (criterion 1; also an NPT Nuclear Weapon State).
- United States of America (criterion 1; also an NPT Nuclear Weapon State).

Not included in this list are nations which were formerly part of the Soviet Union and which, upon independence, returned the Soviet nuclear weapons to the Russian Federation (Belarus, Kazakhstan and Ukraine). Also not included in this list are nations in which nuclear weapons were based but which did not belong to the country in question (this was a relatively long list of countries during the era of the "Cold War", and still includes a number of countries).

The rest of this report addresses the potential for the commercial nuclear (fission) fuel cycle to be used to produce nuclear weapons in countries other than the ten nuclear weapon states identified above. Readers interested in the details of nuclear weapons programmes of the ten nuclear weapon states will have no difficulty in finding an abundance of publicly available documentation on this subject.

It should be noted that notwithstanding the risk of proliferation from the commercial nuclear fuel cycle, in the main the ten nuclear weapon states listed above have dedicated facilities and programs (China, France, Pakistan, the Russian Federation, South Africa, the United Kingdom, and the United States) or high power research reactors (India, Israel & North Korea) to produce nuclear weapons materials. There are however some cases that have crossed the boundary and for which some would argue represent cases of proliferation from the commercial nuclear fuel cycle[9].

7.1.3 A Note Regarding Uniform Resource Locator (URL) Addresses in the References

Many of the references to this report (enumerated in Chapter 8) include Uniform Resource Locator (URL) addresses which – at the time the report was written – contained the reference in question. No doubt most readers are well aware of the transient nature of URLs – URLs frequently change. For all references, as complete a citation as is feasible has been provided to aid the reader in locating the document in question. URL addresses are provided where applicable, subject to the proviso that these World Wide Web addresses frequently change.

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[8] South Africa developed six gun-type highly enriched uranium (HEU) nuclear weapons (as well as parts for a seventh) before dismantling these devices and acceding to the Nonproliferation Treaty as a non-nuclear weapon state (Albright 1994; Albright 2001; Horton 1999; NTI 2004a; Von Baeckmann 1995).

[9] The United States is currently using special assemblies in the core of the Watts Bar Nuclear Power Plant to produce tritium for the nuclear weapons program. In addition, the United States produced electric power for grid distribution at the Hanford "N-Reactor", which was a production reactor. The United Kingdom also used production reactors to produce electrical power for the power grid. In addition, both the United States and India have each conducted at least one nuclear test using "reactor-grade" plutonium.

7.1.4 Document Organization

The remainder of the document is organized as follows:

- Section 2 discusses in more detail the potential proliferation vulnerabilities of different parts of the nuclear fuel cycle, and highlights some specific proliferation vulnerabilities.
- Section 3 delves into the issue of how difficult it is (or is not) to design, develop, deploy and deliver nuclear weapons, addressing along the way how far a potential proliferator could go and remain undetected before fielding nuclear weapons.
- Section 4 identifies countries that can be considered to be "nuclear capable" and provides the rationale for this designation.
- Section 5 provides a summary, conclusions and recommendations.
- Section 6 consists of the references for the report (along with, where available, URL addresses for the documents).

For an abbreviated primer on nuclear weapons and proliferation see [Sholly, St. 2006].

7.2 Potential Proliferation Vulnerabilities of the Commercial Nuclear Fuel Cycle

Numerous books have been written on the subject of proliferation vulnerabilities of the commercial nuclear (fission) fuel cycle. Readers wishing a full treatment of this subject should consult one of these books. The object here is to simply identify the principal potential proliferation vulnerabilities of the commercial nuclear fuel cycle.

In order to produce and deploy nuclear weapons, one must: (a) have a workable design and be able to fabricate it; (b) have the required nuclear material; and (c) have the means to deliver the weapon to the target. The picture that emerges from the literature is that items (a) and (c) are relatively easy - the hard part of producing nuclear weapons is obtaining the necessary nuclear material. In order to produce a nuclear weapon, one needs highly enriched uranium (HEU; either U-235 or U-233), "weapons-usable" plutonium, or Neptunium-237 in order to produce a nuclear weapon[10].

Production of a nuclear weapon design can proceed quite separately from the availability of nuclear materials, however the design must of course consider the nuclear materials that are being sought or are planned to be produced. A nuclear weapon design, while of course representing a precondition to producing a weapon, is independent of the nuclear fuel cycle and

[10] There is a great deal of dispute and misunderstanding about the weapons usability of Neptunium-237. Neptunium-237 is a fissile material, and is identified as such in US DOE (e.g., DOE Order 5480.3, Safety Requirements for the Packaging and Transportation of Hazardous Materials, Hazardous Substances and Hazardous Wastes, 9 July 1985; http: //packages.llnl.gov/doe_ord/054803.pdf and IAEA standards. Neptunium-237 is recognized as fissile in other literature as well (Rothstein 1999; Albright 1999), and the experiment at Los Alamos National Laboratory in September 2002 which established the base critical mass of Neptunium-237 has definitively settled the issue (LANL 2002).

can be embarked on without yet having the nuclear fuel cycle stages in place upon which one would ultimately rely to produce the needed nuclear material for the weapon.

Similarly, the means of transporting a nuclear weapon to the intended target also are independent of the nuclear fuel cycle. Studies and production of the means of weapon delivery can proceed apart from the nuclear fuel cycle (with the proviso that the means of delivery must match up with the design in terms of size and weight limits).

This Chapter then focuses on the vulnerabilities of the commercial nuclear fuel cycle from which one could proliferate the nuclear material(s) desired to produce nuclear weapons. Bearing in mind that this report focuses only on the commercial nuclear fuel cycle (dedicated nuclear weapon material production facilities and research reactors are excluded from the scope of the report), the following are the principal points of vulnerability for nuclear weapons proliferation [May][11]:

- Direct enrichment of uranium hexafluoride (UF_6) to HEU.
- Processing fresh LWR fuel (already enriched to 3 % to 5 % Uranium-235), production of uranium hexafluoride and completion of enrichment to HEU level.
- Reprocessing of spent fuel to recover weapons-usable plutonium and/or Neptunium-237.
- Retrieval of spent fuel from a high level waste repository and recovery of weapons-usable plutonium and/or Neptunium-237.

In the first case above, UF_6 feedstock nominally intended for the commercial nuclear fuel cycle can be enriched to HEU instead of stopping enrichment at low enriched uranium (LEU) intended for reactor fuel. In the latter three cases above, these actions can result from diversion of materials from the commercial fuel cycle or from theft.

The first and third cases above are relatively straightforward. Direct enrichment of UF_6 feedstock to HEU requires more time and more energy than stopping enrichment at levels typical of commercial reactor fuel (three to five percent Uranium-235). Reprocessing of spent fuel to recover weapons-usable plutonium and/or Neptunium-237 is also a straightforward manner. Retrieval of spent fuel from a repository and reprocessing it to recover weapons-usable plutonium and/or Neptunium-237 is just a variation on the case of taking the spent fuel from storage. Some further remarks on all four cases will illuminate the relative difficulties involved.

7.2.1 Direct Enrichment of Uranium Hexafluoride to HEU

When uranium enrichment was performed with gaseous diffusion plants and electromagnetic isotope separation (EMIS), enrichment facilities were so expensive to construct and so expensive (in terms of electricity supply) to operate that only a few countries operated uranium enrichment plants and these were already countries which had nuclear weapons. (This did not, however,

[11] The abuse of a Light Water Reactor for proliferation purposes for plutonium production is well described in Diversion and Misuse Scenarios for Light-Water Reactors, Chapter 5 in (May 2001). However, this work assumes that the plutonium route is the most important vulnerability. Considering the discussion below, it is far from evident that this is the case.

prevent Iraq from attempting to enrich uranium using EMIS technology [Albright 1991; Gsponer 1995; Gsponer 2001][12].)

With the advent of other methods of enrichment, however, this restriction no longer applied and it became feasible for other countries with lesser resources and infrastructure to pursue uranium enrichment. In particular, gas centrifuge technology [Oelrich][13] has been spread around the world[14]. Other uranium enrichment technologies that have been used include atomic and molecular laser isotope separation and aerodynamic separation using a vortex tube (successfully used in the South African nuclear weapons program; but this also requires large amounts of electricity).

It no longer requires billions of dollars of investment and hundreds or thousands of megawatts of electric power to accomplish uranium enrichment on a scale that enables a small nuclear weapons program to proceed. The change in scope and scale of uranium enrichment, and the change to making HEU available for weapon design together with the effect of this on the ease of producing nuclear weapons is well explained by Oelrich [Oelrich 2004]:

"A proliferator has two routes leading to a bomb, one exploiting plutonium, the other uranium. Plutonium does not occur naturally and has to be created in a nuclear reactor but, once made, it is easy to separate. But the bombs that use plutonium are much harder to design and manufacture. On the other hand, the simplest uranium bomb, in which one slug of uranium is shot into another, thus called a "gun-assembled" bomb, is quite simple indeed. But the required bomb-grade uranium has been very difficult to prepare, requiring huge, energy-hungry gaseous diffusion plants. Thus, either route presented a would-be proliferator with at least one big technical hurdle, either the bomb or the material. Moreover, the production of either nuclear material required plants that are distinctive and difficult to conceal.

Modern gas centrifuges change this picture. They make the separation of the fissionable uranium-235 much easier and cheaper than it would be using gas diffusion, even potentially easier than producing plutonium, so the easiest route to getting bomb material has become aligned with the simplest gun-assembled bomb design. Modern centrifuges open up a nuclear option for a new group of proliferators with only moderate technical sophistication, such as Iraq, Iran or North Korea. Moreover, centrifuge enrichment plants are modular, much smaller than gas diffusion plants and use potentially just five percent[15] of the electrical power of a gas diffusion plant. Thus, they not only make the development of nuclear weapons easier, they make more difficult both the monitoring of supposedly peaceful uranium enrichment for nuclear power and the detection of clandestine bomb-making programs".

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[12] The lesson to be learned from this experience is not to get blinded by high technology means of accomplishing nuclear weapons proliferation when lower technology means exist. The means of proliferation do not have to be efficient and state-of-the-art to work - they merely have to work at a cost and rate which matches the means and patience of a potential proliferator.

[13] Gas centrifuges work by introducing UF_6 gas into an evacuated chamber with a high speed, "frictionless" rotor. The heavier U-238 bearing gas is more concentrated at the edge whereas the lighter U-235 bearing gas is more concentrated at the center. See, for example, Institute for Science and International Security, "What is a Gas Centrifuge", 2003; http: //www.exportcontrols.org/centrifuges.html; and Federation of American Scientists (Oelrich 2004).

[14] Including Germany, Iran, Iraq, Japan, Libya, Netherlands, North Korea, Pakistan, the Russian Federation, the United Kingdom and soon in the United States (Boureston 2004; CIA 2003; CIA 2004; FAS 2000; Green 2003; DOD 1998).

[15] The Federation of American Scientists estimates that the difference is as little as 2.5 % - they estimate that the electricity requirement for a "separative work unit" (SWU) of uranium enrichment using gaseous diffusion is round 2,400 kWh, while the same requirement for a gas centrifuge plant is only 60 kWh (FAS 2000; DOD 1998).

7.2.2 Processing Fresh LWR Fuel to Uranium Hexafluoride and Completion of Enrichment to HEU

Although it is evidently well known within the confines of the industry, it is not generally known that once uranium has been enriched to the levels typical of light water reactor fuel (that is, enriched in Uranium-235 fraction in the range of 3.5, more than 80 % of the total enrichment work needed to HEU from natural uranium has already been accomplished [Sokolski 2003]. Based on estimates from the Non-Proliferation Education Center [NPEC 2003; Sokolski 2003], a country could start with the initial fuel load for a 1000 MWe LWR and use this as feedstock for further enrichment.

Assuming a 20-kilogram HEU core for an implosion weapon, 50 nuclear weapons could be produced at a rate of one per week with 11,000 centrifuges or a rate of one every two days with about 44,000 centrifuges. Assuming rejection of "tails" from the process at 2 % Uranium-235 content, there would be an additional 1700 kg of Uranium-235 in the tails, much of which could be recovered at a slower rate through continued enrichment and rejection at a lower tails concentration.

This calculation provides some indication of how further enrichment of LEU reactor fuel could be used to produce nuclear weapons. If the process is started with a higher enrichment level (e.g., 5 % enriched LEU for a longer fuel cycle), the rate of production of weapons would be somewhat faster. Obviously, if a smaller or greater number of centrifuges were used, the rate of production of weapons would vary accordingly.

7.2.3 Reprocessing Spent Fuel to Recover Weapons-Usable Plutonium and/or Neptunium-237

The reprocessing of spent fuel to recover weapons-usable plutonium and/or Neptunium-237 is well addressed in the literature in terms of a dedicated, engineered reprocessing facility. The extraction technologies are matters of public record (the PUREX process for plutonium, and a variant thereof for the Neptunium-237).

But how hard would it be for a subnational group to accomplish this? The answer is provided in a special proliferation vulnerability team study performed for the US Department of Energy by experts from four national laboratories (Sandia, Lawrence Livermore, Los Alamos and Savannah River). In short, the pertinent facts and opinions of this group are as follows [Hinton 1996: 9,15, 4-3, 4-4, 4-6]:

- The threat of unauthorized parties attempting to illicitly acquire plutonium-bearing material, whether by overt forcible theft or covert diversion, and to recover plutonium metal sufficient for nuclear explosive devices was considered to be "*quite credible*".

- The technology for extracting plutonium from spent fuel is in the open literature.

- The technology required to extract the plutonium represents a "*rather simple process*" that can be operated by an adversary group in a makeshift or temporary facility, such as a warehouse or small industrial plant.

- The resources required for extracting a significant quantity of plutonium from spent fuel using this technology are relatively modest.

- A small, well-prepared group could recover enough plutonium from spent fuel for a nuclear device within four to eight weeks.

- Four persons with appropriate qualifications would be required for the operation to extract plutonium from spent fuel.

7.3 How Difficult is it to Make a Nuclear Weapon?

7.3.1 General Considerations

During World War II, the United States "Manhattan Project" developed four nuclear weapons and the related plutonium production and uranium enrichment technologies in a three-year period with the expenditure of $ 2 billion (1945 dollars) and the work of thousands of scientists and engineers. About forty years later, South Africa produced six nuclear weapons at a cost of about $ 1 billion (1980 dollars) with the work of 400 people and indigenous technology. Clearly, it does not require the replication of the "Manhattan Project" in order to produce nuclear weapons [O'Shei 1976; Stumpf 1995].

The following statements from experts in the field are taken as illustrative concerning the difficulty of producing nuclear weapons:

- *"The relevant technology is increasingly available. In the nuclear domain, much information about the production, fabrication and behaviour at high temperatures and pressures of such materials as uranium, plutonium and beryllium is now in the open literature. Continuing advances in such areas as computers, explosives and precision machining make the task of reinventing nuclear weapons easier. If it is not essential to minimize the weapons' size and weight and to predict its yield, the computational power available in today's personal computers should suffice to develop weapons of all levels of technical sophistication, including thermonuclear ones, with only minimal full-scale nuclear testing. Relatively unsophisticated fission weapons might be stockpiled under such conditions without any nuclear testing, especially if a range of non-nuclear testing methods is available."* [Cohen 1991]

- *"Once adequate quantities of enriched uranium or plutonium are available, the problem of fabricating a simple fission weapon should not prove too difficult for any state that has developed even a modest level of competence in the nuclear field. The basic design features of first generation fission weapons are now widely known. A small number of scientists and engineers whose experience was derived from a peaceful nuclear power program could develop a workable design. The actual fabrication of a device would require a small team of fairly qualified experts in a number of fields with access to laboratory and fabrication facilities using easily obtainable equipment."* [Goldberger 1985: 229]

- *"Once weapons-usable material has been acquired, actually designing and manufacturing weapons is the next issue. Compared to the problem of manufacturing fissile material, this is comparatively easy however. The fundamental technologies to actually build a weapon is possessed by any nation with a significant arms industry (that is, virtually any country with a significant military). The technologies used to actually build the weapons employed by the US in WWII are crude by today's standards, and are widely available. ... Virtually any* *industrialized nation today has the technical capability to develop nuclear weapons within several years if the decision to do so where made. Nations already possessing substantial nuclear technology and arms industries could do so in no more than a year or two. The larger industrial nations (Japan and Germany for example) could, within several years of deciding to do so, build arsenals rivalling those planned by Russia and the U.S. for the turn of the millenium following the implementation of START II. It is also very likely that most any country with advanced military capabilities system will have undertaken design work in nuclear weapons to some extent. This is almost mandatory for national security reasons, if only to provide indigenous expertise in evaluating intelligence and projecting the capabilities of possible foes.*" [Sublette 2001]

- "*...[T]here are very simple nuclear weapon designs available to a potential proliferator. Weapons based on these designs would bear little resemblance to the more advanced weapons deployed by today's nuclear powers, but that is beside the point, since even simple weapons could reliably produce an explosion equal to hundreds or thousands of tons of TNT. That is a much easier task than most people think; the main obstacle has been the difficulty of securing an adequate supply of fissile material.*" [Coté 1996]

- "*A significant point is that a simple fission design would not require testing to prove that it would work. The only debate would be about the yield.*" [Hinton 1996: 4-7]

- "*Although weapons-grade plutonium is preferable for the development and fabrication of nuclear weapons and nuclear explosive devices, reactor grade plutonium can be used. The technology for recovering plutonium from spent fuel is in the open literature and can be easily adapted for the material forms within the alternatives. The resources required for the recovery of a significant quantity of plutonium are estimated to be relatively modest. The presence of a radiation barrier sufficient to require shielding and the need for chemical processing during recovery provide the greatest discrimination among the material forms. However, a small, well-prepared group could recover sufficient plutonium for a device within perhaps two months. Keeping plutonium inaccessible is the key to proliferation resistance.*" [Hinton 1996: 4-7]

- "*Nuclear weapons testing is not essential now for proliferating nations, as it once was, because information related to nuclear weapons is now widespread. The technological hurdles faced by US weapon designers in the 1940s are long gone. Universities teach courses in physics, engineering, metallurgy and chemistry that can provide a sound basis for a nuclear weapons program. The information superhighway enables researchers in remote locations to access thousands of relevant articles and reports, as well as to seek assistance from experts who, prior to the invention of the Internet, were inaccessible. Advanced computers, although not a prerequisite, are readily available and make weapons design easier. The state of knowledge has also advanced with regard to materials, which makes it easier for a nation to design lighter, less bulky weapons than those built at the outset of the US nuclear weapons program. When combined, these variables make feasible for a nation to design with high confidence a nuclear weapon that, in the not-so-distant past, would have considered relatively sophisticated.*" [Bailey 1998]

It could be that knowledge of the lack of difficulty in fabricating simple fission weapons was a factor in the military strikes against nuclear facilities in Iraq on at least three occasions (by Israel and the United States) and Iraqi airstrikes on the reactor construction site in Iran on seven occasions [Vandenbroucke 1984].

7.3.2 The Nth Country Experiment

In the middle 1960ies, Lawrence Radiation Laboratory (later Lawrence Livermore National Laboratory) conducted what was called the "Nth Country Experiment". This experiment was intended to evaluate whether a non-nuclear country would be able to develop a successful nuclear weapons design from publicly available sources *then* available (i.e., in the middle 1960s).

The three-person team, all with Bachelor's degrees, deliberated selected a spherically symmetric plutonium implosion design because it was more difficult. One of the three members of the team quit and was replaced by an Army Lieutenant with a PhD [Stober 2003][16].

A total of three person-years of effort was expended on the design [Frank 1967]. Their design was characterized as too big for a missile, but small enough to be carried on an airplane or a truck. The design was never tested in nuclear detonation, but it was evaluated using the nuclear weapon codes in use at the time, and it was concluded that it was a viable design [Stober 2003].

According to one published report, the Nth Country experiment was successful in that a viable design was produced [Pethokoukis 2003][17]. As that author observed [Sublette 2001]:

"In the years since, much more information has entered the public domain so that the level of effort required has obviously dropped further. This experiment established an upper limit on the required level of effort that is so low that the hope at lack of information may provide even a small degree of protection from proliferation is clearly a futile one."

7.4 Nuclear Capable Countries

This Section of the report identifies "nuclear capable" countries. It also identifies countries with "breakout capability". For the purposes of this report, a country is considered to be nuclear capable if it possesses the requisite technical knowledge and industrial capacity to produce nuclear weapons, as well as a source of weapons usable nuclear material. It should be observed that since nearly all nations (with four exceptions, all of which are already nuclear weapon states) belong to the NPT, transitioning from a nuclear-capable country to a nuclear weapon state would require either breaking treaty commitments (which has occurred on several occasions), or opting out of the NPT with 90 days notice as North Korea recently did (the first country to do so).

A designation of a country as nuclear capable in this report is not a statement of the intention of that country to produce nuclear weapons. The purpose here to assess the capability but not the intent of non nuclear weapon states to produce nuclear weapons from the commercial nuclear fuel cycle. No inference of intentions is either intended or can reasonably be inferred from this report. Nonetheless, some of the states designated as nuclear capable in this report have had political or military experts, or organizations, which have in the past expressed an interest or desire that their country produce nuclear weapons, or in some cases the nations have had nuclear weapon programs which have since been terminated.

[16] The group of three initially consisted of David Dobson, David Pipkorn (who left after a few months) and Robert Selden (Stober 2003). Selden was later to become part of the Nuclear Emergency Search Team (NEST), working at Lawrence Livermore National Laboratory and later at Los Alamos National Laboratory.

[17] A story which ran in US News & World Report indicated an estimated yield of 15 kilotons (Pethokoukis 2003).

It should be noted, in viewing the list of "nuclear capable" states, that simply possessing an operating nuclear power plant in most cases confers "nuclear capable" status on a state. Spent fuel from light water reactors (PWRs, BWRs, RBMKs and VVERs) and pressurized heavy water reactors (PHWRs) can be reprocessed using *ad hoc* methods to recover plutonium to be used in the fabrication of nuclear weapons [Hinton 1996]. Factors which further affect nuclear capability include the following:

- Presence of a national nuclear research institute or institutes.
- Presence of a large nuclear infrastructure (e.g., nuclear-related equipment suppliers, nuclear utility engineering staff, consulting nuclear engineering industrial companies, nuclear services organizations, etc.), especially a reactor vendor.
- Presence of nuclear fuel cycle facilities, especially uranium enrichment facilities.
- A reprocessing facility foremost, or at least prior or current experience or research programs in spent fuel reprocessing, or in partitioning and transmutation. The presence of existing hot cells could facilitate reprocessing activities on an ad hoc basis.
- University departments or national science academies in nuclear physics and/or nuclear engineering.
- Presence of defence industries, especially in the areas of high explosives.
- Previous or current experience as a nuclear weapon host state, providing storage or basing of nuclear weapons from another country.

A summary list of "nuclear capable" states is provided below in Table 4.1. Note that this list is based on the potential to proliferate solely from the commercial nuclear fuel cycle. There are other states that are capable of proliferating from large research reactors [Cordesman 2003][18], as India, Israel and North Korea have done. This list was created considering a large number of references[19] as well as interpretations of these references by the author of the current report. Twenty-six "nuclear capable" states are identified, of which fourteen are considered to have "breakout" capability.

[18] One current suspect for such a proliferation route is Algeria (Cordesman 2003; WP 2004; SIPRI 2004).

[19] Among the key references are the following: CEIP 2004; DOD 2001; NTI 2004b; Sublette 2001. In addition, in cases where they were readily available, the National Reports filed by the countries for the Convention on Nuclear Safety and the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management were used as primary factual resources.

Tab. 7-1 **NUCLEAR WEAPONS CAPABLE STATES**

Argentina	Finland	Lithuania	**Spain**
Armenia	**Germany**	Mexico	**Sweden**
Belgium	Hungary	**Netherlands**	**Switzerland**
Brazil	**Iran**	Romania	**Taiwan**
Bulgaria	**Italy**	Slovak Republic	**Ukraine**
Canada	**Japan**	Slovenia	
Czech Republic	Kazakhstan	South Korea	

Some of these states have „breakout" capability; that is, the capability to produce a large number of nuclear weapons (of the order of dozens or more) in a very short period of time. Those states which are considered to have such breakout capability are shown in bold text in the table above. As with the designation of a state as nuclear capable, the designation of a state having breakout capability does not reflect an intention - merely the capability to do so.

7.5 Summary and Conclusions

The purpose of this report is to provide a perspective on the potential nuclear weapons proliferation pathways available from a commercial nuclear (fission) power plant fuel cycle, considering all the steps from mining to final waste disposal (including reprocessing and recycling). For the purpose of this document, proliferation is defined as "*the spread of nuclear weapons, nuclear weapons materials and nuclear weapons technology*".

This report does not address, except in passing, proliferation arising from other aspects of nuclear sciences (such as research reactors, accelerators, etc.). Proliferation pathways potentially arising from fusion power concepts are also not addressed. Finally, this report also does not address radiological dispersal devices (so-called "dirty bombs").

The commercial nuclear fuel cycle is inherently associated with a risk that nuclear explosive devices or nuclear weapons can be produced if internationally agreed safeguards arrangements are not followed. It can be argued how easy or difficult it is to proliferate from various steps in the nuclear fuel cycle, but a potential for the nuclear fuel cycle to be used to produce nuclear weapons cannot be avoided. The risk of nuclear weapons proliferation among methods of producing electricity or process heat is unique to the commercial nuclear (fission) power fuel cycle. The risk can be minimized, but it cannot be made to "go away".

There are ten nuclear weapon states: China, France, India, Israel, North Korea (DPRK), Pakistan, the Russian Federation, South Africa (which has decommissioned its weapons and joined the NPT as a non-nuclear weapon state), the United Kingdom and the United States. The question here is whether there is a potential for the commercial nuclear (fission) fuel cycle to be used to produce nuclear weapons in countries other than the ten nuclear weapon states identified above.

The answer to this question is clearly yes. Limited solely to consideration of the nuclear fuel cycle, this report identifies twenty-six other countries which are "nuclear capable" - that is, possessing sufficient technical and industrial capacity along with a source of weapons usable nuclear material (spent reactor fuel or separated civil plutonium, or the enrichment capability to produce highly enriched uranium) such that they could (if a decision were taken) produce nuclear weapons. Fourteen of these twenty-six states (nearly half) are considered to have "breakout" capability – the capability to produce a large number of nuclear weapons very rapidly if a decision were taken to do so.

Nuclear weapons, especially first generation nuclear weapons of the type used by the United States in the Second World War (and developed by several countries since then), are not as difficult to produce as is commonly believed. Indeed, this is so much so that it is broadly believed within the non-proliferation community that the only thing standing between a country and nuclear weapons is the need for weapons usable material.

It is true that none of the ten existing nuclear weapon states have achieved this status based on a commercial nuclear power program. Rather, they have used dedicated weapon material production facilities or (in a two cases) research reactors for this purpose. As this report has pointed out, however, the commercial nuclear fuel cycle provides two principal means of proliferation – from enrichment facilities (by means of HEU), and from reactor spent fuel (by means of reactor grade but weapons usable plutonium). In addition, Neptunium-237 (which can also be recovered by reprocessing) is also weapons usable.

As this report has highlighted, diversion of fresh low enriched reactor fuel (about 3.5 %) to further enrichment can provide a very fast enrichment path to HEU because at 3.5 % enrichment, over 80 % of the total enrichment work required to get from natural uranium to 90 % enriched HEU is already accomplished by the time the fuel is enriched to 3.5 %. Obviously, at higher enrichment levels typical of reactors with long fuel cycles (18-24 months instead of 12-15 months), the figure is even greater than 80 % complete.

Weapons made from reactor grade plutonium, unless adapted by tritium boosting and other modifications to the design, would be expected to have a greater potential than weapons made from weapons grade plutonium to predetonate and result in less than full yields – even so-called "fizzle" yields are possible. However, fizzle yields are not trivial and certainly not a "dud". The minimum expected fizzle yield for an implosion weapon fabricated from reactor grade plutonium is of the order of one kiloton. A one kiloton yield is still 4000 times larger than the explosion of a typical 500-pound military bomb, and if detonated in a large city would have devastating consequences.

It is clear that there is a proliferation potential associated with the commercial nuclear fuel cycle that is unavoidable with current and near-term technology. Even in the best cases of future technology, the proponents of the technology call it "proliferation resistant" – not "proliferation-proof".

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8 Timeliness of the Nuclear Energy Option

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September 2006

Content

8 Timeliness of the Nuclear Energy Option

8.1 Introduction

The nuclear option is often hailed as a valuable contribution towards achieving the aims of the Kyoto Protocol: by replacing fossil fuel technologies greenhouse gas (GHG) emissions by the electric power industry could be reduced. Achieving a substantial contribution however implies a considerable growth of worldwide nuclear capacity.

Under the Kyoto Protocol, countries agreed to individualized reductions of GHG emissions to be met over the 2008 to 2012 period. The question is whether enough new nuclear capacity can be installed in time to contribute to the reductions targets in the short period remaining – not individual nuclear pilot projects, but nuclear capacities of Gigawatt dimensions.

However, it is not only the climate protection discussion that gives the nuclear industry hope for a revival. Some energy scenarios foresee a substantial increase in nuclear power for covering an expected increase in electricity demand caused by economic growth and also for closing the expected energy gap due to foreseeable shortages in fossil fuels (oil, gas). Here again the question is, whether the hoped for increase of nuclear power can be achieved within a reasonable timeframe.

A significant expansion of installed nuclear capacity will be possible only if nuclear energy can overcome the substantial disadvantages it is being charged with – mainly the extraordinary risks involved and the problem of nuclear waste. Of course, it is fair to require that fossil fuels should be replaced with environmentally friendly and sustainable technologies. Contrary to what the nuclear industry sometimes claims, it has not yet demonstrated how the nuclear option will fulfill these requirements.

This paper focuses on the question of timeliness. It examines whether nuclear energy can expand quickly enough to contribute to the solution of the above mentioned challenges. The question of timeliness cannot be treated without at least briefly touching upon nuclear safety, fuel availability and the nuclear waste problem, even though these topics are treated in other papers in this publication. These aspects are very relevant for the question of timeliness, because they strongly influence the time needed for the development of new reactor types before entering commercial operation.

To clarify the question of timeliness would require an examination of the entire fuel cycle from the mining activities to the final repositories of radioactive waste and the complete system of facilities, equipment and operational structures. Needless to say, each step in the chain of production would have to multiply its efforts, accompanied by far-reaching technological improvements, to make a timely growth of nuclear possible. This raises a number of questions:

- How large a share of the total energy demand should and can nuclear power deliver in the time period until 2020? What will the necessary framework look like in this period? Which direction of development would the nuclear industry have to embark on?

- Are the optimistic assumptions promising a revival and a significant expansion of existing nuclear capacities in the near future justified or overoptimistic when looking at the potential for growth of the involved industry branches and of the work force of trained personnel?

- Are the mentioned increases for this period realistic or will there be delays in the implementation, the market introduction and testing of new reactor concepts? Will uncertainties dominate planning and expectations not be fulfilled?

- Is it possible for the financial markets to provide the exorbitant investments needed? Are the high initial investments still an effective deterrent?

It is not possible here to conduct a thorough analysis of these questions, however, some substantial aspects critical to timeliness will be discussed. If the discussion of these issues casts doubts concerning the timeliness of the nuclear option, it is not necessary to examine the other aspects.

Lastly, we need to point out that most of the data cited is of high uncertainty due to discrepancies between the sources used and to the inherent uncertainty of forecasts for extended time periods.

8.2 Requirements

8.2.1 Size of Capacity

To answer the question what the potential demand for nuclear energy will be in the future, three basic factors are considered:

- the emission reductions needed to combat climate change,

- the increase in electricity demand and,

- the expected energy gap as a consequence of a gas and oil shortage.

The number of nuclear power plants that will be taken from the grid within the time period considered after having reached the end of their service life and that therefore need to be replaced is an additional factor.

The emission reductions necessary to mitigate climate change are not limited to the 5 % Kyoto Protocol aim for the first commitment period (2008-2012) because an increased contribution by nuclear in the remaining 6 years is no longer possible. Rather, the reductions decided upon for the post-Kyoto period must be considered, even if the final numbers are still being negotiated. Climatologists claim that at least 30 % reductions of Greenhouse Gas emissions compared to 1990 are necessary by 2030 and 60 - 80 % worldwide by 2050 to make a global temperature rise of more than 2 °C unlikely. When these percentages are applied to CO_2-emissions from electricity generation this implies that CO_2-emissions in 2030 must be about 2,100 kt lower than 1990. Based on present emission factors[1] and the assumption, that the reductions are achieved by replacing fossil fuels solely by nuclear energy this implies that in 2030 about 3.000,000 GWh must be produced additionally in nuclear plants or at least 435 more NPPs[2] must be in operation than today. Assuming optimistically that the first new power plants could begin operation in 5 years,

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[1] For the present mix of fossil fuels in Germany this is 0.73 kt CO_2/GWh and for nuclear power plants 0.025 kg CO_2/kWh is assumed.

[2] For an 80 % load factor and 1GWe installed capacity per NPP. Reserve requirements for peak loads are not included in the calculations.

i.e. 2012, then 24 NPPs would have to start operation per year. This also would result in almost a doubling of the present number of power plants, but with a higher capacity for most of them. These calculations do not take account of shut downs of existing plants nor of demand increase.

Currently, around 2 billion people do not have access to electricity, a situation which, according to international declarations of intent, should be rectified as soon as possible. Accordingly, electricity demand will increase much quicker than total energy consumption: projections vary considerably, but a doubling of demand by about 2030 is frequently assumed. The IEA [IEA 2004] estimates an additional demand of around 1400 to 1700 GWe of power generation capacity for the period 2000 to 2020, and a further 1000 to 1300 GWe by 2030. If the current share of nuclear, around 16 %, is to be maintained, an additional 480 to 600 new NPPs need to be put in operation by 2030[2]. Assuming again optimistically that the first new power plants could begin operation in 5 years then 27 to 34 NPPs would have to start operation per year – that is one ever 10 to 14 days – most of these in the developing world. In these calculations nuclear does not contribute to the reduction of CO_2 by replacing fossil fuels nor are compensations for shut downs of nuclear power plants taken into account.

If nuclear power is to contribute a larger share (more than 16 %) towards demand growth or towards closing the energy gap due to foreseeable oil and gas scarcities, e.g. through nuclear production of hydrogen, correspondingly higher capacities would be needed.

Assuming NPP service lives of 40 years[3] and a 5-years construction time for all plants presently under construction the installed capacity would drop under 100 GWe by 2030 [Zittel 2006]. This means that just to sustain the present production level about 260 GWe are required, that is 18 new NPPs per year.

To simultaneously compensate the shut down of older power plants, support future electricity demand growth – with the current 16 % share – and decrease CO_2-emissions through boosting the nuclear contribution to a significantly higher level than 16 %, on the order of 70 nuclear plants would have to go into operation per year in the near future – keeping in mind that a simple addition of the above numbers is not permissible. In order to implement nuclear in new fields, such as e.g. hydrogen production for the transport sector, the requirements would be even higher.

One of the scenarios of the Intergovernmental Panel on Climate Change (IPCC) assumes that nuclear power will supply 50 % of worldwide electricity production in 2075 (3000 GWe installed capacity) and 75 % in 2100 (6500 GWe installed capacity). With an assumed lifetime of 50 years it would be necessary to put around 70 reactors into operation per year [Feiverson 2003].

Obviously, it cannot be expected that nuclear energy covers all these needs: energy efficiency increases and alternative energies will supply the largest contribution, and hopefully the projections of demand prove to be overestimations as a consequence of the development of completely new energy policies. These upper bound calculations only serve to demonstrate the size of the problem and to dampen any hopes that nuclear could make a significant and timely contribution to the energy problems in the near future.

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[3] The average life time of decommissioned nuclear power plants, including some very short lived prototypes, is presently 22 years.

8.2.2 Timeframe

For the climate discussion there are two periods that have to be viewed separately: first the initial Kyoto Protocol commitment period (2008-2012), binding under international law; second, the period consisting of the Post-Kyoto-Measures, which is still under discussion. According to a European Union proposal, this would be the periods until 2020 or 2030, until 2050 respectively, during which emission reductions of not yet decided extent should be attained. In other words, for a contribution of nuclear energy to become relevant in the first commitment period, nuclear has to start playing a bigger role in the energy mix in the next 2 to 6 years. For the Post-Kyoto Process, it has another 10 to 40 years.

The time frame resulting from the looming energy gap is of a very similar order of magnitude. The increase in electricity consumption in itself is quite a challenge for the next 20 years, independent of climate protection and possible shortages of fossil fuels.

Thus the question is whether nuclear will be able to contribute substantially in the next one or two, or at the most four decades.

8.2.3 Options

To achieve a larger contribution to energy production, the yield from nuclear power plants must be increased. In the present period of declining yield due to power plants being taken off the grid after having reached the end of their service life, increase means compensation of these lost capacities and additional new capacity.

The decline in yield can be reduced or delayed through life time extensions of presently operating nuclear power plants. This is of importance because the number of nuclear power plants approaching their end of life within the next years is such that a decrease is inevitable in spite of the implementation of new plants. Life-time extensions are the only way to influence the nuclear contribution in the short term defined by the Kyoto agreement. Because of the long construction time for nuclear power plants no nuclear plant that is not yet under construction will feed electricity into the grid within the next 6 years – thus, it must be clear that at most the loss of yield can be delayed.

Market analyses have spurred technological development of new power plant types into two directions:

- "Inherently safe" concepts for up to 1.5 GWe power output and

- Autonomous small installations with outputs in the range of 10 to 100 (300) MWe, [President's Council 2005] allowing largely automatic operation [IAEA/NEA/IEA (2002)].

Research and development on "inherently safe" reactors has been going on for about a decade. They are part of the so-called third and fourth generation nuclear power reactors. Their concepts, their strengths and weaknesses are briefly described in the paper on safety of nuclear power plants. Some Generation III reactors are already in operation, the first Generation IV reactor is not expected to be put into operation before 2020.

The autonomous small stations (comparable with an energy container) will be centrally maintained in a maintenance facility, where they are brought for recharging. The first demonstration plants are scheduled to be ready and licensed by 2015. Commercial introduction will take place after 2020.

Both of these technical developments need time to mature, even if it is likely that there may be synergies from parallel development of new technologies and the operational modes. However, first experience can only be gained after introduction and application.

Apart from the technical challenges, the economic conditions of a liberalized electricity market must be taken into account. Pressure is high to reduce investment and operating costs, even though the increase of fossil fuel prices have brought some relief. The nuclear industry is looking at a range of measures to reduce high investments costs:

- Capturing economics-of-scale;
- Streamlining construction methods;
- Shortening construction schedule;
- Standardization, and construction in series;
- Multiple unit construction;
- Simplifying plant design, improving plant arrangement, and use of modeling;
- Efficient procurement and contracting;
- Cost and quality control;
- Efficient project management; and
- Working closely and co-operating with relevant regulatory authorities.

In this context, it is necessary to mention that of course there are efforts to influence the political conditions in favor of the nuclear option.

These conditions are hoped to produce a climate inductive to investments: attractive conditions to finance high investment costs and avoidance of financial bottlenecks due to exceeding financing needs. It remains to be seen whether the monetary market can accept these conditions under strained financial markets.

8.3 Plant Life Time Extension

In view of the difficulties in licensing new plants due to a lack of public acceptance and because of the investments involved, there is a tendency to extend the life time of existing nuclear power plants. This means that the operation of a nuclear power plant is prolonged beyond the originally licensed or planned operational time frame, towards the technical life expectancy. A wave of applications for licensing renewals for plants facing shutdown in the near future has been handed in.

If all applications are approved, the forecasted decline of nuclear power to 50 % installed capacity could be reduced significantly. Such a development would allow for an additional reconciliation period and – according to nuclear promotion groups – a possibility to achieve both, better design concepts and improved acceptance.

Logically, life time extension will also influence the development of production costs and consumer prices. Continued operation of an old nuclear power plant is usually very profitable because it has been amortized a long time ago.

It should be pointed out that life time extension should be accompanied with special and stricter safety controls since, in general, the probability of failure of components and materials increases with aging. Logically, those plants that are ready for closure are older plants (Generation I and older Generation II plants), which according to Probabilistic Safety Assessments (PSA) have probabilities of severe accidents of a factor of 10 to 100 above the general safety level (see also paper on Nuclear Safety).

In view of timeliness of the nuclear option life time extension of existing power plants represents only a minor relief.

8.4 New Power Plants

At present, the construction period for a standard nuclear power plant (start of construction until start-up of operations) is considered to be in the range of 6 to 8 years as compared to 10 years at the beginning of the construction of the present generation of power plants. However, a substantial expansion of nuclear power can only be considered based on the next or the following generation of reactors (Generation III and IV, today's reactors are generally considered to be Generation II). But for these reactor concepts are available only partly, and for those Generation III reactors that are under construction or running, there is still a lack of experience with design, construction and operation.

Early nuclear energy development showed that safety requirements in some cases demand the application of already tested technology. It is therefore necessary to have gathered operational experience not only with components but also with the system prototypes and with complete plants. It is not possible to allow commercial operation of improved Pressurized Water Reactors (PWR: e.g. EPR) or Boiling Water Reactors (BWR), or "inherently safe" reactor concepts (ISR) before having tested the prototypes in-depth to present them from the very beginning as a sufficiently "tested" technology.

These periods of development and testing have to be added to the construction period, and this can cause a lead time of 15-20 years. Taking into account the extensive know-how regarding design and the operation of nuclear power plants already acquired, it is probably possible to reduce the above mentioned time periods for prototype design, planning and testing of the most advanced prototypes of the NPP concepts now being developed to 8 to 14 years. If those projects were engaged in right now, the start of operation of the first plant would be expected to be in 2020, that is, in the post-Kyoto period.

The timetable laid out here does not allow much space for the further development of the "inherently safe" reactor (ISR), which is meant to be failure tolerant and have advanced passive features for accident consequences mitigation and improved intervention possibilities for accident management. The features protective against severe accidents will require extensive demonstration and appropriate testing. Even after successful plant vintage licensing, a host of prototype tests and evaluations still have to be completed, adding another 7 to 10 years to the schedule. "Inherently safe" reactors can therefore be expected to arrive at the earliest between 2030 and 2040. Only this generation of nuclear power plants can be expected to increase public acceptance for the nuclear energy option.

The timetable for reactors based on completely new physical concepts (e.g. the accelerator-driven high temperature reactor concept) foresees only feasibility tests of separate subsystems in the next few years. These reactors will most likely not be available before 2018, i.e. near the end of the above mentioned time period of 8 to 14 years.

8.5 General Framework

8.5.1 Capacity Development Until Now

Nuclear power reached its maximum increase in 1985 when 31 GWe/y were added. Since then, the growth rate has decreased to between 2 and 9 GWe/y in the past few years.

Currently, the share of nuclear in the total energy production is shrinking and this process is likely to accelerate until about 2020. The reason for this is that the first plants were commissioned in the sixties and average plant life is limited to about 35 years of operation. Very few nuclear plants have been ordered in the last few years and therefore new plants only minimally influence this development.

Until now only 20 % of the 537 nuclear power plants have been retired, and out of these many were prototypes. Their operational lifetime was on average only 7 years. As of October 21, 2004, there were 440 nuclear power plants in operation and 25 nuclear power plants under construction. The installed nuclear electrical capacity was 365.5 GWe, and this would – according to forecasts – drop to 180 GWe around 2024. Embarking on a 2 %/y increase ratio scenario would mean that the initiated decline should lead to a minimum of 294 GWe by 2021, followed by an increase.

Facing this development, it is necessary to ask the question whether it is realistic that the above mentioned need for more than 70 new nuclear power plants per year – even without reference to climate protection policies - can be satisfied. And in fact, the ratio of increase of nuclear capacity starting at the time the new power plants are available, is estimated at about 1-2 %/y [EIA 2004, EIA 2005]. This is significantly below the level necessary to maintain the 16 % contribution to global electricity production, if the EIA growth scenario is assumed.

8.5.2 Know-How and Qualified Workforce

The attractiveness of the nuclear industry, which was once very high, has all but disappeared today, after more realistic estimation of its possibilities have been made and due to the continued lack of orders for nuclear new-builds. The economic development – the quest for a higher shareholders' value and higher profits – caused many producers and operators to reduce the number of employees. Some experienced professionals have retired and some have switched to other sectors. There has been a noticeable reduction of output of nuclear engineering graduates from American and European university courses; many university have substantially reduced their nuclear programs, a number of nuclear research centers have been largely dismantled or reorganized to conduct research into other areas. The attempt to halt this development by starting work on new concepts was successful only to a minor extent. This is a worrisome development for nuclear industry and many IAEA and NEA conferences have addressed the gap of experienced and well trained professionals.

The indispensable contributions made by specialized TSOs (Technical Support Organizations) have – in many instances – been lost because these small companies had to adapt to the market situation and to emerging markets. In many instances they had to abandon former core competence areas in nuclear for new, more profitable ones.

Mergers between various vendors and the realignment of co-operating consortia have alleviated the immediate threat of unavailability of suitable and experienced professionals to the industry, but it has also left some fields of knowledge abandoned, particularly in design.

Modular designs of nuclear power plants, which would be service free for several years of operation, could help to improve the difficult situation regarding trained personnel. Especially, in the context of construction of new plants in developing countries the modular concepts could become important. Increased energy demand and the economic structure could make the construction of nuclear power plants profitable to vendors. The limited availability of a skilled workforce and the low mobility of experienced personnel could, however, become a major problem for conventional nuclear stations.

In a rough estimate it can be assumed that each new power plant project will absorb a skilled workforce of roughly 10,000 over a ten-year period. The operational staff and personnel now used for recurrent maintenance are not the resources needed for the new projects, this aside from the fact that they are needed for the operation of the existing plants. The Technical Support Organizations (TSOs) are also already drawn on by the industry putting them in charge of some plants operations.

Thus, a new generation of skilled and later on experienced personnel must be trained: Basic courses take at least five years; learning to develop new equipment and technologies requires at least another five to ten years of job-oriented training and training on the job. A switch of pre-skilled people from other sectors, where similar skills are required, is made more difficult by the high requirements of the nuclear energy sector concerning safety and durability, which is less developed in other sectors.

The attempt to embark on an enhanced nuclear program immediately, or in the very near future, would therefore most likely fail due to the limited availability of a skilled workforce and the limited mobility of experienced personnel. Timeliness of a substantial nuclear energy expansion can be achieved only with sufficient numbers of experienced staff. However, the current development in the nuclear sector still indicates a loss in proficiency in the nuclear sector.

8.5.3 Economic and Structural Conditions

Technological development depends to a large extent on economic and structural conditions. These changed dramatically in the last few years and will continue to change in the future: a more favorable and quiet climate for the development of nuclear energy is not in sight.

The expansion of large technology companies into global players is not so much a consequence of inner growth, but of mergers with and takeovers of other companies. The primary goal is more efficient production and therefore the focus is on re-structuring and optimization of processes and less on technological development. The relocation of clearly defined technological sub areas to serve corporate strategy aspects, is part of the process that keeps key functions of strategic management in one hand.

At the same time, a counter-current development can be observed, namely the concentration on core competencies and the outsourcing of marginal and specialized sub areas. The number of companies with high reliance on external sources for technology and technological development has for this reason increased over the past decade.

It could be expected that the resulting larger structures have a stabilizing effect enabling a fruitful coexistence between corporations and smaller, more specialized suppliers. It has turned out, however, that the corporations themselves are subject to continuous change, partly due to a widely spread management structure. This in turn leads to a rapid change of partners with highly specialized know-how. Similar to a stormy sea, where small ships cannot dock on huge ships, the small specialized suppliers cannot really benefit from the ever changing big corporations.

These developments can also be observed in the nuclear supply sector. Already in the 1990s, a decrease in the number of manufacturers and technical support organizations (TSO) through mergers could be observed. This was driven by the shrinking market, which was partly caused by a lack of public acceptance for nuclear technology.

This structure is not supportive of a long lived advance of nuclear energy: neither can a stable development of the important TSOs be expected, nor an early consolidation of the large suppliers of nuclear technology.

8.5.4 Market Development

In order to supply timely replacement for existing nuclear power plants, soon reaching their end of life, the ordering of new technologically advanced nuclear power plants would have been necessary many years ago. A number of factors did not encourage this further development: the general lack of orders, the shrinking of the market, the life extension programs for plants in operation, and the financial cutbacks in research and engineering programs sponsored fully or in part by public means.

The situation has since changed, with some markets for nuclear power plants picking up again. However, these are buyer markets, and therefore of limited interest to the nuclear industry, and they are regarded more as confidence-building activities than commercially interesting undertakings.

The question remains, can a market that first has to re-establish itself resurrect a technology, and with it technological know-how? Further, can it be re-established at a quality level necessary for an advanced technology? Above all, can the market accomplish all of this within a short time frame?

8.5.5 Public Acceptance

In some European countries a nuclear critical climate has led to political guidelines (like the act prohibiting nuclear installations in Austria), which were unfavorable to the further development of nuclear power. The critical viewing of nuclear power has not changed substantially until now: An opinion poll by the EU in 2003 (Table 8-1) showed that even under the assumption that nuclear waste could be stored safely, the acceptance of nuclear power as an electricity generation option is under 50 % in 7 out of 15 states, the EU-average is a slim 50 %.

Tab. 8-1 **SHOULD NUCLEAR POWER REMAIN AN OPTION FOR ELECTRICITY PRODUCTION**

	Strongly Agree	Tend to Agree	Tend to Disagree	Strongly Disagree	Average	Don't know	Nuclear Option
Country	Attitude poll results in [%]						
A	8.0	16.6	23.2	38.6	1.93	13.6	5
B	13.1	46.9	11.01	5.9	2.87	23.1	11
DK	29.5	24.7	13.4	25.3	2.63	7.1	4
D-W	12.7	33.3	21.7	14.0	2.55	18.3	16
D-E	11.9	42.1	16.7	9.6	2.70	19.7	19
D	12.5	35.1	20.7	13.1	2.58	18.6	17
GR	19.0	29.4	13.9	8.1	2.84	29.6	2
E	9.0	22.6	17.9	10.0	2.52	40.6	4
F	15.8	43.4	13.6	8.7	2.81	18.6	8
IRL	7.2	30.3	14.8	10.7	2.54	37.0	7
I	13.7	40.8	11.4	6.6	2.85	27.5	13
L	14.9	40.5	18.8	12.9	2.66	12.9	7
NL	30.8	29.4	10.0	14.6	2.90	15.2	14
P	5.7	32.5	12.4	7.6	2.62	41.8	5
FIN	26.5	38.5	14.7	9.5	2.92	10.8	27
S	47.3	26.3	9.9	8.0	3.23	8.5	32
UK	14.0	38.6	13.0	7.9	2.80	26.5	18
EU 15	14.9	35.6	15.1	10.4	2.72	24.0	12
EU 25							12

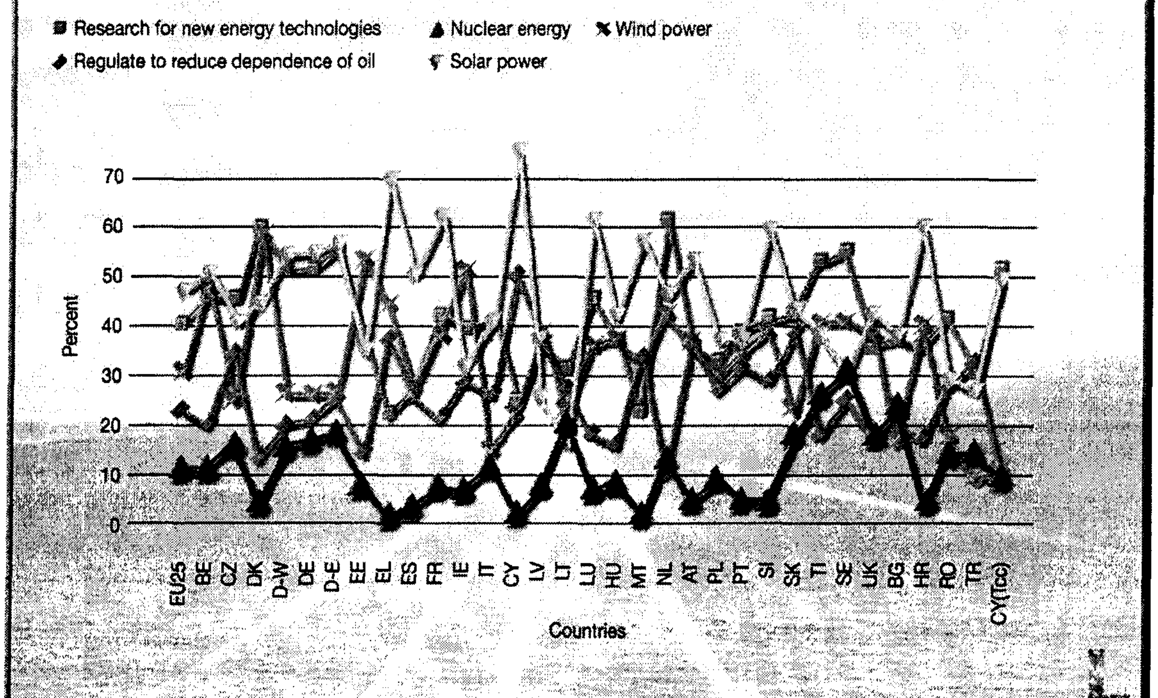
Public Opinion Poll in Europe in response to the question:
„If the waste is managed safely, should nuclear power remain an option for electricity production in the European Union". [Ann Bisconti Research 2003] and the result of a Eurobarometer poll 2006: Which of the following should the (national) Government mainly focus on the years to come to reduce our dependence on imported energy resources?" (last column)

Quelle: Ann Bisconti Research 2003 / EBS 2006

An opinion poll in winter 2005 [EBS 2006] showed that only 12 % of those questioned named enhanced reliance on nuclear energy as an option to reduce dependence on energy imports, even though only five options were offered (solar energy, advanced research on new technologies such as hydrogen, wind energy, nuclear energy and regulatory measures to decrease dependence on oil), and two could be selected. The nuclear option ranged clearly behind all other options in almost all countries (Figure 8-1).

Fig. 8-1 EUROBAROMETER POLL ON THE DEVELOPMENT OF NUCLEAR ENERGY

Result of a Eurobarometer poll on the development of nuclear energy as one of five options to reduce dependence on energy imports, two nominations possible



Source: EBS 2006

However, climate change and energy shortages could lead to a rethinking about nuclear. A rise in acceptance seems to have taken place among politicians and media in the last months. This could grow stronger and the population may also latch on. However, one has to keep in mind that, especially in the past few years, a number of "almost-accidents" ("near-misses") and cover-up affairs have occurred that have shattered the belief in safety and partly also in the integrity of nuclear power plant operators. Moreover, it must also be assumed that the next larger accident will with quite some probability be the final "out" for nuclear power, at least in Europe.

It is therefore currently not possible to give a reliable prediction on the attitude of the public – it is very likely that the strong geographical differences will remain against a background basically critical of nuclear.

8.5.6 Political Conditions

Politicians can support the revival of nuclear energy in multitude of ways, although most of these are not in line with free market economy nor with the liberalized energy market: guaranteeing nuclear its share of electricity production, subsidies, tax concessions, state steps in with liability against delayed start-up, relaxed safety requirements and licensing procedures, cutback of citizens rights, cutback of provisions for waste disposal, discrimination of competing technologies, etc. Some of these and other measures are now being offered in the USA as incentives for the construction of new nuclear power plants. In Europe, some claim that the financing conditions for the construction of the Olkiluoto nuclear power plant in Finland were modified to include some alleviating measures not generally applied.

There are indications that policies towards nuclear might change under the impact of shrinking resources, and that this might be supported not only by the operators but also by the licensing authorities and possibly also a certain part of the population. This could ease and speed up the commissioning of nuclear power plants and contribute to timeliness. However, the licensing authorities would have to make sure that any easing of requirements does not entail a lowering of safety.

Designers and operators understand the need to reduce production costs and operating expenses, and to face the scarcity of resources: risk informed maintenance is an example of more efficient use of the available know-how, personnel, resources, time, etc. This can also be used as a solution to "important things first", when the available maintenance support is insufficient. The extension of refueling periods, maintenance during operation, etc. are other measures taken to lower production costs and use diminishing resources sparingly. In this manner, the personnel need is reduced, which could allow the operation of additional installations with qualified personnel.

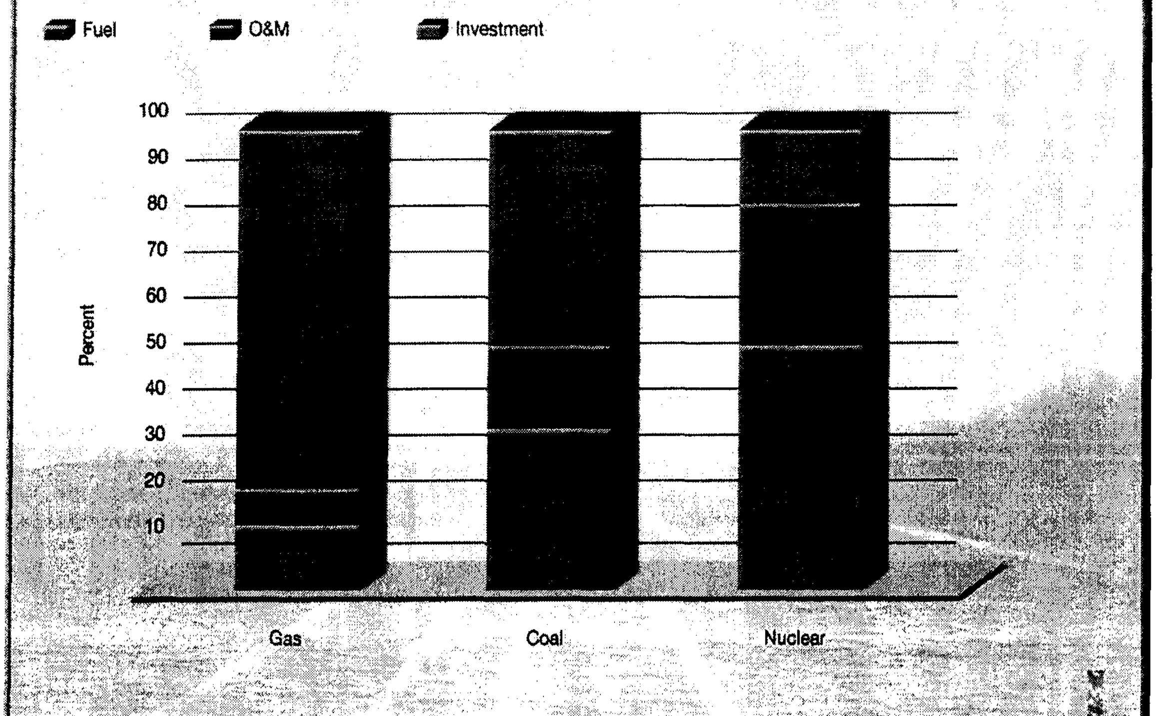
However, more favorable political conditions will not alone be able to substantially speed up the expansion of nuclear energy because they are subject to quick changes. However, at the present crossroad for the future of European energy, politics could create a more favorable climate for nuclear power.

8.5.7 Financial Markets and Investments

The initial investments needed for nuclear power are much higher than for other technologies. According to OECD (Dujardin 2005) the investment costs surpass the sum of operating and fuel costs in nuclear (Fig.8-2). Even though this comparison is strongly dependent on assumptions, mainly concerning fuel prices, and the figures quoted by different sources vary widely, the tendency regarding the relation between investment costs and operating and fuel costs is valid. The rise of fossil fuels costs during the last months reduce the portion of investment costs in non nuclear technologies even farther.

Fig. 8-2 **COMPARISON OF INVESTMENT, O&M AND FUEL COSTS**

Comparison of investment, operating & maintainance (O&M) and fuel costs for several electricity generation technologies



Source: based on data from Dujardin 2005

The problem of high investment costs is aggravated by the high risk potential of nuclear technology and the acceptance problem that nuclear energy is facing. Due to high initial costs, the installation has to stay in operation for a certain, rather long minimum period to provide investors with a return of investment (ROI). The statistics of nuclear power plants built and operated up to now show that a high percentage of plants were shut down long before reaching the end of planned life time – medium life time is currently 22 years, planned life time is 30 to 40 years. The most extreme case is the nuclear power plant on Long Island in the US, which was shut down for good by the authorities a few days after start-up. It is has to be pointed out, however, that the share of very early shut-downs has decreased and that average life time of nuclear power plants has increased in the past years.

With regard to the enormous damage potential and to the critical public, authorities and operators are forced to take very restrictive measures, e.g. to close down a plant for apparently slight reasons, sometimes only because a similar station is having problems (case in point: in August 2006 four Swedish Nuclear Power Plants were shut-down after an incident on July 25th in NPP Forsmark). When power plants repeatedly have to be taken off the grid because of occurring problems, attracting high media attention, attractiveness as an investment option is lost.

One could get the impression that politicians and media are talking about the revival of nuclear energy while energy utilities are much more cautious and investors are still rather disinterested. According to an analysis made by Standard and Poors 2006, the development of a new generation of nuclear power plants in a de-regulated energy market is a highly risky undertaking because of long development times and high capital costs. Siting is nowadays seen as much more sensitive than in the 1970s and 1980s when most plants were built. The political support will remain unreliable and dependent on safety performance worldwide. Basic matters, such as solving the nuclear waste storage and achieving far-reaching social consensus are still viewed as necessary before a wide-ranging nuclear power revival is possible. [Standard and Poors 2006]

For Europe alone the "Business-as-usual" Scenario forecasts a need of investment in the order of USD 2 trillion in the energy sector until 2030, and more than a half of it for electricity (IEA 2003). With such investment offers and investment demands it is hard to believe that the enormously high capital investment needed on short term for a timely expansion of nuclear would be placed in the most insecure of all investment options, nuclear power.

8.6 Nuclear Waste Problem

A substantial expansion of nuclear energy – whether with conventional reactors or fast reactors – will in any case cause a substantial increase of highly radioactive waste. Even though efforts are being made to intensify work on this most controversial topic, it is still far from being solved. There is no solution in sight that the public would approve of.

The problem is of a different quality than the operation of nuclear power plants: is it dominated by incomprehensibly long periods of time during which high-level radioactive nuclear waste (HLW) needs to be taken care of and is therefore a burden on society. German authorities currently demand a verifiably safe storage for one million years. Near surface, retrievable storage is not a solution, but hands over the problem to future generations. Irretrievable repositories in deep geological formations also put the burden on future generations, only with a time delay and the uncertainty whether some future generation, confronted with a resurfacing of nuclear waste will be in a position to handle radioactive materials in these large quantities.

Some other potentially promising concepts to handle HLW would have to be further examined and should – if proven to be feasible – be implemented while nuclear power plants are still in operation. Transmutation of actinides (the fraction of the waste with the most extensive half lives of its isotopes) or "burning" some of the waste will only be considered if there is a financially sound enterprise (a nuclear power plant) to make this profitable. At the same time, the solution must not use up substantial parts of the energy produced in the nuclear power plant. Thus, the solution for HLW must also be considered a time critical process: What quantities of HLW with which properties can be processed depends on reactor technology employed and its further development.

For many years the "wait-and-see" approach has been officially implemented. The lack of clear political guidelines and the lack of understanding of responsibilities has caused systematic delay of promising attempts to solve the problem. If new nuclear power plants are to be developed and built on a larger scale, waste strategies and technologies should be developed and implemented in parallel. To achieve this, it would be necessary to enlarge the development tasks of the nuclear industry and to clearly define the requirements for a solution of the waste problem. The necessary direction for policy guidelines must be derived from the goal to reach public acceptance and from the necessity to develop financing models for the storage or disposal of spent fuel and radioactive waste.

Without convincing proposals for a real solution, available in time, rather than a re-allocation of the problem in time or space, the waste problem poses a real hurdle to the timely expansion of nuclear power.

8.7 Summary and Conclusions

Although nuclear is frequently advocated as a potentially significant contributor towards the achievement of the Kyoto Protocol goals and towards the global energy demand, it is obvious that the nuclear option will not be able to fulfill these expectations in the short or midterm.

The reduction of greenhouse gases needed to attain the Kyoto aims or the Post-Kyoto proposals of the EU in electricity production necessitates compensation for about 70 GWe by 2010 and 380 GWe by 2030 produced from fossil fuels so far. If these capacities were supplied exclusively from nuclear energy about 14 nuclear power plants of 1 GWe per year would have to be built till 2030, some 425 in total. To maintain the present share of nuclear (16 %) in the rising world electricity production about 15 plants per year would need to be built without consideration of necessary emission reductions. To simultaneously attain both aims, nuclear must grow considerably faster than the sum of both numbers indicates. In any case, the losses through shut downs of plants reaching the end of their life time must be compensated additionally.

Feasible growth rate of nuclear capacity is estimated at 1-2 % per year from the moment new reactors are available. This is substantially lower than the level needed to maintain the nuclear share of 16 % of the global electricity generation according to the IEA growth scenario.

The nominal nuclear capacity reached its peak in 1985 and has since declined. All scenarios expect a further reduction until about 2020 due to an increasing number of plants shutting down at the end of their service life. Thus no significant contribution can be expected from nuclear power in the first commitment period (2008-2012) of the Kyoto agreement, and probably beyond (2020). Life time extensions that are being sought by many plant operators can delay the reduction – but the price is the operation of older, less safe plants of the first and second generation for a longer period of time.

In view of the risks of the present generation of nuclear power plants and due to the lack of acceptance of nuclear energy by the public a significant increase in nuclear power plants can only be expected if improved versions of the present Pressurized Water Reactors and Boiling Water Reactors or – more likely – a new generation of "inherently safe" reactors is available for commercial electricity production. The estimates are that prototypes of the new generations will be available between 2015 and 2020. The penetration of the market will take another decade.

At present a shortage of qualified and experienced personnel is experienced in the nuclear industry, particularly in the development sector: universities and research institutions do not supply enough graduates. While this also has an impact on the plants in operation, it poses a much larger problem for the development of new technologies and additional nuclear capacities. The recruitment and training of needed skilled employees takes some 5 to 10 years. This could be a strong limitation to the timely availability of a higher contribution of nuclear energy to the global energy production.

The economic and structural conditions – considerable movement amongst the large nuclear technology suppliers and loss of specialized Technical Support Organisations (TSO) – are not conducive to a long lasting rise of nuclear power. Neither a stable development of the important TSOs nor a rapid consolidation of the large nuclear suppliers is in sight and the market at present is not strong enough to push these issues.

No significant change in public acceptance of nuclear has taken place, considerable reservations are documented in practically every opinion poll in Europe, though there are regional differences. Whether climate change and problems with energy security will cause a change of attitude remains to be seen, especially in view of the repeated safety relevant incidents in nuclear installations all over the world.

In some countries special incentives for investments in nuclear are offered through political measures, however the high initial investments, the unsolved problems of safety and waste disposal as well as the lack of public acceptance especially in western democracies are a considerable obstacle for the expansion of nuclear energy.

The problem of high-level nuclear waste storage has not yet been solved either. The public will not accept any significant increase in nuclear capacities unless there is a realistic concept for the disposal of nuclear waste. The more sophisticated disposal concepts, such as "burning" and transmutation of actinides, are closely linked to the operation of nuclear power plants for technological and economic reasons. Thus, future nuclear power plants should make arrangements to include waste disposal facilities. These would need to be developed in parallel with the nuclear power plants. The waste disposal could, however, turn out to be a more difficult and time consuming problem than expected and could also challenge the timely availability of the nuclear option.

To sum up, the vision that the nuclear energy option can be available in time to contribute significantly to the big challenges – climate change, increase of energy demand and energy gap due to scarcity of oil and gas – must for multiple reasons be viewed with ample skepticism. In the short and medium term no contribution above the present contribution can be expected. Under conditions favourable for nuclear an important increase in nuclear energy could possibly be achieved in the second half of this century.

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9 Nuclear Energy and the Kyoto Protocol in Perspective*

Anthony Froggatt
September 2006

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* This paper was based on "Nuclear Energy and Kyoto Protocol in Perspective" by Peter Biermayr, Manfred Heindler, Reinhard Haas, Brigitte Sebesta. Unpublished, November 2004

9 Nuclear Energy and the Kyoto Protocol in Perspective*

9.1 Predicted Global Energy Consumption

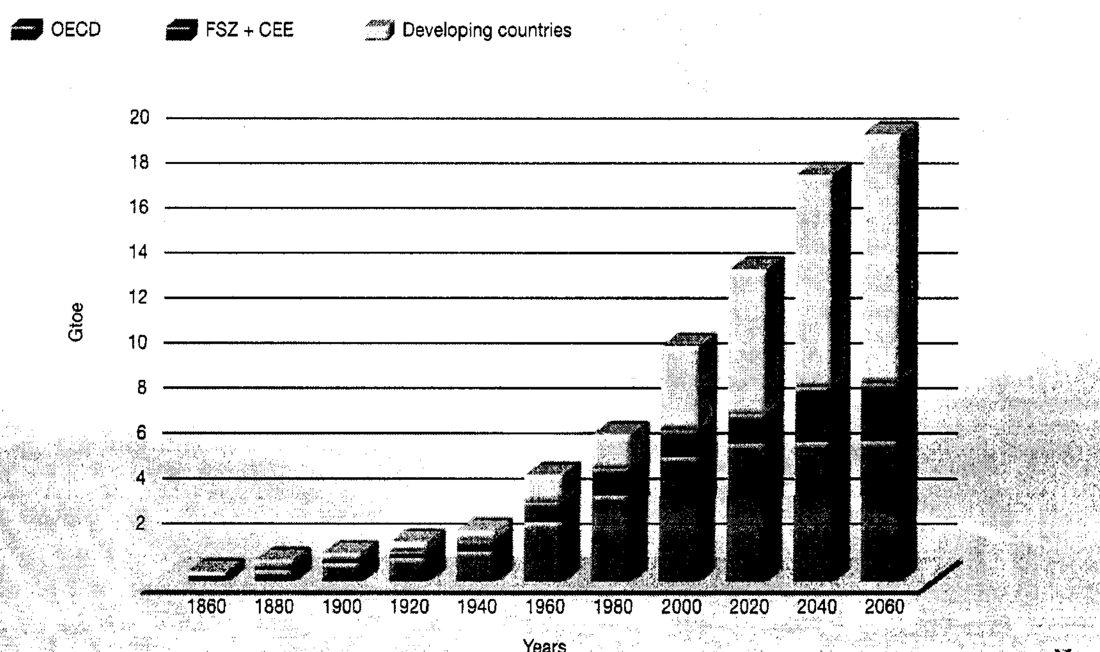
Global energy consumption is increasing year on year. In 2004 the global average was 4.3 %, with the highest growth level in Asia-Pacific, 8.9 %, continental Europe, 1.9 % and North America 1.6 % (BP 2005). Growth therefore is not just in developing countries, as they try to reach parity with northern countries, but globally. The graphic below (Figure 9-1) demonstrates the extent to which global energy consumption is expected to increase over the next 50 years.

In 2004 global commercial energy consumption is around 10 G tonnes of oil equivalent, which under this scenario would double in the next 50 years.

The reference case projection of the International Energy Agency (IEA) foresees a significant increase in CO_2-emissions, 62 % increase between 2002-2030. This is in the main as a result of this increased energy demand. Of this, the increase of CO_2-emissions from North America would amount to 33 %, in Western Europe to 20 %, in the OECD countries in Asia and Pacific regions to 20 %. The largest increase is forecast to be seen in economies in transition, 40 %, and from the larger developing countries, China, India, Indonesia and Brazil, 120 – 160 %.

Fig. 9-1 **GLOBAL ENERGY CONSUMPTION**

Global Energy Consumption since 1860 and forecasts. The graph for the period 2000 to 2060 shows a scenario of future energy consumption based on the current trends



Source: World Energy Council, World Bank

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Half of the projected emissions growth in the period of 2002 to 2030 originates from the power sector, and about one-third from coal-based power generation. The second key sector is transport that causes about 26 % of the emissions growth.

9.2 Is a Low Carbon Economy Achievable?

According to the IEA's business as usual scenario over the next three decades the projected annual increase in energy demand is thought to be 1.7 %. This will require a massive $ 16 trillion in global investment consuming around 4.5 % of the total investment between 2001-30. OECD Europe is expected to require around $ 2 trillion of energy related investment during this period. Globally and in Europe, most of the investment will be required in the electricity sector, with a total investment requirement of $ 10 trillion, while in the EU this will be around $ 1.1 trillion. This is forecast to result in the construction of 650 GW of new capacity (of which 330 GW will be the replacement of existing capacity) [IEA 2003].

The scale of the investment required highlights the importance of the next decade in determining the global direction of the energy sector. With power plants and infrastructure set to last for around 50 years, decisions about the fuel types used in the power sector will determine emissions levels for decades to come.

However, in addition to the reference scenario the IEA analysed the impact of energy policy measures currently under consideration that were targeted towards curbing CO_2-emissions and reducing import dependency. This alternative scenario did not lead to an increase in nuclear power, but rather an increase in the use of renewable energy, combined heat and power and energy efficiency. The alternative scenario led to a 30 % decrease in investment requirement, through lower development costs for the transmission and distribution sectors [IEA 2003].

If the alternative scenario were adopted it would lead to a stabilisation of CO_2-emissions from the energy sector at 2000 levels by 2030. The IEA conclude that "*The alternative policy scenario illustrates that if existing policies were strengthened and new policies adopted to curb emissions and reduce electricity consumption, the reduction in CO_2 would be considerable*".

9.3 European Union: Dynamics of Energy Demand

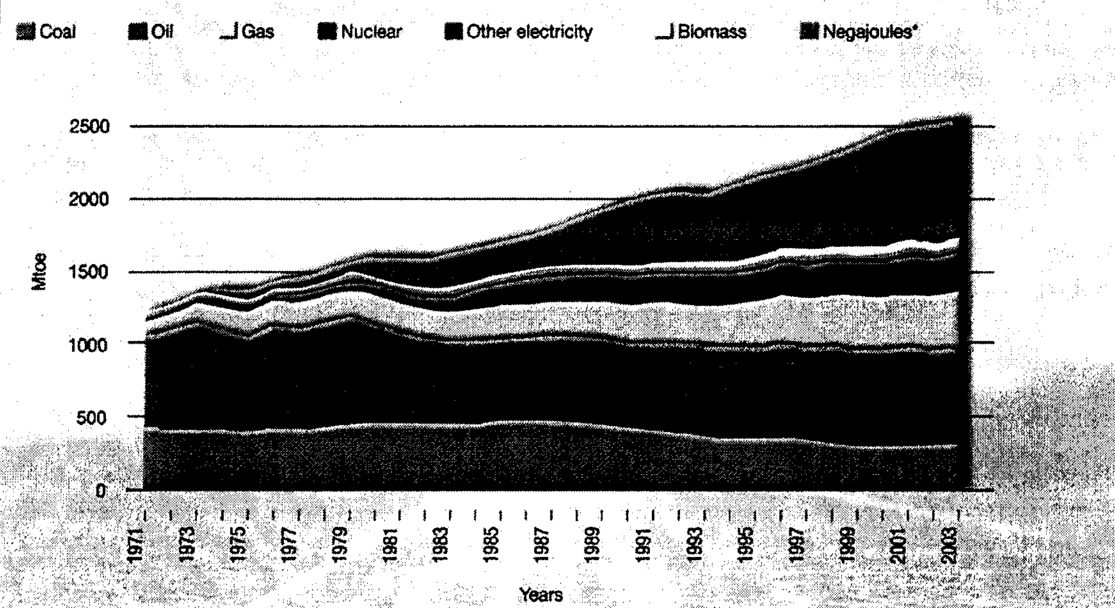
The European Union, with about 15 % of global primary energy consumption and with more than a third of its electricity produced in nuclear power plants, is of particular interest in the context of the question what role nuclear energy can play in the attempt to meet the Kyoto target. Current energy demand in the EU-25 is increasing by 1.3 % per year.

The European Commission state that the energy savings potential is considerable and that using existing measures and technologies 20 % of the EU's energy could be saved with a saving of € 60 billion a year. [European Commission 2005]

The phenomenon of economic growth with essentially constant energy demand, which had been referred to as "decoupling of the economic growth from energy demand", has been observed in the industrial sector of EU, and was also true for the entire economy as a whole during the 1970s and 1980s. However, this has been a passing phenomenon, linked to particularly higher energy prices at a particular time and, unfortunately, not to an efficiency policy aimed at lasting impact. Recently, energy demand and GDP have increased at about the same rate, a result of low energy prices and the absence of policy measures that would appropriately guide the market forces, in spite of low prices. The consequences of the recent, substantial, rises in energy prices remain to be seen.

Figure 9-2 below shows that (a) fossil energy increased slightly while its mix shifted to natural gas, (b) the increased energy demand was essentially met by nuclear energy, and, most importantly, (c) even in the European context – i.e. starting from an already relatively high level of energy efficiency, as compared to countries in development or with economies in transition – more than half of the GDP growth was "powered" by decreased energy intensity.

Fig. 9-2 DEVELOPMENT OF THE PRIMARY ENERGY DEMAND AND OF "NEGAJOULES"* – EU25



* "negajoules": energy savings calculated on the basis of 1971 energy intensity
Source: Biermayer et al. 2004

Within the last three decades, the contribution of energy efficiency and structural change to GDP growth was about 2.4 times that of nuclear energy. Had the energy intensity decreased at a slightly higher rate (30 %) than it actually did this could have "replaced" the contribution of nuclear energy.

9.4 Nuclear Power Plants are a Comparatively Expensive Measure to Reduce CO_2-Emissions

Extensive analysis has been undertaken to assess the role of nuclear power in helping to reduce CO_2-emissions. Nuclear power is only CO_2-free during operation, not throughout the fuel cycle, and there are other technologies or programmes that also have very low or zero CO_2-emissions connected with their operation. This means that Governments or utilities have a range of options available to them to reduce CO_2-emissions.

There have been a number of studies that have compared the opportunity cost of different technologies, these have included:

Bill Keepin and Gregory Kats: They compared the economic cost of investing in nuclear power or energy efficiency measures and concluded: *"Even if the most optimistic aspirations for the future economics of nuclear power were realized today, efficiency would still displace between 2.5 and 10 times more CO_2 per unit investment. We conclude that revitalizing nuclear power would be a relatively expensive and ineffective response to greenhouse warming, and that the key to reducing future CO_2-emissions is to improve the energy efficiency of the global economy"* [Keepin and Kats 1988]

Florentin Krause: A study published by the International Project for Sustainable Energy Paths (IPSEP) [Krause 2000] shows that it is possible to achieve the Kyoto target EU-wide at the same time as increasing economic efficiency and opting out of nuclear energy by 2020. The key results of the study are:

- Assuming plausibly imperfect policies starting in 2000 that will mobilize no more than 50 % to 65 % of Europe's efficiency and other low carbon resource potentials, it will be possible to reduce EU emissions in 2010 to 8 % below 1990 levels, and thus meet the Kyoto target.

- The above CO_2-reductions can be achieved assuming an accelerated phase-out of nuclear energy by 2020. Thus, according to this study, the EU has a technological choice in meeting global environmental goals, rather than having to trade off nuclear and climate risks to achieve the Kyoto target.

- Measures to reduce CO_2 normally go hand in hand with an increase in productivity, which means that investments in climate protection measures do not only lead to a reduction of CO_2 but also to an increase in economic productivity.

Three studies in 2006 also highlight the expense of using nuclear power as a mechanism to reduce CO_2-emissions.

Amory Lovins: Analysis from the Rocky Mountain Institute in the US estimates that *"nuclear power saves as little as half as much carbon per dollar as windpower and traditional cogeneration, half to a ninth as much as innovative cogeneration, and a little as a tenth as much carbon per dollar as end-use efficiency".* [Lovins 2006]

Uwe Fritsche: *"If we are optimistic and use the low range of nuclear GHG abatement costs to compare with the fossil alternatives (cogeneration) and renewable energy (biomass and off-shore wind) as well as some electricity efficiency, the alternative mix offers GHG abatement costs three to four times lower than that those of nuclear power".* [OKO 2006]

UK Sustainable Development Commission: *"Nuclear power is not the answer to tackling climate change or security of supply."* In response the Government's current energy review, the SDC nuclear report draws together the most comprehensive evidence base available, to find that there is not justification for bringing forward a new nuclear power programme at present. [SDC 2006]

9.5 Nuclear Energy in Countries with Emerging/Developing Economies

There is huge inequality in the use of energy in the world. An individual in a developed country will use around five times more energy than someone from a developing country. There are currently 2.4 billion who lack access to modern energy services [Canrea 2005]. Cooking and heating with solid fuels on open fires results in high levels of indoor pollution, which is said to be responsible for 1.6 million deaths per year, most of which are under five, making it one of the most lethal activities [WHO 2005].

In 2000 the United Nations adopted the Millennium Development Goals which included the objective of reducing by half the proportion of people living on less than $ 1 per day by 2015. There is a clear and recognised link between giving access to energy services and achieving this objective. Despite this, the number of people lacking access to modern energy services is forecast by the International Energy Agency (IEA) to increase to 2.63 billion by 2030.

The future of global energy demand will significantly result from what will happen in developing countries and in emerging economies, in particular China and India. There energy demand is expected to double or treble within the next 30 years, the share of global energy demand will exceed that of OECD countries shortly after the turn of the century, and incremental energy demand is expected to be supplied almost exclusively by fossil fuel.

Nuclear power is currently deployed in 10 countries outside Europe and North America. Apart from South Korea (38 %), Japan (23 %) and Taiwan (23 %) it only plays a minor role in electricity production in these countries: Argentina (8.2 %); South Africa (6.6 %); Mexico (5.2 %); Brazil (3 %); India (2.8 %); Pakistan (2.4 %); and China (2.2 %). This means that nuclear power contributes less than 1 % of the commercial energy consumed in the regions concerned, compared to global average of 6.2 %.

It is suggested that the current growth in nuclear power will be seen outside the OECD. This is reflected by the fact that of the 28 reactors under construction, only two, in Finland and Japan are in OECD countries as can be seen in the graphic below (Figure 9-3).

Fig. 9-3 **REACTORS UNDER CONSTRUCTION**

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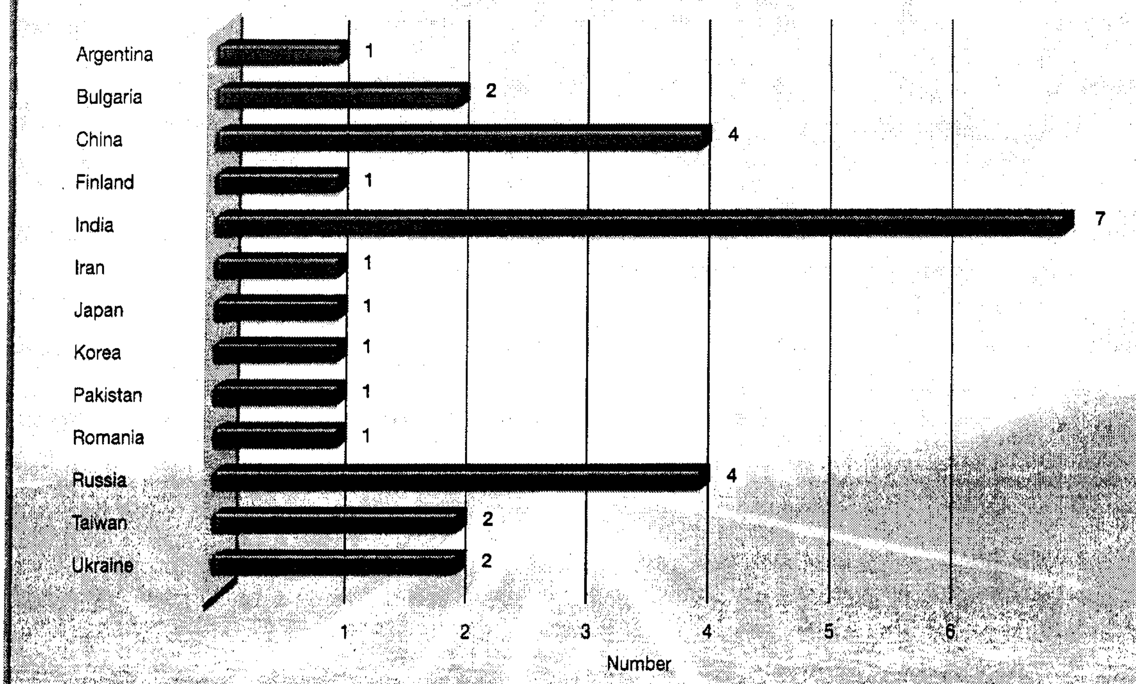

Source: It should be noted IAEO PRIS Databasis[1]

[1] It should be noted that this data is based on official reports from Governments and may not reflect the continuation of physical contruction. For example in Bulgaria the completion contracts for Belene are still subject to tender.

Over the next decades there will be unparalleled levels of investments necessary for the Chinese energy sector. Most of this is expected to go into the power sector, with nearly $ 2 trillion in investment in the next 30 years. In total nearly 500 GW of new generation capacity is expected to be build, with around one tenth of this being nuclear. This would increase nuclear's share of electricity generation from around 2 % to around 6 %.

In view of this, nuclear energy can only play an essential role in mitigating CO_2-emissions if it addresses the markets in these countries, i.e. if the nuclear technology can be made compatible to the respective social, economic and legal structures and safety cultures. The present generation of nuclear power plants does not fulfill this requirement: Present nuclear power technology requires safety culture, infrastructure and specialized education which are at the limit of what the industrialized world is able to provide. Nuclear power technology is therefore not adapted to countries with emerging/developing economies.

There are several mismatches between nuclear technology as developed in and for industrialized countries, and the needs of developing countries:

Dimensional incompatibility: Due to the economy of scale, the "economic" size of the current reactor generation is of one GW(e) and more, designed for base load, whereas the need is for small, adaptable, load following plants.

Infrastructure incompatibility: If the prerequisite of implementing the present nuclear power technology was to modify a society - its industry, its labor force, its regulatory processes – to make it suit the needs of present nuclear power technology, this could hardly be called a sustainable approach. If these countries were to be reduced to vendors of sites for nuclear power plants to be operated by companies and crews from highly industrialized countries, this could not be called an "adapted technology", and would not be acceptable.

9.6 Widespread Deployment of Nuclear

Nuclear power is operated in 32 countries around the world with a total of 443 nuclear reactors. In 2004 nuclear generated electricity provided 16 % of the global total and around 6 % of the world's commercial energy. If non-commercial energy is included – e.g. the using of solar thermal and biomass (collected by individuals for personal use), then the nuclear contribution provides even less of the total energy consumed. Over the last decades the construction of new nuclear power plants around the world has slowed significantly and there are now only 28 reactors being built anywhere in the world. Furthermore in 2005 construction only began on two new reactors in the world, at Chasnupp 2 in Pakistan and Olkiluoto 3 in Finland.

If an operational life of 40 years is assumed for modern reactors, which is relatively optimistic given the average age of reactors closed to date is 22 years, but which seems possible given the progress that has been achieved on the current generation of plants compared to the previous one, then just to maintain the current contribution of nuclear power to the global energy mix over the next 10 years, 82 new reactors would have to start up operation within a decade [Schneider 2004]. This alone would require a rapid upturn in the global view of nuclear power and is highly unlikely given the long lead times required for nuclear power (from ordering to power production).

Nuclear power uses uranium fuel, which along with fossil fuels, is limited in its use by the earth's reserves. Currently, there are a variety of estimates for the extent of the global reserves. These estimates are dependent on both exploration techniques, exploitation costs as well as the current price of fuel. As the price of fuel increases, so exploration and exploitation of reserves tends to increase. The World Energy Assessment has reviewed both the current expected reserves, but also gives the larger figure for the total resources – i.e. the expected total availability of a resource, regardless of cost of extracting the material – of the various fuels. A table summarising their findings can be seen below (Table 9-1). This indicated that fossil fuel reserves are currently thought to be sufficient for between 80-229 years of consumption at 1998 levels, compared to uranium reserves of 47 years.

Tab. 9-1 **EXPECTED ENERGY RESERVES AND RESOURCES**

	Consumption in 1998 (10^3 Exajoules)	Reserves (10^3 Exajoules)	Reserves last (yrs)	Resources (10^3 Exajoules)	Resource last (yrs)
Oil	0.14	11.11	80	21.31	152
Gas	0.08	14.88	186	34.93	436
Coal	0.09	20.67	229	179.00	1988
Uranium	0.04	1.89	47	3.52	88

Source: WEA 2004

Other authorities give slightly different figures, especially for the level of resources. The joint International Atomic Energy Agency/Nuclear Energy Agency assessment – known as the "red book" – estimates that the total reserves at extraction prices of less than $ 80/kg (about double the current world market price) is around 3.5 million tonnes, and resources are estimated to be around 9.7 million tonnes[1]. They assess that uranium consumption in 2003 was 68,815 tonnes per year, therefore the reserves will last around 50 years with total resources lasting around 140 years. [IAEA/NEA 2003]

If a global nuclear power programme is to be expanded then the rate at which the world's uranium reserves are depleted will increase (see also Sholly, St. "Nuclear Generated Hydrogen Economy - A Sustainable Option?", in this volume).

To exploit lower grade uranium ores requires energy which itself results in CO_2-emissions. Using current uranium ore grades – around 2 % concentration – results in around 33 g of CO_2 equivalent per kWh of nuclear electricity in Germany. Other estimates cited in the study by the Ökologie Institut [ÖKO 2006] suggest that the international norm is in the range of 30-60 g CO_2 /kWh. However, the World Nuclear Association operators suggest that the range should be lower, at 6-26 g CO_2 /kWh [WNA 2005]. The Ökologie Institut study also cites the estimated emissions using lower grade ores (0.1-1 % concentration) might increase the CO_2-emissions up to 120 g CO_2 /kWh. These resulting emissions are on a par with the most efficient combined heat and power combined cycle gas turbines. [ÖKO 2006]

If nuclear power is to play a major role in meeting global energy needs, then there will need to be a massive scaling up of the current programmes. Nuclear power currently produces around 6 % of commercial primary energy production and 16 % of electricity consumed. The Intergovernmental Program on Climate Change (IPCC) put forward a scenario in which nuclear power plays a more central role in reducing CO_2-emissions and increases to 3000 GW of installed capacity in 2075 (providing 50 % of the world's electricity) and then to 6500 GW in 2100 (75 % of electricity). Under this scenario it would reduce by one fourth the CO_2-emission predicted by 2100. Even assuming an operating life of around 50 years (a compromise date between current and future expected operating lives and certainly very optimistic), it would require the construction of around 7000 reactors in the next century, or 70 reactors per year. Given that, at the peak of the global nuclear industry in the 1980s, the highest number of reactors connected to the grid in a year was 33 and that in 2005 only 5 were connected, this scenario is extremely optimistic from a nuclear point of view. If only uranium fuelled reactor were used, this would result in 600 tonnes of plutonium being produced annually and if plutonium fuelled reactors were deployed, which is likely given the current reserves of uranium and the favoured designs of the Generation IV reactors, around 4000 tonnes of plutonium being per year [Feiverson 2003].

The use of plutonium fuels in reactors has the advantage that it increases the potential energy resource available from uranium sixty fold. Thus hugely increases the longevity of the uranium resource. However, experience with plutonium fuelled fast breeder reactors (FBR), has not been successful. In Europe reactors planned or in operation in France, Germany and UK have all been closed, leaving only one research reactor – Phenix in France. In the rest of the world there are only operational reactors of this type in Japan and Russia and one under construction in India.

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[1] As the price of uranium increases less economically viable (lower grade) ores may be used.

Used fuel from conventional reactors is partly reprocessed, which separates the plutonium to allow it to be made into fuel. In the 1970s and 1980s reprocessing plants were ordered and subsequently built in France and UK. Reprocessing is a technically complex process which creates, by volume, far more waste than the original spent fuel. The factors given vary significantly. The failure of the FBR has resulted in a stockpile of over 200 tonnes of separated plutonium.

A revival of the plutonium fuel cycle, even if it became technologically and economically viable significantly increases the proliferation risks associated with civilian nuclear power. This is because only a relatively small amount of plutonium, around 5 kg, is necessary to make a nuclear bomb.

9.7 Conclusion

There needs to be a global effort to reduce CO_2-emissions in order to reduce the impacts of climate change. Globally, emphasis must be placed on safe, sustainable and secure technologies that have wide-spread applicability.

The arguments presented in this paper strongly suggest that the reduction of energy intensity, i.e. the increase of the efficiency of conversion and use of energy needed to meet the increasing demand for goods and services is the only way in which CO_2-emissions can be reduced significantly.

Relying on nuclear energy to mitigate CO_2-emissions therefore seems to imply forgoing the much larger potential of reducing the energy intensity of our economies at a much faster pace than in the past. Furthermore, the limited availability of uranium at sufficient ore concentrations make the larger use of nuclear power even less acceptable, as the only longer term large scale nuclear programme will have to depend on plutonium fuelled reactors, which vastly increase the waste and proliferation dangers of nuclear power.

For efficiency alternatives to become the choice of the market, higher energy price strategies may be necessary, but are certainly not sufficient. The reasons for the energy intensity decrease of past decades would have to be carefully analysed: What part was technology driven, what part policy driven? Transaction costs, legal, social and technical barriers would have to be identified and overcome by appropriate strategies, often yet to be developed. Past (negative and positive) experience would also have to be carefully analysed with respect to driving and opposing factors. This is probably more difficult to organize than to launch a new nuclear initiative, but it would certainly be more appropriate for solving the climate problem (rather than the problem of the stagnating nuclear industry).

9.8 Summary

This paper concludes that using nuclear energy is no favourable option for CO_2-reduction. The major arguments for this conclusion are:

If nuclear energy is to play a non-marginal role in reducing CO_2-emissions, its rate of use would have to be increased to a level at which it would essentially compensate the anticipated increase in fossil fuel consumption. This would require a rate of commissioning of nuclear power plants, which is about an order of magnitude above that experienced in the "golden" decades of nuclear energy, i.e. in the 1970s and 1980s. However, there is no basis for such a rate of deployment, neither regarding production capacity nor regarding the ability of host countries to absorb such a growth.

In the past decades, the increase of global CO_2-emissions would have been about two times higher than it actually was, that is to say about twice as much additional fossil energy would have been consumed, if the growth of our economies had not been associated with an important reduction of their energy intensities. In comparison, all CO_2-lean energy sources, among them nuclear, have had a much more modest contribution to the reduction of the rate at which CO_2-emissions have actually grown. That is, the contribution of nuclear and renewable energy has been outweighed by far by the increase of efficiency and structural changes in energy conversion and use.

The rate at which total world energy intensity decreases (historically about 1 % per year) can be substantially influenced. Had this rate been slightly higher, for example 1.2 % instead of 1 %, this additional "production of negajoules" would have equalled the actual production of nuclear energy. A doubling of the rate (2 % instead of 1 %) would have roughly led to a world wide decoupling of economic growth and energy demand. That means economic growth can be provided without an increase in energy demand. Through appropriate policies, such as minimum efficiency standards for buildings or appliances, this would be feasible.

Additional energy demand is increasingly shifting from industrialized to developing countries and emerging economies, in particular China and India. Therefore, nuclear energy can only be expected to play an essential role in mitigating CO_2-emissions if it is marketed in a form which matches with the respective social, economic and legal structures and safety cultures of these countries. The present generation of nuclear power plants does not fulfil these requirements. This seems to suggest that present nuclear power technology would have to be substantially adapted to these requirements. No such development is in sight, which would suggest that nuclear energy in developing countries and in emerging economies could or should be implemented at a rate that would make it significant for climate protection.

A global increase in the use of nuclear power as a technological tool to reduce CO_2-emissions would bring its own environmental and security problems. The lack of high grade uranium ores would require the deployment of plutonium reactors which would significantly increase the nuclear waste and proliferation problems already associated with the current, relatively limited, nuclear energy programme.

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10 Nuclear Energy – The Economic Perspective

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10 Nuclear Energy – The Economic Perspective

10.1 Introduction

Most energy policies, such as that in the EU, have three pillars: sustainability, security of supply and economic competitiveness. Over the last decades, in particular following the introduction of the liberalised energy market, the key issue for nuclear power has been its economic performance. Until recently, it has been largely accepted that nuclear power was more expensive than its mainstream alternatives. This was due to increased transparency with the introduction of the liberalised market coupled with significantly higher construction costs than for natural gas and coal power stations, and, relative to current day prices, low fuel prices for oil and gas. Nuclear industry observers described the situation as "*Deregulation of the European markets could represent an even bigger threat to the future of nuclear power than anti-nuclear ideologues*" [NUKEM 1997].

Analysis released by the Nuclear Energy Agency in 1998 shows that in virtually all OCED countries, electricity from nuclear power was more expensive than conventional thermal power plants such as gas and oil. In only three countries (France, Japan and Russia) was nuclear power cheaper than coal or gas fired power stations – when using a 10 % discount rate[1] (the interest rate applied during construction and a key factor in the economics of nuclear power). Taking a global average, nuclear power was 15 % more expensive than gas and 6 % more expensive than coal generated electricity. [IEA/NEA 1998]

However, higher fuel costs of the main alternative, natural gas, are leading some to now claim that nuclear power is now comparatively cheaper than the mainstream alternatives. In particular the NEA, in its revised forecast in 2005 concluded that using a 10 % discount rate the cost of electricity from coal power stations was in the range of $ 35-60/MWh, natural gas $ 40-63/MWh and nuclear at $ 30-50/MWh. [IEA/NEA 2005]

Many other economic reports and indicators do not fully support the conclusions of the recent NEA report and point to a number of issues that will impact upon the economic attractiveness of nuclear power. This report will look briefly at these issues.

1. Are the assumptions being taken for the costs of new build justifiable?
2. Are there financial risks associated with new build programmes?
3. Do new nuclear power plants require additional Government support or subsidies to compete i in a liberalised market?
4. Is there a need to consider the full environmental costs of different energy options?
5. What are the costs of nuclear power compared to other CO_2-reduction technologies?

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[1] The choice of discount rate influences the result of these types of calculations significantly.

10.2 Are the Assumptions Being Taken for the Costs of New Build Justifiable?

In recent years there have been numerous economic analyses undertaken which have reviewed the predicted cost of building more nuclear power plants. Table 10-2 (at the end of this section) compares and details some of these studies, showing the main parameters which affect the final electricity cost from nuclear power plants.

Construction Times:

The nuclear industry, as do other large construction projects, has not historically had a good reputation of building to time. The paper-studies reviewed estimate that construction times will be significantly reduced to around 5 years (60 months). However, Table 10-1 highlights how data from the countries with the two largest nuclear power programmes suggest that the optimistic timetable for new construction will be difficult to meet.

Recent experience is available from Finland, where the only nuclear power plant under construction in the European Union is being built at Olkiluoto: construction is now thought to be a year behind schedule, after less than two years of construction.

Tab. 10-1 **MONTHS ELAPSED FROM CONSTRUCTION START TO COMMERCIAL**

as of Dec 31, 2001

	Average (months)	Minimum	Maximum	Standard Deviation	Last Plant Begun
U.S nuclear plants connected to grid	111	40	280	44	1977
French nuclear plants connected to grid	79	51	195	24	1985

Source: IAEA 2002

Construction Costs:

The forecasts for construction costs show considerable variation, from € 810 to € 3,650/installed kW. However, an even greater range can be seen when comparing the theoretical costs with those of actual construction. As only a few reactors have been built in recent years little data is available on actual construction costs. In the UK the last reactor to be completed was in the 1990s at Sizewell B and it is thought that the cost of completion was around € 5,110/kW. While in Japan General Electric estimated that the new 1300 MW Advanced Boiling Water Reactor could be constructed at a cost of $ 1,528 per kilowatt. However, when the units were built for Tokyo Electric Power Company the construction costs were $ 3,236/kW for the first unit and $ 2,800/kW for the second. [CRS 2001]

Cost of Capital:

The cost of borrowing is one of the most important variables, as due to the large construction cost, small changes in the interest rate can have a significant impact on the final electricity price. The studies reviewed give a range of between 5-12 % discount rate for their analysis. The cost of capital is affected by the risk associated with the project.

Load Factor:

Over recent years the average load factor for reactors has increased. This is in part as a result of the efforts by the operators to reduce outages to increase profits and in part due to the average age of the reactors. Over the life-time of a reactor, the capacity factor tends to start poorly – teething troubles – then have a good period, when the reactor should operate efficiently, before age related problems set in – sometimes at 20, increasingly at round 30-40 years. The average age of reactors globally is now 22 years and therefore on average in their optimum operational period. Despite this the average capacity factor globally is 77,8 %. The estimates for over 85 % life-time lead factor are seen by some to be optimistic.

Operating Life:

As noted the average operating life of current reactors is 22 years, while the average age of reactors closed is also 22 years. However, plans in some countries – such as the US – are now being implemented to operate the existing reactors for 60 years. Consequently, some of the economic analysis now being undertaken are suggesting that economic life of the reactors are 40 years and above. This may be optimistic given the lack of technical and economic experience of trying to operate light water reactors for forty years.

10.3 What are the Financial Risks Associated with New Build Programmes?

The economic uncertainties over the viability of nuclear power have given rise to concerns in the financial community over investing in nuclear power. In particular, there is recognition that oil and gas prices are volatile and as such can once again decrease. Nuclear power has such large fixed costs – for construction and decommissioning – and long construction times. On average the price per installed kW of constructing a nuclear power plant is around double that of coal and four times that of a gas plant. Furthermore, the times it takes to build a nuclear power plant is between 5-10 years, while a gas plant is built in 3 years and a wind farm around 6 months. This means that from a financial perspective there are both significantly larger upfront costs and a longer time before any revenue can be generated. This as well as projected operating times – now 40-60 years – is why investment in new nuclear power plants have been described by the consultancy UBS as *"a potentially courageous 60-year bet on fuel prices, discount rates and promised efficiency gains..."* [UBS 2005].

The report also notes that for nuclear to be competitive the price of oil must be above $ 28/barrel, which it currently is. However, as the graph below demonstrates this has not always been the case in the last fifty years, with it only meeting these conditions in less than 40 % of the time. However, declining oil reserves and increasing demand will tend to lead to higher oil prices in future.

Tab. 10-2 ELECTRICITY GENERATION COSTS OF NUCLEAR POWER PLANTS

Comparison of assumptions in recent forecasts of generation costs from nuclear power plants

Forecast	Construction cost (€/kW)	Construction time (months)	Cost of capital (% real)	Load factor (%)	Operating life (years)	Generating cost (€ c/kWh)
Canadian Nuclear Ass. [1]	1,657	72	10	90	30	4.82
Chicago University [2]	810 1,216 1,460	84	12.5	85	40	4.23 4.96 5.69
IEA/NEA [3]	1,606-3,650	60-120	5 10	85	40	1.75-3.94 2.6-5.5
Lappeenranta Univ [4]	1,748		5	91	40	2.23
OXERA [5]	2,372 first plant 1,679 later unit			95	40	
Massachusetts Institute of Technology [6]	1,622	60	11.5	85 75	40 25	5.4 6.4
Performance & Innovation Unit [7]	<1,226	-	8 8 15	>80	30 15 15	3.37 4.13 5.53
UBS [8]	2,044	60		91	45	3.06
EPR [9]	2,031	60	8	90.3	60	3.00

[1] Canadian Energy Research Institute, August 2004, Levelised Unit Electricity Cost Comparison, Ontario
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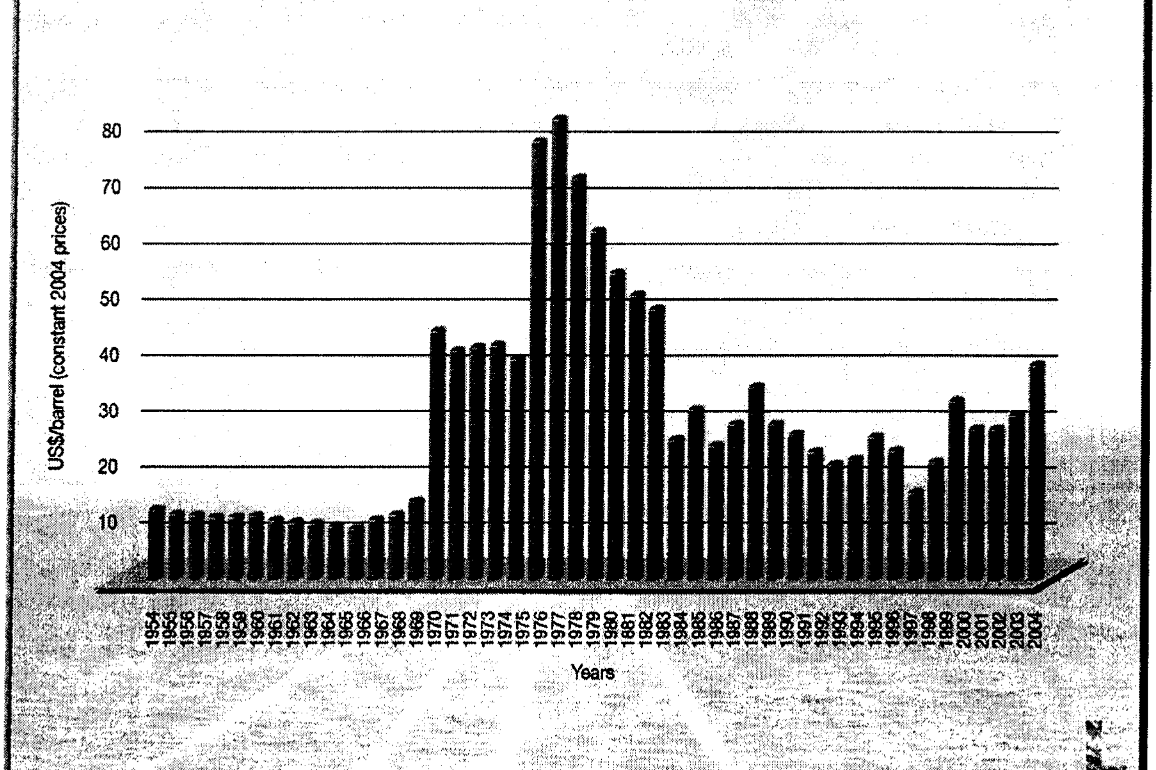
Another report by the Bank HSBC also highlights the risks associated with investment in new nuclear when it said: (HSBC 2005) "*Hence this financial risk* [new build] *coupled with unforeseen construction delays, the risk of cumbersome political and regulatory oversight, nuclear waste concerns and public opposition could make new nuclear a difficult pill to swallow for equity investors.*"

Fig. 10-1 **DEVELOPMENT OF OIL PRICE**



Source: BP 2005

Other financial institutions highlight the high risk of investing in nuclear power and look at other issues that will impact upon the technology's ability to give secure investments. In particular Standard&Poors, point to problems of nuclear accidents, nuclear waste storage and public acceptance as key factors.

Developing new nuclear generation in the deregulated European market environment is a high-risk venture, given the long construction times and high capital costs. Siting issues are likely to be more sensitive today than in the 1970s and 1980s when most reactors were built. Furthermore, political support will remain fragile to nuclear safety performance worldwide. Another Chernobyl-like accident can rapidly cool the current cordial sentiments. Fundamental issues, such as the final storage of nuclear waste and far-reaching social consensus, are still likely to be required before a potential large-scale renaissance can happen [S&P2006].

10.4 *Will New Nuclear Power Plants Require Additional Government Support or Subsidies to Compete in a Liberalised Market?*

As has been stated the nuclear sector and its advocates believe that the industry is now economic. The World Nuclear Association is so confident that they now claim that *"nuclear power in the 21st Century will be economically competitive even without attaching economic weight to the global environmental virtues of nuclear power or to national advantages in price stability and security of energy supply"*. [WNA 2005]

However, this view is not shared by non-industry observers, who see that Government support and subsidies will be needed. In December 2005, Standard&Poor's stated on the potential for new investment that: *"If new construction of nuclear power is to become a reality in the U.K., Standard&Poor's has significant concerns over the future structure of the generating industry. In particular, the potential for increased regulation of the liberalized generating industry, a higher level of political interference in the market structure, and the ongoing prospects for nuclear power in a competitive power market. Standard&Poor's expects that investment in nuclear power will rely on the long-term sustainability of high electricity prices in the U.K. energy market." [S&P 2005]*

If Governments are to create the necessary market for nuclear power then there are a number of subsidy routes that might be considered, these include:

- Nuclear Obligation: This would require any electricity supplier to ensure that a percentage of their electricity came from nuclear sources. The Government could then fix the amount of nuclear electricity that had to be in the energy mix.

- Capital Grants: The Government could award capital grants for new construction.

- Cost Over-Run Guarantees: Utilities may seek Government assurances that they will compensate for any time or cost over-runs resulting from extended licensing processes. This could be in the form of the Government paying the interest on any loan extensions.

- Tax Breaks: The nuclear industry could become tax exempt, deferred or have reduced rates. This could be on a local level, through adjusted business rates or on a national level.

- Licensing: The nuclear industry would like to see a streamlining of the licensing process. This would ensure that a number of questions (energy justification, nuclear safety, economic etc.) were dealt with on a national level and therefore the planning inquiry was primarily to assess local environmental issues.

- Carbon Price Guarantees: The nuclear industry is looking for additional financing and guarantees on the price of carbon. Some proposals would like nuclear to gain additional financing from the fact that no CO_2 is emitted during the production of electricity from nuclear (although it is produced during the construction of facilities and the mining and fabrication of uranium fuel). Furthermore, proposals are being considered that would result in Governments giving a long term guarantee – maybe up to 30 years – for the price of carbon.

The need for additional support has been highlighted by plans and actions in some of OECD countries. In early 2005 construction began on the first European Pressurized Water Reactor (EPR) in Finland. When ordered the reactor was said to cost in the range of € 1,500-1,800/installed kW [AREVA 2005]. However, this price was artificially low due to the financing package available (which included, highly unusual for intra EU projects, Government Export Credit Guarantees from France and Sweden [Nucleonics Week 2005a] and an unrealistically low turn-key contract construction price - this appeared to be a "loss leader" from the constructors). This was further highlighted by the fact that the price for a similar reactor in France is reported to be about 25 % higher per installed kilowatt [Nucleonics Week 2005b].

In the US, where there hasn't been a new reactors order for over the 30 years, the Government has announced a subsidy programme in an attempt to start a nuclear construction programme. This package includes [ICF Consulting 2005]:

- a tax credit of 1.8 cents/kWh for the first 8 years of generation for the first six units;
- a federal loan guarantee of up to 80 % of the cost of innovative technologies;
- a support framework against regulatory or judicial delays, worth up to $ 500 million for the first two reactors and $ 250 million for the next four;
- further research and development funding worth $ 850 million; and
- assistance with historic decommissioning costs (up to $ 1.3 billion).

It is estimated that this series of deals will cost the US taxpayer $ 13 billion [Lovins 2006].

10.5 The Need to Include the Full Environmental Costs of Different Energy Options

Energy producers and users do not pay the full environmental costs, e.g. the economic costs of pollution, such as CO_2, SO_2 or nuclear waste and other emissions. This is a subsidy to the polluting energy sources, like coal, gas and nuclear power and disadvantages clean technologies such as renewable energy. In fact analysis from Germany has suggested that the environmental costs of energy are greater than the more obvious direct support given to renewable energy. Work undertaken by the DLR suggested that in 2003 the support schemes for renewable energy in Germany cost a little over € 1 billion. However, if there was no support scheme and instead the same amount of energy was produced by conventional energy then the environmental cost would be over € 1.2 billion [DLR 2004].

Calculating the costs of the different pollutants and potential risks is extremely complex. A large study, part funded by the European Commission, is ongoing. In July 2001 the European Commission issued a press release on the findings of the first phase of the study. This concluded the "*cost of producing electricity from coal or oil would double and the cost of electricity production from gas would increase by 30 % if external costs such as damage to the environment and to health were taken into account. It is estimated that these costs amount up to 1-2 % of the EU's Gross Domestic Product (GDP), ...They have to be covered by society at large, since they are not included in the bills which electricity consumers pay*".

The report has been criticised for failing to fully consider the costs associated with nuclear power, its potential impacts and the full environmental impact of global warming. On nuclear power the report states that it "*involves relatively low external costs due to its low influence on global warming and its low probability of accidents in the EU power plants*". However there are a number of statements in the report text that qualifies – to some extent – the conclusion of the report regarding nuclear power. These include: "*Reliable values of accident, high level wastes impacts, nuclear proliferation and impacts of terrorism have not been developed in ExternE. These omissions may well be significant and therefore should be clearly noted in any assessment*" [Externe 1998]. The 2005 update of the ExternE study continues to not include estimates for the full costs of nuclear power [Externe 2005].

Regarding nuclear power there are two key areas in which the industry is affectively subsidised or given favourable conditions relating to its environmental costs these are:

A) Decommissioning and Waste Management Costs

After a nuclear facility has been closed significant additional work is needed to make it environmentally secure and to manage the radioactive waste that has been produced. Many of these processes are untried and therefore their final cost cannot be estimated with a high degree of certainty. In Europe it is thought that the work necessary to dismantle and dispose or store the Union's radioactive waste are likely to cost in excess of € 200 billion. Citigroup estimated that the global waste and decommissioning market is likely to be in the order of € 1 trillion [Citigroup 2006].

As noted funds are supposed to be set aside during the operational life of a facility so that future clean-up work can be financed. If sufficient funds are not put aside then there are two consequences. Firstly, the electricity being sold is not reflecting the true environmental cost and thus this is an unfair advantage to nuclear power over other non-nuclear generating sources. Secondly, the clean-up with will still have to be done and therefore it is more than likely that this will be funded by future taxpayers, probably from another generation.

In Europe the issue is not new but is acute due to the differences between polices in Member States and the introduction of common EU energy market rules. Subsequently, European Commission has noted that "*this situation [lack of uniformity of decommissioning policies] could lead to distortion and discrimination between now competing nuclear electricity producers from different Member States. Decommissioning costs are clearly seen as part of the electricity production costs. They may not be cross-subsidised from the transmission activity nor be directly subsidised via state aid.*" [European Commission 1998]

As a result of these concerns the Commission proposed legislation that would introduce new requirements for Member States to ensure that adequate reserves were put aside in segregated funds. A requirement for a segregated or separate fund is to stop utilities using these funds for their own, potentially high risk, purposes – such as market acquisitions. However, this was rejected by Member States, and in particular from France and Germany, who currently do not require segregated funds, therefore their utilities are not barred from accessing their decommissioning funds.

On the EU level the Commission is now drafting a new recommendation for Member States. This is non-binding legislation that would suggest best practice for utilities across the Union. It is not thought that this will fulfil either the legislative requirements or require sufficient transparency and guarantees to improve the current situation.

B) Nuclear Insurance

There are international agreements that create a framework for insurance cover for nuclear installations; one of them is the so called Vienna Convention on Civil Liability for Nuclear Damage. This convention creates a three tiered system, whereby part is covered by the operator, part by the State in which the facility is located and part by member states of the international convention. However, even these three tiers do not cover the full cost of a severe accident and there is a fixed ceiling for nuclear damage compensation. In February 2004 it was agreed that the current ceiling should be increased from $ 350 million to $ 1.5 billion. A nuclear operator will be required to have $ 700 million minimal liability cover, the nation State will cover a minimum of $ 500 million and the public funds from the international tier will cover $ 300 million. However, even this increase in costs both allows restrictions on the level of insurance that a utility is required to take out in the event of an accident and the total compensation that can be claimed following a nuclear accident. Were a nuclear generator required to fully cover the potential cost of a nuclear accident would significantly increase the cost of generating nuclear electricity. It has been estimated that if Europe's largest nuclear utility, Electricité de France (EdF), were required to fully insure their power plants with private insurance but using a limit on liabilities of approximately € 420 million, it would increase EdF's insurance premiums from 0.0017 c€/kWh, to 0.019 c€/kWh, thus adding around 8 % to the cost of generation. However, if there was no ceiling in place and an operator had to cover the full cost of a worst cost scenario accident it would increase the insurance premiums to 5 c€/kWh, thus increasing the cost of generation by around 200 % [European Commission 2003].

10.6 Can Costs for Nuclear be Expected to Go Down?

The cost problems that nuclear power face are further demonstrated by looking forward. The costs of renewable energy are expected to fall, due to improved technologies and economies of scale. As a rule of thumb it is said that for a doubling in production, the price of renewables falls by 20 %. Table 10-3 highlights the historical "learning rate" whereby the price of technologies have fallen. What can be seen is that the prices of nuclear power have not fallen significantly.

Renewable energies are being actively developed all over the world and are suitable for a range of activities including for transport, heating and cooling and electricity production. Furthermore, their versatility means that they can be rapidly introduced at a size that it suitable for every application. In 2004 about $ 30 billion was invested in renewable energy capacity and installations [REPN 2005].

Tab. 10-3 **HISTORICAL IMPACT OF LEARNING RATES ON DIFFERENT TECHNOLOGIES**

Technology	Period	Learning Rate %
Wind – OECD	1981-95	17
Solar PV – EU	1985-95	32
Compact Florescent Lamps (US)	1992-98	16
Gas Turbine – OECD	1984-94	34
Gas Pipelines – onland	1984-97	4
Nuclear Power – OECD	1976-93	6
Electric Power Production	1926-70	35

Source: McDonald und Schrattenholzer 2001

Figures from the UK Government's Department of Trade and Industry in Table 10-4 highlight how the price of electricity from some renewable energy is expected to fall considerably in the next decade, but remain relatively constant for nuclear power.

Consequently, the economic arguments that favour renewables over nuclear power today are forecast to get stronger over time.

Tab. 10-4 **AVERAGE COSTS OF RENEWABLE ENERGY AND NUCLEAR POWER**

Technology	Current cost (US Cents/kWh	Projected future costs beyond 2020 as the technology matures (US Cents/kWh)
Biomass Energy:		
Electricity	5-15	4-10
Heat	1-5	1-5
Ethanol for vehicle fuels	3-9	2-4
(c.f. petrol and diesel)	(1.5-2.2)	(1.5-2.2)
Wind Electricity		
onshore	3-5	2-3
offshore	6-10	2-5
Solar Thermal Electricity (insolation of 2500kWh/m² per year)	12-18	4-10
Hydro-electricityt		
Large scale	2-8	2-8
Small scale	4-10	3-10
Geothermal Energy:		
Electricity	2-10	1-8
Heat	0.5-5.0	0.5-5.0
Marine Energy:		
Tidal Barrage (e.g. the proposed Severn Barrage)	12	12
Tidal Stream	8-15	8-15
Wave	8-20	5-7
Grid connected photovoltaics, according to incident solar energy („insolation"):		
1000 kWh/m² per year (e.g. UK)	50-80	~8
1500 kWh/m² per year (e.g. southern Europe)	30-50	~5
2000 kWh/m² per year (most developing countries)	20-40	~4
Stand alone systems (incl. Batteries), 2500 kWh/m² per year	40-60	~10
Nuclear Power	5-7	3-5
Electricity Grid supplies from fossil fuels (incl. Transmission and distribution)		Capital costs will come down with technical progress, but many technologies largely mature and may be offset by rising fuel costs
Off peak	2-3	
Peak	15-25	
Average	8-10	
Rural electrification	25-80	

Source: DTI 2005

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10.7 Conclusion

In recent months and years there has been renewed optimism from the nuclear industry that new nuclear power stations will be ordered within liberalised energy markets. This optimism is largely based on the increasing cost of oil and gas, which is causing electricity from nuclear power's main competitor, gas fired power stations, to be more expensive, and thus improving the relative economics of nuclear power.

As a result the nuclear industry is now arguing that it is fully competitive with conventional electricity generation options. However, despite this, the financial community is sceptical of the longer term economic viability of nuclear power. In particular they point to unresolved financial and public issues, such as siting, nuclear waste management and the dangers of nuclear accidents. Furthermore, some in the financial community note that the large fixed costs of nuclear power increase the financial risk of nuclear investments.

Despite claims that nuclear power is economically viable the countries in the OECD that are considering embarking again on nuclear power construction programme, Finland and the US, have all proposed direct or indirect financial support programme for their nuclear sector. In the case of the US, this involves a complex series of measures which are likely to cost the taxpayer some $ 13 billion for a six to eight reactor programme.

As a mechanism to reduce CO_2-emissions nuclear power cannot compete with a variety of already available alternatives. In particular energy efficiency, in addition to its overall environmental advantage has a clear economic benefit but also brings additional security of supply improvements. Furthermore, analysis on the projects costs of other low or zero CO_2-emitting technologies demonstrate that renewable energies will becoming increasingly price competitive with nuclear power due to low prices from economies of scale.

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11 Nuclear Generated Hydrogen Economy – A Sustainable Option?

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August 2006

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11 Nuclear Generated Hydrogen Economy – A Sustainable Option?

11.1 Rationale: Why a Hydrogen Economy?

Nuclear power is frequently identified as an important element of a coming hydrogen economy, which in turn is hailed by some as the solution to both the climate change and "Peak Oil" issues. The discussion of some aspects of sustainability of both the nuclear production of hydrogen and the hydrogen economy itself are the subjects of this report.

The generally cited rationale for a hydrogen economy (i.e., the replacement of fossil fuels by hydrogen for transportation) is in principle straightforward:

- Transportation worldwide is currently strongly linked to the availability of petroleum-based fuels.

- Fossil fuels are also used for electric power generation and heating.

- Petroleum discoveries peaked in the early 1960ies, and the general trend since then is downward. Petroleum production has already peaked in many areas and is expected to peak in all current production areas within the next decade and then decline[1]. As economic development proceeds in Asia and elsewhere, there will be a growing disparity in fossil fuel supplies and demand, and thus a growing competition for the available supplies.

- Coal, which has a longer expected supply lifetime than petroleum, is currently cost effective only for electrical generation and, to a lesser extent, heating. The environmental impacts of coal burning are not yet reflected in the price paid for coal or for electrical power generated using coal. Unless carbon sequestration[2] is incorporated in proposed additional uses of coal (e.g., as a source of methane for steam reformer production of hydrogen), larger releases of CO_2 will result from wider use of coal.

- Imported fossil fuels represent, for a number of countries and areas (including the European Union) a significant economic and national security dependence owing to the expense involved in maintaining more than a 60-90 day supply and the ease with which imports can be interrupted.

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1 Notwithstanding this conclusion, which has very broad support in the technical community (including OECD's International Energy Agency), the EU-funded "European Hydrogen and Fuel Cell Technology Platform" blithely assumes that oil production will increase from the current 80 million barrels per day to 120 million barrels per day in 2030 [HFP 2005]. No supporting analysis is provided.

2 Carbon sequestration describes processes that remove carbon from the atmosphere and store it either in depleted oil or gas wells or – in future possibly - in the deep ocean. The viability and sustainability (in terms of the permanence of sequestration) of carbon sequestration is not addressed here. In addition, the environmental impacts of carbon sequestration (both the environmental impacts from the sequestration technologies themselves, as well as the environmental impacts that would arise from problems with the permanence of sequestration technologies) are also not addressed here. It is well recognized, however, that proof of the permanence of sequestration is essential to the strategy [IEA 2004b]. The significance of the issue of permanence of sequestration is easily seen in a 2005 report from IEA examining the legal implications of carbon sequestration [IEA 2005b].

There is thus an incentive to replace fossil fuels with another energy source if an economically feasible source with less of a security vulnerability can be identified for particular uses[3].

- Climate change is linked to greenhouse gas emissions from fossil fuel use as the main anthropogenic factor by most scientists. One means of limiting greenhouse gas emissions is, of course, to replace current uses of fossil fuels by other power sources that are not associated with greenhouse gas emissions.

- Provided that hydrogen can be produced, distributed or stored, and used economically and with minimal environmental impact, it is a "clean" fuel with emissions mainly consisting of water vapour (plus nitrogen oxides in case hydrogen is used for high temperature combustion). It might therefore qualify as one contributor to the replacement of fossil fuels – especially in the transportation sector.

One fuel replacement strategy that is being suggested is to use nuclear power plants (initially from fission power plants and, later – after commercial demonstration - from fusion power plants[4]) to produce hydrogen. Many of those who consider nuclear energy to meet the criteria mentioned above – i.e., economic production and minimal environmental impact – see a hydrogen economy based on nuclear production as a viable and sustainable option to meet the energy demands of the future. This claim in part triggered the present study.

Of the various facets of a possible hydrogen economy, the current study focuses on nuclear produced hydrogen as a vehicle fuel for light duty vehicles (passenger cars, pickup trucks, sport utility vehicles, etc.).

11.2 The Energy Carrier Hydrogen

11.2.1 Introduction

Hydrogen is not a primary energy source as a result of its chemical affinity for other elements such as oxygen (forming water). There is very little hydrogen found free in nature. As a result, in order for hydrogen to be used as a fuel, it must first be chemically liberated from a source material. Chemical liberation of hydrogen from a source material is a process which itself requires energy.

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[3] Note that it is assumed and asserted by many that nuclear power is such a source. The fact is, however, that for the European Union uranium represents an imported fuel. While it is easier (in terms of storage space) to store a supply of uranium as a hedge against supply disruptions, the supply can nonetheless be cut off. In 2004, 99 % of the uranium purchased by the EU came from 10 countries outside the EU (75 % from only four countries: Australia, Canada, Niger and the Russian Federation). Only about 1 % came from sources within the EU [Euratom 2004]. Developing another source of supply is not a simple matter since identifying suitable uranium deposits and constructing necessary facilities to extract the ore, convert the ore to yellowcake, and converting the yellowcake to uranium hexafluoride for use in uranium enrichment all take years to accomplish.

[4] Fusion power plants based on tokamak concepts are in the planning stage of feasibility demonstration (the ITER tokamak experimental fusion reactor has been designed but not yet built). If current concepts prove to be workable, it seems likely that rather large unit sizes would be required in order to make the process an economic source of power, and very large units (in the range from 2000-5000 MWe) could be necessary in order to compete in a liberalized market [IRF 2004]. At such large unit sizes, off-peak capacity will be considerable, and it could be used to produce bulk hydrogen which could then be consumed in power plants to support load levelling with peak load power generation units.

Thus, hydrogen is best thought of as an "energy carrier". Bulk hydrogen production can support the use of hydrogen as a fuel for producing electricity in fuel cells for stationary and transportation use.

Ultimately, one needs to question whether it makes sense (from the standpoint of efficiency, primary energy source consumption, environmental impact, etc.) to use a primary energy source to produce hydrogen instead of using it directly. But hydrogen production from off-peak electricity could supplement hydrogen production from other sources. Hydrogen could also be produced from intermittent power sources - such as solar or wind power – and be stored for later use when the intermittent power source is not available. [IEA 2003b]

Hydrogen can be stored, distributed and transported as a compressed gas or liquid. In order for a major "hydrogen economy" to be developed and used, there are fundamental requirements for an economic source of hydrogen production and for the development and deployment of the infrastructure needed to support its use.

Hydrogen can be produced from many sources, including water[5] and natural gas (the source of most current hydrogen production). Using hydrocarbon feedstock to produce hydrogen has the same detriments as burning the hydrocarbon fuels directly – this reduces the hydrocarbon feedstock available for production of petrochemicals, and unless it is accompanied by carbon sequestration (which has consequences for the economics and the sustainability of the process) it also releases greenhouse gases (carbon dioxide, primarily). Even if vastly expanded production of hydrogen from natural gas were pursued together with carbon sequestration as a means of reducing greenhouse gas emissions, and if there were no sustainability problems involved in sequestration, the process would not be sustainable due to the limited natural gas resources. Using natural gas as a feedstock to produce hydrogen could at most be a transitional strategy in reducing greenhouse gas emissions[6] until other non-fossil sources of hydrogen could be developed and brought into commercial operation.

11.2.2 Current General Situation

Hydrogen is currently mainly used in the production of ammonia to make fertilizer and in hydrocracking of petroleum, with minor percentages also used for diverse high-purity chemical and industrial uses, as vehicle fuel (fuel cells), as fuel for fuel cell-based peaking power stations and as missile fuel.

Current world hydrogen production amounts to about 50 million metric tonnes annually[7], consuming 1.5 % of the total world energy consumption [ACIL 2003]. Current annual hydrogen production in the United States is about 11 million metric tonnes, while in Europe it is about 8. Because hydrogen storage and distribution are currently expensive, most hydrogen is currently produced where it is used. Where hydrogen is transported, this is done by pipeline or by road

[5] It is clear that there are regions of the earth where (relatively) clean water in abundance is a problem. Such regions would not be expected to be used for hydrogen production, and would be better suited to use available energy resources in a primary form such as electricity generated by wind or solar facilities. If hydrogen is needed as a vehicle fuel in such areas, it could prove to be more sensible to produce the hydrogen elsewhere and transport it to areas where it is needed.

[6] Methane could be produced from biogas sources, and then used to produce hydrogen. Such a procedure would be inefficient - and it would probably make more sense to simply use the methane directly rather than take the extra step of using it as feedstock to produce hydrogen.

[7] If all of this hydrogen were burned to produce electricity, the net electrical generation would amount to about 200 GW of capacity [Forsberg 2002]. The total world electrical generating capacity is about 3,600 GW (of which about 370 GW is nuclear capacity) [EIA 2005].

via cylinders, tube trailers and cryogenic tankers, with a small amount shipped by rail or barge. Transport of high-pressure cylinders and tube trailers is normally done over distances of 160-320 kilometres from the production facility. For distances up to 1600 kilometres, hydrogen is transported as a liquid in cryogenic tankers, railcars or barges. In the US, hydrogen pipelines are used in few areas where large hydrogen refineries and chemical plants are located (mostly in California, Indiana, Louisiana and Texas). Hydrogen pipelines also exist in Europe.

The current sources of hydrogen production are as follows:

- 48 % from natural gas
- 30 % from petroleum
- 18 % from coal
- 4 % from electrolysis of water[8]

It should be noted from this that 96 % of current production of hydrogen comes from fossil fuel sources, predominantly (78 %) combined from natural gas and oil involving greenhouse gas emissions. If a hydrogen economy is to develop, these sources of hydrogen will have to be nearly completely replaced or accompanied by carbon sequestration.

Projected demand for hydrogen for industry in 2030 is expected to be five to six times greater than current production levels [Buckner 2002]. Note that this projected increase is for industrial demand alone and is separate from any demand that might occur due to a hydrogen economy for vehicle fuel or other purposes[9].

11.2.3 Advantages and Disadvantages of Hydrogen

Hydrogen has certain advantages as a fuel. Hydrogen is non-toxic and it is not a carcinogen or a mutagen. Hydrogen is odorless, colourless and tasteless. The combustion product of hydrogen is water vapour. Hydrogen in its gaseous and compressed gaseous forms is much lighter than air and thus quickly disperses when released. (The same is not true of liquefied hydrogen, which when initially released is heavier than air.)

Hydrogen also has disadvantages as a fuel. Hydrogen is extremely combustible and it is subject to the same hazardous combustion regime (Boiling Liquid Expanding Vapour Explosion or BLEVE) as Liquefied Petroleum Gas (LPG) and Liquefied Natural Gas (LNG). Hydrogen must be significantly compressed or liquefied to be useful as a fuel. Due to its very small molecular size, hydrogen migrates rapidly through very small openings, thus the requirements for leak tightness of piping and container systems are much more stringent for hydrogen than for hydrocarbon-based fuels.

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[8] This source of hydrogen is mostly a byproduct of bulk chlorine production.

[9] This increase (from 50 million tonnes to 250-300 million tonnes) is far larger than is estimated to be required to support a hydrogen economy for vehicle fuels (23 million tonnes per year for the EU). Industry will have to come up with a way to produce this hydrogen irrespective of a hydrogen economy for vehicle fuels, and it is clear that the sources will not be able to continue to be principally natural gas and oil.

11.2.4 Hydrogen Storage

If hydrogen is produced in bulk, it must either be used at the source or liquefied and stored as a cryogenic liquid. If it is produced in distributed fashion as a gas, it must again be used at the source or be compressed and stored for distribution. Both compression and liquefaction are energy intensive processes, which – independently of the means and expense of producing the hydrogen in the first place – reduce the overall efficiency of the hydrogen economy and increase its cost.

For use as a vehicle fuel, more recent studies are based on concepts where hydrogen is produced by electrolysis at the point of delivery (i.e., at vehicle fuelling stations). This avoids the costs and impacts associated with bulk production, storage and transport and makes the whole process more of a "just-in-time" nature. (Of course, if the electrical grid goes down, hydrogen cannot be produced or distributed. But this is no different from the existing gasoline- and diesel-based passenger transportation systems, since when power is not available, gasoline or diesel fuel cannot be pumped.)

The longer hydrogen is in storage or distribution, the more of it is lost to the environment. A "just-in-time" hydrogen electrolysis system for vehicle fuelling stations appears to be both more efficient and more cost-effective in the long run than a centralized bulk hydrogen production, storage and distribution to vehicle fuelling station concept.

Hydrogen storage from bulk production would either be short-term storage as a compressed gas prior to distribution via hydrogen pipeline to end users, or more likely as a cryogenic liquid awaiting use or distribution. Cryogenic hydrogen storage and distribution has risks associated with it that require careful consideration (see Section 2.3, and see also Section 7 for more detail).

11.2.5 Hydrogen Distribution

For bulk hydrogen production that is not used at the point of production, in addition to a storage system a hydrogen distribution system would have to be created to deliver the hydrogen to end users. Two possibilities for hydrogen distribution to end users are cryogenic tanks (either by truck or rail) and compressed hydrogen gas pipelines.

Cryogenic hydrogen distribution trucks in Europe typically carry 3.35 metric tonnes of liquid hydrogen. Cryogenic hydrogen railcars carry 2.3-9.1 metric tonnes of liquid hydrogen, depending on their size. Boil-off liquid hydrogen loss rates from cryogenic truck and rail tank cars are 0.3-0.6 % per day. Losses during transfer of cryogenic hydrogen from a tank truck to a storage tank at the end user are 10-20 % of the total shipment [Amos 1998]. The effects of such losses on atmospheric chemistry are not well understood, particularly on the scale that such losses could occur in a full-blown hydrogen economy. This is something that requires further investigation.

Compressed hydrogen gas pipelines are in use in a number of areas of the world (including Belgium, Canada, France, Germany, Netherlands, United Kingdom and United States), the longest of which is nearly 900 km long (an Air Liquide network in France, Belgium & Netherlands) [Vinjamuri 2004].

Owing to the expense involved with hydrogen storage and distribution (resulting from hydrogen's low density, even in a liquid state), more and more frequently the literature indicates a focus for hydrogen fuelled vehicles on distributed production using electrolysis and other production methods rather than centralized bulk production. This entirely shifts the nature of the hydrogen economy from a traditionally large industry focus to local focal points, where hydrogen is produced "just-in-time" in necessary quantities without resorting to centralized bulk production facilities requiring massive storage and distribution infrastructure.

11.3 Hydrogen Production Methods

11.3.1 Overview

There are basically only three types of hydrogen production and all of the other "methods" of hydrogen production are variations on a theme. These three methods are:

- Electrolysis;
- Steam reforming of methane;
- Thermo-chemical water-splitting:

Of the above processes, electrolysis and steam reforming of methane are well understood and currently in use. Steam reforming of fossil fuel methane, in the context of the hydrogen economy, requires the sequestration of carbon from the process, otherwise it makes no sense because it releases huge quantities of greenhouse gases.

Thermo-chemical water-splitting, despite for decades of discussion and research, remains demonstrated only in laboratory scale[10]. The scale-up from laboratory scale to the commercial scale anticipated by the advocates of nuclear thermo-chemical water-splitting is of the order of a factor of ten millions. There appear to be rather significant materials problems involved with the two main thermo-chemical water-splitting cycles (I-S, and Ca-Br) due to high temperature (800 °C) processes involving extremely corrosive sulfuric or hydrobromic acid (respectively). In addition, there seems to have been little serious consideration given to the chemical accident hazards attendant on thermo-chemical water-splitting schemes.

Unfortunately, neither the proponents of nuclear production of hydrogen nor its critics have produced convincing economic arguments. What is needed is a thorough life cycle cost analysis - with all costs, economic, environmental and others included - in order to place the comparison between nuclear-produced hydrogen and hydrogen produced by other processes.

11.3.2 Processes for Nuclear-Generated Hydrogen

11.3.2.1 Introduction

Although any nuclear power plant technology can be used for production of hydrogen through electrolysis or thermo-chemical water-splitting, more efficient technologies will be required in order to achieve economically competitive hydrogen costs. Several technology choices are highlighted

[10] The peak production cited to date has been 0.031 m^3/hour for one week at bench scale in 2004 (Shiozawa 2006). This is a factor of 3 million smaller than the industrial scale facility envisioned by the Japanese (Shimizu 2001).

in the following as exemplary of those currently being discussed. Using nuclear power as an energy source to produce hydrogen is not currently being done except on an experimental scale[11].

11.3.2.2 Electrolysis

Any nuclear power plant that produces electricity could be used to produce hydrogen in an electrolytic process. In this case, the electrolytic production facility could be located at any convenient place with a sufficiently large grid connection and would not necessarily have to be close to the nuclear power plant. (Of course, the closer the electrolytic production facility is located to the power plant, the lower the transmission line losses would be. This would result in a modest increase in overall efficiency of the use of electricity for electrolytic hydrogen production.)

Electrolytic production of hydrogen is currently too expensive for bulk hydrogen production and is mostly used in applications where very high purity hydrogen is required (which hydrogen is too expensive to use as a vehicle fuel). The difficulty with electrolytic hydrogen production is the relative inefficiency of the process (the efficiency is around 25-30 %) [Schultz 2002: 5]. An inexpensive source of electricity (e.g., cheap hydroelectric power) would be required for electrolysis to be economical for other uses.

An international coalition of countries has formed the Generation IV International Forum[12]. This coalition has identified six advanced reactor technologies for deployment in the 2030 time frame. Only one of these six designs – the Very High Temperature Reactor or VHTR – is identified with nuclear-generated hydrogen production. The current design concept is for a 600 MWt modular design cooled by helium [Park 2003]. The goal of the VHTR Nuclear Hydrogen Initiative is to commence operation of a demonstration nuclear powered hydrogen production facility in 2017 [Henderson 2004]. Hydrogen could be produced by two processes: First, the electrical output of the station could be used to produce hydrogen by electrolysis; second, the high temperature process heat (about 50 MWt of the 600 MWt output) could be used to produce hydrogen by a thermo-chemical process.

11.3.2.3 Thermo-Chemical Processes

Hydrogen could also be produced using nuclear power plant process heat in a thermo-chemical process. Direct use of process heat to support hydrogen production, however, requires a reactor with a very high coolant temperature. The efficiency of thermo-chemical production of hydrogen is estimated to be about 50 % [Schultz 2002: 5]. The coolant temperature of most currently operating reactors is far too low to make thermo-chemical hydrogen production economically feasible[13]. Future reactor designs using high temperature helium gas or liquid salt or liquid metal

[11] The High Temperature Test Reactor (HTTR) facility in Japan is being used on an experimental basis for producing hydrogen from nuclear power [Ryskamp 2003: 13].

[12] At the time this report was written, the Generation IV International Forum consisted of ten nations (Argentina, Brazil, Canada, France, Japan, the Republic of South Africa, the Republic of Korea, Switzerland, the United Kingdom and the United States) plus Euratom.

[13] The coolant temperature of currently operating LWRs is in the range of 320 °C. High temperature reactors intended for use in thermo-chemical production of hydrogen have primary coolant temperatures of 750 °C and higher. The higher the coolant temperature, the more efficient the thermo-chemical process is expected to be.

coolants (e.g., lead, lead-bismuth) are being investigated for possible use in thermo-chemical hydrogen production[14].

11.3.2.4 High-Temperature Hydrolysis

Finally, a hybrid process called high temperature hydrolysis has been suggested which uses both high temperature process heat (700-900 °C) and electricity [Forsberg & Pickard 2002: 7]. This process is estimated to be about 40 % efficient [Schultz 2002: 5], but the efficiency would depend on the temperature of the reactor coolant heat source used to power the process. Higher temperature reactors could be expected to yield some improvement in efficiency.

11.4 Hydrogen Economy

11.4.1 The Scale of the Hydrogen Economy

Bounding calculations indicate that the scale of production required is in the order of 23 million metric tonnes of hydrogen annually just to fuel the current light vehicle fleet in the 25 European Union countries. To illustrate what the production of this amount of hydrogen would mean in terms of effort and costs, rough estimates were made for different energy sources (IRF 2006):

a. Sixty-three EPR nuclear stations at a capital cost of € 159 billion for the nuclear stations.

b. Something over 5,000 km² of solar photovoltaic stations with capital costs of the order of € 1.08 trillion.

c. About 63,000 three megawatt wind turbines, requiring about 2,500 km² of land area; capital costs of the order of € 1-3 million per wind turbine, plus ancillary facilities and land costs.

d. One hundred and five H2-MHR modular nuclear stations (MHR: Modular Helium Reactor) with co-located thermo-chemical water splitting plants for bulk hydrogen production, at a capital cost of € 154 billion.

e. Hydrogen production from biomass using biogas production and steam-methane reforming technology for bulk hydrogen production, requiring 464 plants and a total acreage in biomass production 259,376 km² (6.5 % of the land area of the EU), with capital costs of € 175 billion for the biogas and the steam reforming plants alone. To this would have to be added cryogenic liquefaction facilities and cryogenic hydrogen distribution infrastructure.

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[14] Another nuclear generated hydrogen concept (called the Advanced High-Temperature Reactor or AHTR) has been proposed by Oak Ridge National Laboratory in which the fuel is cooled by molten fluoride salts. Coolant temperatures of 750 °C or even 850 °C are envisaged [Forsberg & Pickard 2002].
Argonne National Laboratory and Texas A&M University have proposed the STAR-H2 (Secure Transportable Autonomous Reactor for Hydrogen Production) design for hydrogen production. STAR-H2 is a 400 MWt lead-cooled fast reactor with a core outlet temperature projected at 780 °C. A helium-based intermediate cycle would take the process heat from the nuclear plant to a thermo-chemical hydrogen production plant. STAR-H2 is a Generation IV reactor, forecast to be deployable after 2030 [Wade, Doctor & Peddicord 2002].
The Japan Atomic Energy Research Institute (JAERI) is preparing to demonstrate nuclear production of hydrogen using its High-Temperature Engineering Test Reactor (HTTR). A thermo-chemical, iodine-sulfur-based process for hydrogen production is being developed to use the process heat output of HTTR to produce hydrogen [Forsberg & Pickard 2002].

In all cases above, hydrogen fuelling infrastructure (and in two cases a cryogenic hydrogen distribution system as well) and annual operations and maintenance (O&M) costs are additional. Hydrogen fuelling infrastructure for distributed production of hydrogen by electrolysis is estimated to be in the range of € 94.5 - € 202.5 billion for the EU 25. The infrastructure costs for a system based on cryogenic distribution for bulk hydrogen production and fuelling stations based on production of compressed gas from cryogenic fluid have not yet been estimated.

In short, the cost of transition to a hydrogen economy is clearly in the range of at least € 250 to € 500 billion just to fuel the current light vehicle fleet in the 25 European Union countries. For comparison, the Gross Domestic Product (GDP) of the EU for 2005 was estimated to be about € 10,000 billion [CIA 2006].

Apart from the costs, there are, of course, other constraints to the different options, such as availability of land (b,c,e), iodine (d) or acceptance by the population (a,c,d). The Iodine needed per year for the 105 H2-MHR modular nuclear stations e.g. amounts to 15 % of the worlds known iodine resources [Anzieu 2006].

11.4.2 Time-Scale Required for the Hydrogen Economy

If the hydrogen economy is expected to alleviate concerns over price, magnitude of supply and security-of-supply over oil as a vehicle fuel, the hydrogen economy will have to be established much sooner than current planning seems to envision. Many government-sponsored "road map" documents suggest 2040 - 2050 for the hydrogen economy.

For example, the EU's high level hydrogen advisory panel – whose report serves in significant part as the impetus for current EU R&D plans regarding hydrogen – assumed that only about one-third of all the vehicles on the roads of Europe would be hydrogen powered by 2040, and that a little over one-third of the new vehicles sold in that same year would be hydrogen-powered [EC 2003]. This can be contrasted with IEA estimates for 2024 which show a disparity between supply and demand for oil as large as was the production of oil as recently as 1997.

Simply put, the oil supply crunch for which the hydrogen economy is being advertised is coming much faster than is being acknowledged. The hydrogen economy would have to be accelerated in terms of time scale, or it will likely come into being too late. At the same time, the hydrogen economy has to take account of the economic, security and environmental concerns about existing transportation fuels, and resist the temptation to resort to fossil fuel-based sources of hydrogen without engaging in carbon sequestration.

11.4.3 Limits to the Availability of Uranium

Due to the limited uranium resources it is clear that unless nuclear fission-based power sources resort to widespread use of fast breeder reactors and a plutonium recycle economy, nuclear produced hydrogen is not "sustainable"[15].

[15] The concept that the nuclear industry is not sustainable is hardly a radical notion; see, for example, (Rothwell & Van der Zwaan 2002). However, this concept is in contradiction to what is almost an article of faith within the nuclear industry itself.

Numbers regarding the uranium reservoirs vary considerably with the source, but a total of about 4 million metric tonnes of uranium ore recoverable for € 108/kg or less available worldwide are a plausible estimate [WEC 2001]:

- 2.96 million metric tonnes of "Reasonably Assured Resources" of uranium ore and
- 0.99 million metric tonnes of "Estimated Additional Resources" (EAR-I) of uranium ore.

The current demand for uranium is about 62,000 metric tonnes per year, and is expected to expand to 79,800 metric tonnes per year by 2015. Assuming a linear trend the uranium resources will last about 41 years. Additional speculative resources of about 10 million metric tonnes are thought to be available [WEC 2001]. This would extend the period of supply to 95 years.

Full recycling of plutonium in MOX fuel could extend the period by perhaps 30 %, but many current reactors are not able to use MOX fuel and the period of extension is not so remarkable since plutonium is already being recycled in some countries. The degree to which the fission reactor era could be extended by full plutonium recycle without resorting to fast breeder reactors is not significant enough for fission technology to escape the conclusion that it is not sustainable.

If however, nuclear power is more than doubled to account for an increased demand for electricity (demand for electricity worldwide is expected to double by 2030, and if nuclear power merely keeps pace with its current contribution it will also double) [Birol 2004] and to support a hydrogen economy, the fission era without fast breeder reactors and plutonium recycling will be over in half this time – that is, in about half a century. As above, this period could be stretches by about 30 % through plutonium recycling – i.e. about 65 years.

These figures are somewhat more optimistic than those given by IAEA [IAEA 1997] and DOE [DOE 2002b] based on slightly different shares of nuclear in the overall energy supply and energy demand increases. According to DOE without deployment of fast reactors, uranium identified resources would be depleted by 2030 and the (currently) speculative resources by 2060. Other sources [e.g. Matthes et al. 2005] are even more restrictive.

Whatever the real numbers are, they will likely meet very few peoples' expectations for sustainability[16].

It is perhaps not widely appreciated outside the nuclear industry that demand for uranium actually outstripped supply in 1990, with the excess (about 40 %) coming from drawdown of reserves, recycling of highly enriched uranium formerly used in nuclear weapons programmes, enrichment of previous tails from the enrichment process and rejecting tails at a lower concentration of Uranium-235 and recycling and enrichment of uranium from reprocessing.

[16] One could resort to extraction of uranium from seawater for reactors other than fast breeders in order to extend the era of fission power, but the cost of doing so would take the cost of the resulting nuclear-generated hydrogen out of reach for all except critical uses (including perhaps defence, public protection, etc.). It is broadly assumed within the nuclear industry that extracting uranium from seawater would cost ten times more than recovery from uranium ore. This would double the cost of power from nuclear fission, and the cost of hydrogen produced from this power would also be doubled. Using uranium from seawater would extend the period of operation of fission power plants in a non-breeder mode by making available a resource estimated by the Uranium Information Center at 4000 million (4 billion) metric tonnes [UIC 2005]. Whether this is practical or not remains to be seen; it represents speculation only at the current time.

Fission technology is *only* sustainable in the sense of resource deployment if a relatively near-term (within 40-50 years) transition is made to fast breeder reactors. Given the performance to date of fast breeder reactors, there is little about which to be optimistic that fast breeder reactors could be commercialised and brought into widespread use in time support a hydrogen economy within the next two or three decades. The only nuclear alternative would be widespread deployment of fusion technology to power the hydrogen economy. If neither of these technologies proves to be feasible on a large scale, another (probably renewable) source of energy would be needed for the hydrogen economy.

11.4.4 Other Perspectives of the Hydrogen Economy

Whatever its potential as a vehicular fuel, hydrogen is in danger of being over-sold by its advocates seemingly as the answer to everything. Hydrogen will not be a major source of base load electrical generation. This conclusion derives from the fact that hydrogen must be produced from another energy source. For base load generation it makes far more sense (and is far cheaper and more efficient) to simply use the primary energy source to produce electricity directly. High temperature fission power plants and possibly future large fusion power plants (some 50 or more years in the future, if demonstrated to be feasible) may be able to economically produce bulk hydrogen during off-peak hours for use in load levelling during peak demand periods. In addition, hydrogen may be useful for electricity production on a small scale for remote sites, but if small, modular nuclear units prove to be feasible, even this use of hydrogen for power generation could be in question.

The burning or modification of a fuel, or using another power source (uranium, wind, solar or hydroelectric), to produce hydrogen is inefficient for electrical generation purposes. It is much more efficient to simply generate electricity directly from the original sources (fuel, uranium, wind, solar, biomass gas or hydroelectric). Hydrogen production and use only makes sense in the case of distributed uses (transportation, remote locations, etc.) and peaking power (load balancing). In the case of burning hydrogen for peaking power, however, it must be recognized that this use of hydrogen is not greenhouse gas-free because the high-temperature combustion process results in production of nitrous oxides (NO_x) which are greenhouse gases. It therefore seems more likely that use of hydrogen for peaking power will be by means of hydrogen fuel cell power plants.

11.5 Environmental Impacts from the Hydrogen Economy

In the explosion of articles, reports, papers and books about hydrogen in the past five years, the issue of environmental impacts from the hydrogen economy tends to get lost in the wake of dreams of a greenhouse-gas free energy economy. Production, storage, distribution and use of hydrogen all have environmental impacts that need to be systematically considered. In some cases, the environmental impacts are probably not going to be very different from those currently experienced with other fuels. In others, the environmental impacts are perhaps not as obvious as with existing fuels. Regardless, the environmental impacts of a hydrogen economy need to be identified and systematically assessed, as much as they are with any other energy technology.

Contrary to frequent and widespread statements, use of hydrogen is not entirely free of pollutants, depending on the energy source and chemical process used to produce the hydrogen, the nature of the storage and distribution system for the hydrogen and the end uses of the hydrogen. If hydrogen is burned in flame, for example, nitrous oxides (NO_x) will be formed due to hydrogen's flame temperature [Solomon & Banerjee 2004: 2; Bellona 2002].

In the case of nuclear power-related production of hydrogen, there is the usual suite of environmental issues associated with any nuclear power plant as well as those related to uranium mining and processing. The radioactive waste disposal issues also remain. Special attention must be paid to the hitherto little known environmental effects of the new generation of nuclear power plants and the plutonium economy. These issues are treated in other papers in this volume.

11.6 Safety and Risk Considerations for the Hydrogen Economy

11.6.1 Hydrogen BLEVEs and other Risks

Many of the discussions of the hydrogen economy assert a "low" risk. However, the risks posed by widespread adoption of a hydrogen economy have unfortunately not been systematically assessed and will undoubtedly vary depending on the concept at issue.

Bulk production, storage and distribution of liquid hydrogen have a particular risk that must be well understood – namely the occurrence of what is known in the industry as a "Boiling Liquid Expanding Vapour Explosion" or BLEVE.

BLEVE phenomena are applicable to any cryogenic liquid tank which fails due to fire. The tank pressurizes as the contents heat up, and a relief valve (if present) opens but – not being sized for such a pressure transient – the relief valve merely serves to maintain the pressure in the tank at the relief valve setpoint. As the fire progresses, if not extinguished soon enough, the tank wall will weaken and then structurally fail. The tank tends to fail catastrophically, blowing tank debris through a large area (upwards of about a kilometre or so). If the cryogenic fluid stored in the tank is combustible, the tank contents tend to explode, adding a shock wave and thermal pulse to the damage caused by the BLEVE[17].

From 1950 to 2004, there were nine BLEVE's recorded in Europe involving LPG transport (one involving rail transport, and the other eight involving truck transport) [Molag & Kruithof 2005]. BLEVEs are also applicable to cryogenic hydrogen transport and stationary cryogenic hydrogen storage tanks in case of fire.

There is apparently little publicly available data on liquid hydrogen BLEVEs. The limited data available on LPG BLEVE's suggest a frequency for tank farm BLEVEs of 4×10^{-4} per tank farm year. If such a frequency is also applicable to liquid hydrogen storage (this is unknown at present), it would pose a potential problem in the case of bulk hydrogen production using nuclear power. Considering the EU-25 example above, if 2,373 four-module H2-MHR hydrogen production stations were built, this would result in a BLEVE at a nuclear hydrogen production station on average about every year.

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[17] An indication of the recognition within governmental emergency response agencies of the hazards posed by cryogenic hydrogen transport and storage is provided the fact that the North American Emergency Response Guidelines (2004) recommend an immediate evacuation in all directions to a distance of 1600 meters whenever a cryogenic hydrogen tank is involved in a fire; see [DOT 2004].

Another potentially important risk that needs to be understood in the context of bulk hydrogen production is the potential for process or storage system failures which result in the release of large quantities of hydrogen to the air. Such a release can result in a confined vapour cloud explosion (but typically not in a well designed facility, which prevents confinement of releases) but more likely an unconfined vapour cloud explosion (UVCE). Such explosions have occurred in non-hydrogen facilities, causing extensive damage (e.g., Flixborough, United Kingdom, 1974)[18].

Non-fire related tank failures are not so uncommon. Statistics from the Loss Prevention Association of India indicate frequencies around 1.5×10^{-3}/a for low temperature vessels and up to 2.7×10^{-3}/a for process vessels [Viswanathan 2004].

The limited available statistics for cryogenic tanks (with and without fires) indicate that if bulk hydrogen production and large storage tanks are used for the hydrogen economy (which is clearly envisioned by advocates of using high temperature gas-cooled reactors for production purposes), there could be a non-negligible likelihood of large explosions. The effects of such explosions on structures, systems, components, and operating staff at the co-located nuclear facility will require very careful design and analysis to mitigate potential risks.

11.6.2 Hydrogen Infrastructure Vulnerability

An assessment of infrastructure vulnerability for the hydrogen economy requires a definition of how the hydrogen economy will be structured, requiring answers to questions such as:

- Will hydrogen production be centralized or distributed?

- If centralized, will the hydrogen be distributed via pipeline or bulk transport by rail and/or truck?

Consider possible security/terrorism implications of shipping liquid hydrogen – at about 17,500 shipments per day for the EU (350 per day for Austria), one would need a veritable army of guards solely to protect liquid hydrogen shipments. And how effective could the guards be against terrorists armed with assault weapons and Rocket-Propelled Grenades (RPGs) if their adversaries are attacking liquid hydrogen transport trucks? How many guards are needed for each truck?

If bulk production, storage and distribution are used in the hydrogen economy, a very careful assessment of infrastructure vulnerability will be required, if for no other reason than to understand the degree of difficulty (or simplicity as the case may be) with which significant disruptions could occur due to man-made and natural phenomena hazards, particularly extreme events such as earthquakes, high winds and incidents of sabotage and terrorism. In the latter regard, security vulnerability concerns are already being expressed for gasoline, LNG and LPG facilities

[18] This accident resulted in a release of cyclohexane which was subsequently ignited, resulting in an explosion with a yield equivalent variously estimated to the explosion of 9-280 tonnes (more commonly cited as 16 tonnes) of TNT. A variety of easily accessible sources provide additional information (http: //www.hse.gov.uk/comah/sragtech/caseflixboroug74.htm; http: //en.wikipedia.org/wiki/Flixborough_disaster; http: //www.icheme.org/about_icheme/medals/Venart2004.pdf).

and transport. The concerns for bulk cryogenic hydrogen storage facilities and liquid hydrogen transport are no less serious[19].

The environmental impact issue is not developed in detail here, but clearly it is one requiring detailed attention if a move is made to go to a hydrogen economy. The issue needs to be addressed up front and on a continuous basis so that consideration of environmental impact is one of the "drivers" of the technologies, instead of waiting until the last step (implementation) before concerning oneself with environmental impact.

11.6.3 Nuclear Risks

The safety (and risk) issues involved with nuclear power plant-based hydrogen production depend on the reactor type (and power level) selected, the hydrogen production method used, reactor site-related features and hazards and the proximity and type of hydrogen storage and/or transmission technologies employed. The nuclear risks of power plants and waste disposal sites are extensively treated in other contributions to this volume.

The nuclear industry is well aware of the necessity to ensure that the nuclear reactor and the hydrogen production facility are sufficiently isolated from one another that an "upset" in one facility does not impact the other [Forsberg & Pickard 2002]. If this aspect of the risk posed by nuclear production of hydrogen is satisfactorily addressed, there should be no additional radiological safety issues attendant on nuclear production of hydrogen compared with operating a nuclear power plant as a producer of electricity and/or process heat. However the larger number of plants increases the overall risk.

11.7 Conclusions

The following conclusions are suggested based on this paper:

- Hydrogen is not a primary energy source – it is an energy carrier and must be created by using some other primary energy source (nuclear, wind, photovoltaic, biomass, etc.). Energy is required to create hydrogen, compress or liquefy it for storage and distribute it. The overall efficiency of this centralized hydrogen economy is low.

- Hydrogen production methods are variations of three basic methods: (a) electrolysis, (b) steam reforming methane and (c) thermo-chemical water-splitting schemes. Of these, electrolysis and steam reforming methane are well developed. Thermo-chemical water-splitting is still at only laboratory scale despite four decades of research and in application involves what appear to be considerable problems with corrosion of materials as well as chemical hazards which have yet to be systematically assessed.

- Electrolysis and thermo-chemical water-splitting schemes could be powered by nuclear plants, but the use of present generation nuclear power plants would not be efficient.

[19] Clearly any security threat incident which involved catastrophic failure of a cryogenic hydrogen tank under pressure due to external fire would pose a BLEVE hazard. Note that security threats could include hijacking of a cryogenic hydrogen tank truck and driving it to a "high-value" target of choice. The US Army has warned brigade and battalion commanders, and staff officers, about such a hazard involving hijacked gasoline tank trucks since at least 1992 [US Army 1992].

- Centralized, bulk hydrogen production, storage and distribution carries with it risks of specific types of chemical accidents (BLEVEs & UVCEs) which require careful probabilistic and deterministic analysis on the scale of hydrogen production contemplated in current replacing passenger vehicle fuels with hydrogen.

- A decentralized, "just-in-time" hydrogen economy is only just beginning to be explored, but appears to more adaptable to diverse primary energy sources and eliminates risks associated with BLEVEs which are only possible in the case of bulk distribution of cryogenic liquid hydrogen[20].

- The amount of hydrogen needed to support a hydrogen economy for light duty vehicles in the 25 EU states is of the order of 23 million metric tonnes per year. This about half of the current world production.

- Production of such a quantity of hydrogen is a huge undertaking, the costs of which will run into the range of € 250-500 billion.

- The hydrogen needed annually just to fuel the current light vehicle fleet in the 25 European Union countries would appear to require of the order of sixty-three EPR nuclear stations, supporting distributed production of hydrogen via electrolysis or of the order of one hundred and five H2-MHR modular nuclear stations with co-located thermo-chemical water-splitting plants for bulk hydrogen production.

- The security and terrorism threat implications of a hydrogen economy have barely begun to be considered. But it would imply – in the case of a transportation system centred around bulk cryogenic hydrogen – providing security for 6.4 million shipments of liquid hydrogen per year. That's over 17,500 shipments per day in the EU (for Austria about 350 shipments per day) – each potentially requiring security.

- The environmental problems associated with the hydrogen economy are only beginning to be addressed. More research is needed before the impact of releasing gaseous hydrogen into the atmosphere on a scale attendant upon the hydrogen economy is adequately understood.

- At present it is difficult to see hydrogen – nuclear or non-nuclear - as a significant contribution towards the solution of either the climate problem or the emerging energy gap; it is certainly not one that can be rapidly deployed.

[20] The US Department of Energy has issued a draft hydrogen roadmap report indicating that distributed production is the most viable option for introducing hydrogen and building hydrogen infrastructure (DOE 2005b).

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12 Sustainability and the Production of Electricity by Nuclear Power Stations – The Legal Dimension

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October 2004

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12 Sustainability and the Production of Electricity by Nuclear Power Stations – The Legal Dimension

12.1 Avant Propos

This analysis is performed on three levels. To begin with the term "sustainability" the problem of its substantiation within extra-legal normative systems is considered. The second level is dedicated to the discussion of "sustainability" in the field of public international law and the law of the European Community. On the third level the intrinsic incompatibility of electricity production by nuclear power stations with the principle of sustainability is derived from some examples of legal provisions on the licensing, the operation and the dismantling of nuclear power stations and the management of radioactive waste.

12.2 Law and Other Normative Systems

12.2.1 Law and Society

The legal evaluation of segments of societal reality is reduced to the dichotomy of "legal" and "illegal". Even the most complex legal systems consist of nothing else but a hierarchically structured system of formalised criteria for "yes - no" and "if - then" decisions. The result of these decisions is linked to certain societal consequences, which are legally determined. We speak of legal consequences. In this context, one has to bear in mind, that legal systems are self-contained formal systems providing their own creation and their own abolition [Walter 1974][1].

They are linked to societal reality by the law making processes on the one and law enforcement on the other hand. The law making procedure however is of special importance, as it is the exclusive way for rendering legal relevance to societal demands for regulations. Societal demands that do not pass the membrane of law making, remain without legal relevance, no matter what imperative character, they may have - according to whatever value systems.

Another important societal function of a legal system is its creating predictability and by that security. Legal systems are carried by the expectation of all their actors, that the respective other actors will shape their behaviour according to the guidelines provided for in their provisions. Thus legal systems may be seen as mutually conditioned sets of commonly shared behavioural expectations [Luhmann 1993][2]. Deviating behaviour (i.e. illegal) is met by standardized sanctions, the execution of which is reserved to special authorities, endowed with the exclusive right to use force as ultimate ratio. Due to this enforceable general validity of law, the societal values incorporated in legal norms carry an enhanced importance and stability as compared to other values.

[1] See Robert Walter, Der Aufbau der Rechtsordnung, 2. Aufl. (1974), p. 13 ff.

[2] Especially Niklas Luhmann, Das Recht der Gesellschaft, 1. Aufl. (1993); ibid., Rechtssoziologie, 3. Aufl. (1987), passim, with further references.

12.2.2 Extralegal Normative Systems

Yet behavioural expectations are also created by other normative systems as e.g. custom, morals and other social conventions. Among the latter we may list the principles of environmental protection, which are carried by increasing though not unlimited consensus. These extra legal normative systems comprise those societal demands for regulation which have not - or not yet - passed the membrane into the contents of legal systems.

It is important however to distinguish clearly between legal and extra legal normative systems. They differ in their creation and in the formal quality of the sanctions against deviating behaviour. Legal systems are created by specially legitimated authorities according to a particular, formalised procedure. Extra legal normative systems arise from unspecified societal processes in various ways, without any formalised procedure.

Legal systems standardise and formalise sanctions against deviating behaviour. Their application is reserved to especially legitimated authorities, in order to secure the binding character of law even by force as a last resort.

Extra legal normative systems are not generally binding. Their sanctions are not standardised and their application and execution are left to the discretion of the actors of the system. Their consequences, however, may be more severe than legal sanctions, as for instance social isolation within a society or economic embargoes on the international plane[3].

12.3 The Operationalization of Sustainability

12.3.1 The Brundtland – Formula

The term sustainability seems to have been used as early as in the 18th century in German forestry suggesting the utilisation of forests in perspective of the needs of future generations [Deutscher Bundestag][4]. The current version of sustainability was coined in the Brundtland Report: "Sustainable development is a development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [Report of the World Commission on Environment and Development][5]. Although phrased in the indicative, this sentence clearly has the marks of a postulation, of an imperative that is to say of a norm. A norm that belongs to an extra legal normative system, yet with the capacity of creating predictability in the sense given above.

The broad consensus, which carries this understanding of sustainability to a great extent, was facilitated by the ambiguity of its phrasing. Contents and set-up of the Brundtland Report[6] however clearly indicate its designation as a master plan for shaping nearly all fields of societies. The EU Commission too, in a proposal to the European Council emphasised: "Sustainable

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[3] E.g. UN Charter Art. 41.

[4] Wissenschaftliche Dienste des Deutschen Bundestages, Fact Sheet 06/2004, [www.bundestag.de/bic/analysen] visited: 28.10.2004.

[5] "Our Common Future", Report of the World Commission on Environment and Development (Independent Expert Commission founded by the UN 1983) under the chairmanship of Gro Harlem Brundtland, UN-Doc. A/42/427, August 4 ,1987, p. 54.

[6] 12 Chapters with 336 pages. The topics covered range from "New Approaches to Environment and Development" to "Conflict as a Cause of Unsustainable Development".

development should become the central objective of all sectors and policies."[7] The forthcoming reviews of Common Policies must look at how they can contribute more positively to sustainable development. The fields covered by this paper therefore reach from Common Fisheries Policy (especially fish stocks management and protection of the maritime ecosystems) to the improvement of law making procedure in the European Communities in view of assessing the potential economic, environmental and social benefits and costs of action.[8]

The demand for sustainable development has numerous dimensions. That entails the necessity of its specification not just in general but according to the needs of the respective fields of its application.[9] The above mentioned origin of sustainability from forestry hints better than any other reference, that sustainability basically is a question of distribution of resources between the present and future generations. The operationability of such an understanding of sustainability requires however a renewable amount of resources, as in forestry. To distribute a limited amount of non-renewable resources between the present and future generations in a sustainable way will pose an unsolvable enigma, as the somehow assessable size of the present generation has to be confronted with the (hopefully) infinite chain of future generations.

12.3.2 Sustainability as a Paradigm for Distribution

Yet in the context of producing electricity from nuclear power it does make sense to deal with sustainability in view of the issue of resources sharing. The main resource, we have to deal with here is global environment, which basically has a self healing and self renewing capacity, but is structurally consumed and impaired by the operation of nuclear power stations. This is due to the inevitable emission of radiation in normal operation and the still unsolved question of permanently reposing (disposal)[10] of spent nuclear fuel and nuclear waste. A potential consumption and impairment of the environment lies in the possibility of grave nuclear accidents.

The reality of nuclear industry, by the way, proves the European Commission to be quite right in adding the field of law making (as shown above) to those to be considered in the context of enhancing sustainability. A good deal of the lacking sustainability of nuclear industry lies in the fact that its regulatory need is met exclusively by national legislation without serious institutionalized international control or control by the European Communities, so as if the consequences of nuclear accidents would stop at national frontiers.

12.3.3 Sustainability as Rule of Proportionality

We may hold at this point that sustainability is widely accepted as a socio-ethical norm and thus could well serve as a guiding line for forming future societies. And yet we have to realise that in its generality sustainability is a norm, whose normative value has to be established in the concrete circumstances. There is no universally valid concept of sustainability. It has to be enhanced with additional values and aims in order to be applicable to specific situations. To this end we also need a convincing definition of the "needs" of the present generation and the "abilities" and "needs" of the future generations.

[7] A Sustainable Europe for a Better World: A European Union Strategy for Sustainable Development, COM (2001) 264 final, p. 6.

[8] Ibid.

[9] This is also reflected in the Proceedings of the International Law Association attempting to furnish sustainability with an international law dimension. The International Law Association, Report of the Seventy-First Conference (Berlin 2004), *Committee on International Law on Sustainable Development* p. 566-620, report p. 566-586.

[10] Different sources use different terms.

In other words, we are confronted with problems with no convincing solutions in sight. All we can do is to search with the best of our *present* abilities for ways of *approximating* plausible solutions for practically infinite times to come. Never the less it is urgent to set the ground for conceiving convincing *methods* for at least developing eventually satisfying solutions.

The normative character of the principle of sustainability referred to above suggests an approach to the problem of its operationability with normative reasoning. Sustainability provides the inseparable dependence of the future generations on the existing present generations, yet without any standing for claiming whatever rights they may have. A truism of course, as only those who exist are in a position to lay claims. The principle of sustainability is a norm of self restraint with only virtual claimants. Yet in order to make sense, even such a unilateral social norm requires to be applicable to individual cases, which requires operationability.

This could be achieved by analogy to the principle of proportionality as laid down for instance in the Treaty on European Community (EC), which deals with a comparable situation, as it seems. Its aim is to prevent the EC from taking more legal competences from its Member States than is absolutely necessary for achieving the goals of the EC. The principle of sustainability on the other hand is to prevent the existing generations from consuming an excess of natural resources at the expense of the future generations.

Against this background the principle of sustainability in the field of energy production could be operationalized as follows:

The present generation's demand for energy is to be kept as moderate as possible and should be covered with the least possible expense of resources and at the least possible environmental costs. According to the principle of real cost assessment the burdens of energy production are to be met by those generations exclusively, which take advantage of it. [fn.58][11]

This solution of the dilemma of operationalizing the principle of sustainability would also easily fit into the range of the objectives of EC environmental policy.[12]

12.3.4 Sustainability as Global Conviction

Notwithstanding the difficulties of specifying the term sustainability it was introduced into two meanwhile historic final declarations of international UN conferences on environment. In the Rio Declaration on Environment and Development [Report of the UN Conference on Environment and Development][13] sustainability is understood as a human right to "a healthy and productive life in harmony with nature" (Principle 1) and environmental protection is considered the central element of sustainable development (Principle 4). In order to secure sustainable development: "States should reduce and eliminate unsustainable patterns of production and consumption and promote appropriate demographic policies" (Principle 8).

[11] See also below at fn. 58 and the Argumentarium of the German Federal Government about Sustainability in context with the so called "Ausstieg aus der Atomenergienutzung", [http: //www.bmu.de/de/1024/js/download/b_nachhaltigkeit_kernenergie] (visited: 28.10.2004).

[12] Art. 174 EC Treaty.

[13] Annex I to the Report of the UN Conference on Environment and Development (Rio de Janeiro, June 3-14, 1992).

The next UN summit on development in Johannesburg (August 24 till September 4, 2002) was already named "World Summit on Sustainable Development".[14] The measures adopted during its course reveal a specification of the policy of sustainability towards the global raising of the lowest social levels of sanitation-, water-, health- and energy-supply. Commitments to combat desertification, to reduce biodiversity loss, activities to improve access to the markets for the Least Developed Countries and measures to improve their management of natural disasters round off the concept of sustainability of the Conference. Even there a definition of sustainability was avoided.

The final declarations of both Conferences are of national and international political significance though not legally binding. They reflect however the global consent over the indispensability of a policy of sustainability.

12.4 Sustainability as Legal Norm

12.4.1 The UN Framework Convention on Climate Change

The multilateral UN Framework Convention on Climate Change 1992[15] was concluded in the realm of the Conference of Rio. It is in force since March 1994[16]. The Framework Convention seems to be the first international treaty to contain "sustainability" in varying contexts as substantial part of international legal regulations. The measures to be taken by the parties to the Convention in order to prevent dangerous anthropogenic interference with the climate system for instance should allow for "the economic development to proceed in a sustainable manner"[17]. In the broad spectrum of the numerous commitments undertaken by the parties to the Convention sustainability repeatedly is referred to as decisive specification of the measures required by the Convention.[18] This is of special significance as the Convention contains various provisions on reviewing and controlling the implementation of the commitments undertaken by the parties[19] and on dispute settlement[20] including the possibility of submitting disputes to instances of arbitration or even the International Court of Justice. The parties to the Convention thus indicate their intention to accept sustainability in its respective specification at least as potential criterion for solving legal disputes.

The necessity of specifying sustainability for each individual case, as said above, still remains of course. The Convention however paved the way for eventually specifying "sustainability" by legal (in the sense of the Convention) authorities, with legal relevance for the given case before it. It is quite common that the legislator leaves the specification of substantially difficult or just controversial terms to the wisdom of the ensuing legal practice of administrative authorities or courts of justice. We speak of the so called "unbestimmte Gesetzesbegriffe" (indeterminate legal

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[14] Final Report (incl. Corrigendum) [http: //www.johannesburgsummit.org/html/documents/documents.html] (visited: 28.10.2004).

[15] United Nations Convention on Climate Change, (31 International Legal Materials (ILM) 1992, p. 851, [http: //unfccc.int/resource/docs/convkp/conveng.pdf] (visited 21.11.04).

[16] BGBl. 414/1994; BGBl. III 12/1999.

[17] Art. 2

[18] Art. 4

[19] Art. 7 - 10

[20] Art. 14

terms)[21]. As "sustainability" is also twice referred to in the preamble of the Convention it gains additional legal quality as guidance for interpreting its provisions in case of doubt, according to the international law of treaties.[22]

12.4.2 The Kyoto Protocol

The so called Kyoto Protocol[23] even more elaborates on sustainability. It is based on the above presented Framework Convention and was signed by the majority of its parties on December 11, 1997. The protocol is in force[24] since February 12, 2005, as it was approved by both houses of the Russian parliament on October 27, 2004.[25]

The Kyoto protocol provides the reduction of the carbon dioxide emission of its parties according to individually assessed quotas for each of them, with the possibility of trading the quotas. What interests here, is the fact that after its entering into force, those of its provisions referring to sustainability as legal criterion become applicable too. The whole amount of commitments listed in Art. 2 is intended "to promote sustainable development." To this end we find in Para. 1, lit a ii "promotion of sustainable forest management practices, afforestation and reforestation" and in lit a iii "promotion of sustainable forms of agriculture in the light of climate considerations". The control of the compliance with the various provisions of the Protocol including the application of the elements of sustainability is vested with the conference of the Parties to the Protocol[26]. Similar to the above mentioned Framework Convention the measures of dispute settlement under the Protocol may also comprise authorities or courts of arbitration or even the (UN) International Court of Arbitration. In other words, both international treaties, the Convention and the Protocol provide the legal norms as well as the procedure, to give sustainability a genuine legal quality.

12.4.3 Sustainability in the Law of the European Community

We find the term "sustainability" in the wide meaning, as shown above in the Treaty Establishing the European Community (TEC) in various places. Art. 2 lists "balanced and sustainable development of economic activities" and "sustainable and non-inflationary growth" among the other tasks of the Community.

In Art. 6 "the promoting of sustainable development" is made an integral aim of integrating environmental protection requirements into the definition and implementation of Community policies...". Thus "sustainability" is made an integral part of common environmental protection, although it is neither expressively referred to among its objectives in Art. 174 nor in the operational regulations of Art. 175. As the requirements of environmental protection have to be observed in all other fields of Community tasks sustainability has, or at least will, become a key paradigm for

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[21] As for instance "Einbruch der Dunkelheit" (beginning of darkness); Reinhold Zippelius, Juristische Methodenlehre, 6th Ed. (1994), p. 43 et seq.

[22] Vienna Convention on the Law of Treaties, Art. 31 Para 2. See Alfred Verdross - Bruno Simma, Universelles Völkerrecht, 3rd Ed. (1984), p. 492

[23] Kyoto Protocol to the United Nations Framework Convention on Climate Change (1997), 37 ILM 1998 p. 22.

[24] According to its Art. 25 the Kyoto Protocol enters into force after the ratification by at least 55 Signatories or more until the ratifying parties together account for more than 55,5 % of the global carbon dioxide emission.

[25] "Russisches Oberhaus verabschiedet Kyoto Protokoll" [http: //www.welt.de] (visited: 27.10.2004).

[26] Art. 13. and additional institutional provisions Art. 14 to Art. 19.

Community policies. It is or will increasingly become part of what doctrine calls a cross-section matter.[27]

In the realm of third world politics and development co-operation "sustainability" is an explicit aim of common development policy. According to Art. 177, the Community fosters "the sustainable and social development of the developing countries, ...".

Sustainability as part of environmental protection was also introduced into the "Charter of Fundamental Rights of the Union". Art. 37 reads: "A high level of environmental protection and the improvement of the quality of the environment must be integrated into the policies of the Union and ensured in accordance with the principle of sustainable development." The Charter of Fundamental Rights is not part of the existing Community law but it should be taken into consideration as guiding line for its enacting, administration and interpretation. It was increasingly referred to in the judgements of the European Court of Justice[28] and the Court of First Instance[29].

Meanwhile the Charter of Fundamental Rights was made part of the Draft Treaty establishing a Constitution for Europe, signed on October 29, 2004. If the European Constitution should ever enter into force against all odds,[30] the right to environmental protection in accordance with the principles of sustainable development Art. II-97 not only will become part of existing law but also an individual right of the European citizens, however only within the still weak competences of the EC in environmental policy. [31]

12.4.4 Provisionary Outlook

We may conclude this chapter with the following resumé: Sustainability is a practicable item for legal systems. As far as now, we have no convincing indicator though, that it has already become part of international customary law. The examples of the two international treaties show however, that sustainability may very well be litigable, once the respective authorities are established.

Under EC law "sustainability" is established without doubt as one of its numerous operational components. The necessary legal requirements are prepared. Only the facts for respective cases are lacking. That is the reason for the absence of administrative and judicial practice.

Both in international law as well as in Community law it will rest with the deciding administrative or judicial authorities to specify "sustainability" for each individual case.

It has to be warned however against too high expectations. All that can be said now[32] is that sustainability has been made part of legal norms. Whether a given situation, even if considered

[27] Rudolf Streinz, Europarecht, 7th Ed. (2003), RZ 1113 uses the term cross-section clause.

[28] See e.g. the opinions of Attorney-General Juliane Kokott of October 14th, 2004, Joint Case C-387/02, C403/02, Silvio Berlusconi et al., not yet in ECR.

[29] Case T-177/01, Jégo-Quéré/Kommission, ECR 2002, II-2365 (para. 47), Case T-54/99, max.mobil Telekommunikation Service GmbH/Kommission der Europäischen Gemeinschaften, ECR 2002, II-313 (para. 48).

[30] As a consequence of the negative referendums in France (May 29, 2005) and the Netherlands (June 1, 2005) the project of a European constitution failed, as its Art. IV-477 requires the constitutional assent of all member states.

[31] The present role of sustainability in existing Community law will remain unaltered under the new European Constitution with a good chance of even gaining importance.

[32] February 16, 2006.

to be a grave nuisance, can successfully be brought before administrative tribunals or courts of law, depends on its specification for the given circumstances. The many dimensions of sustainability leave the addressed legal authorities with a wide range of creative discretionary power for interpretation. In a legal dispute however, the interpretation of sustainability lies in the competence of the deciding authority exclusively. Sustainability as legal term is neither at the disposal of the parties to a dispute nor the general public. Outside legal systems "sustainability" is an object of public discourse either in general or focused on a given situation.

This is important to stress in application to the question of sustainability of nuclear power stations. If we are able to prove sustainability to be a substantial element of an existing legal norm with appropriate jurisdiction of administrative or judicial authorities, we have a chance of initiating legal procedure, provided we are able to present the necessary evidence for its violation.

As long as the question of sustainability of nuclear power stations remains on the societal, the political plane, we are in an endless chain of political arguments and disputes over the real, the ultimate concept of sustainability.

This structural dichotomy between the legal and the purely societal plane of dealing with the problems of nuclear politics accounts for the reluctance of the governments of nuclear power states to enter into binding legal agreements restricting their freedom of choice.

12.5 The Licensing of the Construction and the Control of the Operation of Nuclear Power Stations as Prerogative of the Individual State

12.5.1 The Convention on Nuclear Safety

1996, ten years after Chernobyl (!) the Convention on Nuclear Safety (1994) entered into force.[33]

Its paramount goal is "to achieve and maintain a high level of nuclear safety world wide".[34] In the perspective of this analysis it is significant, that the Convention reaffirms "that responsibility for nuclear safety rests with the State having jurisdiction over a nuclear installation".[35] Consequently almost every article begins with the stereotype "Each Contracting Party shall....". The ensuing commitments are so common, trivial and unspecific, that 50 years after the construction of the first nuclear power stations they must have been fulfilled by the Parties before signing the Convention.[36] The accomplishment of the safety standards is left entirely to the Parties of the Convention. Occasionally the national safety standards are referred to. Art. 14 for instance amongst others provides that the surveillance of the operation of nuclear power stations ensures, that they continue "to be in accordance with its design, applicable national safety requirements, and operational limits and conditions. Even in the context of radiation protection of workers and the general public it is the "prescribed national dose" that is referred to as limits.[37] All these are

[33] Text in [http: //www.iaea.org/Publications/Documents] Though the Convention was drafted and signed under the auspices of the IAEA, it is not an IAEA Convention in the strict sense of the word.

[34] Art. 1

[35] Preamble Pt. iii

[36] Otherwise the Convention certainly would not have been concluded at all.

[37] Art. 15

no editorial flaws but the expression of the clear will of the contracting Parties. The preamble makes clear, that "this convention entails a commitment to the application of fundamental safety *principles* for nuclear installations rather than of detailed safety *standards*"[38]. Maybe as a kind of relief this paragraph continues with the reference "to internationally formulated safety guidelines, which are updated from time to time". All this would be quite tolerable, if the Convention created a regulatory body in charge of specifying its rather general provisions in the individual cases. But that is not the case. The review of the compliance with the Convention is assigned to Review Meetings of the Contracting Parties, which decide by consensus[39].

The Convention of course had to deal with the possibilities of nuclear accidents. The Parties are aware, "that accidents at nuclear installations have the potential for transboundary impacts".[40] In Art. 18 they are just committed to ensure, that nuclear installations are designed and constructed "with a view to preventing the occurrence of accidents and to mitigating their radiological consequences, should they occur." As easy as that!

No doubt, the nuclear power states were quite successful in preserving the exclusiveness of their competence to regulate their nuclear economy according to their own interests.

12.5.2 The European Atomic Community (EAC)

An analysis of the law of the EAC results in a similar, yet slightly more differentiated picture. Still there is no community wide regulatory standard for the nuclear industry binding all 27 Member States equally. Only the new states had to accept a review of their all ready existing nuclear power stations by the EU Commission as a prerequisite for their admission to the Union. The enlargement procedure thus forced the question of nuclear safety to the Community plane, what was carefully avoided till then since the establishment of the EAC. After preparations under the Austrian Presidency[41] the Cologne summit for the first time considered to raise the safety standards of the nuclear power stations in the accession states to the European level: "The European Council emphasises the importance of high standards of nuclear safety in Central and Eastern Europe. It stresses the importance of this issue in the context of the Union's enlargement and calls on the Commission to examine this issue thoroughly in its next regular progress reports on the applicant countries, due in autumn 1999"[42]. From then on, the question of nuclear safety in the context of the enlargement of the Union gained separate dynamics. The dispute between the Czech Republic and Austria over the nuclear power station in Temelín too was and still is carried by that dynamics.

The European Council of Laeken extended the concern about nuclear safety beyond the acceding states over all nuclear installations in the EU: "The European Council undertakes to maintain a high level of nuclear safety in the Union. It stresses the need to monitor the security and safety of nuclear power stations. It calls for regular reports from Member States' atomic energy experts, who will maintain close contact with the Commission".[43]

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[38] Pt. vii

[39] Art. 22 - 25

[40] Preamble Pt. v

[41] See Council, 24 September 1998.

[42] European Council of Cologne, 3/4 June 1999, Presidency Conclusions; see also European Council of Helsinki, 10/11 December 1999, Presidency Conclusions, para. vii.

[43] European Council of Laeken, December 14/15, 2001, Presidency Conclusions, para. 59.

The Commission started extensive activities to introduce common standards for nuclear safety for all EU states[44] and presented two proposals for Directives dealing respectively with the safety of nuclear facilities and the management of spent fuel and radioactive waste. These initiatives failed. The "powerful nuclear industry"[45] could relax. Looking back, the substance of these two proposals did not warrant hopeful expectations. The proposal for a "Council Directive (Euratom) laying down basic obligations and general principles on the safety of nuclear installations"[46] in general does not exceed the standards of the Convention on Nuclear Safety, mentioned above. Still, two elements deserve attention.

First, the proposal also covered the implications of the closure and dismantling of nuclear power stations[47]. Of course the various concepts - legal or extra legal - of nuclear safety indirectly comprised these implications. Yet they were never dealt with as separate area for regulation. The necessity to do so, arose from the imperative need to close down and dismantle several sub-standard nuclear power stations in the acceding former communist states. One of the various practical tasks to be accomplished in this process was that of funding.[48] The total costs of closure, dismantling and reconditioning of the site are estimated to 15 % of the original investment. In absolute figures that may amount to 200 Millions to 1 Billion Euro.[49]

Second, the national regulatory bodies were to be submitted to the control by the Commission. To this end the Commission was to avail itself of an expert council the members of which were to be nominated by the member states. This had been a great procedural progress, although the main responsibility for securing the compliance of the nuclear industry with the still national safety regulations remained with the national regulatory bodies. The even greater advantage had lain in the fact, that questions of the safety of nuclear installations had become litigable before the European Court of Justice.

In 2004 the Commission again presented revised versions of the two proposals. The amended proposal for a "Council Directive (Euratom) laying down basic obligations and general principles on the safety of nuclear installations"[50] now is completely reduced to the low standard of the Convention on Nuclear Safety. The reference to the problems of closing down and dismantling outdated nuclear power stations was eliminated as well as the supervision of the national regulatory bodies by the Commission. What is left as a last trace of makeshift control is a Committee of Regulatory Authorities composed of *representatives* (!) of the national regulatory bodies for advising the Commission and among other things for summing up the annual reports to be sent in by the member states.[51] The Commission has no material authority what so ever over the

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[44] With further references Manfred Rotter, Nukleare Sicherheit in der Europäischen Union, in Christian Callies (Hrsg.), Der Konventsentwurf für eine EU-Verfassung im Kontext der Erweiterung: Vorträge des Dritten Österreichischen Europarechtstages am 12./13. September in Graz, organised by the Institute for Community Law at Karl-Franzens-Universität Graz, 1. Ed. (2004).

[45] In line with the generally shared convictions of 1957, one of the aims of EAC Treaty was "to create the conditions required for the development of a powerful nuclear industry which will provide extensive supplies of energy, lead to the modernisation of technical processes and in addition have many other applications contributing to the well-being of their peoples,..." (Preamble, para. 4).

[46] COM (2003) 32. The proposal for a "Council Directive (Euratom) on the safe management of the spent nuclear fuel and radioactive waste" in the same document is mentioned here without further comment.

[47] Art. 4

[48] Art. 9, para. 2.

[49] COM (2002)605 final, p. 2 et seq.

[50] COM (2004)526 final.

[51] Art. 12

national regulatory bodies. There seems to remain a vague though possibility of jurisdiction of the European Court of Justice for matters of the safety of nuclear power stations if they amount to a breach of the directive.

In short, the nuclear power states preserved their exclusive authority over the nuclear industry under their jurisdiction. The security requirements in the Convention on Nuclear Safety are far too general to offer quantifiable or otherwise specified criterions for assessing the safety status of a given nuclear installation. The quite impressive first attempt of the Commission to bring the question of the safety of nuclear installations to the Community level failed. The chances of the second substantially milder attempt are open.

12.6 The Provisions for Permanent Repositories (disposal facilities)

Of course the chemical and physical requirements of the permanent reposition of the spent nuclear fuel and highly radioactive waste are known and recognised on the national, the international and the level of EU and its Communities. However, the gathering of the respective scientific findings is one thing, the preparation of the necessary legal regulations, the creation and funding of institutions for coping with their organisational consequences is quite another.

12.6.1 The Spent Fuel and Radioactive Waste Convention

This highly important aspect of the nuclear industry is covered by the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management also drafted under the auspices of the IAEA[52]. The problems of spent fuel management are dealt with in Art. 4 to 10 and those of the safety of radioactive waste management are dealt with in Art. 11 to 17. Then follow regulations common to both parts and some rather weak provisions on compliance control[53]. Within these two main areas of regulations a difference is made between installations for spent fuel management and radioactive waste management respectively on the one side and permanent reposition (in terms of the Convention "disposal") on the other. Installations for the management of spent fuel and radioactive waste are dealt with in more details than those for the permanent reposition. Clearly enough disposal[54] (permanent reposition) does not require specially elaborated rules for "operating" or "decommissioning", once the installations are filled and closed[55]. Yet it is exactly the finality of the reposition that requires special regulations for siting and constructing the respective installations and the emplacement of nuclear waste. These requirements are not met at all, as will be shown below.

The Joint Convention like the Convention on Nuclear Safety follows the principle that every state itself has to provide all that is necessary for the management of spent fuel and radioactive waste of nuclear installations on its territory. That comprises the definition of safety standards

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[52] Text at [http: //www.iaea.org/Publications/Documents/Conventions] (visited: 28.10.04).

[53] They follow the pattern of the Convention on Nuclear Safety.

[54] According to Art. 2 lit. (d): "disposal means the emplacement of spent fuel or radioactive waste in an appropriate facility without the intention of retrieval; " while according to lit. (t): "storage means the holding of spent fuel or radioactive waste in a facility for its containment, with the intention of retrieval".

[55] According to Art. 2 lit. (g): "operating lifetime means the period during which a spent fuel or a radioactive waste management facility is used for its intended purpose. In the case of a disposal facility, the period begins when spent fuel or radioactive waste is first emplaced in the facility and ends upon closure of the facility".

within its own legal system (Art. 18 and 19), to establish regulatory bodies entrusted with the implementation of these standards (Art. 20), to ensure the necessary human and financial resources (Art. 22) as well as radiation protection (Art. 24), to name the most important items only. Specific standards in terms of borderline limits are explicitly avoided. All that is required to "provide for effective protection of individuals and society and the environment by applying at the national level suitable protective methods..." with due regard to "internationally endorsed criteria and standards" (Art. 4, para. 2, lit. iv).

It certainly is a good idea that already at the design state of a disposal facility (permanent repository), the technical provisions for its closure must be prepared (Art.14, lit. iii) and that before its construction a systematic safety assessment and an environmental assessment for the period following closure shall be carried out according to the criteria established by the regulatory body (Art. 15, lit. ii).

The problem, however, is that the main intention of the authors of the Joint Convention was to leave the autonomy of its parties for dealing with spent fuel and radioactive waste including its disposal (permanent reposition) should remain untouched. That may easily be deduced from the fact, that the normative implications of the "closure" of a disposal facility practically are hidden in Art. 2, lit. (a), dealing with definitions. It reads: "*closure* means the completion of all operations at some time after the emplacement of spent fuel or radioactive waste in a disposal facility. This includes final engineering or other work required to bring the facility to a condition that will be safe in the long term."

What measures are to be taken in reality to meet these ends and for how long a term, is left open in the definition and elsewhere in the Joint Convention. And yet, Art. 22, lit iii prescribes that "financial provision is made, which will enable the appropriate institutional controls and monitoring arrangements to be continued for the period deemed necessary following the closure of a disposal facility".

With all these provisions the Joint Convention proves the predicament the nuclear power states moved themselves into rather than to offer practicable solutions on the international plane. It is one thing to realize that there is no alternative to permanent reposition (disposal), and quite another to find physically and societal suitable sites. The choice of reconditioning spent fuel only postpones the problem and generates new ones.[56]

The commitment – or just appeal (?) – to strive "to avoid actions that impose reasonably predictable impacts on future generations greater than those permitted for the current generations...and to avoid imposing undue burdens on future generations" [Art. 4; Art. 11][57] illustrates the dilemma even more. For this reference to sustainability[58], it makes sense only if there was a reasonable choice, which there is not. The somewhat unorganic introduction of "sustainability" into the context of the Joint Convention makes it difficult to avoid the impression, that it is primarily used as a lip service and not really taken seriously.

[56] Preamble, para. vii "Recognizing that the definition of a fuel cycle policy rests with the State, some States considering spent fuel as a valuable resource, that may be reprocessed, others electing to dispose of it."

[57] Art. 4, para. 2, lit. vi and vii and identical Art. 11, para. 2, lit. vi and vii.

[58] See above at fn. 11.

12.6.2 Proposal for a Council Directive 2004

The amended proposal for a Council Directive (Euratom) on the safe management of spent nuclear fuel and radioactive waste[59] does not go beyond the Joint Convention just dealt with. The Commission does not even try to conceive regulations of a higher complexity in accordance with the higher integrational density of the EAC with its 27 members as compared to the Joint Convention addressing an open number of State parties to it without institutionalising ties. That is to say that even within a highly integrated international organisation as the EAC the nuclear power states are left unimpaired in their splendidly exclusive autonomy of regulating the nuclear industry under their jurisdiction.

Also the Commission starts from the assumption that, on the basis of present knowledge, there is no conceivable alternative to "geological disposal" of "long-lived radioactive waste."[60] It is left to the Member States to study the possibility to give priority to the solution of deep geological disposal[61], considering their specific circumstances (Art. 4, para. 1, sub para. 2). The Member states are to ensure public information on the measures to be taken and the state of progress of the decision-making process, notably as regards the disposal sites (Art. 3, para. 5). Suitable timetables should be set up, to support the solution of the nuclear waste problem (Art. 5). As to the control system the Commission explicitly resorts to the system of the Joint Convention (Art. 7 and 8). It clearly was the firm intention of the Commission not to commit the EAC Members beyond the standards of the Joint Convention.

12.6.3 The 10,000 Years Limit and the Yucca-Mountain Case

The "Radioactive Waste Management Committee" of the Nuclear Energy Agency (NEA) of the OECD and the (German) Society for Installations and Reactor Safety (GRS) have issued collections of national regulations on the designing of permanent repositories (disposals)[62], which need not be dealt with here in greater detail. What does interest here however is the fact, that most of the national regulations prescribe a control period for permanent repositories of ten thousand years.[63] The EU Commission in a respective recommendation suggests the same period of time.[64]

On closer look this control period of ten thousand years is just an arbitrary assumption. Two elements among the materials to be deposited, the Neptunium-237 has a half life of more than 2 million years and the Iodine-129 a half life of 17 million years.

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[59] COM (2004)526 final.

[60] Reason 17.

[61] The definitions correspond to those of the Joint Convention.

[62] "The Regulatory Control of Radioactive Waste Management - Overview of 15 NEA Member Countries", NEA/RWM/RF(2004)1, 13.02.2004 [http: //www.nea.fr/html/rwm/docs/2004]; and "Zusammenstellung internationaler Kriterien zur Bewertung und Auswahl von Standorten für die Endlagerung von radioaktiven Abfällen in tiefen geologischen Formationen", GRS-A-2834, Jänner 2001.
[http: //www.akend.de/aktuell/berichte/berichte_an_akend.htm] (visited: 28.10.2004)

[63] For instance France "Règle fondamentale de sûreté (RFS) III.2.f" der L' Autorité de sûreté nucléaire (ASN); or Sweden "The Swedish Nuclear Power Inspectorate's Regulations concerning Safety in connection with the Disposal of Nuclear Material and Nuclear Waste", SKIFS 2002: 1 [http: //www.ski.se/page/5/22.html?29044] (visited: 28.10.2004)

[64] Endlagerung radioaktiver Abfälle – Empfohlene Kriterien für die Standortwahl eines Endlagers, Serie "Euradwaste" Nr. 6, EUR 14598, 1992.

All this has become notorious in the Yucca Mountain Dispute by the judgement of the US Court of Appeals for the District of Columbia Circuit of July 9, 04[65].The Yucca Mountains are in Nevada 150 odd km north west of Las Vegas. They are chosen as disposal site for the highly radioactive nuclear waste of the entire USA (till 2003 40 thousand tons). The central issue among the numerous legal questions before the Court was the decision of the Environmental Protection Agency (EPA), a Federal Authority, to limit the compliance time for the disposal site at 10 thousand years. According to the regulations[66] to be followed by the EPA it should have accepted an expertise by the National Academy of Science (NAS). The compliance time is that period for which the natural and organisational qualities of the disposal site warrant that virtual persons in a given perimeter around the site are exposed to acceptable radiation only. The NAS had demanded a compliance time beyond the peak of radiation of the materials disposed. The EPA however intentionally did overrule the NAS expertise, with the argument, that it could not see much sense in extending the horizon of institutional planning beyond 10 thousand years.

For these here highly simplified reasons the Court finally arrived at the decision: "In sum, because EPA's chosen compliance period sharply differs from NAS's findings and recommendations, it represents an unreasonable construction of section 801(a) of the Energy Policy Act".[67]

This judgement is a severe set back for the EPA and all the other federal authorities involved and above all for the nuclear industry. Nevertheless the original idea of submitting the case to the US Supreme Court[68] for final decision was dismissed. The judgement of the US court of Appeals for the district of Columbia Circuit of July 9, 2004 became final.

Still, the Yucca Mountain Judgement is of crucial importance for the sustainability issue. It reveals in contentious procedure before an independent court of the greatest nuclear power in world the central structural weakness of the nuclear industry: the unsolvable problem of the permanent reposition of highly radioactive nuclear waste.

Thinking of the fact, that the period of written human history covers about five thousand years, the requirement of disposing spent nuclear fuel and radioactive nuclear waste for several million years, ridicules all conceivable concepts of sustainability. This disproportion is even enhanced by the planned legislative measures for saving the Yucca Mountain permanent repository. The allowed maximum radiation emanating from the repository for persons at a distance of 11 miles is to be provided for the first ten thousand years with 15 millirem annually and for the next 990 thousand years with 350 millirem.[69] Legislation and administration for the next million of years! An ordinary case of strictly normal madness.

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[65] Opinion No. 01-1258
[http: //pacer.cadc.uscourts.gov/docs/common/opinions/200407/01-1258a.pdf]
(visited: 28.10.2004). The half lives given above are on p. 6 of the judgement.

[66] Mainly the Energy Policy Act of 1992, H.R.776, Pub. L. 102–486.

[67] Yucca Mountain-Judgement p. 31.

[68] For further information see
[http: //www.reviewjournal.com] of September 16, 2004 ("Yucca Mountain Project: U.S. Supreme Court intervention sought") and
[http: //www.yuccamountain.org/court/lawsuits.htm]

[69] Las Vegas Review Journal Oct. 12, 2005
[http: //reviewjournal.printthis.clickability.com]

12.7 Germany's Renunciation of Nuclear Energy

For all these reasons the Red - Green Coalition Government and the parliament of the Federal Republic of Germany have drawn the sole conceivable consequence that is to renounce the "Kernenergienutzung zur gewerblichen Erzeugung von Elektrizität"[70]. That of course does not relieve Germany from the necessity to provide permanent reposition (disposal) for the hitherto and still in the transitory period generated spent nuclear fuels and radioactive waste. From 2005 on, the criteria for the selection of the disposal site are to be enacted. Upon that the procedure of the actual selection is to be initiated. Meanwhile the deposit for covering possible damages was raised to 2.5 Billions Euro for each nuclear power station, that is ten times of the original amount [dt. Bundesumweltministerium][71]

Without further details, the Federal Republic of Germany is the first state[72], to draw the consequences from the evident incompatibility of nuclear industry with the principles of sustainability.

The general elections of September 18, 2005 did not lead to a substantial change of that line of energy policy, because the partners in the new coalition government were unable to reach agreement on a new concept for NPP policy.[73]

12.8 Conclusions

This analysis based on several key documents beyond any doubt shows that electricity production by nuclear power plants is in clear and indisputable conflict with the principles of sustainability. The economic use of nuclear energy entails risks, which in themselves create demands for legal regulations, which surmount the capacities of the individual national legal systems, which leaves the nuclear industry a comfortably wide range of autonomy. The nuclear power states therefore evade all efforts to enact legal provisions for the use of nuclear energy above the national level, be it on the plane of public international law or within the EAC, in order to supplement and control the national legal systems in this field. The presented international treaties and proposals for EAC Directives on purpose do not exceed general principles. The paramount object of the governments of nuclear power states is to preserve their exclusive regulatory authority for their nuclear industry under as tight as possible exclusion of foreign supervision. That line is also reflected in the very restrictive provisions in bilateral international treaties on the mutual

[70] "The use of nuclear energy for the industrial production of electricity" German BGBl. I 26/2002 (in force since. April 27, 2002).

[71] Information of the German Federal Ministry of Envoirment [http: //www.bmu.de/de/1024/js/sachthemen/atomkraft/kurzinfo/] (visited: 28.10.2004)

[72] Earlier decisions by Sweden (1980) and Italy (1990) to renounce nuclear energy as source for the production of electricity were based on other arguments, not explicitly on the conflict with the principles of sustainability.

[73] "Gemeinsam für Deutschland. Mit Mut und Menschlichkeit. Koalitionsvertrag von CDU,CSU und SPD" [http: //www.spd.de/servlet/PBIshow/1589444/1105_Koalitionsvertrag]

information of nuclear accidents[74] and also in the not yet successful attempts to limit the liability for nuclear accidents by international treaties.[75]

The inevitable dilemma of the regulatory deficit of nuclear industry is topped by the fact, that roughly 60 years after the first nuclear power stations were put into operation there still is no solution for the problem of permanently repositing nuclear waste. Its time dimension of more than one million years ultimately proves the inherent incompatibility of the production of electricity by nuclear power with the principles of sustainability.

12.9 Summary

- The term "sustainability" as used in the *Brundtland* formula needs concretion in order to be applicable to specific problA parties, when signing the agreement.

- The core of the applicability of the principle of sustainability lies in an extended redistribution syndrome in the context of the succession of generations. Thus, it is well suited for being resorted to in the field of producing electricity by nuclear power stations, which in fact is a question of distributing the asset "environment" and the burdens of nuclear energy production among the present and the coming generations.

- In the context of energy production the principle of sustainability could be read as: The present generations demand for energy is to be kept as moderate as possible and should be covered with the least possible expense of resources and at the least possible environmental costs. According to the principle of real cost assessment the burdens of energy production are to be met by those generations exclusively, which take advantage of it.

- Public International Law (especially international treaties) and Community Law show promising items with plausible procedural elements for giving the principle of sustainability legal relevance. Yet here too concretion is required for its applicability in individual cases. It must be warned however against exaggerated expectations and hopes.

- The (IAEA) Convention on Nuclear Safety entered into force ten years after Chernobyl and 40 years after the first nuclear power stations were put into operation. Its contents gives the impression of only those provisions being agreed upon, which were already fulfilled by its parties, when signing the agreement.

- Specific safety standards were intentionally avoided. Only security principles were accepted with vague references to unspecified safety standards, which are to be revised according to the scientific development.

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[74] Not covered here. C.f. Manfred Rotter, Rechtsfragen eines künftigen Tschechisch-Österreichischen Abkommens betreffend gemeinsame Interessen im Bereich der nuklearen Sicherheit und des Strahlenschutzes (Final Report in 2 Volumes); Internal Publication (2002).

[75] Not covered here. C.f. Karl Arlamovsky, Sind Kernkraftwerke aus rechtswissenschaftlicher Sicht ein Beitrag zur nachhaltigen Entwicklung gemäß Art. 12 Kyoto-Protokoll?, in Kernenergie, Klimaschutz und Nachhaltigkeit, Ein Argumentarium zur Vorbereitung der COP6 (Manuscript).

- In the field of nuclear industry the legislative autonomy of the nuclear power states remains untouched. A supervision of the compliance even with the safety principles only is restricted to a system of tri-annual reports presented by the states to a tri-annual Review Meeting of the Member States.

- Impressive attempts by the EU Commission to establish Community wide safety standards for nuclear power stations failed, although they did not exceed the standards of the (IAEA) Agreement already accepted by the EU Member States. It contained however a lean but promising system of supervision and provisions for the dismantling of used nuclear power stations. The real advantage of this attempt had been the implicit establishment of the jurisdiction of the EAC and especially the European Court in matters of safety standards for nuclear power stations.

- The second, substantially milder attempt by the EU Commission again does not exceed the (IAEA) Agreement. The former promising provisions on a system of supervision, too, were reduced to the report standard of the (IAEA) Agreement. The provisions on the dismantling of nuclear power stations were completely omitted. A minimum competence of the EAC and the European Court may be preserved, if this Proposal for a Directive would ever be enacted.

- The costs of the dismantling of nuclear power stations, according to estimates by the EU Commission amount to 15 % of the total original investment, which equals in absolute numbers between 200 Million and 1 Billion Euro each. These costs arise after closing the power station, i.e. after producing electricity and after procuring income. Considering the originally planned life span of 40 years of nuclear power stations, we already now face the problem of cost shifting to generations, which are not benefiting from them.

- The security of permanent national repositories for spent nuclear fuel and high-level radioactive waste for the coming ten thousand years exceeds the capacity of all conceivable societal regulatory systems. In comparison: the written human history covers 5000 years. In other words, the political systems of the nuclear power states are forced to project highly complex decision making systems over a period twice the span of hitherto written human history.

- A closer look, however, reveals that the ten thousand years period is an arbitrary assumption. The half-life of just two elements concerned such as Neptunium-237 is more than 2 million and that of Iodine-129 even 17 million of years.

- For that reason the United States Court of Appeals for the District of Columbia Circuit in a (meanwhile final) judgment of July 9, 2004, vacated the decision of the competent federal US authority limiting the compliance period of the Yucca Mountain permanent repository for spent nuclear fuel and high-level radioactive waste to 10 thousand years. The ensuing legal consequence is US legislation providing the security standards for this repository for the next one million years. An ordinary case of strictly normal madness.

Putting it simple: Frequently Asked Questions (FAQ)

January 2007

Putting it simple: Frequently Asked Questions (FAQ)

January 2007

General

1. In view of Climate Change – can we do without nuclear power?

Yes. Efficiency measures contributed more to the growing energy need in the past decades than nuclear power and the potential of efficiency increase is not exhausted by far. Nuclear power, due to its long lead periods, will not be able to make a significant contribution to climate policy in the foreseeable future.

2. Can we do without nuclear energy even after "Peak Oil" *?

Yes. Nuclear energy cannot replace the oil: in view of the number of power plants that would be needed, a technology with significantly lower risks would be mandatory. This technology is not yet available. In addition, fissile uranium is not accessible to the extent required to operate the large number of power plants. For the important sector of transport nuclear could supply energy only through the very inefficient production of hydrogen. Efficiency increase and structural changes will have to play the leading role in case of "Peak Oil" as well.

3. Is not nuclear energy – clean and CO_2-free – the only sustainable solution to the energy dilemma?

No. Nuclear energy is neither sustainable nor CO_2-free: in order to meet the criteria for sustainability, a technology must be environmentally and (macro-) economically sound, socially acceptable, within human grasp (e.g. all potential technical, social and ecological consequences can be comprehensibly assessed), flexible and tolerant of errors. The technology must also support the development of sustainability. Nuclear energy does not satisfy any of these criteria. Considering the complete fuel cycle, from uranium mining to final repositories, nuclear energy is certainly not CO_2-free.

Normal Operation

4. Are the low irradiation doses that occur in normal operation of nuclear power plants harmful?

Yes. Experiments and the analyses of medical statistics show that there is no harmless dose - only the likelihood of damage is reduced at low radiation levels. Enhanced cancer frequencies were reported from areas near nuclear power plants in Germany, USA, Japan und Canada and from the environs of the reprocessing plants in Sellafied (UK) and La Hague (France). Some types of damage surface on a larger scale only after several generations.

* "Peak Oil" indicates the time when the global oil production rate begins to irrevocably sink and oil prices rise due to scarcity.

Safety

5. **The safety of Nuclear Plants is continuously increasing. Has this not solved the safety problem?**

   No. The Chernobyl catastrophe has clearly shown that even in nuclear power plants said to be safe, severe accidents can occur. In spite of a period of tightening of safety standards, a series of incidents in nuclear power plants over the last few years demonstrates that accidents still cannot be excluded. Besides, many nuclear power plant do not comply with all safety guidelines of the IAEA.

6. **Will future, so-called "inherently safe" reactors solve the safety problem?**

   No. "Inherent safety" has not yet been proven for any reactor. Besides, "inherent safety" only applies to design base accidents, not to external dangers and certainly not to acts of war or terrorism. Reactors of the next but one Generation (IV) are based on completely different concepts that raise new safety problems and imply a plutonium economy. Plutonium is not only radioactive but also highly toxic and enhances the danger of proliferation. It is not realistic to expect that new reactor and fuel cycle technologies willsimultaneously overcome the problems of cost, safety, waste, and proliferation.

7. **Why is the safety aspect focussed on so strongly in the case of nuclear energy? Are not chemical plants burdened with a similar risk?**

   Nuclear risk is special because the likelihood of a severe accident is very small, but the consequences if it does happen are catastrophic. People and states that never profited from the operation of the power plant can be strongly affected, and impacted regions can become uninhabitable for centuries. But of course the call to reduce disaster potentials is valid for other areas, e.g. the chemical industry, as well.

8. **Does the deregulation of the electricity market have impacts on the risk of accidents in nuclear power plants?**

   Yes. The need for cost reductions triggered by deregulation leads to staff reductions and endangers investments in safety measures. In some cases in the past years it has led to downgrading of safety standards and to a decline in safety culture.

9. **Will many nuclear power plants not be shut down anyway due to their reaching the age limit?**

   Due to rising energy needs and lack of acceptance for new plants attempts are being made to extend the life time of plants. Unfortunately, however, the safety risk grows at a certain age*, mainly because some components suffer from material fatigue due to intense strain. The fact that this coincides with cost cuts due to the deregulation of the electricity market and a shortage of spare parts as well as of qualified staff in consequence of the stagnation of the nuclear industry causes serious concern also among proponents of nuclear energy.

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* As in automobiles, technological problems in nuclear power plants generally occur with the highest frequency at the beginning of operation, and again towards the end of plant life.

Radioactive Waste

10 . Are transports and deposits of nuclear waste not essentially safe?

No. Transports as well as interim storages can cause significant radioactive releases in case of accident or attack. There are many knowledge gaps and unsolved details regarding final repositories in deep geological formations. Also, it is not possible to guarantee safe storage for the requested period of 1 million years.

11. Is controlled surface storage the only responsible procedure, as claimed by some?

It is impossible to foresee whether societies in some centuries or millennia will be able to maintain control over the repositories. As all other repository options it puts the burden of handling the waste on future generations. As compared to the deep geological repository the chances of keeping knowledge about the repository alive and of making use of possible advanced technologies to eliminate it are greater, but so is the short term risk of radioactivity being set free.

12. Can radioactive wastes be rendered harmless by transmutation?

Transmutation requires very expensive separation by reprocessing, a process that is connected with high environmental costs and accident risks. Even after transmutation, long term final repositories are needed. Besides, this technology is still far from applicable on a large scale. It must also be considered that low and medium active fractions of nuclear waste that make up by far the greater volume, cannot be treated in this manner. Thus, in spite of high costs, transmutation cannot solve the problem of radioactive waste.

13. How can the problem of nuclear waste be solved?

There is no satisfactory solution to the waste problem. Therefore, the amount of waste that is additionally produced must be minimised. For the waste already accumulated a consensual solution must be sought in a wide and open public debate.

Terrorism and War

14. Are nuclear power plants "attractive" targets for terrorist attacks?

Yes. Due to the long lasting impacts of such an attack, the effects on electricity supply and their symbolic character, nuclear power plants can be considered to be attractive targets from the point of view of terrorists. It is surmised that the airplane that crashed in Pennsylvania on September 11 in 2001 was aiming for a nuclear power plant.

15. What consequences could terrorist attacks or military actions on nuclear installations have?

Attacks on nuclear power plants can lead to radioactive releases that equal those of the most severe nuclear accidents. Countless deaths and contamination of large areas could be the consequence.

16. Are effective counter measures against terrorist attacks or military actions possible?

Technical measures and increased controls at nuclear sites, as well as precautions taken by the police, the secret service or the military can reduce the risks, but cannot eliminate them. Here too, centralised, non sustainable technologies with inherent potential for catastrophe such as nuclear energy have obvious draw backs.

Emergency Management

17. Can an effective emergency management significantly reduce the consequences of a severe nuclear accident?

Under favourable circumstances accident consequences can be mitigated but they can not be eliminated. Timely intake of iodine tablets for instance blocks radioactive iodine from the glands, but they do not protect from other consequences of radiation. In case of severe accidents the radioactive cloud can be emitted into the atmosphere within a few hours and measures such as intake of iodine tablets or evacuation can hardly be taken in time.

18. What do past experiences of nuclear accidents show?

The accidents of Three Mile Island (USA) and Chernobyl (former SU) show that whatever emergency management plans were available at the time, they were insufficient. Even in the recent past – in 1999 – during the accident in Tokai Mura in Japan, officials were informed too late and the start-up of counter measures was too slow. Nevertheless – or because of this – there is manifold and extensive need for action to be less badly prepared for future nuclear accidents.

19. Do only states that operate nuclear power plants need emergency management?

No. Radioactive clouds are not hindered by state borders; they can be transported some hundred kilometers within one day. The Chernobyl accident has illustrated this impressively. Thus, also states that do not harbour nuclear power plants can be affected by nuclear disasters and must plan and take expensive protective action against the case of emergency.

Proliferation

20. Have nuclear weapons ever been proliferated from the commercial nuclear fuel cycle?

No. While it is in principle possible to do so, proliferation from the commercial nuclear fuel cycle has not yet taken place. However, of the countries known or strongly suspected to have developed nuclear weapons, not all have used dedicated nuclear weapons production facilities to produce the nuclear material for their weapon programmes.

21. Can spent fuel from commercial nuclear power plants be used to make nuclear weapons?

Yes. It is widely recognized among experts that nearly all plutonium is "weapons usable". So-called "weapons-grade plutonium" comes from reactors from which the spent fuel is discharged after a relatively short period of "burn up" in the reactor. This maximizes the relative percentage of Plutonium-239 (more than 90 %), which is desirable for nuclear weapons.

22. Can nuclear weapons be designed and built by "newcomers"?

Yes. Most aspects of first generation nuclear weapon design are public knowledge. It is, however, difficult to develop more sophisticated designs in which the physical size and weight are minimized. Weapons usable material is much more plentiful now, and much cheaper to produce than it was some decades ago, and non-nuclear testing provides sufficient confidence that an implosion weapon will work.

Timeliness

23. Can the development of Nuclear Energy be rapid enough to meet the needs of climate policy and diminishing cheap oil?

No. The new generation of so-called "inherently safe" reactors – a precondition for a generous expansion of Nuclear Energy – is only expected to be available in a decade. There are still no acceptable solutions for waste disposal. The expertise and work force needed for nuclear build up could not be made available in time. Even now there is a shortage of trained personnel in several countries. Many nuclear power plants will be taken from the grid in the coming years as they end their projected lifetime. The nuclear power plants that are under construction will not be able to compensate for that loss, and any additional new power plants would come too late.

Contribution to Climate Policy

24. Is not nuclear the cheapest way to reduce CO_2-emissions?

No. As a mechanism to reduce CO_2-emissions nuclear power cannot compete with a variety of already available alternatives. In particular energy efficiency, in addition to its overall environmental advantage, has a clear economic benefit and also brings additional security of supply. Furthermore, analyses on the projects costs of other low or zero CO_2 emitting technologies demonstrate that renewable energies will become increasingly price competitive as prices decline with growing production.

25. *Can nuclear be viewed as a technology to bridge the energy gap on the longterm?*

No. The reserves of fissile Uranium-235 are limited. At the present production rate the known reserves of uranium accessible at around € 100 per ton will last for somewhat less than one century. When doubling the production rate till 2030 the reserves will be used up within 4 to 5 decades. After that, present day concepts envisage reactor types that make use of the plentiful Uranium-238. This, however, would imply the embarkment on a plutonium economy with all its difficulties and risks.

26. Can the Kyoto goals be achieved without expansion of Nuclear Energy?

Yes. There are studies that show that even the long term aim of the European Union – the stabilisation of global temperature at +2 °C – can be achieved without Nuclear Energy, if either sequestration* of a significant amount of CO_2 or a reduction in growth rate of energy demand is assumed.

Economical Aspects

27. Does Nuclear Energy offer commercial advantages?

No. Those countries in the OECD that are considering embarking again on nuclear power construction programme, Finland and the US, have both proposed a direct or indirect financial support programme for the nuclear sector. In the case of the US, this involves a complex series of measures which are likely to cost the taxpayer some $ 13 billion for a six to eight reactor programme. Even though many external costs of nuclear energy are not included in comparative price calculations, nuclear energy is not less costly than most alternative technologies. Efficiency improvement (reduction of energy intensity for the supply of goods, services and private end use) is more advantageous regarding costs as well as CO_2-reduction potential than any form of additional supply of energy.

28. Will the costs for nuclear energy drop?

Not substantially. A comparison of cost developments shows that costs for nuclear energy have dropped much less than those of alternative technologies. There is no reason to expect that this will change in the near future.

29. Is Nuclear Energy presently subsidised by public enterprise?

Yes. The costs for regulatory bodies, radiation monitoring networks and costly emergency planning systems on the national level, and e.g. non-proliferation activities (e.g. CTBTO) on the international level are born by public enterprise. Research and development costs for nuclear are also covered to a much larger extent than for other energy technologies. Besides, nuclear does not bear the insurance burden other industries are compelled to bear.

30. Do insurances cover nuclear risks?

No. The international liability regime for nuclear damage divides liability between the operator, the State in which the facility is located and member states of the conventions. In addition there is a fixed ceiling for nuclear damage. Would Europe's largest nuclear utility Electricité de France e.g. be required to fully insure the full cost of a severe accident it would increase the cost of electricity generation by around 200 %.

* Binding or depositing CO_2 in reservoirs rather than emitting it into the atmosphere is called sequestration.

Nuclear produced Hydrogen

31. Is nuclear produced hydrogen a solution for the transport sector in view of climate change as well as "Peak Oil"?

No. Without resolution of the well known problems of Nuclear Energy the nuclear production of hydrogen is not viable in view of the large number of plants necessary to produce a relevant amount of hydrogen. This view is reinforced by the low overall efficiency of the complete transformation chain and will improve only little with new reactor types. The basic problems connected to a hydrogen economy – independent of the mode of hydrogen production – are also considerable. Encompassing assessments of possible environmental effects are still lacking.

Legal Dimension

32. Could the problems and risks of Nuclear Energy be solved at the international level?

The risks of Nuclear Energy are structurally inherent. At the international or the European level the risks could be reduced by multilateral cooperation, but it could not be fully abolished. All attempts in this direction are hindered by the nuclear industry that resists stringent international or European regulations and control mechanisms.

Abbreviations

Abbreviations

ABWR	Advanced Boiling Water Reactor (General Electric, GE) / boiling light water cooled & moderated
ACR-700	Advanced CANDU Reactor, 700 MWe class (Atomic Energy of Canada, Limited) / heavy water moderated, light water cooled, low enriched uranium fuelled
AECL	Atomic Energy of Canada, Limited
AGR	Advanced Gas-Cooled Reactor, carbon dioxide cooled, graphite moderated
AHTR	Advanced High Temperature Reactor
AP1000	Advanced Passive 1000 MWe class pressurized water reactor (Westinghouse)
AP600	Advanced Passive 600 MWe class pressurized water reactor (Westinghouse)
B	Barrel; 1 B about 159 l oil (see glossary)
BLEVE	Boiling Liquid Expanding Vapour Explosion
BWR	Boiling Water Reactor
CANDU	Canadian Deuterium-Uranium Reactor / heavy water cooled & moderated, natural uranium fuelled (Atomic Energy of Canada, Limited)
CDF	Core Damage Frequency
CO_2	Carbon Dioxide
COP	Conference of the Parties, e.g. in the framework of the UNFCCC
EURATOM	European Atomic Energy Community
EOP	Emergency Operating Procedures
EPR	European Pressurized Reactor (Areva NP) / pressurized light water cooled & moderated
ESBWR	Not an acronym; General Electric designation for an advanced boiling light water cooled & moderated reactor
ETA	Bask Separatist Movement
FBR	Fast Breeder reactor
Gb	Gigabarrel, 1 Gb = 1.000,000 Barrels

GCM	Global Climate Model or Global Circulation Model
GDP	Gross Domestic Product
GFR	Gas-cooled Fast Reactor
GHG	Greenhouse Gases
GT-MHR	Gas Turbine Modular Helium Reactor / a gas cooled, graphite moderated reactor (General Atomics)
Gtoe	Gigatons of Oil Equivalent (s. glossary)
GW	Giga-Watt: 1 GW = 1,000 megawatt
GWe	Giga-Watt electrical power
H2-MHR	Modular High temperature gas cooled Reactor / optimized for Hydrogen producton
HLW	High Level Radioactive Waste
HTTR	High-Temperature Engineering Test Reactor
IAEA	International Atomic Energy Agency
IEA	International Energy Agency
INES	International Nuclear Event Scale
INSAG	International Nuclear Safety Advisory Group of the IAEA
IPCC	Intergovernmental Panel on Climate Change
ISR	Inherently Safe Reactor concept
JAERI	Japan Atomic Energy Research Institute
LFR	Lead-cooled Fast Reactor
LNG	Liquefied Natural Gas
LPG	Liquefied Propane Gas
LWGR	IAEA PRIS abbreviation for RBMK Reactor
MAGNOX	Gas-cooled reactor
MOX	Mixed Oxide (nuclear fuel after reprocessing)

MSR	Molten Salt-cooled Reactor
MW	Megawatt: 1 MW = 1,000 watt
MWe	Megawatt (1000) electrical power
MWt	Megawatt (1000) thermal
NEA	Nuclear Energy Agency
NGL	Natural Gas Liquid
NPP	Nuclear Power Plant
OECD	Organisation for Economic Co-operation and Development
OPEC	Organisation of the Petroleum Exporting Countries
OSPAR	Oslo/Paris Convention (for the Protection of the Marine Environment of the North-East Atlantic)
PBMR	Pebble Bed Modular Reactor / a gas cooled, graphite moderated reactor using low enriched pebble bed fuel (PBMR Pty., Ltd., South Africa)
PHWR	Pressurized Heavy Water Reactor
PUREX	Plutonium and Uranium Recovery by EXtraction
RODOS	Real-time On-line DecisiOn Support system for off-site emergency management in Europe; Realtime Online Decision Support System for nuclear emergency management
ROI	Return of Investment
RPG	Rocket Propelled Grenades
PRIS	IAEA Power Reactor Information System
PSA	Probabilistic Safety Assessment
PWR	Pressurized Water Reactor
RBMK	Reactor Bolshoi Moschnosti Kanalynyi / boiling water cooled, graphite moderated, vertical pressure tube reactor (Russian acronym)
RSK	Reaktor Sicherheitskommission; Reactor Safety Commission
SCWR	Super Critical Water-cooled Reactor, a type of pressurized water reactor

SFR	Sodium-cooled Fast Reactor
STAR-H2	Secure Transportable Autonomous Reactor for Hydrogen Production
SWR-1000	Siedewasserreaktor (German: boiling water reactor), 1000 MWe class (Areva NP)
TSO	Technical Support Organization
UNFCCC	United Nations Framework Convention on Climate Change
UNGG	Natural Uranium fuelled, Gas cooled, Graphite moderated reactor
USD	US Dollar
UVCE	Unconfined Vapour Cloud Explosion
VHTR	Very High Temperature Reactor / a type of gas cooled, graphite moderated reactor
WBGU	Wissenschaftlicher Beirat für Globale Umweltfragen (Germany)
WEC	World Energy Council
WENRA	Western European Nuclear Regulators´ Association
WHO	World Health Organization
WNA	World Nuclear Association
WWER	pressurized light water cooled & moderated reactor / Russian acronym for type of pressurized water reactor, PWR (Voda-Vodyanoi Energetichesky Reaktor)

Glossary

Glossary

Anthropogenic

Anthropogenic effects or processes are such that are derived from human activities, as opposed to effects or processes that occur in the natural environment without human influences. The term is often used in the context of environmental externalities in the form of chemical or biological wastes that are produced as by-products of otherwise purposeful human activities. Anthropogenic sources include industry, agriculture, mining, transportation, construction and habitations.

Burnup

In the field of nuclear energy conversion the burnup is the amount of thermal energy that has been produced per mass unit of a fuel element. Usually it is expressed in gigawatt-days per ton of heavy-metal. In contrast to fossil fuel the fuel in nuclear reactors cannot be converted "in one go" since the fuel undergoes changes during its use in the reactor which require the fuel elements to be exchanged.

Barrel

The barrel (abbreviated bbl) is the name of several units of volume:

Oil barrel: 42 U.S. gallons (158.9873 litres), or approximately 35 Imperial (UK) gallons (34.97231575 UK gallons exactly). This is used for crude oil or other petroleum products. The measurement originated in the early Pennsylvania oil fields. Both the 42-gallon barrels (based on the old English wine measure, the tierce) and the 40-gallon (151.4 liters) whiskey barrels were used. The 40-gallon barrel was the most common size earlier, but companies often underfilled them with less. However, the Standard Oil Company shipped its oil in barrels that always contained exactly 42 gallons. Customers began to refuse to accept anything less and by 1866 the oil barrel was standardized at 42 gallons. Since Standard Oil painted its barrels blue, it was abbreviated "bbl" for "blue barrel". Oil has not been shipped in barrels for a very long time but the "blue barrel" is still the standard unit for measurement and pricing of oil.

Base-load

The share of the overall load in an electrical grid which remains constant for a given time frame (day, week, month or year).

Bentonite

Is an absorbent aluminium phyllosilicate generally impure clay consisting mostly of montmorillonite. Two types exist: swelling bentonite which is also called sodium bentonite and non-swelling bentonite or calcium bentonite. It forms from weathering of volcanic ash, most often in the presence of water.

Bequerel

The becquerel (symbol Bq) is the SI derived unit of radioactivity, defined as the activity of a quantity of radioactive material in which one nucleus decays per second. It is therefore equivalent to s^{-1}. The older unit of radioactivity was the curie (Ci), defined as 3.7×10^{10} becquerels or 37 GBq.

In a fixed mass of radioactive material, the number of becquerels changes with time. Sometimes, amounts of radioactive material are given after adjustment for some period of time. For example, one might quote a ten-day adjusted figure, that is, the amount of radioactivity that will still be present after ten days. This de-emphasizes short-lived isotopes.

SI uses the becquerel rather than its equivalent, the reciprocal second, for the unit of activity measure to eliminate any possible source of confusion regarding the meaning of the units, because errors in specifying the amount of radioactivity, no matter how far-fetched, could have such serious consequences.

BLEVE

Pronounced blevy, is an acronym for "boiling liquid expanding vapour explosion". This is a type of explosion that can occur when a vessel containing a pressurized liquid is ruptured. Such explosions can be extremely hazardous. When the liquid is water, the explosion is usually called a steam explosion.

Business Rates

Business rates are a United Kingdom tax charged to businesses and other occupiers of non-domestic property. The proceeds of the tax are collected centrally and distributed to local authorities to contribute towards the costs of their services.

Carbon sequestration

Carbon sequestration is the term describing processes that remove carbon from the atmosphere. A variety of means of artificially capturing and storing carbon, as well as of enhancing natural sequestration processes, are being explored. This is intended to help mitigating global warming.

Carcinogen

In pathology, a carcinogen is any substance or agent that promotes cancer. Carcinogens are also often, but not necessarily, mutagens or teratogens. Carcinogens may cause cancer by altering cellular metabolism or damaging DNA directly in cells, which interferes with normal biological processes.

Colloids

In general, a colloid or colloidal dispersion is a substance with components of one or two phases, a type of mixture intermediate between a homogeneous mixture (also called a solution) and a heterogeneous mixture with properties also intermediate between the two. Typical membranes restrict the passage of dispersed colloidial particles more than they restrict the passage of dissolved ions or molecules; i.e. ions or molecules may diffuse through a membrane through which dispersed colloidal particles will not. The dispersed phase particles are largely affected by the surface chemistry existent in the colloid.

Combined Cycle Gas Turbines

Combined cycle is a term used when a power producing engine or plant employs more than one thermodynamic cycle. Heat engines are only able to use a portion of the energy their fuel generates (usually less than 30 %). The remaining heat from combustion is generally wasted. Combining two or more "cycles" such as the Brayton cycle and Rankine cycle results in improved overall efficiency.

In a combined cycle power plant (CCPP) or combined cycle gas turbine (CCGT) plant a gas turbine generator generates electricity and the waste heat from the gas turbine is used to make steam to generate additional electricity via a steam turbine; this last step enhances the efficiency of electricity generation. Most new gas power plants are of this type. In a thermal power plant, high-temperature heat as input to the power plant, usually from burning of fuel, is converted to electricity as one of the outputs and low-temperature heat as another output. As a rule, in order to achieve high efficiency, the temperature of the input heat should be as high as possible and the temperature of the output heat as low as possible (see Carnot efficiency). This is achieved by combining the Rankine (steam) and Brayton (gas) thermodynamic cycles. Such an arrangement used for marine propulsion is called COmbined Gas (turbine) And Steam (turbine) (COGAS).

Cogeneration

Cogeneration (also combined heat and power or CHP) is the use of a heat engine or a power station to simultaneously generate both electricity and useful heat.

Cryogenic

Cryogenics is a branch of physics (or engineering) that studies the production of very low temperatures (below –150 °C, –238 °F or 123 K) and the behavior of materials at those temperatures.

Decommissioning

The decommissioning of nuclear facilities is sometimes referred to as nuclear decommissioning, to mark the difference between "conventional" decommissioning and dismantling projects. In fact, the main difference to the dismantling of a "conventional" facility is the possible presence of radioactive or fissile material in a nuclear facility, which requires special precautions. Decommissioning involves many administrative and technical actions, whose purpose, after a facility has been taken out of service, is to allow its release from regulatory control and relieve the licensee of his responsibility for its nuclear safety.

Desertification

Desertification is the degradation of land in arid, semi-arid and dry sub-humid areas resulting from various factors including climatic variations and human activities. Modern desertification often arises from the demands of increased populations that settle on the land in order to grow crops and graze animals.

Dichotomy

A dichotomy is any splitting of a whole into exactly two non-overlapping parts. In other words, it is a mutually exclusive bipartition of elements, i.e. nothing can belong simultaneously to both parts, and everything must belong to one part or the other. They are often contrasting and spoken of as "opposites." The term comes from dichotomos (divided): dich- ([in] two) temnein (to cut).

TEAC

Treaty establishing a European Atomic Energy Community, or EURATOM. It was established on March 25, 1957, signed the same day as the more famous Treaty of Rome, instituting the European Economic Community (EEC). The European Atomic Energy Community is a separate legal entity, but membership and organization is fully integrated with the European Union.

Economies of Scale

Economies of scale and diseconomies of scale refer to an economic property of production that affects cost if quantity of all input factors are increased by some amount. If costs increase proportionately, there are no economies of scale; if costs increase by a greater amount, there are diseconomies of scale; if costs increase by a lesser amount, there are positive economies of scale. When combined, economies of scale and diseconomies of scale lead to ideal firm size theory, which states that per-unit costs decrease until they reach a certain minimum, then increase as the firm size increases further.

Epitome

An epitome (Greek epitemnein, to cut short) is a summary or miniature form; it is also used as a synonym for embodiment. Many lost documents from the Ancient Greek and Roman world survive only now "in epitome" referring to the practice of some later authors (epitomators) who would write distilled versions of now lost larger works. Some writers would attempt to convey the stance and spirit of the original, while others would add further details or anecdotes regarding the general subject. As with all secondary historical sources, a different bias may creep in that was not present in the original.

Fast Breeder Reactor

The fast breeder or fast breeder reactor (FBR) is a fast neutron reactor designed to breed fuel by producing more fissile material than it consumes. The FBR is one possible type of breeder reactor.

Fizzle Explosion

A fizzle occurs if the nuclear chain reaction is not sustained long enough to cause a full-yield explosion. This can happen if, for example, the yield of the fissile material used is too low, the compression explosives around fissile material misfire or the neutron initiator fails to funcion properly. (Yield below the designed full yield but any yield above the yield of the chemical explosives)

Fuel Cell

A fuel cell is an electrochemical energy conversion device. Fuel cells differ from batteries insofar as they are designed for continuous replenishment of the reactants consumed; they produce electricity from an external supply of fuel and oxygen as opposed to the limited internal energy storage capacity of a battery. Additionally, while the electrodes within a battery react and change as a battery is charged or discharged, a fuel cell's electrodes are catalytic and relatively stable. Typical reactants used in a fuel cell are hydrogen on the anode side and oxygen on the cathode side (a hydrogen cell). Usually, reactants flow in and reaction products flow out. Virtually continuous long-term operation is feasible as long as these flows are maintained.

GHG

Greenhouse gases (GHGs) are gaseous components of the atmosphere that contribute to the "greenhouse effect". Although uncertainty exists about exactly how earth's climate responds to these gases, global temperatures are rising. Some greenhouse gases occur naturally in the atmosphere, while others result from human activities. Naturally occuring greenhouse gases include water vapour, carbon dioxide, methane, nitrous oxide, and ozone. Certain human activities, however, add to the levels of most of these naturally occurring gases.

Gross Domestic Product (GDP)

A region's gross domestic product, or GDP, is one of the several measures of the size of its economy. The GDP of a country is defined as the market value of all final goods and services produced within a country in a given period of time. Until the 1980ies the term GNP or gross national product was used. The two terms GDP and GNP are almost identical. The most common approach to measuring and understanding GDP is the expenditure method:

GDP = consumption + investment + government spending + (exports – imports). "Gross" means depreciation of capital stock is not included. With depreciation, with net investment instead of gross investment, it is the net domestic product. Consumption and investment in this equation are the expenditure on final goods and services. The exports minus imports part of the equation (often called cumulative exports) then adjusts this by subtracting the part of this expenditure not produced domestically (the imports) and adding back in domestic production not consumed at home (the exports).

Homozygote

A homozygote's cells are diploid or polyploid and have the same alleles at a locus (position) on homologous chromosomes. When an organism is referred to as being homozygous for a specific gene, it means that it carries two identical copies of that gene for a given trait on the two corresponding chromosomes (e.g., the genotype is AA or aa). Such a cell or such an organism is called a homozygote.

Howitzer

A howitzer or hauwitzer is a type of field artillery. The name is of Germanized origin and derives from the Czech word houfnice, denoting a 15th century cannon used by Hussites during the

Hussite Wars. Howitzers are distinguished from other types of cannon artillery by their trajectory in that they tend to fire at high angles and deliver plunging fire.

Howitzers are used either as unprotected versions moved around by trucks, or as armored Self propelled units. Recoilless howitzers of smaller caliber are also directly mounted on trucks as well as aircrafts.

Hydrocracking

In petroleum geology and chemistry, cracking is the process whereby complex organic molecules (e.g. kerogens or heavy hydrocarbons) are converted to simpler molecules (e.g. light hydrocarbons) by the breaking of carbon-carbon bonds in the precursors. The rate of cracking and the end products are strongly dependent on the temperature and presence of any catalysts. Cracking is also known as pyrolysis.

Hydrocracking is a catalytic cracking process assisted by the presence of an elevated partial pressure of hydrogen. The products of this process are saturated hydrocarbons; depending on the reaction conditions (temperature, pressure, catalyst activity) these products range from ethane, LPG to heavier hydrocarbons comprising mostly of isoparaffins. Hydrocracking is normally facilitated by a bifunctional catalyst that is capable of rearranging and breaking hydrocarbon chains as well as adding hydrogen to aromatics and olefins to produce naphthenes and alkanes.

Major products from hydrocracking are jet fuel, diesel, relatively high octane rating gasoline fractions and LPG. All these products have a very low content of sulfur and contaminants. It is very common in India because of the high demand for diesel and kerosene.

Hydrocarbons

In chemistry, a hydrocarbon is any chemical compound that consists only of the elements carbon (C) and hydrogen (H). They all contain a carbon backbone, called a carbon skeleton, and have hydrogen atoms attached to that backbone. (Often the term is used as a shortened form of the term aliphatic hydrocarbon.) Most hydrocarbons are combustible. Although the term carbohydrate sounds similar, carbohydrates contain oxygen.

Intestine Epithelium

In zootomy, epithelium is a tissue composed of a layer of cells. In humans, it is one of four primary body tissues. Epithelium lines both the outside (skin) and the inside cavities and lumen of bodies. The outermost layer of our skin is composed of dead stratified squamous epithelial cells, as are the mucous membranes lining the inside of mouths and body cavities. Other epithelial cells line the insides of the lungs, the gastrointestinal tract, the reproductive and urinary tracts, and make up the exocrine and endocrine glands.

Least Developed Countries

Least Developed Countries (LDCs or Fourth World countries) are countries which according to the United Nations exhibit the lowest indicators of socio-economic development, with the lowest

Human Development Index ratings of all countries in the world. A country is classified as a Least Developed Country if it meets three criteria based on:

low-income (GNI per capita of less than US $750)

human resource weakness (based on indicators of nutrition, health, education and adult literacy) and

economic vulnerability (based on instability of agricultural production, instability of exports of goods and services, economic importance of non-traditional activities, merchandise export concentration, and handicap of economic smallness, and the percentage of population displaced by natural disasters)

Leukaemia

Leukemia (or leukaemia; see spelling differences) is a cancer of the blood or bone marrow characterized by an abnormal proliferation of blood cells, usually white blood cells (leukocytes). It is part of the broad group of diseases called hematological neoplasms.

Light Water Reactor

A light water reactor or LWR is a thermal nuclear reactor that uses ordinary water, also called light water, as its neutron moderator. This differentiates it from a heavy water reactor, which uses heavy water as a neutron moderator. In practice all LWRs are also water cooled.

Load

The power consumed at a given point

MOX

Mixed oxide, or MOX fuel, is a blend of plutonium and natural uranium, reprocessed uranium, or depleted uranium which behaves similarly (though not identically) to the low enriched uranium feed for which most nuclear reactors were designed. MOX fuel is an alternative to low enriched uranium (LEU) fuel used in the light water reactors that predominate nuclear power generation.

An attraction of MOX fuel is that it is a way of disposing of surplus weapons-grade plutonium, which otherwise would have to be handled as a difficult-to-store nuclear waste product, and a nuclear proliferation risk

Mutagen

In biology, a mutagen (Latin, literally origin of change) is an agent that changes the genetic information (usually DNA) of an organism and thus increases the number of mutations above the natural background level. Mutagens are usually chemical compounds or ionizing radiation.

Negajoules

Negajoules represent energy not consumed because of enhanced energy efficiency.

Nuclear Reprocessing

Nuclear reprocessing separates any usable elements (e.g., uranium and plutonium) from fission products and other materials in spent nuclear reactor fuels. Usually the goal is to recycle the reprocessed uranium or place these elements in new mixed oxide fuel (MOX), but some reprocessing is done to obtain plutonium for weapons. It is the process that partially closes the loop in the nuclear fuel cycle.

Opportunity Costs

Opportunity cost is a term used in economics to describe the cost of something in terms of an opportunity forgone (and the benefits that could be received from that opportunity), or the most valuable forgone alternative. For example, if a city decides to build a hospital on vacant land that it owns, the opportunity cost is some other thing that might have been done with the land and construction funds instead. In building the hospital, the city has forgone the opportunity to build a sporting center on that land, or a parking lot, or the ability to sell the land to reduce the city's debt, and so on.

The consideration of opportunity costs is one of the key differences between the concepts of economic cost and accounting cost. Assessing opportunity costs is fundamental to assessing the true cost of any course of action. In the case where there is no explicit accounting or monetary cost (price) attached to a course of action, ignoring opportunity costs may produce the illusion that its benefits cost nothing at all. The unseen opportunity costs then become the hidden costs of that course of action.

OSPAR Commission

The 1992 OSPAR Convention is the current instrument guiding international cooperation on the protection of the marine environment of the North-East Atlantic. It combined and up-dated the 1972 Oslo Convention on dumping waste at sea and the 1974 Paris Convention on land-based sources of marine pollution. The work under the convention is managed by the OSPAR Commission, made up of representatives of the Governments of 15 Contracting Parties and the European Commission, representing the European Community .

Paradigm

Since the late 1960s, the word paradigm has referred to a thought pattern in any scientific discipline or other epistemological context. Initially the word was specific to grammar: the 1900 Merriam-Webster dictionary defines its technical use only in the context of grammar or, in rhetoric, as a term for an illustrative parable or fable. Also, in linguistics, Ferdinand de Saussure used paradigm to refer to a class of elements with similarities.

Scientific paradigm: Philosopher of science Thomas Kuhn gave this word its contemporary meaning when he adopted it to refer to the set of practices that define a scientific discipline during a particular period of time. Kuhn himself came to prefer the terms exemplar and normal science, which have more exact philosophical meanings.

Paradigm Shift

A change of paradigm

Phenological Phases, Phenology

Phenology is the study of the times of recurring natural phenomena. The word is derived from the Greek Phainomai - to appear, come into view, and indicates that phenology has been principally concerned with the dates of first occurrence of natural events in their annual cycle. Examples include the date of emergence of leaves and flowers, the first flight of butterflies and the first appearance of migratory birds, the date of leaf colouring and fall in deciduous trees, the dates of egg-laying of birds and amphibia, the timing of the developmental cycles of honeybee colonies. Because many such phenomena are very sensitive to small variations in climate, especially to temperature, phenological records can be a useful proxy for temperature in the study of climate change.

Proliferation

Nuclear proliferation is the spread of nuclear weapons production technology and knowledge to nations that do not already have such capabilities.

PUREX Process

PUREX is a nuclear reprocessing method which is the de facto standard aqueous method based on liquid-liquid extraction for the recovery of uranium and plutonium from used nuclear fuel. This process can be used to recover weapon-grade materials as well as reprocessed uranium from spent nuclear reactor fuel, and as such, its component chemicals are monitored. PUREX is an acronym standing for Plutonium and Uranium Recovery by EXtraction. The PUREX process is a liquid-liquid extraction method used to reprocess spent nuclear fuel, in order to extract uranium and plutonium, independent of each other, from the fission products.

Radiolysis

Radiolysis is the dissociation of molecules by radiation. It is the cleavage of one or several chemical bonds resulting from exposure to high-energy flux. For example water dissociates under alpha radiation into hydrogen and oxygen. The chemistry of concentrated solutions under ionizing radiation is extremely complex. Radiolysis can locally modify redox conditions, and therefore the speciation and the solubility of the compounds.

Radiotoxicity

Measure of how nocuous a radio nuclide is to health. The type and energy of rays, absorption in the organism, residence time in the body, etc. influence the degree of radiotoxicity of a radio nuclide.

RODOS (Software)

In case of a nuclear accident in Europe, the Real-time On-line DecisiOn Support system for off-site emergency management in Europe (RODOS) provides consistent and comprehensive information on the present and future radiological situation, the extent and the benefits and drawbacks of emergency actions and countermeasures, and methodological support for taking decisions on emergency response strategies. Main users of the system are those responsible at local, regional, national and supra-national levels for off-site emergency management. The application of the system for training and exercises was a further important consideration in its development.

RPG (Rocket-Propelled Grenades)

A rocket propelled grenade (RPG) is a loose term describing hand-held, shoulder-launched anti-tank weapon capable of firing an unguided rocket equipped with an explosive warhead. RPG is the Russian acronym of "Ruchnoy Protivotankovy Granatomyot" and is translated into English as "handheld antitank grenade-launcher". The commonly used term "rocket-propelled grenade" is a mistranslation, backformed from the acronym RPG and does not follow correct naming conventions used by English speaking militaries to describe these weapons.

Sustainability

Sustainability is a systemic concept, relating to the continuity of economic, social, institutional and environmental aspects of human society, as well as the non-human environment. It is intended to be a means of configuring civilization and human activity so that society, its members and its economies are able to meet their needs and express their greatest potential in the present, while preserving biodiversity and natural ecosystems, and planning and acting for the ability to maintain these ideals in a very long term. Sustainability affects every level of organization, from the local neighbourhood to the entire planet.

"Sellers Market"

Jargon for a climate that generally favors sellers. Such a market exists when the number of qualified buyers seeking products generally exceeds the available inventory. In other words, it is a case of Supply and Demand, with the demand of buyers out-pacing the supply of the required goods.

Steam Reformer Production

Steam reforming, hydrogen reforming or catalytic oxidation, is a method of producing hydrogen from hydrocarbons. On an industrial scale, it is the dominant method for producing hydrogen. Small-scale steam reforming units are currently subject to scientific research, as a way to provide hydrogen to fuel cells.

Tamper

In nuclear weapon design, a shell surrounding the fission core and keeping the nuclear material assembled during the explosion for longer time, raising yield.

Tar-sand

Oil sands, also referred to as tar sands or bituminous sands, are a combination of clay, sand, water, and bitumen. Technically speaking, the bitumen is neither oil nor tar, but a semisolid, degraded form of oil which will not flow toward producing wells under normal conditions, making it difficult and expensive to produce. Oil sands are mined to extract the oil-like bitumen which is upgraded into synthetic crude oil or refined directly into petroleum products by specialized refineries. Conventional oil is extracted by drilling traditional wells into the ground whereas oil sand deposits are mined using strip mining techniques, or persuaded to flow into producing wells by in situ techniques which reduce the bitumen's viscosity with steam and/or solvents. On average bitumen contains 83.2 % carbon, 10.4 % hydrogen, 0.94 % oxygen, 0.36 % nitrogen and 4.8 % sulphur.

Transaction Costs

In economics and related disciplines, a transaction cost is a cost incurred in making an economic exchange. For example, most people, when buying or selling a stock, must pay a commission to their broker; that commission is a transaction cost of doing the stock deal. Or consider buying a banana from a store; to purchase the banana, your costs will be not only the price of the banana itself, but also the energy and effort it requires to find out which of the various banana products you prefer, where to get them and at what price, the cost of travelling from your house to the store and back, the time waiting in line, and the effort of the paying itself; the costs above and beyond the cost of the banana are the transaction costs. When rationally evaluating a potential transaction, it is important to consider transaction costs that might prove significant.

Transmutation

Transmutation is the conversion of one object into another. Transmutation of chemical elements occurs through nuclear reactions. This is called nuclear transmutation. Natural transmutation is when radioactive elements spontaneously decay over a long period of time and transform into other more stable elements. Artificial transmutation occurs in machinery that has enough energy to cause changes in nuclear structure of the elements. The machines that can cause artificial transmutation include the particle accelerator and tokamak reactor.

Ton of Oil Equivalent

The ton of oil equivalent (toe) is a unit for measuring energy. It corresponds to 10 $Gcal_{th}$ or 41,868 GJ, or 11.63 MWh. It is the rounded-off amount of energy that would be produced by burning one metric ton of crude oil. Since crude oil of different provenance will have a different chemical make-up and therefore give off varying amounts of heat when burnt, the value is conventional to a certain extent.

Toxicity

Toxicity is a measure to the degree to which something is toxic or poisonous. The study of poisons is known as toxicology. Toxicity can refer to the effect on a whole organism, such as a human or a bacterium or a plant, or to a substructure, such as the liver. By extension, the word may be metaphorically used to describe toxic effects on larger and more complex groups, such as the family unit or "society at large".

UNFCCC

The United Nations Framework Convention on Climate Change (UNFCCC or FCCC) is an international environmental treaty produced at the United Nations Conference on Environment and Development (UNCED), informally known as the Earth Summit, held in Rio de Janeiro in 1992. The treaty aimed at reducing emissions of greenhouse gas in order to combat global warming.

Uranium Hexa Fluoride

Uranium hexa fluoride, or UF6, is a compound used in the uranium enrichment process that produces fuel for nuclear reactors and nuclear weapons. It forms solid grey crystals at standard temperature and pressure (STP), is highly toxic, reacts violently with water and is corrosive to most metals. It reacts mildly with aluminum, forming a thin surface layer of AIF3 that resists further reaction.

Yellowcake

Yellowcakes (also known as urania) are uranium concentrates obtained from leach solutions. They represent an intermediate step in the processing of uranium ores. Yellowcake concentrates are prepared by various extraction and refining methods, depending on the types of ores. Typically yellowcakes are obtained through the milling and chemical processing of uranium ore forming a coarse powder which is insoluble in water and contains about 80 % uranium oxide, and which melts at approximately 2878 °C.

World Bank

The World Bank Group is a group of five international organizations responsible for providing finance and advice to countries for the purposes of economic development and poverty reduction, and for encouraging and safeguarding international investment. The group and its affiliates have their headquarters in Washington, D.C., with local offices in 124 member countries.

World Energy Council

World Energy Council (WEC) has Member Committees in over 90 countries, including most of the largest energy-producing and energy-consuming countries. Established in 1923, the organisation covers all types of energy, including coal, oil, natural gas, nuclear, hydro, and renewables, and is UN-accredited, non-governmental, non-commercial and non-aligned. WEC is a UK-registered charity headquartered in London.

The Authors

The Authors

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Oda Becker studied physics and education science at the University of Hanover. She has been working as an independent scientific consultant in the field of nuclear safety and security for many years. Her clients include the Austrian Federal Government as well as German municipalities and NGOs.

Recent work includes: Studies of the hazards of spent fuel cask storage facilities; contribution to a study of the vulnerability of the German nuclear power plants Biblis and Brunsbüttel to terror attacks; contribution to a study of the ongoing dangers of operating nuclear technology in the 21st century; study of the situation at the NPP Chernobyl site; work concerning the planned lifetime extension of Paks NPP, Hungary; study of severe accidents at the NPP Unterweser in Northern Germany (focus: terror attacks).

Antony Froggatt

Independent European energy consultant

Since 1997 Antony has worked as a freelance consultant on energy and nuclear issues in the EU and neighbouring states. He has worked extensively on EU energy policy issues for European Governments, the European Commission and Parliament, environmental NGOs and commercial bodies. He has given evidence to inquiries and hearings in the Parliaments of Austria, Germany and the EU. He has also worked extensively with environmental groups in Eastern Europe, particularly, in the run up to enlargement, helping to establish a network on energy efficiency. Furthermore, he is a regular speaker at conferences, universities and training programmes across the region and the EU.

Prior to working freelance Antony worked for nine years as a nuclear campaigner and co-ordinator for Greenpeace International.

Helmut Hirsch, Dr.

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Training in radiation protection at the Austrian research center Seibersdorf, study of physics at Vienna University. In the 30 years of his career as nuclear expert, Helmut Hirsch has been working for the Austrian Federal Government as well as for German state governments and municipal administrations and international NGOs. He was scientific coordinator of the Austrian Government's nuclear energy information campaign 1976/77 and founded Gruppe Ökologie Hannover, an ecological research institute, in 1981, where he remained until 1995. Subsequently, he was employed as nuclear expert in the German Greenpeace office and is working freelance since 1997.

Recent work includes: Participation in the technical support for the monitoring process for the Czech NPP Temelín; participation in a study of potential hazards due to the spent fuel storage facility at Skull Valley, Utah (USA); evaluating possible countermeasures against terror attacks against NPPs; evaluation of the Swiss plans for a nuclear repository, concerning potential effects on Austrian territory, and of the Swiss procedure of repository site selection; membership of the Expert Group on Impacts of Longer Term Operation of Nuclear Capacities of the OECD/NEA; work concerning the planned lifetime extension of Paks NPP, Hungary.

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G. Kastchiev graduated from University of Sofia in Bulgaria in 1972 as a diploma physicist. In 1972 he started his career as reactor physicist in NPP Kozloduy. He received a Ph.D. in reactor physics and safety from the University of Sofia in 1987. Dr. Kastchiev worked as a lecturer at the Institute of Nuclear Engineering, Kozloduy/Sofia from 1989 to 1993 and as a guest engineer in the AP 600 Project, Westinghouse, USA in 1994. During 1995-1997 Dr. Kastchiev acted as a consultant to the Institute of Risk Research, University of Vienna, Austria, until he was appointed head of the Bulgarian Nuclear Safety Authority in 2002. He worked there for four years and he spent one year as a guest professor in the Tokyo Institute of Technology. Since 2002 he is back in the Institute of Risk Research, University of Vienna, Austria.

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Professor, Ph.D. in Physics, University of Vienna, Head of the Institute of Risk Research of the University of Vienna, Faculty of Earth Sciences, Geography and Astronomy, forty years of experience in research and teaching at university level, extended research fellowships and visiting professorships at the Max-Planck Institute in Stuttgart, Germany and the Carnegie-Mellon University in Pittsburgh, USA. Research in the area of material related problems, using ultrasonic techniques for material testing and composition; focus on material related questions concerning nuclear safety. W. Kromp is member of the Scientific Commission of the Austrian Federal Ministry of Defence and the Technical Committee for Standardization ON-K 246 Risk, Safety and Crisis Management of the Austrian Standards Institute. Konrad Lorenz Environmental Award 1991 of the Austrian Ministry of the Environment. Participation in safety assessments of several nuclear power plants and spent fuel interim storages; research on radioactive contamination and risk perception; socio-economic research on fusion (SERF). Feasibility and risk studies on sustainable energy production from biomass. Study on security of food production in oil reduced agriculture.

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Helga Kromp-Kolb had her schooling in France, Luxemburg, India and Austria and studied meteorology at the University of Vienna. As a university teacher and researcher she has focused on environmental meteorology, engaging in problems of air pollution dispersion, UV-radiation and stratospheric ozone depletion as well as climate change. Her publications include assessments of radioactive dispersion from Chernobyl as well as for potential accidents at near border NPPs and methodological and practical work on downscaling of GCM climate scenarios to the Alpine region. She is member of a number of scientific boards as well as advisory committees to the Austrian Government. With one short interruption she has headed the Austrian Nuclear Advisory Board since its founding in 1990.

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Meister studied history, political sciences and philosophy at the University of Vienna. Beginning 1986 he worked at the Österreichisches Ökologie-Institut in the energy department before moving to the Umweltbundesamt in 1991. His main topics of interest are: energy and environment, energy and emission modelling and risks of nuclear power plants near the Austrian border. He coordinated projects of the Umweltbundesamt on the NPPs Chmelnitzky-2/Rowno-4, NPP Temelín, NPP Mochovce, NPP Bohunice, NPP Packs, the German interim storage projects, the Swiss final repository project, as well as assessments of the energy concepts of the Czech and the Slovak Republics.

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Müllner studied Physics at the University of Vienna and at the Technical University of Berlin. After graduating in 2001 he was working two years in the field IT in London, and decided 2003 to accept an offer to work as research associate and to start as Ph.D. student at the Institute for Risk Research. In this frame he is currently staying at the University of Pisa. His fields are Safety Analyses with the Thermal Hydraulic System Codes Relap5 and Cathare2, and Analyses of Severe Accidents with the Integral Code MELCOR, as well as project preparation and project management.

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Member of the Austrian Nuclear Advisory Board (Forum für Atomfragen, FAF)

Professor for Public International Law, European Community Law and International Relations (1983 - 2004); Head of the Institute for European Community Law (1990 - 2004); Head of the Institute for Public International Law and International Relations (1996 - 2004); Director of the European Documentation Centre of the European Commission at Linz University (1990 - 2004); Member of the Scientific Board of the Conference of Rectors of the Alps-Adria Community (1982-97); Member of the Governing Board of the Joint Programme of the Czech Republic and Austria for Scientific Co-operation (since 1996).

Numerous Publications on various problems of Public International Law, European Community Law and International Relations. The latest are dedicated to the legal fallacies of Nuclear Security, the traces of Kelsen's Pure Theory of Law in Public International Law, the changes in the concept of Defence and the legal dimension of Israel's so called Security Fence on Palestinian Territory.

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Steven Sholly graduated from Shippensburg State College (now Shippensburg University) in Pennsylvania in the United States in 1975 with a Bachelor of Science degree in Science Education. Since 1979 he has been engaged in hazard analysis, safety analysis, risk assessment, and environmental impact assessment work primarily involving nuclear and hazardous chemical facilities. Mr. Sholly served as a contract seismic analysis reviewer for the US Nuclear Regulatory Commission's Individual Plant Examination of External Events (IPEEE), and also performed accident analyses of the US Department of Energy's nuclear weapon-related facilities at Los Alamos National Laboratory and the former Rocky Flats facility (now largely decommissioned). Mr. Sholly has lived in Austria and worked at the Institute of Risk Research since early 1998. Mr. Sholly is a member of the IAEA's Nuclear Safety Standards Committee (NUSSC) for 2004-2007.

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Member of the Austrian Nuclear Advisory Board (Forum für Atomfragen, FAF)

After obtaining a degree in mechanical engineering at the University of Technology in Vienna and working on plant projects, he acquired in graduate trainings for nuclear technology in the US and Germany basic knowledge on safety in nuclear installations. Practical experience in licensing and start-up, as well as emergency planning and accident consequences management followed. Design of pressurized water reactors, high temperature reactors, one fast breeder reactor and safety analyses for spallator and fusion installations were applications. He analysed questions of long term options for energy supply and of energy saving technologies at Austria's EU accession. As a nuclear technologist engaged in a number of safety analyses regarding design and operation, as well as in the long term operation of nuclear power plants, he has 35 years experience in energy technology. He is co-author of a number of detailed studies in the related areas.

Peter Weish, Univ.-Doz. Dr.

University Docent at the University of Vienna, Faculty of Ecology,
Member of the Austrian Nuclear Advisory Board (Forum für Atomfragen, FAF)

Peter Weish is a graduate of the University of Vienna (Chemistry, Physics, Biology); he was professional active at the Institute for Radiation Protection of the Austrian Research Centre Seibersdorf, at the Institute of Zoology of the BOKU University of Renewable Resources and Applied Life Sciences and at the Institute for Environmental Sciences and Nature Protection of the Austrian Academy of Sciences.

Since the late 1960ies he has focussed on the problems of nuclear energy from the human ecology viewpoint, as well as on general questions of energy, nature- and environmental protection and development cooperation. Cooperation with various environmental organisations and advisory bodies. Lecturing at the BOKU and the University of Vienna in the fields of Human Ecology and Environmental Ethics.

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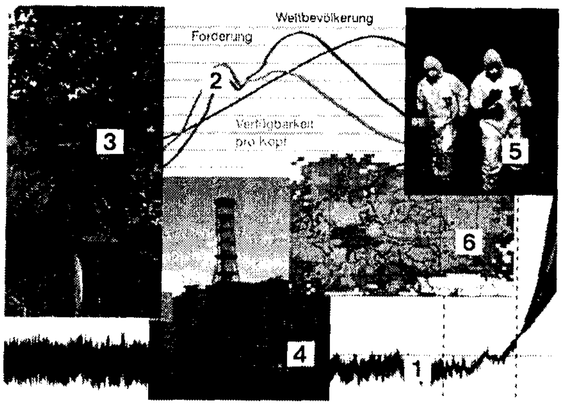

1 Average temperature on the Northern Hemisphere during the last 1000 years [IPCC 2001]
2 Production rate of oil, world population and availability of oil per capita through the years 1950 to about 2100, with production peaking around 2010 [Kromp-Kolb und Formayer 2006]
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6 Distribution of nuclear risk by commercial power plants in Europe as modelled in the "Riskmap" project 1999 [http://www.umweltbundesamt.at/umwelt/kernenergie/akw/riskmap/?wai=1]

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Informationen zu Landwirtschaft, Lebensmittel, Wald, Umwelt und Wasser:
www.lebensministerium.at

Das Aktionsprogramm des Lebensministeriums für aktiven Klimaschutz:
www.klimaaktiv.at

Die Jugendplattform rund ums Wasser:
www.generationblue.at

Die bundesweite Initiative zur getrennten Sammlung von Altstoffen:
www.richtigsammeln.at

Die Internetseite zur Österreichischen Nachhaltigkeitsstrategie:
www.nachhaltigkeit.at

Das Internetportal der Österreichischen Nationalparks:
www.nationalparks.at

Der Walddialog ist die Suche nach Problemlösungen für Interessenkonflikte im Waldbereich:
www.walddialog.at

Das Österreichische Umweltzeichen ist Garant für umweltfreundliche Produkte und Dienstleistungen:
www.umweltzeichen.at

Umweltdaten u.a. zu den Bereichen Wasser, Luft, Lärm, Kernenergie, Klima, Gentechnik, Altlasten, erhebt laufend das UBA:
www.umweltbundesamt.at

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Posted to the Web on September 28, 2007

CARBON-FREE AND NUCLEAR-FREE

A Roadmap for U.S. Energy Policy

Arjun Makhijani, Ph.D.

A Joint Project
of the
Nuclear Policy Research Institute
and the
Institute for Energy and Environmental Research
August 2007

Foreword by
S. David Freeman
President, Los Angeles Board of Harbor Commissioners
and former chairman of the Tennessee Valley Authority
and
Afterword by
Dr. Helen Caldicott
Founding President, Nuclear Policy Research Institute

RDR
Books

Published jointly by
IEER Press
Takoma Park, Maryland
and
RDR Books
Muskegon, Michigan

IEER Press

Carbon-Free and Nuclear-Free
A Roadmap for U.S. Energy Policy

published jointly by

RDR Books
1487 Glen Avenue
Muskegon, MI 49441
Phone: (510) 595-0595
Fax: (510) 228-0300
E-mail: read@rdrbooks.com
www.rdrbooks.com

IEER Press
6935 Laurel Avenue, Suite 201
Takoma Park, MD 20912
Phone: (301) 270-5500
Fax: (301) 270-3029
E-mail: ieer@ieer.org
www.ieer.org

ISBN: 978-1-57143-173-8

Library of Congress Control Number: 2007936263

Cover painting: Pushpa Mehta
Cover design and production: Richard Harris
Interior design: Elizabeth Thurlow-Shields and Ken Shields

Distributed in the United Kingdom and Europe by
Roundhouse Publishing Ltd.
Millstone, Limers Lane,
Northam, North Devon EX39 2RG, United Kingdom

Distributed in Canada by
Scholarly Book Services
127 Portland St. 3rd Floor
Toronto, ON M5V 2N4

Printed in the United States of America

To

Helen Caldicott and S. David Freeman

who both inspired this book

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FOREWORD

by S. David Freeman

In the summer of 1972, Arjun Makhijani walked into my office at 1776 Massachusetts Avenue in Washington, D.C. for an interview. He had a head full of hair and numbers. At the time, I was the Director of the Energy Policy Project of the Ford Foundation. Working in the White House in the 1960s, I felt that U.S. energy policy was seriously adrift and that we would soon run into trouble if oil imports kept rising inexorably. I wanted to lead an effort to change U.S. policy to one that would give us economic growth with much lower energy growth or even zero energy growth. It would free our foreign policy and literally allow us to breathe freer in our cities, which were choking with pollution. Zero energy growth with positive economic growth was considered economic heresy then; the experts believed that economic growth and energy use growth inevitably went hand-in-hand. But some of us saw the crisis coming and the Ford Foundation agreed to set up an internal project to see what could be done. I had the vision for the direction that the country should take. In Arjun, I had found the man with the numbers savvy to help me figure out the efficiency angle.

As a doctoral student at the University of California at Berkeley, he had already done preliminary estimates of the energy efficiency potential of the U.S. economy, two years before the Arab oil embargo. He was the principal author of a seminal 1971 study on energy efficiency with a typically vague and academic title: *An Assessment of Energy and Materials Utilization in the U.S.A.* Arjun's work on energy efficiency soon became the technical core of the demand-side of the "Technical Fix" and "Zero Energy Growth" scenarios that we had set out to construct.

When the energy crisis broke over the United States like a political and economic tsunami in October 1973, our project was the only independent game in town. The country needed answers and we had been asking the right questions. Though much remained to be done, the numbers were ready; we published them in a preliminary report, *Exploring Energy Choices*, in January 1974. That work, and our final report, *A Time to Choose: America's Energy Future*, became the foundation of President Carter's energy policy. I have recounted that story in my own book, *Winning Our Energy Independence*, published by Gibbs-Smith on October 1, 2007.

When President Carter appointed me to the Board of Directors of the Tennessee Valley Authority, and then promoted me to be the Chairman, the country was in the midst of a profound change in its energy consumption patterns. Economic growth had resumed, but energy growth had not. The Zero Energy Growth scenario that the then-President of Mobil Oil Company, William Tavoulareas, had been so critical about (he was on our Board of Advisors) was actually being realized in practice. But TVA had its head in the sand; it was building 14 nuclear reactors at once, as if 1973 had been just another normal year. It was business-as-usual in the worst way.

I wanted someone to advise me on how to put a thorough energy efficiency program into place at TVA. Arjun came to TVA to work with me as a consultant in 1978. Typically, he took a look at the big picture of TVA's supply and demand first. He wrote a report whose gist was that unless TVA cancelled at least eight reactors (he actually named the ones), an energy efficiency program would be counterproductive. It would reduce demand growth when it was already slowing. At the same time the reactors would greatly increase TVA's capacity to generate electricity that would likely have no market. It was a recipe for trouble. I had a long, tough road ahead of me to put TVA's house in order, but by 1982 I did manage to get all eight of them cancelled; I also put in place what was then the country's largest energy efficiency program. Once more, Arjun's analysis was right on target.

With *Carbon-Free and Nuclear-Free*, he has done it again. But this time he had to be goaded into doing the study. Last year, I gave a talk at an energy conference sponsored by Helen Caldicott's Nuclear Policy Research Institute. I said that the United States should jettison both coal and nuclear power. The future lay with solar energy. We should begin the transformation now and finish it as soon as possible. Helen was in enthusiastic agreement. But Arjun came up to me afterwards and said: "You are proposing a course that is so costly that it would drive every industry we have to China." I told him to stop being a naysayer and analyze how we could move from our polluting oil addiction to renewable energy. He didn't believe it could be done, but he agreed to take a preliminary look out of respect for Helen and me. To his surprise, he found there was a technological revolution going on that he had missed, because he focused for so many years on the environmental and health problems caused by nuclear weapons production and testing.

Sharing our concerns about climate change, the risks of nuclear power, and the problems of oil import dependence, he agreed to take up the challenge of examining the feasibility of a renewable energy economy. Helen agreed to raise the money. His very diverse Advisory Board, of which I am a member, critically reviewed the outline of this book and its first draft. He has carefully taken our suggestions into account. He interviewed leaders of established and emerging industries. He reviewed an enormous amount of recent technical literature on energy that seems to have attracted little notice in Washington, D.C. *Carbon-Free and Nuclear-Free* is the result.

This Roadmap could liberate us from an energy policy that is trashing our climate and our mountain tops, that is polluting our land, sea, and air, that is trying to resurrect dangerous nuclear power, and that has America so dependent on imported oil that our foreign policy is the prisoner of oil. It shines a light on the path to a renewable energy economy. It will not be easy to get there, but it can be done. Arjun's head has less hair (he says he has "grown old and bald doing environmental work for thirty seven years") but it is still full of reliable numbers.

My advice in these turbulent energy times is: when Arjun talks numbers, policymakers should listen. He has a stellar technical track record. It is time again to choose. Last time, we achieved zero energy growth with positive economic growth when few thought it was even within the realm of possibility. I have no doubt that, with determination and guts, we can achieve a renewable energy economy. Arjun has laid out a thoughtful and practical approach to get us there.

S. David Freeman
President, Los Angeles Board of Harbor Commissioners
August 2007

ACKNOWLEDGEMENTS

I would like to thank the Nuclear Policy Research Institute (NPRI) for having sponsored the project that resulted in this book. Dr. Helen Caldicott was the star who raised the funds, provided critical comments and suggestions, and, most of all, had the vision that this study should be done because it is urgently needed. I am deeply grateful to her.

The project was conceived at NPRI's 2006 energy conference, where S. David Freeman, who led the Energy Policy Project of the Ford Foundation in the early 1970s, was among the speakers. He presented a vision for a solar energy future that, along with Helen's vision for this project, inspired this book.

This project to create a Roadmap for a zero-CO_2 emissions, non-nuclear energy future for the United States was immensely helped by the insights and comments of an Advisory Board. Only the names of those who were able to participate are included:

1. Helen Caldicott, President, Nuclear Policy Research Institute, which is sponsoring this project.
2. Paul Epstein, Associate Director, Center for Health and the Global Environment, Harvard Medical School
3. S. David Freeman, President, Los Angeles Board of Harbor Commissioners and former chairman of the Tennessee Valley Authority
4. Dawn Rittenhouse, Director, Sustainable Development, DuPont
5. Jenice View, Education and Training Director, Just Transition Alliance
6. Hisham Zerriffi, Ivan Head South/North Chair at the University of British Columbia

They provided extensive comments on an outline of this report and on a draft of the full report. They attended an all-day meeting on March 15, 2007, during which they provided criticisms and suggestions for the final product and ideas for outreach. I also corresponded with Hisham and Dawn on several technical topics. John Carberry of DuPont provided very helpful comments; he and Dawn did an interview with me, which is reproduced as Appendix B of this book, which provided insights on industrial energy efficiency, among other things. I am very grateful to them.

I wish to note here that DuPont's position on nuclear power is to keep that option open, in contrast to the recommendation in this book that it be phased out. Their position on carbon caps is also different. Please refer to http://www.us-cap.org/USCAPCallForAction.pdf for details.

While the comments have helped to improve this work greatly, as the author of this work, I alone am responsible for any remaining errors or omissions and for the analysis, findings, recommendations in it.

Mark Selden, editor of *Japan Focus* (www.japanfocus.org) , interviewed me after the summary of this book was published on July 29, 2007. His questions were very sharp and practical. The interview sets this book in an international context and is republished here as Appendix C. Thanks to Mark for his questions, editing of the interview, and permission to republish it here.

I also want to thank Becca Brown, Michele Boyd, and David Hoffman, who also provided suggestions during the Advisory Board meeting. I interviewed several people in industry, government, and academia, who gave generously of their time and expertise. They included Isaac Berzin (GreenFuel Technologies), Dick Post (Lawrence Livermore National Laboratory), Joel Schindall (Massachusetts Institute of Technology), John Morris (Sunlight Direct, Inc.), Michael Winkler (Schatz Energy Research Center, Humboldt State University), Randy Zwetzig (Ice Energy), and John Miller (Maxwell Technologies). John Miller also provided comments on the draft report. Melissa Kemp provided me with data and insights into the practical world of residential solar photovoltaic system costs and installations. And thanks also to Scott Powell for his volunteer proofreading. I would also like to thank all those who generously gave permission to use their images. They are credited at the appropriate locations in the text.

This project was something of a research adventure and the IEER staff played a critical role. Lois Chalmers was, as usual, a careful fact-checker and compiled the bibliography and found reference materials for me. Annie Makhijani compiled the energy use and supply data, checked my calculations, researched several topics, including biofuels, and did many of the graphics. Betsy Thurlow-Shields typeset the manuscript with Ken Shields' help. Natasha Makhijani researched documents on energy efficiency and compiled them into an easy list. She also proofread the manuscript, copy-edited it, and helped prepare the index. Brice Smith checked my energy demand spreadsheets and some of the financial calculations. Dr. Pushpa Mehta did the original painting reproduced on the cover especially for this book. Her artistry and generosity (she donated the work) are deeply appreciated.

It has been a special pleasure to work with Julie Enszer, Executive Director of NPRI. She has managed this project with insight and shepherded it along with care. For their support of this project, NPRI and IEER wish to thank The Park Foundation, The Lear Family Foundation, The Lintilhac Foundation, and many individual donors who wish to remain anonymous. Grateful appreciation is extended to all who supported this work.

Arjun Makhijani

PREFACE

A three-fold global energy crisis has emerged since the 1970s; it is now acute on all fronts.

1. Severe climate change, caused mainly by emissions of carbon dioxide from fossil fuel burning and associated emissions of other greenhouse gases;
2. The security of oil supplies, given the political and military turmoil in much of the oil exporting world, centered in the Persian Gulf region;
3. Nuclear weapons proliferation and its potential connections to the spread of nuclear energy to address climate change.

These issues are intimately connected. Oil is a leading source of global and U.S. carbon dioxide (CO_2) emissions as well as a principal source of local air pollution, and often the main one in cities. Concerns about the insecurity of oil supply are not new – they were expressed as long ago as 1952 by the Paley Commission,[1] when the United States was just turning from an oil exporter to an oil importer. To complicate matters, many, including some environmentalists, now propose that nuclear power should be one of the sources of energy used to reduce carbon dioxide emissions. The U.S. energy legislation of 2005 provides significant subsidies, not only for renewable energy sources, but also for new nuclear power plants.[2] But nuclear power and nuclear weapons proliferation are quite entangled with one another.

This report is not about the tangle of these difficult problems, but about a central, indeed indispensable, part of the solution – greatly reducing U.S. emissions from fossil fuel burning, which constituted 84 percent of U.S. greenhouse gas emissions in 2004. Its focus is to assess the feasibility of a zero-CO_2 economy in the United States and to lay out a roadmap to achieve that as early as is technically and economically practical, without resort to nuclear power. This preface lays out the reasoning for that framework and discusses the scope of the report.

A. Climate Change

The end of 2006 and the start of 2007 saw a flurry of initiatives from business, Congress, and the Bush administration,[3] on energy and climate change that seems to provide some hope the United States, by far the richest country in the world and the largest emitter of greenhouse gases, will begin to take national action. Many states, local governments, some corporations, many non-government groups, scientific panels, as well as many European countries had begun to take action years ago.

Action is surely necessary. The evidence of serious climate change, induced mainly by anthropogenic emissions of greenhouse gases, is now overwhelming; it need not be recounted here in detail, since this report is devoted to solutions. A few bullet points will suffice:

- Glaciers are melting across the world.
- Arctic ice is disappearing at a much faster rate than estimated just a few years ago – fast enough for the U.S. Fish and Wildlife Service to propose putting polar bears on the endangered species list.[4]
- CO_2 is a greenhouse gas and has increased by more than one-third in the last century and a half, due to human emissions.[5]
- Millions of acres of Alaskan forests are dying of insect infestations because the summers are longer and much warmer.[6]
- The Siberian permafrost is beginning to melt, raising the possibility that large amounts of methane now immobilized in the permafrost as methane hydrates would be released into the atmosphere.[7] (Methane is the primary chemical component of natural gas.) Such releases could suddenly aggravate existing trends and make temperature increases and sea-level rise greater and faster than now estimated. Even a one or two foot average sea-level rise would cause severe harm to tens of millions of people living in coastal areas around the world, from Florida to Bangladesh to the small island countries.
- Evidence of more frequent extreme climatic events is mounting. It is still difficult and controversial to try to pin a single extreme event, such as a hurricane, on climate change. But there is enough cumulative evidence to indicate that suffering and grievous damage of the type experienced in 2005 by the people of New Orleans and other parts of the U.S. Gulf Coast may become more frequent. The economic consequences will be long lasting. The population of New Orleans has not recovered. The poor and African Americans continue to be disproportionately affected, raising larger questions about society's ability to equitably handle more frequent serious climate-induced disruptions.

As of early 2007, the atmospheric concentration of CO_2 is over 380 parts per million (ppm).[8] Some ecosystems are already being extensively damaged, notably coral reefs.[9] The consequences that are unfolding from the tropics to the tundra do not depend on additional increases, which will only make the problem worse. The most recent work of the Intergovernmental Panel on Climate Change estimates that the cumulative CO_2-equivalent must be within the 445 to 490 parts per million range in order to limit the mean global temperature rise to 2.0 to 2.4 degrees Celsius (3.6 to 4.3 degrees Fahrenheit).[10] According to the Stern Review, at that level, we risk the "possible onset of collapse of part or all of the Amazonian rainforest,"[11] which has been called the lungs of the planet. The estimated effects at various levels of CO_2-equivalent concentrations of greenhouse gases are shown in Figure P-1, reproduced from the Stern Review.

The Intergovernmental Panel on Climate Change (IPCC) estimates that it will be necessary to reduce global carbon dioxide emissions by 50 to 85 percent relative to 2000 by 2050 in order to limit the temperature rise to less than 2 to 2.4 degrees Celsius.[12] With a 50 percent reduction, the IPCC estimates only a 15 percent chance of limiting the temperature rise to this range; with 85 percent CO_2 emissions reduction, the IPCC estimated that there would be an 85 percent chance of achieving the temperature limitation goal. Relatively simple calculations show that if global emissions are allocated according to even minimal norms of equity and the requirements of the United Nations Framework Convention on Climate Change, a near-total elimination of emissions from fossil fuels will be required in the United States (see Chapter 1).

B. Nuclear Power and Nuclear Weapons Proliferation

The connection of nuclear power to potential nuclear weapons proliferation has been recognized as a potential problem from early in the nuclear age. Yet, the urgency of the buildup of greenhouse gases is such that nuclear power is being promoted in quarters other than the nuclear industry as a part of the solution to greatly reducing greenhouse gas emissions.

IEER has addressed the inadvisability of such a course in the past, including recently in great detail, in a book by Dr. Brice Smith entitled *Insurmountable Risks: The Dangers of Using Nuclear Power to Combat Global Climate Change.*[13] Nonetheless, given the importance of the nuclear power debate and its security significance, the arguments are summarized in Appendix A of this book. In brief, the core arguments relate to:

- nuclear non-proliferation (and the connections between nuclear power and nuclear weapons technologies and infrastructure);
- the risks arising from severe accidents on the scale of the 1986 Chernobyl accident. Though the probabilities of an accident vary from one reactor to the next and are likely much lower in the United States than in the former Soviet Union (given historical data), accidents on the scale of Chernobyl could occur in all commercial reactor designs;
- the nuclear waste problem, which has not been solved so far in any country; The significant long-term health, environmental, and safety problems associated with spent fuel or high level waste disposal continue to bedevil nuclear power and make its future uncertain. It should be noted in this context that official assessments of the risk of harm from exposure to radiation continue to increase;[14]
- the high financial risks of nuclear power, including long-lead times and uncertainties relating to high level nuclear waste disposal, including the costs of repositories;

- the insurance problem. The damage from severe accidents has always been officially assessed as so severe that the nuclear industry continues to rely essentially completely on government-provided insurance, which itself is capped at a level far lower than official accident damage estimates.

It is strange that more than half a century after the then-Chairman of the Atomic Energy Commission, Lewis Strauss, proclaimed that nuclear power would be "too cheap to meter," the industry is still turning to the government for loan guarantees. But it should not be a surprise, since the original "too cheap to meter" campaign was part of a global propaganda campaign designed to make the U.S. atom look peaceful following the U.S. and Soviet tests of thermonuclear weapons.[15]

Further, the Bush administration is jointly promoting a scheme with Russia that would deprive parties in good standing under the Nuclear Non-Proliferation Treaty (NPT) their right to acquire commercial nuclear power technology. Article IV of the NPT actually states that it is an "inalienable right." But the administration's "Global Nuclear Energy Partnership" proposes to restrict commercial uranium enrichment and plutonium separation to the countries that already have it.[16] It is also a transparent attempt to change the Nuclear Non-Proliferation Treaty without going through the bother of working with the signatories to amend it.[17] This undermines the treaty and non-proliferation generally.

Uranium enrichment is at the center of U.S.-Iranian nuclear tensions. Iran claims it is pursuing commercial nuclear power; the United States believes it is acquiring nuclear weapons capability. In reality, the two are compatible statements – and that is the core of the problem. Building large numbers of nuclear plants across the world will multiply the need for commercial uranium enrichment plants. It is unlikely that countries will voluntarily give up their right under the NPT to acquire them.

Already, a number of developments in the world, including the above mentioned concerns about Iran, as well as the failure to achieve progress towards a nuclear weapons free zone in the Middle East, envisioned by the parties to the NPT at the time of its permanent extension in 1995, have intensified interest in acquiring nuclear power infrastructure in the region. For instance, at its 27th Summit, the Supreme Council of the Gulf Cooperation Council, consisting of the United Arab Emirates, Bahrain, Saudi Arabia, Oman, Qatar, and Kuwait, announced its intent to pursue civilian nuclear power technology, with an unmistakable link to nuclear weapons developments in the region. The remarks of the Saudi Foreign Minister on this topic are reported in the following news story:

> The leaders of Saudi Arabia, Bahrain, Kuwait, Oman, Qatar, and the United Arab Emirates called for a peaceful settlement of the conflict over Iran's nuclear program, and demanded that Israel, the only country in the Middle East believed to have nuclear weapons, join the nuclear Non-Proliferation Treaty.

Speaking to reporters after the summit, Foreign Minister Prince Saud Al-Faisal said the GCC states' intention to pursue civilian nuclear technology was not a "threat" to anyone. "We are announcing our intention to pursue the ownership of nuclear technology for peaceful (purposes)," he said.

"It is not a threat. It is an announcement so that there will be no misinterpretation of what we are doing. We are not doing this secretly. We are doing it openly," he said.

"We want no bombs. Our policy is to have a region free of weapons of mass destruction," the prince added. "This is why we call on Israel to renounce (nuclear weapons)." The "original sin" was from Israel as it established a nuclear reactor with the only purpose of producing nuclear weapons, Prince Saud said.[18]

This is a recipe for an intensification of problems both in the oil sector and in nuclear proliferation. The time for preaching temperance from a barstool is over. The twentieth century saw countries slowly struggle for freedom from domination. Unfortunately as part of that process, they also viewed the world powers refusing to give up their own nuclear weapons, even though the latter retained unquestioned superiority in conventional weaponry and power. The best way to approach the problem of non-proliferation is for the United States to undo what it began with Atoms for Peace and replace it with energy for peace. This book shows it is possible to have a secure and economical energy system without the headaches and risks of nuclear power. Why would one want to expand its role in an already insecure world?

For the record, we are not opposed to all nuclear technology or even all nuclear power technology. Nuclear fission has been a problem, but certain approaches to nuclear fusion, such as the proton-lithium reaction, could result in excellent power sources, if they could be made to work. Unfortunately, nuclear fusion, whose scientific feasibility as a power source remains to be established, is too far off to help with the problem of abating CO_2 emissions. Hence it is not considered in this report.

It should also be noted that infrastructure for regulatory, safety, and training needs must be maintained for existing nuclear power plants until they are phased out. Even after that, the problem of spent fuel management and disposal will be with us for many years. But the bottom line has been clear for some time. To attempt to solve the problem of climate change by resorting to reliance on nuclear power would be to exchange one serious problem for another when there is no need to do so. This roadmap, therefore, seeks to lay out a course for a zero-CO_2 economy without resort to nuclear power. At the same time, it is also clear that nuclear power supplies too large a portion of U.S. electricity to be switched off quickly. Hence, the approach taken here is a phase-out of nuclear power plants as their licenses expire. This is a normative assumption, and the actual course will depend on the specific phase-out policy that is adopted, and the phase-out duration may be shorter or longer than that modeled here.

C. Oil

The use of oil is responsible for about 44 percent of U.S. fossil-fuel-related CO_2 emissions. Currently, U.S. requirements are just over 20 million barrels per day, about 60 percent of it being imported.[19] Whatever the reasons for the origins of the Iraq War, it now appears to be tangled up with concerns about the security of oil supply from the Persian Gulf.[20] Former Secretary of State Henry Kissinger noted emphatically in an op ed piece in the *Washington Post* that

> American forces...are in Iraq not as a favor to its government or as a reward for its conduct. They are there as an expression of American national interest to prevent the Iranian combination of imperialism and fundamentalist ideology from dominating a region on which the energy supplies of the industrial democracies depend.[21]

The Iraq Study Group put it less bluntly, but part of its message was the same.[22] The direct costs to the United States of the Iraq war are running at $100 billion per year – roughly $100 per barrel of oil imported by the United States from the Persian Gulf.[23] The human cost in lives of Iraqis and of U.S. and allied soldiers and other personnel is incalculable.

Oil and democracy have never mixed in the Middle East. Its very map and political arrangements were created by the West, notably by the British and the French, in the wake of the collapse of the Ottoman Empire after World War I, with an eye on oil.[24] Side by side with the technological brilliance that has resulted in a vast river of oil flowing from the depths under turbulent oceans and forbidding desert sands, oil has gone hand in hand with war, violence, intrigue, coups, counter-coups, and revolutions.[25] Now, it is tangled up with the terrorism and the War on Terror that the United States undertook in the wake of the attacks on September 11, 2001.

A flourishing U.S. economy that has vastly lower CO_2 emissions than at present is necessary – based on considerations of global climate change alone. But it is also indicated by the need for disentanglement of U.S. economic well-being from oil. Such a course would produce a situation in which the political and developmental interests of the people of the Middle East could be disconnected from the Western need for – or, as President Bush said in his 2006 State of the Union speech, "addiction" to – oil.[26]

D. Lifestyles and Values

The analysis in this book does not address lifestyles and values as they relate to energy. That omission has nothing to do with my assessment of the importance of the topic. Rather, it has to do with a practical consideration. My goal was to assess the technical and economic feasibility of a U.S. economy with neither nuclear power nor CO_2 emissions. This can be done in a most straightforward way by using standard economic assumptions about future sizes of homes and offices, numbers of personal vehicles, and overall income and expenditure in society. It so happens that the use of energy is so inefficient that a several-fold growth is possible in gross domestic product without any growth in energy use and even while energy use declines. For instance, it is possible to design homes with available technology and architectural concepts that use just one-tenth the energy per square foot as is typical at present. Similar economies are possible in personal vehicles and in the commercial sector. Our approach enables the technological, economic, and policy recommendations developed here to be compared to others that are part of the present climate change debate. It is therefore not necessary to the objective of this study to address the issues of lifestyles and values, though, of course, that does not diminish the importance of the topic.

A large number of other questions, including environmental and health questions, associated with an ever increasing flow of materials through society, are also important. For instance, the mining of copper, gold, titanium, tantalum, and other minerals on ever increasing scales, the making of large amounts of chemicals, and other similar economic activities create environmental and health problems that are far beyond the energy use involved. Mining also often contributes to regional and global inequities, whereby certain regions become suppliers of specific raw materials while other regions and people become the main consumers.

Finding better approaches to meeting the material needs of a comfortable life to which essentially all people aspire is critical to environmental protection but beyond the scope of this book, except for the energy aspect of the issue. But it is clear that such approaches are needed, if only to enable economic development to meet the needs of much of the world where a majority of people are still poor, and where millions of children go hungry to bed, which is often the floor of a mud hut.

Beyond the matter of better technical means, there is the question of how much material throughput the world can sustain. That issue is also beyond the scope of this study. But it is clearly important in a world of eight to ten billion people, who are acquiring the means to live well. For the first time in the history of civilization (societies ruled from cities), a world in which all people can realistically aspire to achieve a comfortable life appears to be a real possibility.

The history of development shows that the norms for the "good life" are set by the wealthy. In that context, it appears necessary to develop the notion of "enough." Such a notion is not contrary to the pursuit of happiness, in the felicitous phrase of the Declaration of Independence. Rather, research shows that once poverty has been overcome, money seems to make little difference to happiness.[27]

The problem of how a change in values might occur to a long-term sustainable pattern that includes economic life broadly is a complex one. Specific changes in economic culture can occur rapidly, as for instance, has happened in many urban areas with recycling. Separating trash into recyclable and non-recyclable parts was not considered very practical in the United States just two decades ago. But it is now the norm. This indicates that similar changes could also occur in personal habits and tastes in relation to broader choices, including the way we use energy, the settings of our thermostats, the size of our homes and cars, etc.[28] It is obviously desirable; but when and how it might occur is difficult to predict and quantify, which is one of the reasons it is not part of the analytical framework of this book.

E. Conclusions

The power of setting a goal of a zero-CO_2 economy should not be underestimated. A U.S. economy that is in a ferment of innovation and investment in efficiency and new energy sources and technologies will spur the world energy economy in the same direction far more powerfully than can now be imagined. Even a single, short paragraph in President Bush's 2007 State of the Union message about climate change reverberated around the world.[29] His promise at the G8 summit at Heiligendamm, Germany, in June 2007, that the United States would seriously consider at least a 50 percent cut in greenhouse gas emissions by 2050[30] has even bigger implications. It is functionally equivalent to a zero-CO_2 emissions economy, defined as being within a few percent on either side of complete elimination (see Chapter 1). More than 100 percent reduction would mean removal of some of the CO_2 that has already been emitted from the atmosphere. This may become necessary should climate change turn out to be more severe than now estimated.

The goal of zero-CO_2 emissions does not mean that other greenhouse gas emissions should not be addressed. They should be; in many cases large reductions can be achieved rapidly in these other areas. It makes sense to reduce such emissions along with reducing CO_2 emissions.[31] But the size of the fossil fuel contribution to greenhouse gas emissions in the U.S. picture is so large that any overall goal of greenhouse gas emissions reductions translates directly into about the same percentage goal for reduction in CO_2 emissions from fossil fuels.

A new determination in Congress, a greatly expanded leadership at the state level, the immense success of *Inconvenient Truth*, the documentary on climate change featuring former Vice President Al Gore, who has recently called for a 90 percent reduction in greenhouse gas emissions by developed countries,[32] and a remarkable and possibly historic statement calling for a 60 to 80 percent reduction in greenhouse gas emissions issued by the U.S. Climate Action Partnership are among the many signs that a moment of decision on action at the federal level on climate change is at hand or at least near in the United States.

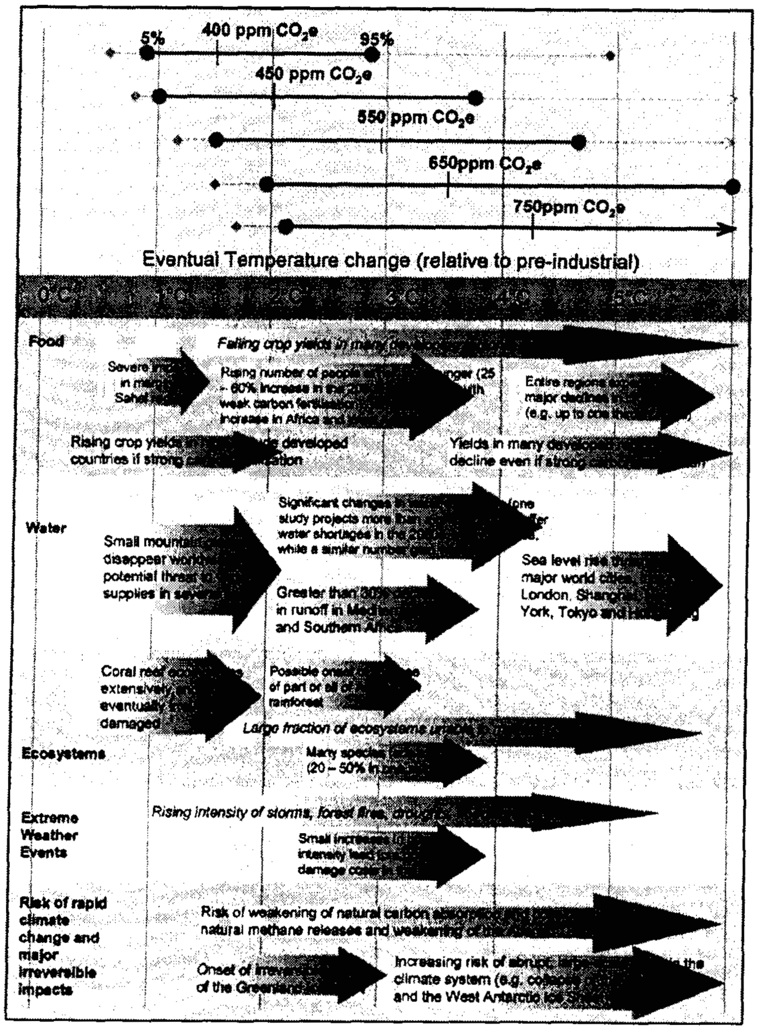
The present movement towards action on climate change seems analogous to the 1985-1987 period, when environmentalists, scientists, corporations, the federal government, and other governments arrived at an agreement on ozone layer protection that pointed at first to a large (50 percent) reduction in emissions of chlorofluorocarbons. The agreement expanded rapidly towards a complete elimination of CFC emissions. There were those who feared that a rapid phase-out of ozone depleting compounds would send humanity back to the caves without refrigerators or air conditioners, but once the key players decided it was time, the changes were as remarkable as they were rapid.

My hope – and I know it is Helen Caldicott's as well – is that this report will provide the occasion for a national debate on setting a goal of eliminating CO_2 emissions for the U.S. economy as rapidly as is economically sensible without recourse to nuclear power. It is also intended as a stepwise but flexible technical and economic guide for the actions that are needed in the next two decades to set the United States on such a course. Helen and I also thought that it would help that debate if the project were to have a diverse and experienced Advisory Board to help shape the outline and review the draft report.

Arjun Makhijani
Takoma Park, Maryland
July 2007

Figure P-1. Stabilization Levels and Probability Ranges for Temperature Increases

The figure below illustrates the types of impacts that could be experienced as the world comes into equilibrium with more greenhouse gasses. The top panel shows the range of temperatures projected at stabilisation levels between 400ppm and 750ppm CO_2e at equilibrium. The solid horizontal lines indicate the 5 – 95% range based on climate sensitivity estimates from the IPCC 2001[2] and a recent Hadley Centre ensemble study[3]. The vertical line indicates the mean of the 50th percentile point. The dashed lines show the 5 – 95% range based on eleven recent studies[4].
The bottom panel illustrates the range of impacts expected at different levels of warming. The relationship between global average temperature changes and regional climate changes is very uncertain, especially with regard to changes in precipitation... This figure shows potential changes based on current scientific literature.



[2] Wigley and Raper 2001. [3] Murphy et al. 2004. [4] Meinshausen 2006

Source: Stern Review 2006, Executive Summary, Figure 2 (page v). Crown copyright material is reproduced with the permission of the Controller of HMSO and the Queens Printer for Scotland.

CHAPTER 1: SETTING THE STAGE

A. The Need for a Zero-CO_2 Economy in the United States

At the June 2007, G8 summit on Heiligendamm, Germany, the heads of state, including President Bush, made a commitment on climate change that implies drastic changes in the U.S. energy economy:

> Taking into account the scientific knowledge as represented in the recent IPCC reports, global greenhouse gas emissions must stop rising, followed by substantial global emission reductions. In setting a global goal for emissions reductions in the process we have agreed today involving all major emitters, we will consider seriously the decisions made by the European Union, Canada and Japan which include at least a halving of global emissions by 2050. We commit to achieving these goals and invite the major emerging economies to join us in this endeavour.[1]

The commitment was rather more vague than sought by the European Union, especially Germany's Chancellor Angela Merkel (who is also a physicist). The EU has the goal of limiting temperature rise to 2 to 2.4 degrees celsius, which implies reducing CO_2 emissions globally by at least 50 to 85 percent by 2050 (see below). But the statement was a radical departure for the Bush administration, which in its first year went back on its campaign statement that it would reduce CO_2 emissions, among other pollutants, from power plants.[2] Until 2007, it even showed a reluctance to acknowledge the seriousness or the urgency of the problem of human-induced climate change.

Global greenhouse gas emissions are a mix of emissions from fossil fuel use (55 percent) and other sources, such as methane emissions from landfills, pipelines, and agriculture (16 percent), nitrous oxide emissions from fertilizer use (9 percent), CO_2 emissions from forest burning and other land use changes (19 percent), and emissions of certain organic compounds known as halocarbons (1 percent).[3]

The situation for the United States is somewhat different in that a far larger proportion – 84 percent – of greenhouse gas emissions are due to CO_2[4] – almost all of it from fossil fuel use. Hence, any overall commitment for a reduction of greenhouse gas emissions will translate almost directly into a requirement for about the same reduction of CO_2 emissions from fossil fuel use.

Halving CO_2 and other greenhouse gas emissions would mean considerably larger cuts for Western countries, most of all the United States, which has the largest emissions. This is because developing countries will likely insist, at least, on an equal per-capita global norm, given historical inequities, even if it is not part of a formal agreement. Their arguments are straightforward and compelling:

- The vast majority of the increase in CO_2 concentration from the pre-industrial level of about 280 parts per million to about 380 parts per million in 2005 was due to the burning of fossil fuels in the West.
- The consumption of commercial energy in developing countries per person is far lower today, in part due to their long domination by the West, which began to be reversed only in the course of the twentieth century. The economies of many developing countries, especially China and India, which together have almost two-fifths of the world's population, are growing rapidly. Any arrangements that institutionalize material inequalities between developing countries and the West are very unlikely to be politically acceptable.
- China, India, and other developing countries are becoming the industrial manufacturing centers of the world. The Chinese have recently pointed out that much of the greenhouse gas emissions in China are actually attributable to exports consumed in the West.[5]
- Without the larger developing countries, such as China, India, Brazil, Mexico, and South Africa, in the dialogue there is little hope of actually achieving the needed reductions of global greenhouse gas emissions by mid-century.

A per-capita norm is therefore the minimum that would likely be needed for a global agreement to significantly reduce greenhouse gas emissions by 2050.

According to the Intergovernmental Panel on Climate Change, the likely range of CO_2 emissions reductions required by 2050 relative to the year 2000 for this goal is 50 to 85 percent in CO_2 emissions.[6] At the lower end of this range, a reduction of about 88 percent would be required in U.S. CO_2 emissions. At the higher end of this range, the U.S. reduction would have to be about 96 percent.[7] For the United States this translates directly into approximately the same reductions of CO_2 from the energy sector.[8] These figures are based on a per-capita norm.

Former Vice President Al Gore has called for a 90 percent cut in "global warming pollution...in developed countries." [9] Since the per person emissions in Europe and Japan are considerably lower than in the United States, this would amount to a reduction of about 95 percent for the United States.[10] But he has specified a framework for reductions that would imply an even greater reduction

– an essentially zero-CO_2 economy in the United States, Western Europe, and Japan. That is because his argument for CO_2 reductions goes beyond a per-capita allocation norm:

> A new [climate] treaty will still have differentiated commitments, of course; countries will be asked to meet different requirements based upon their historical share or contribution to the problem and their relative ability to carry the burden of change. This precedent is well established in international law, and there is no other way to do it.
>
> There are some who will try to pervert this precedent and use xenophobia or nativist arguments to say that every country should be held to the same standard. But should countries with one fifth our gross domestic product – countries that contributed almost nothing in the past to the creation of this crisis – really carry the same load as the United States?[11]

The most directly applicable international law is the United Nations Framework Convention on Climate Change (UNFCCC), which was ratified by the United States in 1992. It notes both the historical disparities in creating the problem as well as the present inequalities. The parties to the treaty noted that

> ...the largest share of historical and current global emissions of greenhouse gases has originated in developed countries, that per-capita emissions in developing countries are still relatively low and that the share of global emissions originating in developing countries will grow to meet their social and development needs...[12]

As a result, the UNFCCC places a greater responsibility on the developed countries for a reduction of emissions:

> The Parties should protect the climate system for the benefit of present and future generations of humankind, on the basis of equity and in accordance with their common but differentiated responsibilities and respective capabilities. Accordingly, the developed country Parties should take the lead in combating climate change and the adverse effects thereof.[13]

An equal per-capita norm is a minimal equity requirement of the UNFCCC. In sum, the demands of averting the worst effects of climate change and considerations related to global politics and international law combine to mean that the United States will likely have to eliminate 95 percent or more of its energy-related CO_2 emissions by the middle of the century. This is the definition of a zero-CO_2 economy discussed in the preface of this book. In point of fact, the practical actions that need to be taken to reduce emissions by 90 percent or more are along the same lines as those needed for a 100 percent elimination of CO_2 emissions. The sooner we prepare for and act to achieve a zero-CO_2 economy, the smaller will be the cost of the transition. One reason is that the less time we have to achieve this goal, the higher the fraction of expensive and less commercialized technologies that will have to be deployed to get there.

B. Historical Overview

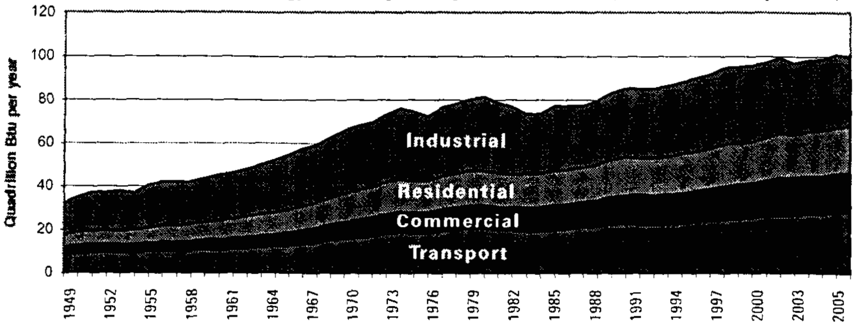
Before the first energy crisis in 1973, it was generally accepted that growth in energy use and economic growth, as expressed by Gross Domestic Product (GDP), went hand in hand. In that year, in the midst of a period of rising demand, a political-military crisis in the Middle East enabled the Organization of Petroleum Exporting Countries (OPEC) to suddenly raise prices. At the same time, in October 1973, the Arab members of OPEC imposed an oil embargo on the United States and its Western European allies and Japan. Multinational oil companies were able to manage the global supply so as to keep the United States and other affected countries provided with oil (though not without some disruption and confusion). But the price increases and embargo caused the United States and Europe to take a fresh look at energy and, not least, at the assumption that energy demand growth and GDP growth were destined to be in lockstep.

The Ford Foundation's Energy Policy Project, headed by S. David Freeman,[14] was in the midst of producing technical scenarios and economic assessments that showed that the United States had wide latitude in choosing its energy future. Depending on the energy policy adopted, energy growth could continue in lockstep with economic growth ("business-as-usual scenario"), with attendant environmental and security problems, including growing dependence on imported oil, or modest energy growth ("technical fix scenario"), or even zero energy growth ("zero energy growth scenario") – the latter after a modest period (about ten years) of adjustment. As it turned out, the economic and political shock of rising energy prices and the oil embargo led the United States government, private industry, and not a few states, California being the first, to adopt energy policies and practices that transitioned to the new mode of economic growth without energy growth by the mid-1970s.[15]

Figure 1-1 shows the historical energy growth in the United States since 1949 and the clear, sharp break that occurred in 1973. The decline in energy use in the immediate aftermath was partly due to a recession, but economic growth resumed in the mid-1970s without energy growth (on average) until the mid-1980s. The economic-energy relationship overall and the relationship of energy sources to fossil fuel sources is shown in Figure 1-2.

After a decline in the immediate post-World War II decade, the energy required to produce a dollar of GDP stayed approximately constant overall until 1973 (with compensating variations within the period). Since 1973, there has been a steady decline, steep at first, in the period up to the mid-1980s, and then at a lower rate until the early part of the 21st century, but still much different than the period prior to 1973. As a result, in the year 2000, the energy required to produce a unit of GDP was about 55 percent of that in the mid-1950s. We note here that the period from 1982 onwards was characterized by falling petroleum prices and by a laissez-faire attitude to energy policy at a national level.

Figure 1-1: Historical U.S. Energy Consumption, by End Use Sector (Quadrillion Btu perYear)

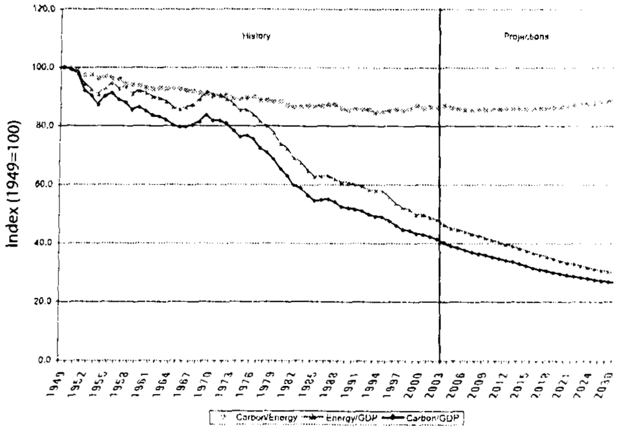


Source: EIA AER 2006 Table 2.1a

The decline in energy/GDP ratios, was reflected in the reduction of CO_2 emissions per dollar of GDP. In fact, the carbon/GDP ratio declined slightly faster than the energy/GDP ratio, notably in the 1950s and 1960s, reflecting the relative increase of the use of natural gas in the U.S. economy.

The decline in the carbon intensity of the U.S. economy was not reflected in a marked decline in the relative carbon dependence of the U.S. economy for a variety of reasons, including a continued reliance on coal for electricity generation and on oil for transportation. In other words, even as carbon emissions per unit of GDP declined, the dependence of the United States on fossil fuels as a proportion of its energy supply has not changed much since 1973. Hydroelectric power did not grow much, while nuclear power supplies only about eight percent of total energy use.[16] A central result has been the increasing dependence on imported oil, from about one-third of demand in the early 1970s to about 60 percent in recent years.[17]

Figure 1-2: Energy, GDP, and Fossil Fuel Relationships: History and Official Projections



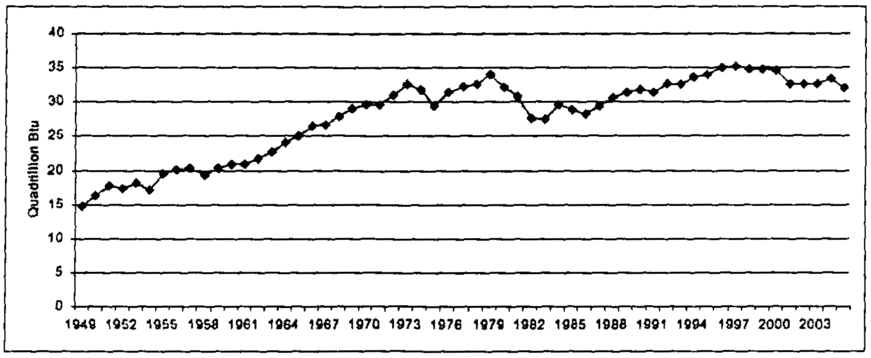
Courtesy of the Energy Information Administration of the United States Department of Energy

Even with a resumption of energy growth since the mid-1980s, the business-as-usual picture does not resemble the pre-1973 picture:

- Industrial energy use stayed about the same between 1973 and 2004, but the value of industrial production has more than doubled.[18]
- The ratio of energy demand growth to GDP growth has declined from about 0.9 in the mid-1950s-1973 period to about 0.5 by the year 2000 (See Figure 1-2). As in the 1973-1985 period, this increase in efficiency has been driven partly by price and partly by regulations.
- Residential, commercial, and transportation energy use has driven up energy use. Between 1995 and 2004 the growth rates in these sectors were 1.35 percent, 1.88 percent, and 1.60 percent respectively.[19]

In effect, "business-as-usual" in the industrial sector has meant economic growth without energy growth for over three decades. A part of this is may be due to the migration of energy intensive industries to countries with cheaper energy supplies. But a central factor has been an increase in efficiency of energy use in industry. Historical data for industrial energy use are shown in Figure 1-3.

Figure 1-3: Industrial Energy Use – Historical Data



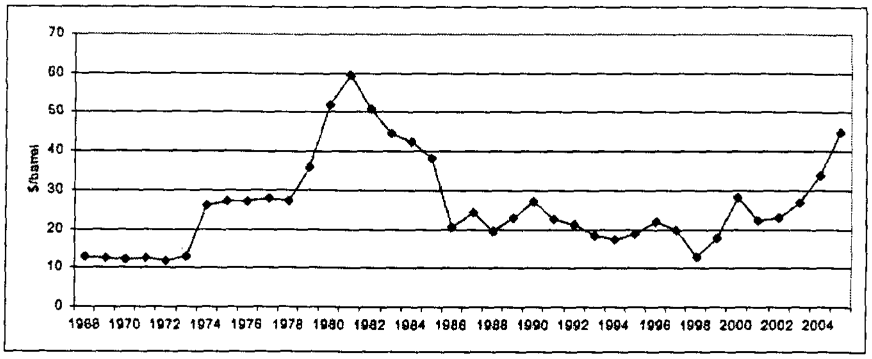
Source: EIA AER 2006 Table 2.1d

The overall trend to declining requirements of energy per unit of GDP is only partly due to prices. The decline in the use of energy per dollar of GDP has continued even through periods of declining energy, and especially petroleum, prices since 1973. The consistent trend, through both rising and falling prices, is largely due to

- Continued increases in industrial energy efficiency (in terms of energy input per dollar of output)
- Federal and state efficiency standards for appliances[20]
- Mileage standards for passenger vehicles that created very large energy efficiency increases in the first two decades after 1973.[21]

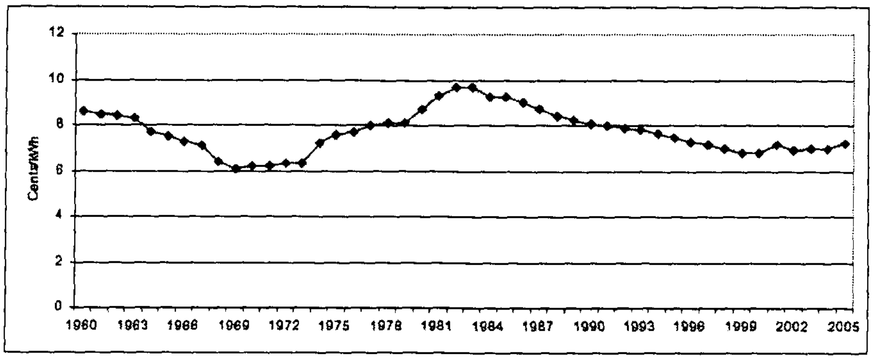
Figures 1-4, 1-5, and 1-6 show historical oil, electricity, and natural gas prices in constant 2000 dollars, respectively.

Figure 1-4: Historical Crude Oil Refiner Acquisition Costs, in Constant 2000 Dollars per Barrel



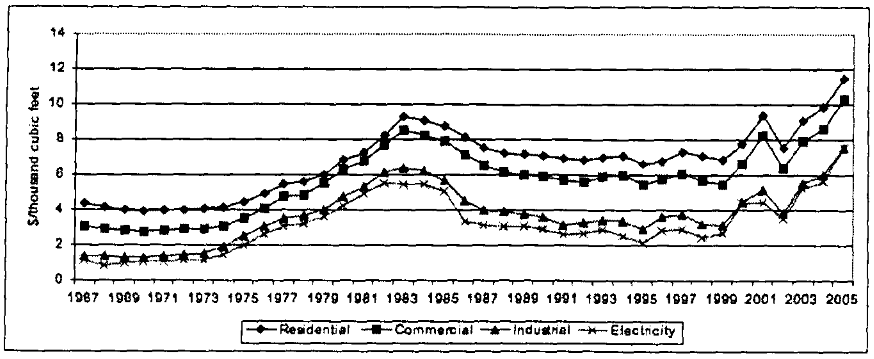
Source: EIA AER 2006 Table 5.21

Figure 1-5: Historical Average Retail Electricity Prices, in Constant 2000 cents per Kilowatt Hour, Including Taxes



Source: EIA AER 2006 Table 8.10

Figure 1-6: Historical Natural Gas Prices by Sector, in Constant 2000 Dollars per Thousand Cubic Feet



Source: EIA AER 2006 Table 6.8

The overall effects of the changes on the economy as a whole, as well as the energy sector, have been dramatic. Rosenfeld and McAuliffe have summarized the net effects by hypothesizing what might have been under "business-as-usual," i.e., a continuation of pre-1973 trends compared to the actual result, since 1973:

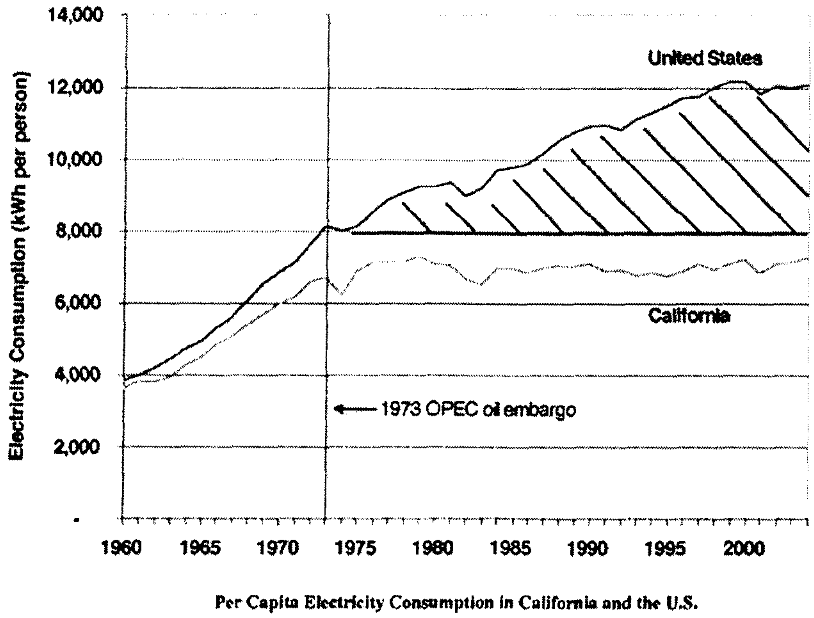
1. Under "Business as Usual," US primary energy demand could have been 170 Quads by 2005 rather than the Actual 100 Quads

2. Energy expenditures in 2005 could have been $1.7 trillion rather than $1.0 Trillion. The savings are on the order of $700 billion. To put this into perspective, U.S. energy purchases totaled about $ 1 trillion in 2005 out of the GDP of 11.7 trillion (nominal dollars or $10.8 trillion in chained 2000 dollars).

3. We only had to meet 25 Quads of increased demand for primary energy, not 95 Quads (the difference between 170 Quads and 75 quads in 1973). The remaining 70 Quads were avoided. To be able to deliver an additional 25 Quads, hundreds of power plants were built, refineries upgraded and expanded, new tankers constructed, pipelines and transmission facilities added and coal, natural gas and petroleum combusted. Alternately, to avoid 70 Quads we drastically changed our energy policies, invested in more efficient buildings and appliances, altered our transportation fleet to be much more fuel efficient, developed new and ingenious products and processes, and responded to increasing prices in many other ways.[22]

However, the State of California has done much better than the national norm. Figure 1-7 shows the evolution of per person electricity use in California since 1960. In 1976, the national figure was only about 15 percent greater than that of California. By the turn of the century, it was 70 percent greater. California's milder climate cannot explain most of the trend since the relative climate situation is approximately the same today as it was three decades ago. It is the more active approach to energy policy that California has taken that is mainly responsible for the difference.

Figure 1-7: California Electricity Use Trends Compared to the United States

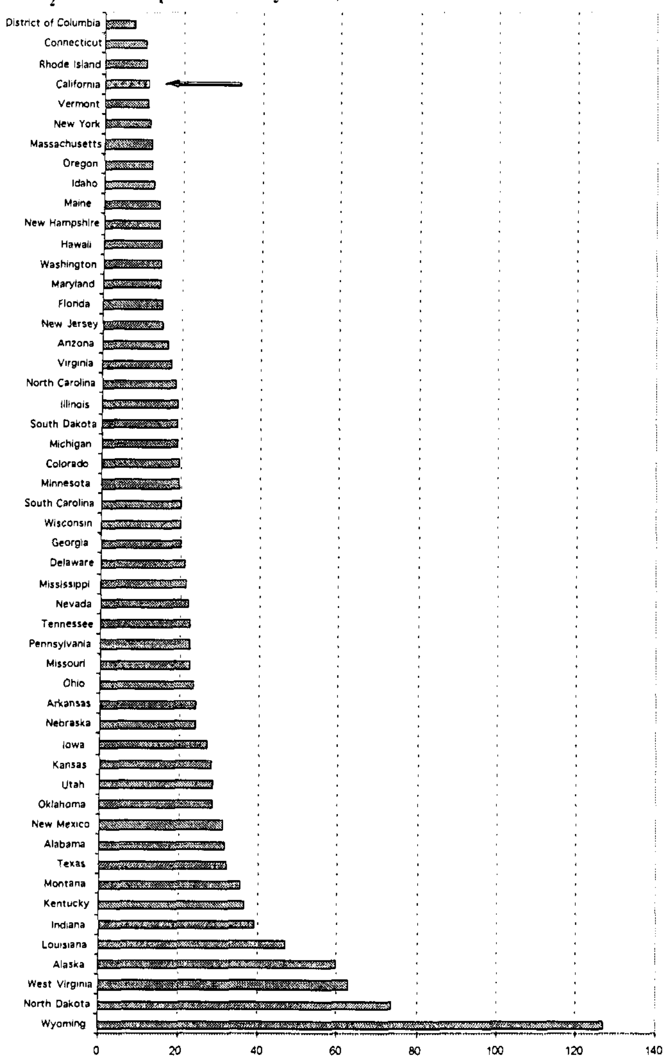


Source: Chang, Rosenfeld, and McAuliffe 2007 Figure 7 (page 13)

The hatched area in Figure 1-7 provides an approximate idea of the excess U.S. electricity consumption per person since 1973 relative to California. It represents about ten billion metric tons of CO_2 extra emissions in the United States relative to California policies.

The relative unimportance of climate is also indicated by the fact that the states with the lowest energy use per unit Gross State Product (GSP) are not necessarily the ones with the mildest climate. Figure 1-8 shows CO_2 emissions per person by state. CO_2 emissions are a good proxy for energy use, since about 86 percent of energy use involves burning of fossil fuels.[23] Leaving aside the District of Columbia because it is a city, the other states with low per-capita emissions have widely varying climates.

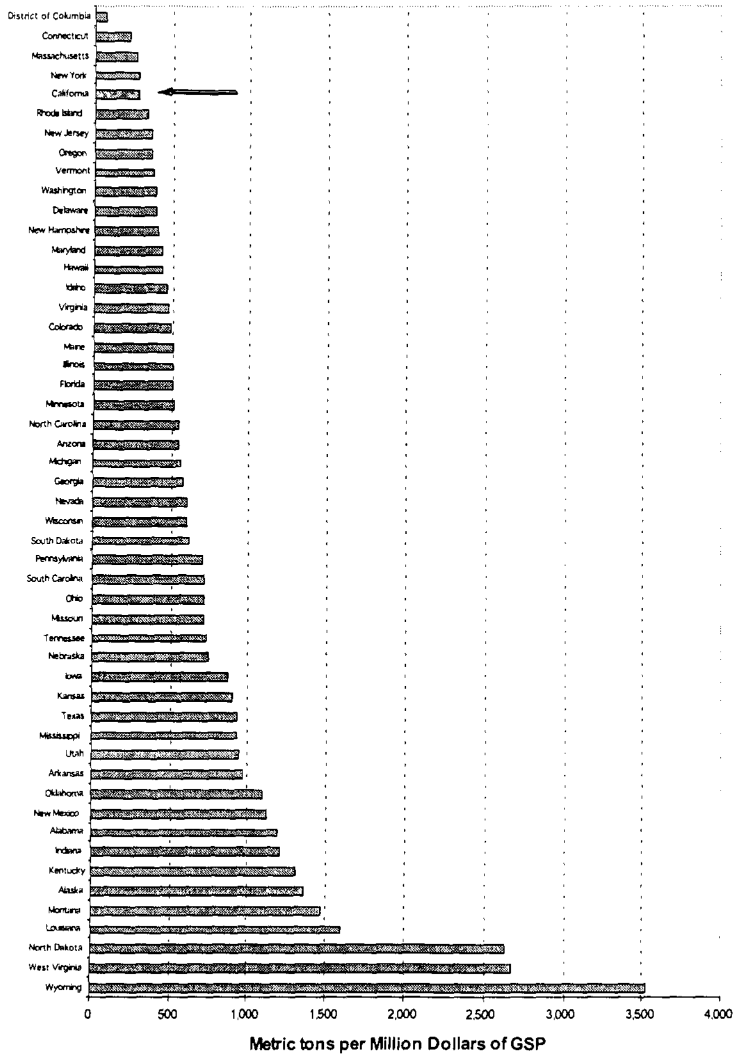
Figure 1-8: CO_2 Emissions per Person by State, 1999



Source: Bemis and Allen 2005 Figure 8 (page 18)

Finally, Figure 1-9 shows the metric tons of CO_2 emissions per thousand dollars of gross state product. It is evident that per-capita emissions are more linked to the structure of the economy than to the weather. For instance, mining and agricultural states, like Wyoming, West Virginia, or Kansas, tend to have higher per-capita emissions than service and manufacturing states like the New England or mid-Atlantic states or California, even though the heating and cooling requirements among the latter group of states is quite variable. Some states like Wyoming also have mine-mouth coal-fired plants for exporting electricity out of state.

Figure 1-9: CO_2 Emissions per Gross State Product by State: 1999 (in Metric Tons of CO_2 per Thousand Dollars)



Source: Bemis and Allen 2005 Figure 9 (page 19)

The factors that go into the energy structure of an economy are obviously quite complex in their technical detail. But it is clear that from a macro-economic point of view, market factors and regulatory policies can have and have had a fundamental impact on the structure and amount of energy consumption per person or per unit of economic output. The reason is not far to seek. Existing efficiencies of energy use are quite low by the criterion of how much of the available energy is actually applied to the task at hand. After all, except for sunshine and food, energy is not a need in itself (though sometimes it is still discussed that way). It is the services that energy provides that are important.[24] For instance, when we flip a light switch that turns on an incandescent light bulb, only about 1 percent of the fuel input into electricity generation shows up as visible light. High-efficiency compact fluorescent lamps reduce energy consumption by about a factor four while providing approximately the same visible light output. As another example, photoelectric switches that turn off outdoor lights in the daytime or motion detectors that turn off lights when rooms are not occupied do not change the utility provided by energy use to people, but reduce energy use and greenhouse gas emissions.

Many of these changes, including adopting the use of motion detectors, photoelectric switches, efficient electric motors for industrial applications, and compact fluorescent lamps can be accomplished more economically than the present high energy use, high emissions approach. A rather dramatic example of a change brought about by energy efficiency standards for appliances is provided by refrigerators. In 1973, the electricity use per cubic foot of an average refrigerator freezer was about 100 kilowatt hour, electrical. California enacted standards in 1978 that were then tightened. The federal standards went into effect in 1990 and tightened subsequently. The typical refrigerator in 2001 consumed about only about a fifth as much per cubic foot,[25] despite having more features. *Moreover, real prices of refrigerators have come down significantly in the same period, despite larger size. Between 1987, when federal standards were enacted, and 2002, the unit value of a refrigerator fell from about $575 to just over $400.*[26]

As a final example, consider the efficiency of personal passenger vehicles. Only about 15 percent of the energy contained in petroleum actually winds up as mechanical energy that moves the car or SUV from one place to another.[27] Moreover, the "payload" in the car, the weight of the passengers, is about seven percent of the weight of the vehicle, using the average vehicle weight of 3,240 pounds[28] and occupancy of 1.64 person-miles per vehicle mile.[29] Hence, the actual energy used to provide the utility for which the car is designed to move people from one place to another is typically about one percent.

The use of lighter, stronger materials that provide safety similar to heavier vehicles, regenerative braking, automatic engine cutoff when the car is stopped, more efficient engines, and efficient electric cars are all approaches that can greatly improve the efficiency of passenger transport. Excellent public transport, which makes for more livable cities, might increase GDP and improve the environment in a variety of ways, while at the same time decreasing energy use by reducing the need for personal vehicles for commuting, shopping, etc. Many of these approaches have been tried on various scales. The goal here is to explore a more efficient energy economy that is set in the technical context of zero-CO_2 emissions in the supply sector. The social goal is that this transition should be accomplished with justice for the affected workers and communities.

Plan of the Book

A combination of efficiency increases and changes in the sources of energy supply will be needed to achieve a zero-CO_2 economy. We first provide an overview of the macroeconomic assumptions for the energy economy in Chapter 2. This chapter also includes the economic assumptions regarding energy prices and the implicit price on carbon dioxide emissions under various circumstances. Energy supply and storage technologies and their possible evolution in the next decade or two are explored in Chapter 3.

Chapter 4 sets forth the demand-side scenario for each broad consuming sector, along with the technology assumptions, that provides the basis for the analysis of options for a zero-CO_2 energy supply. When all is said and done a large supply of energy will be required for a U.S. economy that is three times larger than today, even with great improvements in energy efficiency. Chapter 5 describes a reference scenario for a zero-CO_2 emissions economy. Chapter 6 describes variations on the reference scenario. The objectives of describing a reference scenario and possible variations are to

- Demonstrate that a zero-CO_2 economy, without recourse to nuclear power, is possible within a few decades.
- Explore the land-use implications of a large-scale reliance on biofuels.
- Explore alternative approaches to meeting the requirements of critical and difficult sectors such as aircraft fuel.
- Explore possible alternative paths that would make the transition faster, more economical, and/or more desirable from other economic, environmental, and security standpoints than the reference scenario.

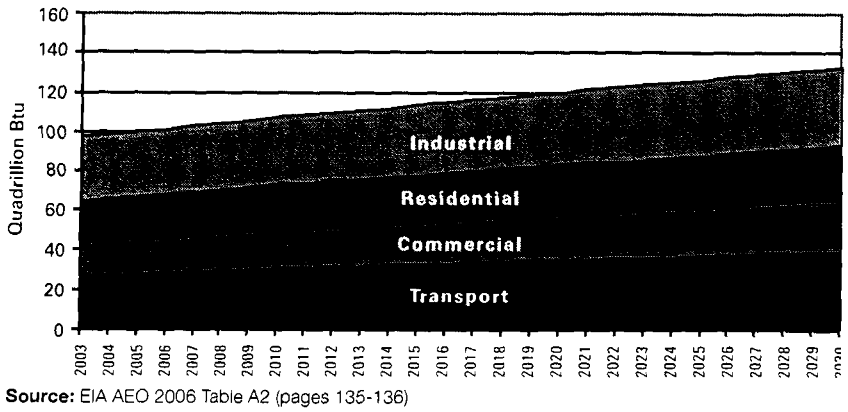
Chapter 7 discusses the policy framework at the federal and state levels as well as actions that can be taken at the private level – whether corporate or individual drawing on existing examples. Finally, Chapter 8 sets forth a roadmap for a zero-CO_2 economy without nuclear power, with goals and policies that need to be taken and alternatives that need to be pursued. Note that electricity generation costs are based on 2002-2004 data. Costs of most sources except solar and some new technologies have been rising, which will make efficiency and solar energy more attractive than some of the estimates in this book. The plan here is to develop an approach that will have flexibility built into it. The aim of the roadmap is not so much to look into an energy crystal ball and foretell the exact route all the way to a zero-CO_2 emissions economy but to set forth a technical and policy approach that can deal with uncertainties and setbacks. The principal technical approach is to develop backup technologies and multiple approaches to the same result. In that case, if some of the advanced technologies that now appear promising falter, there will be others to take their place. Chapter 9 summarizes the main findings and recommendations.

CHAPTER 2: BROAD ENERGY AND ECONOMIC CONSIDERATIONS

Since the mid-1990s, the efficiency of energy use per unit of GDP has been increasing at about two percent per year on average.[1] On this basis, a three percent annual GDP growth would result in energy growth of about one percent per year. This scenario, which we might call business-as-usual in the present context – that is, assuming no dramatic changes in energy prices or policies, would result in an increase in energy use from about 100 quadrillion Btu in 2004[2] to about 160 quadrillion Btu in 2050 (all figures are rounded). Energy use actually declined slightly in 2006 to below the level in 2004.

Official energy projections corresponding to expected trends under prevailing conditions, that is, corresponding to business-as-usual trends, prepared by the Energy Information Administration (EIA), go only to 2030. The demand projection is shown in Figure 2-1 and the supply projection is shown in Figure 2-2.

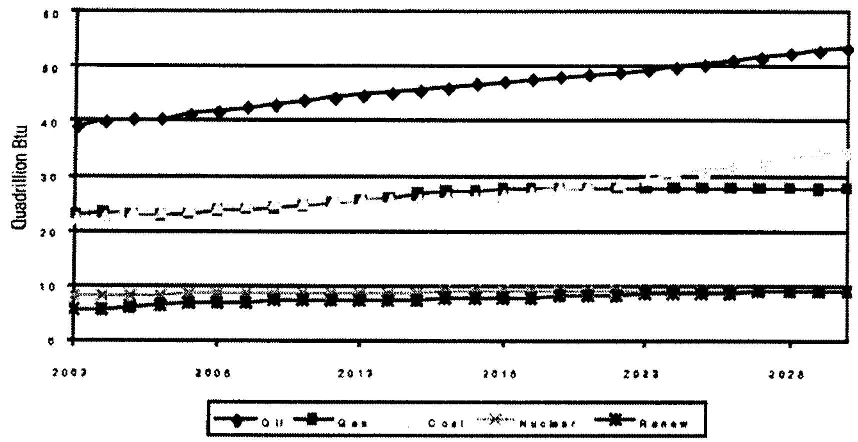
Figure 2-1: EIA Projection of Energy Demand, by End Use Sector to 2030



Source: EIA AEO 2006 Table A2 (pages 135-136)

Oil and coal, the main sources of CO_2 emissions in the United States, are projected to grow the fastest. Nuclear energy, often presented as being the solution or at least a major part of the solution to global warming, is officially projected to decline in share from eight percent today to less than seven percent in 2030.

Figure 2-2: EIA Projections for Energy Supply, by Fuel, in Quadrillion Btu



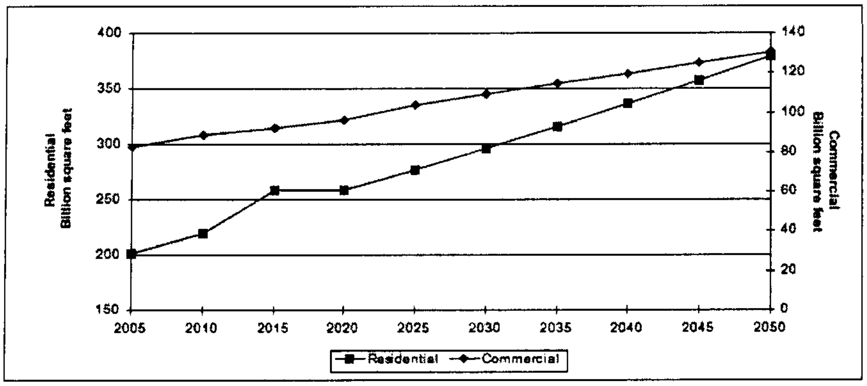
Source: EIA AEO 2006 Table A2 (pages 135-136)

Note: EIA AEO 2006 does not give the breakdown for renewable energies, but says that the contribution is mostly from hydroelectricity and biomass (wood and ethanol), not wind and solar energy.

In this book, we use present energy use along with the economic assumptions in the EIA projections to create the reference energy and economic scenario that is needed to explore approaches to a zero-CO_2 economy.

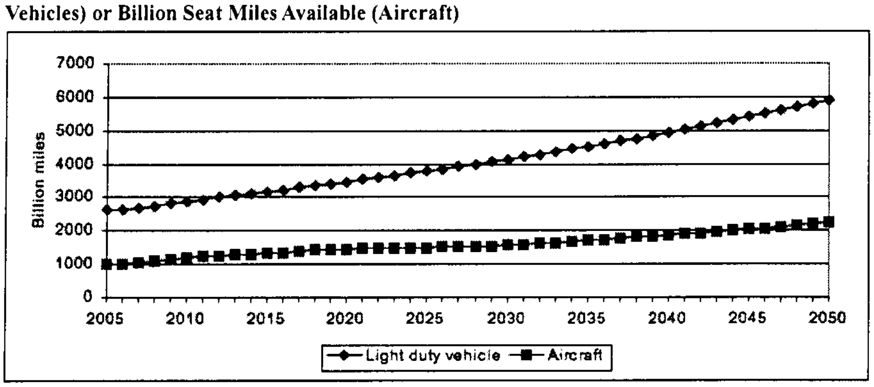
Figure 2-3 shows the floor space projections for the residential and commercial sectors and Figure 2-4 shows the projections for the transportation sector in terms of the demand for services, based on present trends of square feet per house or office, number of homes, growth in passenger miles traveled by road and air, etc. These projections are extended to 2050, based on the reference conditions underlying the EIA projections to 2030 in Figures 2-1 and 2-2 above.

Figure 2-3: Residential and Commercial Sectors, Projections of Floor Space, in Billion Square Feet



Sources: Commercial: EERE 2006 Table 2.2.1 (page 2-5) and Residential: EIA AEO Assumptions 2006, page 23 and EERE 2006 Table 2.1.1 (page 2-1) EIA AEO gives an average square footage for 2001 and 2030. We have interpolated the values for the years in between and multiplied them with the number of households listed in EERE 2006. The values after 2025 for commercial area and after 2030 for residential area were extrapolated.

Figure 2-4: EIA Transportation Projections, in Billion Vehicle Miles Traveled (for Light-Duty Vehicles) or Billion Seat Miles Available (Aircraft)



Source: EIA AEO 2006 Table A7 (pages 145-146) up to 2030, projected thereafter by IEER.
Note: Light duty vehicles are defined as weighing less than 8,500 pounds.

While it is possible to construct zero-CO_2 scenarios at various levels of overall demand (including energy conversion losses in electricity production), even for those above the level of about 100 quadrillion Btu in 2004, the pressure on resources, notably land, could be serious (see Chapters 5 and 6). Moreover, the economics of attempting to do so would also be dubious at best and, more realistically, poor. Even at present prices, there are plenty of foregone opportunities for energy efficiency investments due to a variety of factors. For instance, developers of residential and commercial real estate generally do not pay the utility bills. Automobile manufacturers do not pay the fuel bills. These disconnects create economic inefficiencies as well as pollution. They mean that policies that ensure more cost-effective and environmentally sound results, while allowing markets to function in terms of allocating investments, are essential.

Cost effectiveness will be set in the context of policies that are aimed at reducing and then eliminating CO_2 emissions. For instance, a system in which large users of energy must buy allowances for emitting CO_2 will increase the effective price of fossil fuels, making both renewable energy sources and efficiency measures relatively more attractive. Carbon taxes could, in theory, accomplish the same purpose (see Chapter 7). For instance, energy use in industry has stayed constant over more than three decades without carbon taxes and with fluctuating energy prices. With higher fossil fuel costs in the form of a price on CO_2 emissions, it is reasonable to expect that industrial energy use would decline somewhat – possibly at a rate of one or two percent per year.[3]

As will be discussed in more detail, the opportunities in the transportation, commercial, and residential sectors for economic implementation of energy efficiency are substantial. For instance, well-insulated homes designed to capture solar heat passively – that is, in their structures – can eliminate most of the space heating requirements under most circumstances prevailing in the United States. And near-term technology will allow far greater efficiencies in all sectors. For instance, all-electric cars are now being made with a new generation of lithium-ion batteries in which the carbon has been eliminated for safety reasons and which can be charged in ten to fifteen minutes at a gas station-like service stop. First generation all-electric cars and pickup trucks made with lithium-ion batteries can go 3.3 to 5 miles on a single kilowatt hour of electricity. Plug-in hybrids can get 70 to 100 miles per gallon with an input of just over 0.1 kWh of electricity.

The analysis of energy efficiency potential in this report indicates that instead of requiring one percent energy growth for three percent economic growth (the approximate business-as-usual case), the same economic growth can be accomplished with an absolute reduction of about one percent in delivered energy use per year. (Delivered energy excludes electricity losses in electricity generation and other losses incurred in the production of the energy supply; it includes only the energy as consumed at the point of end use.) Such an approach would make a transition to a low or zero-CO_2 economy much more manageable both for creating the supply from renewable sources and for transitioning to a better balance between supply and efficiency than has been characteristic of the U.S. economy in the past. With a special emphasis on the transportation sector efficiency, it would also alleviate the security concerns now associated with the large-scale of oil imports on which the U.S. economy is now so dependent.

A one percent decrease in delivered energy use per year means approximately two percent per year overall improvement in efficiency compared to recent trends (discussed in Chapter 1 above). This would mean that instead of delivered energy growing from about 75 quadrillion Btu per year in 2005 to about 120 quadrillion Btu in 2050, it would decline to between 40 and 50 quadrillion Btu. This is shown in this study to be eminently feasible, largely with existing technology.

Significantly greater efficiencies are possible in many areas but they have not been assumed in the reference scenario (See Chapter 6).

A. Analysis of Energy Prices and Implicit CO_2 Prices

Any substantial reduction of CO_2 emissions implies some price that would be attached to CO_2 emissions. For instance, the cost of coal-fired generation from a new pulverized coal-fired power plant is about 4 cents per kWh.[4] But these plants, of course, emit the most CO_2 of any type of large-scale power plant– about 950 grams per kWh.[5] Policies to reduce and eventually eliminate CO_2 emissions would therefore effectively attach a cost to the fossil fuel user for emitting the CO_2 that was at, or just above, the cost of reducing the marginal emission at any particular stage. That is, if the user faces the prospect of paying a price for a CO_2 emission allowance just greater than the cost of eliminating the emissions of CO_2, investments would gravitate to the necessary areas to reduce the emissions. The cost can be added in various ways, by imposing taxes, regulations, or caps on emissions implemented through auctions of CO_2 emission allowances (a "hard cap" on emissions that would decline in quantity each year). These approaches are discussed in Chapter 7.

In this report, however, we seek to achieve multiple objectives: eliminating CO_2 emissions and nuclear power in the same process and also ensuring the reliability of liquid fuel supplies, which today are mainly in the form of petroleum.

The marginal cost of reducing CO_2 emissions varies a great deal according to the application. Sometimes, the implicit CO_2 price may even be negative. In other words, the cost of doing things with lower CO_2 emissions may be lower than the methods used at present. Combined heat and power generation in a part of the commercial sector (large buildings, for instance) provides an example in many circumstances.[6]

The exercise here, in the context of a goal of zero-CO_2 emissions, is to assess the implicit CO_2 price of eliminating essentially all the CO_2 from a given sector on the understanding that the price of CO_2 emissions allowances would rise to this level in the last stages of CO_2 emissions elimination (assuming orderly and efficient markets in CO_2 emission allowances).

1. Implicit CO_2 Price in the Electricity Sector

Let us first consider direct elimination of CO_2 from a coal-fired power plant in its simplest conceptual form. To do this, we try to estimate a market price that would result in a steady reduction of CO_2 from the electricity sector, recognizing that different technologies would come into play at different stages.

The most straightforward approach to estimating a long-term price for reduction of CO_2 emissions from coal-fired power plants is to consider the cost of preventing CO_2 emissions from such a plant. A commonly proposed way for doing this is to use a coal gasification system combined with a power plant. The system is called the Integrated Coal Gasification Combined Cycle (IGCC) power plant. The CO_2 generated by the combustion process is captured, rather than being emitted to the atmosphere. It is then piped to a location where it can be injected into a deep geologic system, where it would be expected to remain for thousands of years. The entire system is called carbon capture and sequestration (CCS). This system has been much studied and is being developed because of the extensive use of coal in the electricity generation systems of the United States, China, Russia, India, and other countries.

The main difficulty lies in estimating a cost of sequestering carbon dioxide successfully for thousands of years in deep geologic formations. Injection of carbon dioxide into oil and gas reservoirs for stimulating production has been done commercially; sequestration of CO_2 in geologic formations on a limited basis has also been demonstrated.

However, there is also some uncertainty as to the long-term success of sequestration. With many reservoirs required for large-scale application of the technology, it is possible that one of them could fail and suddenly emit a large amount of carbon dioxide. Since CO_2 is denser than air, it would hug the ground, possibly asphyxiating a nearby population. This has occurred in the case of a natural venting of CO_2 from a lake in western Africa in 1986.[7] The question of liability associated with such venting from CO_2 sequestration is an important one both from the point of view of safety of nearby populations and for financial risk. The process of safely siting CO_2 repositories and the cost and availability of insurance are still open questions, especially given the long time frames involved.[8] There is also some uncertainty associated with what it might cost to make sure that sequestration has low leakage rates over thousands of years.[9] In other words, though CO_2 injection into geologic reservoirs has been demonstrated, there are still outstanding issues in applying it to the vast amounts of CO_2 that are generated by coal-fired power plants and in ensuring that the CO_2 remains sequestered for very long periods of time.

Present estimates of cost are made on the basis of rather limited experience relative to requirements of sequestering billions of metric tons of CO_2 each year if large-scale use of coal continues. Nonetheless, the available data provide a useful benchmark in attempting to estimate how much it would cost to prevent CO_2 emissions compared to operating pulverized coal-fired power plants. The estimated costs have a wide range, which provides one indication of the uncertainties. Overall, the added costs of an IGCC plant and the capture, transport, and sequestration of CO_2 have been variously estimated as being between 1 cent and 4.2 cents per kWh compared to a pulverized coal plant with no CO_2 emission controls.

For the purposes of this report, we will assume a cost range of 1 to 4 cents per kWh for carbon capture and sequestration, in order to develop an implicit CO_2 price. The term "CO_2 price" is a theoretical price that would have to be charged to a power plant owner in order to induce the installation of equipment to prevent the CO_2 emissions. Of course, this does not ensure that the equipment will be installed; rather it provides a way of comparing the costs of different approaches of avoiding CO_2 emissions. Different policy approaches to actually accomplish that have their own advantages and disadvantages. These are discussed in Chapter 7.

If the price of an emissions allowance for a metric ton of CO_2 emitted is $10, a power generating company would, in theory, be willing to spend almost that much to capture and sequester CO_2. At about 35 percent generation efficiency, the added cost would amount to about 1 cent per kWh. Since the cost range for IGCC with carbon capture and sequestration is estimated to be in the range of 1 to 4 cents per kWh, the CO_2 price that would induce an investment in CCS would be $10 to $40 per metric ton.

We can also develop a price to be imputed to CO_2 (that electricity generators using coal would pay) by comparing the cost of replacing electricity from coal with electricity from nuclear power. The base case estimate range provided in the MIT study published in 2003 was 6.7 to 7 cents per kWh, or nearly 3 cents more than coal.[10] The assumptions underlying this study are somewhat optimistic, given the experience of building nuclear power plants in the United States in the 1980s and 1990s. For instance, it assumes a construction time of six years and an overnight capital cost (assuming zero construction time) of $2,000 per kilowatt. The CEO of Duke Energy, which owns nuclear power plants and advocates building more, stated in 2007 that the cost was likely to be more in the $2,500 to $2,600 range.[11] Further, there are large uncertainties in relation to the cost of spent fuel management. With the one investigated disposal location facing delays and questions about its licensability (Yucca Mountain in Nevada), it is unclear what the costs of deep geologic disposal might be. The Bush administration is pursuing a reprocessing initiative for commercial spent fuel. If this is actually pursued as the main disposal path, it could add at least 2 cents per kWh or more to nuclear electricity generation costs. Two cents per kWh is the estimated added cost of the world's largest program (as implemented by France) to reprocess spent fuel and to use the separated plutonium as a fuel in reactors.[12]

A realistic range of nuclear power costs, not taking into account insurance subsidies and uncertainties relating to proliferation, severe accidents, or prolonged construction delays, is that it would be 2 to 5 cents per kWh higher than the cost of coal-fired power plants without CO_2 capture and sequestration. It corresponds to a CO_2 price of $20 to $50 per metric ton of CO_2 emissions.[13]

There are options for reducing CO_2 emissions that can be achieved at lower costs. For instance, if time-of-use pricing is permitted – that is, if the price recovered during peak and intermediate hours is relatively high – off-peak wind energy can be priced at 2 to 3 cents per kWh. Under these circumstances, the early reductions in CO_2 emissions from coal-fired power plants could be achieved by purchasing off-peak wind power and reducing output from coal-fired power plants, which have off-peak costs of about 2 cents per kWh. The implicit cost range for avoiding CO_2 emissions in this case is zero to $10 per metric ton of CO_2. However wind energy has added transmission and infrastructure costs. Adding these costs yields an estimate of $5 to $15 per metric ton of CO_2 for using off-peak wind to displace coal.

For the initial tranches of CO_2 reductions, it is possible that an emerging technology may provide an opportunity for negative CO_2 costs – that is, if the costs are roughly as projected by the developer, it would be possible to reduce CO_2 emissions commercially, even in the absence of climate change considerations. Technology to capture CO_2 from power plant effluent gases in microalgae grown in plastic tubes exposed to sunlight was recently demonstrated on a significant scale at a 20 megawatt (MW) natural gas-fired cogeneration plant at MIT. According to the leader of the technical team that developed the technology, Isaac Berzin, the algae can be profitably converted to biofuels (biodiesel and ethanol) so long as the price of petroleum stays above about $30 a barrel. The approach is in the engineering demonstration phase. A 0.3 acre plant has been built in cooperation with Arizona Public Service.[14] The performance of the plant at MIT in terms of CO_2 capture efficiency has been independently confirmed. The technology has not yet been commercialized and the developer's cost estimates remain to be demonstrated both for microalgae and liquid fuel production.

This cost structure must be reevaluated for a higher penetration of renewables, when the intermittency of wind and solar energy becomes more of a concern. Some portion of the intermittency problem in wind can be addressed by geographical diversity. Another very important portion can be addressed by coordinating and optimizing the capacity of central station solar power plants built in sunny areas, such as the Southwest and parts of the West, with large-scale wind farm installations. Since the weather is more predictable from the standpoint of day-ahead planning for central station solar power plants, standby capacity requirements can be minimized. Further optimization can be achieved by taking advantage of the fact that, in many areas, the wind blows preferentially in the evening and night hours, thus complementing solar energy during the daytime.

Finally, solar thermal plants can also be built with a few hours of storage to supply the peak demand in the early evening hours (see Chapter 3). Still, one can safely assume that a considerable reserve capacity in some form will be required at high penetration levels of wind and solar.

The most readily available, large-scale reserve of electrical power generation capacity is combined cycle natural gas plants.[15] A vast expansion of such plants began in the 1990s making them economically attractive. The capacity was built to operate economically at natural gas prices of $2 to $3 per million Btu, which were the prevalent prices in the electricity sector through almost the entire 1990s (see Figure 1-6). Construction of such plants continued into the first years of the present decade, when natural gas prices fluctuated a great deal. They have stayed above $4 for the electric generation sector since about 2003 and were about $8 per million Btu in 2005.[16] The net summer capacity for natural gas-fired power plants in 2005 was 383,000 megawatts.[17] The high price of natural gas has meant that at the present time the capacity utilization of these plants is very low – in 2005, the average capacity factor was only about 22.6 percent.[18]

At $8 per million Btu, the fuel cost alone for a typical combined cycle power plant is about 5.6 cents per kWh.[19] After adding a variable maintenance cost of about 0.5 cents per kWh, the off-peak avoided cost is about 6 cents per kWh (rounded). This is greater than the cost of new wind energy capacity of about 5 cents per kWh.[20] At natural gas prices of about $6.50 per million Btu, natural gas power combined cycle power plants can be idled and kept on standby at zero added cost to provide electricity when wind farms cannot meet demand. There is an implicit net zero-CO_2 price at $6.50 per million Btu of natural gas since at that price the marginal operating cost of the natural gas plant is about equal to that of new wind capacity. At natural gas prices greater than $6.50 per million Btu there would be a net reduction in overall generation cost if combined cycle capacity is idled in favor of wind. This means that at current prices of about $8 per million Btu, CO_2 emission reductions can be achieved by using wind to displace combined cycle and single stage turbine capacity with a net economic benefit to consumers in the form of lower electricity prices.

It is possible, of course, that natural gas prices will again decline below $6.50 per million Btu. This would create a positive implied CO_2 price. At $4 per million Btu, which is approximately the cost of marginal supply (imported liquid natural gas, or LNG), the off-peak marginal cost of a combined cycle plant is 3.3 cents per kWh. With wind at about 5 cents per kWh, there is then a 1.7 cent per kWh differential. This corresponds to a CO_2 price of about $46 per metric ton. At $5 per million Btu, the implicit CO_2 price is about $26 per metric ton. Combining the best wind sites with combined cycle natural gas standby will likely be economical at $5 per million Btu of natural gas or more at an implied CO_2 price that is zero or negative (that is, a net reduction in cost would be achieved). There are also other options for standby capacity for renewables in the long-term.

Compressed air storage could be used, for instance (see Chapter 3). Another example is the potential for using plug-in hybrids or all-electric cars using new designs of lithium-ion batteries in a vehicle-to-grid (V2G) mode, where electricity flows from the cars back to the grid at certain times of the day. Such cars are expected to be economical at a battery cost of about $200 per kWh of storage. One battery design has been tested in the laboratory over more than 10,000 charging and discharging cycles (see Chapter 3). The collective installed power of automobiles is vastly greater than that of the electric power system. It should be possible to provide backup power using vehicle-to-grid at a modest cost, using only vehicle fleets (such as corporate or government fleets under contract for such services) and parking structures in the commercial sector.

If battery life proves to extend in practice to over 10,000 charging cycles, then the marginal cost of the V2G would be very low. It would essentially equal the electricity losses in the battery, which are low. This is because over a ten or twelve year vehicle life, the expected number of charging cycles for motor vehicle operation itself would be far lower than 10,000. The main costs would be for the V2G infrastructure itself. One study of fuel cell vehicles estimated them to be about 0.5 cents per kWh for an operation involving 5,000 vehicles providing 10 kW each.[21] The energy-related costs would be those associated with the electricity losses in charging and discharging the battery, however, these are small.[22] Some rental charge would be paid to the vehicle owner and the owner of the docking station. If the battery depreciation is low, this cost could also be low. Assuming an overall added cost of 0.5 cents per kWh in this evaluation gives a total cost estimate about 1 cent per kWh. In other words it would cost $10 to reduce CO_2 emissions by one metric ton. Of course, this calculation is contingent upon the technology becoming economical in the coming years. However, in the context of the options for eliminating CO_2 from the electricity sector, it would not be needed for perhaps two decades, since other options to reduce CO_2 with present or near-present technology are available. We have used a cost estimate of less than $26 per metric ton for V2G to replace natural gas standby for wind.

In the near future, plug-in hybrids are a logical place to start building the infrastructure for efficient transportation and vehicle-to-grid experimentation. These are gasoline-electric cars that have extra batteries that store enough charge to enable much or most commuting on electricity only. Depending on the battery capacity, the liquid fuel efficiency is 70 to 100 miles per gallon. There is no real obstacle to commercialization of this technology. Efficiency standards set for the year 2020 should reflect this. And plug-in hybrids should become standard issue for federal government cars by 2015 (see Chapter 3 for more details and Chapter 7 for a policy discussion).

In sum, the short-term CO_2 emissions can be reduced from fossil fuel power plants at low cost – in the zero to $15 per metric ton of CO_2 range.[23] In the long-term a zero-CO_2 economy appears to imply a price of CO_2 of $10 to $40 per metric ton for a goal of eliminating it from the electricity sector. Given the financial, proliferation, and other risks associated with nuclear power (see Appendix A), it is difficult to justify reliance on nuclear power to reduce CO_2 emissions. Equal or lower cost solutions are either available or on the near-term (ten-year) horizon. The available data certainly do not justify providing subsidies to nuclear power plants to further climate change goals. On the contrary, the same money could be used to greater effect in other sectors.

Table 2-1: Summary of Costs for CO_2 Abatement (and Implicit Price of CO_2 Emission Allowances) - Electricity Sector

CO_2 source	Abatement Method	Phasing	Cost per metric ton CO_2, \$	Comments
Pulverized coal	Off-peak wind energy	Short-term	\$5 to \$15	Based on off-peak marginal cost of coal
Pulverized coal	Capture in microalgae	Short-and-medium-term	Zero to negative	Assuming price of petroleum is >\$30 per barrel
Pulverized coal	Wind power with natural gas standby	Medium-to-long-term	Negative to \$46	High costs corresponds to a low natural gas price (\$4 per million Btu)
Pulverized coal	Nuclear power	Medium-and-long-term	\$20 to \$30	Unlikely to be economical compared to wind with natural gas standby
Pulverized coal	IGCC with sequestration	Long-term	\$10 to \$40 or more	Many uncertainties in the estimate at present. Technology development remains.
Natural gas standby component of wind	Electric vehicle-to-grid	Long-term	Less than \$26	Technology development remains. Estimate uncertain.

Notes:

1. Heat rate for pulverized coal = 10,000 Btu/kWh; for natural gas combined cycle = 7,000 Btu/kWh.
2. Wind-generated electricity costs = 5 cents/kWhe; pulverized coal = 4 cents per kWh; nuclear = 6 to 9 cents per kWh.
3. Natural gas prices between \$4 and \$8 per million Btu.
4. Petroleum costs \$30 per barrel or more.
5. CO_2 costs associated with wind energy related items can be reduced by optimized deployment of solar and wind together (see Chapter 5)

2. CO_2 and Petroleum

Assessing the implicit price of CO_2 at which petroleum-related emissions would be eliminated is much more complex than the analysis for the electricity sector presented above for a variety of reasons:

- Unlike coal, almost all of which is used on a large-scale in electricity generation or industry, most petroleum is used in transportation in a manner that makes capture of the CO_2 practically impossible. Hence, no direct estimate of costs of CO_2 capture and sequestration is possible.

- The cost of producing oil in much of the world, notably the Persian Gulf region, is unconnected with its price. In the prolific oil fields of the region the cost is less than \$3 per barrel,[24] while the price has fluctuated in the past decade between just over \$12 and well over \$70 per barrel.[25] The marginal cost of production from Canadian tar sands is about \$30 to \$35 per barrel, well below spot market oil prices since 2005.[26] Fluctuations in future prices based on non-economic security and political factors are still possible and may be considered likely.
- The indirect security costs of imported petroleum to the United States are high. If one is to take one's cue from Henry Kissinger, as quoted in the preface, then the need to continue a U.S. military involvement in Iraq is centered on protecting the flow of oil from the Persian Gulf region. In that case, the security cost of oil imported from the Persian Gulf by the United States amounts to about \$100 per barrel. It is still about \$22 per barrel if the cost of the war is spread out over all U.S. oil imports.[27]
- The net greenhouse gas reductions of ethanol made from corn, the largest alternative fuel in the United States, are small. Moreover, estimates vary considerably, making a net estimate of cost per unit reduction of equivalent CO_2 emissions very difficult. Whatever the exact figure, the cost would be very large because the net emission reduction is low, indicating that more efficient approaches need to be pursued.[28]

Security costs in the sense discussed here are distinct from any costs associated with reduction of CO_2 emissions. In theory, a security cost, distinct from a CO_2 reduction cost, should in some way be reflected in the price of petroleum and products derived from it. But how should such a security cost be calculated and how much should be attributed to petroleum? Answers to such questions are certain to be very controversial and difficult. It is unclear, for instance, whether the \$100 billion per year being spent on the direct costs of the Iraq war should be attributed entirely to petroleum imports. That does not take other foreign policy goals into account. On the other hand, \$100 billion per year represents only a very partial accounting of the total costs of the Iraq war. It does not include expenditures on the care of injured veterans, for instance.

We can approach the question of costs of reducing petroleum use and CO_2 emissions at the same time in a somewhat different way, at least for passenger vehicles. We will use a reference price range of \$50 to \$70 per barrel for petroleum here. This is above the marginal cost of \$30 to \$35 per barrel (from Canadian tar sands), which is the cost of extracting and producing the most expensive oil that is on the market today in significant quantities. The spot market price for crude oil over the past two years has been considerably over \$50 per barrel and is about \$70 per barrel at the time of this writing (early July 2007).[29] At \$50 per barrel, the retail price of gasoline would be somewhat under \$2 per gallon, including refining, retailing, and transportation costs, but not including taxes. With taxes, it would be about $2.25 to $2.50.[30] Using $2.25, the annual fuel cost of operating a typical 25 miles per gallon vehicle for 15,000 miles is $1,350. At $70 per barrel the price is closer to $3 per gallon, which gives an annual fuel cost of $1,800. If we add $0.50 per gallon for security costs, $0.50 for air pollution costs, and $0.50 for costs of avoiding CO_2 emissions, a reasonable overall working figure for social cost of fuel is about $4.50 per gallon. This gives an annual operating cost of $2,700.

We can now consider a reference vehicle used in this report for personal passenger transport and estimate what added costs can be paid for the vehicle at this price to eliminate gasoline use. Google is monitoring its plug-in hybrids for gasoline and electricity consumption. The average in early July 2007 was 73.5 miles per gallon and also uses 0.113 kWh per mile of electricity.[31] If it is mainly charged off-peak, the annual operating costs would be $564 to $717 (for $2.25 and $3 per gallon of gasoline). Using a discount rate of 7 percent over five years, typical of a car loan, an added cost of $3,310 to $4,560 for a plug-in hybrid can be accommodated without a change in overall operating costs relative to the average car. If the environmental and security costs are added, then an added cost of over $7,000 can be justified for a plug-in hybrid.

It is possible that the imputed price of CO_2 in the transportation sector could be very low. In the discussion on electricity above, we briefly discussed the capture of CO_2 from fossil fuel power plants in microalgae for the purpose of producing liquid fuels (biodiesel and ethanol) from it. Ethanol can be used as a feedstock for producing biobutanol, which is a direct gasoline substitute.[32] If the estimates made by Isaac Berzin, the Chief Technology Officer of GreenFuel are close to the mark, then liquid fuels could be economically produced if crude oil prices are above about $30 per barrel. Since this is about equal to or less than the marginal cost of oil production (from tar sands) of $30 to $35 per barrel, the imputed cost of CO_2 in this case would be zero or negative. At the present time, the overall system has not been demonstrated on a large-scale, so there is some uncertainty about cost estimates.

B. Defining "Zero-CO_2 Emissions"

As noted in the preface, the term "zero-CO_2 emissions" is not to be taken literally in the sense of eliminating the last ton of CO_2 emissions. A margin of a few percent either way would need to be preserved, especially when the zero-CO_2 target is connected with a particular date or narrow range of dates. We elaborate on this concept here.

It is possible that in some sectors the cost of eliminating fossil fuels may turn out to be high. For instance, aircraft can only be fueled with renewable energy sources in two ways, liquid fuels made from biomass or hydrogen made from renewable energy sources. Land constraints on the former may become important, especially if there are large demands for liquid and gaseous fuels in other sectors, such as cars and industrial feedstocks. A hydrogen-based air transportation sector is in the infancy of its development (though the technology has been shown to be feasible). Moreover, burning hydrogen creates water vapor, which acts as a greenhouse gas, especially if emitted at altitudes much above 30,000 feet (see Chapter 4). Hence, a considerable trade-off between economy, energy efficiency, and exchanging one greenhouse gas for another may face this sector. It is difficult to foresee how that might affect the price of biofuels or the price of the last five or ten million metric tons of CO_2 allowances for the commercial air transport sector. The approach in this report is to set forth options that can result in eliminating CO_2 emissions, but also preserve flexibility in the energy sector sufficient to prevent disruptions in the U.S. economy. The research for this study did not uncover any insuperable problems to actually eliminating all CO_2 emissions associated with the energy sector.

There is also the prospect that achieving zero-CO_2 emissions will not be enough, due to the accumulated impact of past emissions. At an atmospheric concentration of 380 parts per million of CO_2 today, there are already indications of serious climate change. Even if we reach zero-CO_2 emissions globally by mid-century, greenhouse gas concentrations are set to go beyond 450 parts per million CO_2 equivalent. In this context, it may well be necessary to go beyond zero-CO_2 emissions. This means we must make provision for technologies that could remove CO_2 from the atmosphere at reasonable costs.[33] What the extent of the need to go beyond zero-CO_2 emissions to negative CO_2 emissions (i.e., net removal of CO_2 from the atmosphere) will be for the United States is not now possible to foresee. This is especially so given that the first stage of the job – turning the economy around from a direction of increasing CO_2 emissions to one of decreasing CO_2 emissions – has barely begun. Hence, it is prudent to set a course that would aim for a zero-CO_2 economy, but also one that would allow for net removal of CO_2 from the atmosphere should it be deemed necessary.

In sum, the scenarios in this study are oriented to examining the feasibility of an actual zero-CO_2 economy, and to creating a roadmap for how it might be accomplished. So in the context of the technical analysis of the numbers in this report, zero-CO_2 is taken literally. However, in the context of the policies that are outlined, the term is regarded with more flexibility –"zero" is to within a few percent of present-day CO_2 emissions.

CHAPTER 3: TECHNOLOGIES—SUPPLY, STORAGE, AND CONVERSION

A large and fundamental transformation of the energy supply system will have to occur in the coming decades in order to transition to an economy with zero-CO_2 emissions without nuclear power. The division of investment resources between supply, storage, conversion (to electricity and/or hydrogen), and efficiency in utilization of energy will vary with policy and prices, but a basic reshaping of energy supply must take place. In this chapter, we will survey the energy sources that can provide the basis for such a transformation along with the conversion and storage technologies that are likely to be needed. Specifically, the configuration and roles of conversion and storage technologies in the electricity grid will be very different in a context where there are no fossil fuels or nuclear power. The grid itself will be much more a distributed grid, with generating plants of all scales contributing significant amounts, rather than one that depends almost wholly on central station power plants, which is the case at present. Further, with solar and wind energy playing very large roles, the role of storage and standby capacity will be more important than it is today.

This survey of technologies does not aim to be comprehensive. There is a tremendous ferment of innovation (literally and figuratively) in energy and it would take volumes to do technical justice to properly evaluate and compare the potential of the various ideas that are being developed. Even so, such a survey is likely to be quickly overtaken by events. The aim here is to present a sufficient technical evaluation of major energy supply sources and delineate the potential of each as it is best understood today so as to be able to create credible supply scenarios by combining them (Chapters 5 and 6). Some connection to the realities of the present demand structure are also needed, since not all energy sources can, at present, supply all demand sectors:

- Solid fuels – coal mainly – are used primarily in electricity generation and to a much lesser extent in industry (steel, cement, paper),

- Liquid fuels are used mainly in transportation and in industry, with feedstock use being a major application in the latter,
- Natural gas is used in the residential and commercial sectors mainly for space and water heating, for electricity generation, and for many applications in the industrial sector,
- Electricity is used widely in all sectors except transportation.

Table 3-1 shows the structure of energy supply in the United States, along with the main applications for each fuel in 2004. Table 3-2 shows a breakdown for natural gas use in 2004.

The connections of fuels to major end uses are not fixed, of course, but there is a considerable inertia in the system in that the utilization equipment, such as heating systems in homes and office buildings or boilers and process heat in industry, is structured to use certain fuels. Hence, the new supply sources also need to be evaluated for the kinds of demand they may satisfy and how the evolution of the demand sector may affect supply-side developments. Such considerations are left to Chapter 5, where a reference zero-CO_2 scenario is developed and to Chapter 6, where options for optimizing the system and providing flexibility and backup are discussed. These provide the basis for the policy considerations (Chapter 7) and the roadmap (Chapter 8).

Table 3-1: U.S. Energy Supply, 2004, in Billion Btu

Fuel	Billion Btu	Percent	Comments
Coal	22,603,933	22.5	Mainly for electricity generation
Gas	23,035,841	22.9	See Table 3-2
Oil	40,593,665	40.3	Mainly transportation and industry
Nuclear	8,221,985	8.2	Electricity generation
Hydro	2,690,078	2.7	Electricity generation
Renewable	3,529,674	3.5	Wood, geothermal, wind (electricity generation)
Total	100,675,176	100.0	

Source for the individual fuels: EIA AER 2006 Table 1.3

Table 3-2: Natural Gas Consumption in the United States, 2004

Sector	Percent
Industrial	37
Electricity	24
Residential	22
Commercial	14

Source: EIA AER 2006 Table 6.5

The major sources of renewable energy supply considered here are:

- Wind energy
- Solar energy, not including biofuels, but including solar photovoltaics and solar thermal power plants
- Solar energy in the form of biomass, including biofuels derived from it
- Direct hydrogen production from solar energy
- Hot rock geothermal energy
- Wave energy

We assume that hydroelectric resources will remain about the same as they are today.

The first four resources have the theoretical potential to supply the entire U.S. energy requirement. However, each faces certain constraints, such as intermittency with wind and solar, and land-area considerations with biofuels. In the case of use of solar energy for direct hydrogen production, a considerable amount of technological development remains to be done. It is included here because of its overall potential to transform the biofuels portion of a renewable energy structure in ways that would have a number of benefits compared to most biomass-based biofuels.

A. Wind Energy

Wind-generated electricity has been growing very rapidly in the last decade. Additions to capacity around the world far outstrip nuclear energy. In the United States, no new nuclear plants have been completed in many years and, despite much talk and expenditure, none have been ordered since 1978. The last order to be completed and commissioned was placed in October 1973. In contrast, wind capacity grew by about 2,700 MW in 2006 alone in the United States,[1] enough to supply the output of about one large nuclear power reactor. Similar additions to capacity are expected in the coming years. Figure 3-1 shows the Colorado Green Wind Farm, near Lamar, Colorado. (See color insert.)

Table 3-3 shows the wind energy potential in the top 20 states. It does not include offshore potential.

Table 3-3: Wind Energy Potential in the Top 20 Contiguous States, in Billion Kilowatt Hours/Year

State	Wind potential
North Dakota	1,210
Texas	1,190
Kansas	1,070
South Dakota	1,030
Montana	1,020
Nebraska	868
Wyoming	747
Oklahoma	725
Minnesota	657
Iowa	551
Colorado	481
New Mexico	435
Idaho	73
Michigan	65
New York	62
Illinois	61
California	59
Wisconsin	58
Maine	56
Missouri	52
Total	**10,470**
U.S. elec. generation, 2005	**4,000 (rounded)**
Potential percent of 2005 generation	**261 percent**
Wind energy generation, 2006	about 30 (0.7 percent)

Sources: AWEA 2006b; EIA AER 2006 Table 8.2a, AWEA 2007, and EIA AEO 2006 Table 16.
Note: For wind class category 3 and higher. Land use exclusions such as national parks, urban areas, etc., have been factored in to the estimate.

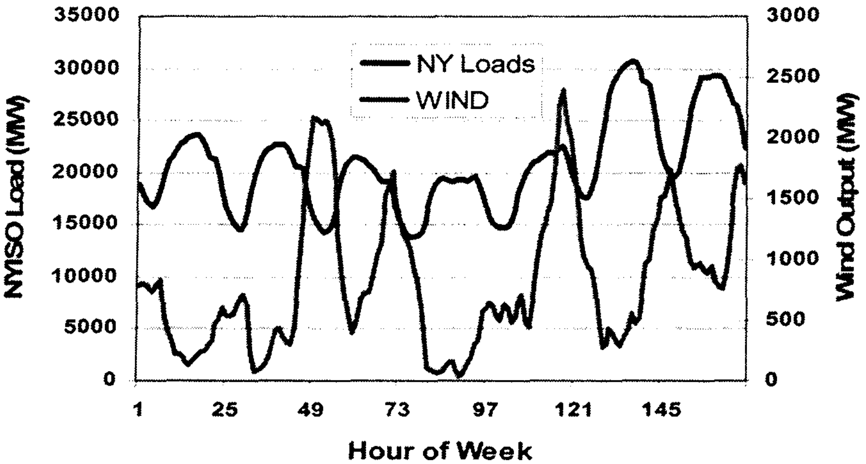
It is clear that overall potential is vast – over two-and-a-half times total U.S. electricity generation in the United States in 2005. The wind energy potential in *each one* of the top six states – North Dakota, Texas, Kansas, South Dakota, Montana, Nebraska – is greater than the total nuclear electricity generation from all 103 operating U.S. nuclear power plants. The wind energy resource is quite sufficient to supply the entire electricity requirement of the country for some time to come under any scenario, if total potential were the only consideration. Of course, it is not. Intermittency is a critical issue. Secondly, the geographic location of the wind resource is another potential constraint. It is concentrated in the Midwest and the Rocky Mountain states while the population of the United States is concentrated along the coasts. Figures 3-2(a) and 3-2(b) illustrate this issue; the former shows population density and the latter shows the map of wind energy.[2] (see color insert) Tapping into a large amount of the high-density land-based wind resource will require transmission infrastructure to take the electricity to transmission system hubs from where it would be taken to population centers. Transmission corridors exist going eastwards and westwards from the center of the country. But the wind resource is dispersed and it must be delivered to the hubs. Second, the capacity of some of the lines to carry the electricity would have to be expanded. The maps illustrate the importance of developing offshore wind energy resources, which are closer to the large population and electricity consumption centers of the United States.

One advantage of the geographic concentration of wind resources in the continental United States is that much of it is located in the Midwestern Farm Belt. Since crops can be planted and cattle can graze right up to the wind turbine towers, wind farms are quite compatible with growing crops and ranching. They can provide a reliable and steady source of income to farmers and ranchers, insulating them, to some extent, from the vagaries of commodity markets.

The largest single problem with wind energy is intermittency. This intermittency affects the system at many levels: short-term wind fluctuations, hourly or daily variations, and week-to-week and seasonal variations.

Figure 3-3 shows wind energy availability over a week compared to the fluctuations in electricity demand. Note that in this example, wind is frequently low at times of peak demand. Capacity of various types could be planned if wind could be accurately forecast. Day-ahead forecasts that are reasonably good and hour-ahead forecasts that are more accurate (on average) can be made, though there are times when the wind will be above or below those forecasts, occasionally by large amounts. The variability of wind energy therefore necessitates the addition of reserve capacity other than wind that can be tapped when the wind falls below the forecasted level over a period of hours or days. Electricity system planning takes place over various time intervals, with power plant availability being planned at all times from daily to seasonal.

Figure 3-3: Illustration of Wind Energy Variability



Provided by the U.S. Department of Energy. **Source:** Parsons et al. 2006 Figure 5 (page 7)
Note: The wind capacity is shown on the right hand scale and does not contribute more than 10% of demand at the highest wind generation.

Besides the need for extra reserves, there are other costs of wind integration with electricity grids. Winds fluctuate over very short periods of time (seconds to minutes) creating disturbances in the system that could affect the stability of the frequency of the electricity supply. A constant frequency (in the United States, 60 cycles per second, called 60 hertz) is essential for much consuming equipment, such as clocks and computers and automated controls in industry dependent on electronic timing systems. The frequency of the electricity supply is therefore maintained within narrow limits at all times. The added cost of maintaining constant frequency as the proportion of wind energy in the system increases is called the regulation cost.

In between these two times scales (seconds to about a day) is the issue of load following. As we turn lights on and off and industries are brought on line or taken off, as millions of televisions are turned on in the evening when people return home from work, the electricity system must be able to follow the load and increase or decrease the output according to the demand. This is more complex if there is no actual control of the fuel supply that can change the output, which is the case with wind energy. It is analogous to a third party controlling the accelerator of a car.

These issues are managed by having some form of added reserve capacity and the reserves have to increase as the proportion of wind-supplied electricity increases. This is obviously an added cost that must be attributed to wind energy. It is the grid equivalent of having a battery storage for solar or wind energy in off-grid systems. Since loads can fluctuate rapidly over periods of minutes, every electricity system must have spinning reserve capacity – that is capacity that is available whenever the demand goes up – somewhat like electricity "on tap." The additions to reserve capacity needed for maintaining the reliability of supply are a critical aspect of wind energy integration into electrical grids and represent part of the costs of this energy source. These costs are low when the proportion of wind-generated electricity is small, and tend to rise as that proportion increases.

Wind energy is now becoming a mature and very large industry. By the end of 2006, the total world wind energy capacity was over 74,000 MW – a capital investment worth about $100 billion. The worldwide additions to capacity in 2006 were about 15,000 MW – that is, the capacity grew about 25 percent in one year and is set to grow that much again in 2007. The United States' total capacity by December 2006 was 11,600 MW or 15.6 percent of the world total.[3]

A great deal of effort, study, and practical experience has gone into addressing problems such as wind integration to rather high levels of generation – up to about 20 percent – mainly in Europe (Denmark, Germany, Spain). Though the penetration of wind in the U.S. electricity market is still very low (about 0.7 percent of electricity generation), there have been many rigorous studies of wind integration costs. Overall, these have been assessed to be modest – in the range of 0.25 to 0.5 cents per kilowatt hour ($2.50 to $5 per megawatt-hour (MWh). For instance, the National Renewable Energy Laboratory published brief descriptions of several studies. One study in Minnesota found $4.60 per MWh was a conservative estimate of wind power integration cost at a level of 15 percent capacity:

> The costs of integrating 1,500 MW of wind generation into the Xcel North control area in 2010 are no higher than $4.60/MWh of wind generation and are dominated by costs incurred by Xcel Energy in the day-ahead time frame to accommodate the variability of wind generation and associated wind-generation forecast errors. The total costs include about $0.23/MWh resulting from an 8-MW increase in regulation requirements and $4.37/MWh resulting from scheduling and unit commitment costs. The study characterized these results as conservative, since improved strategies for short-term planning and scheduling and the full impact of new regional markets were not considered.[4]

Another study described the 300 MW pumped-storage (that is, the use of excess wind capacity to pump water from a low reservoir to a high reservoir) in Xcel's Colorado service territory. The water can then be run through an existing hydroelectric plant when the wind is not blowing. This smooths out some of the fluctuations in wind energy availability and reduces the costs of integration of wind into the grid. The cost reduction is dependent on the contribution of wind-generated electricity to the total. At a 10 percent level, the cost reduction estimated was $1.30/MWh.[5]

Development of wind resources in a manner that takes advantage of the large areas over which the resource is available would provide a great advantage in that it reduces the time when generation from wind energy is zero or very low. Studies have found that the costs of wind energy integration into the grid can be kept modest or small up to fairly high levels of penetration if geographic diversity is taken systematically into account as one design factor in the utilization of the resource.

A study commissioned by the Minnesota state legislature, published in November 2006, has examined this issue in considerable detail.[6] It found, for instance, that the ability to forecast available wind resources was considerably improved when the geographic diversity of the wind generation was increased. Hence, the dispersion of wind generation not only reduces the times for which no or low wind energy is available, it also improves the reliability of forecasting upon which reserve capacity requirements are based. Of course, this has a direct bearing on reducing the costs of integrating wind generation into the electricity grid. Table 3-4 shows that the reserve requirements for Minnesota's electricity system with 25 percent of the generation coming from wind would increase from 5 percent with no wind generation to just over 7 percent at the 25 percent level.

Table 3-4: Minnesota Reserve Requirements at Various Levels of Wind Generation

Reserve Category	Base		15% Wind		20% Wind		25% Wind	
	MW	%	MW	%	MW	%	MW	%
Regulating	137	0.65	149	0.71	153	0.73	157	0.75
Spinning	330	1.57	330	1.57	330	1.57	330	1.57
Non-Spin	330	1.57	330	1.57	330	1.57	330	1.57
Load Following	100	0.48	110	0.52	114	0.54	124	0.59
Operating Reserve Margin	152	0.73	310	1.48	408	1.94	538	2.56
Total Operating Reserves	**1049**	**5.00**	**1229**	**5.86**	**1335**	**6.36**	**1479**	**7.05**

Source: EnerNex 2006 Table 1 (page xvii)

A complementary approach, and one that would greatly increase geographic diversity, would be to develop offshore wind resources. This has been a topic of some controversy in the United States in a period when several European countries have developed significant offshore capacity and expertise. Offshore wind farms have other advantages besides being closer to large population centers. The wind over the oceans is steadier, providing for more reliable output and hence lower reserve requirements. A preliminary estimate of offshore U.S. wind energy resources (continental United States), excluding all areas within five nautical miles, two-thirds of the area between 5 and 20 nautical miles, and one-third of the area between 20 and 50 nautical miles is 908,000 megawatts of capacity.[7] This is sufficient to supply about 70 percent of U.S. generation in 2005.[8] Higher penetration of wind energy can and should be optimized with other renewable energy sources to take advantage of the diversity of supply and the greater ability of combinations of sources to more closely match demand. This is particularly true of wind and solar electricity. We are not aware of any thorough study (comparable to the many studies of wind integration) that has been done to examine the combinations of wind and solar electricity supply that could optimize cost and reduce requirements for reserve capacity.

Any large-scale development of wind resources or any other energy resource will have some environmental impact. Much of the focus for wind has been on bird kills, noise, and preservation of scenic values. The first two have largely been addressed by turbine design. The latter, of course, is a matter of one's aesthetics and how that competes with the need to reduce CO_2 emissions and with other available means to do so. Finally, very large-scale development of wind may also have climatic impacts that need to be more carefully studied. It has been postulated that wind power development may have adverse temperature change impacts, for instance. But such effects are not yet well-understood; indeed they are not yet amenable to reliable assessment. At levels 100 times today's level of wind penetration, at which level wind would supply a large fraction of the world's electricity requirements, the impacts may be somewhat negative to positive.[9] The reference scenario in this book envisages about a 20-fold increase in wind-generated electricity in the United States by about 2050 compared to 2006 but it would remain at less than 15 percent of total supply.

Small-scale wind turbines (a few hundred watts to 10 kW) are also available. These are considerably more expensive than large wind turbines and are used mostly for off-grid applications. There are also attempts to develop wind turbines for urban applications. This would work more like rooftop solar cells, with reverse metering. Such systems would be connected to the grid and feed into it or take energy from it depending on the wind level and the household demand. We will not consider these sources explicitly in this study, though they may become more important in present off-grid applications or, in the future, due to new designs and lower costs that would make them widely usable. The same considerations that apply to decentralized solar systems would also largely apply to decentralized grid-connected wind sources, though siting and some technical issues are likely to be more complex.

Large-scale wind energy development costs are about 4 cents per kilowatt hour at the very best sites to about 5 cents per kilowatt hour at very good sites, and about 6 cents per kilowatt hour at moderately good sites.[10] As discussed in Chapter 2, these costs are generally below the costs of new nuclear capacity. Wind energy is economical today. The main constraints lie in a lack of transmission infrastructure and an overall policy to reduce CO_2 emissions that would give rise to more rapid investments in this area.

B. Solar Electricity

The average solar energy incident on the continental United States is far greater than the wind energy potential. At about 5 kilowatt hours per square meter per day (annual average, 24 hours-per-day basis), the total is four thousand times the annual electricity generation in 2005.[11] Of course, only a small part of the area can be used and less than half of the incident energy is converted into usable electricity even under the best circumstances in a laboratory. But even at 20 percent efficiency and with one percent of the land area, the total potential for solar electricity generated by photovoltaic cells (solar PV) is about eight times the total U.S. electricity generation, and about three times greater than the wind energy potential shown in Table 3-3 above. Efficiencies of 40 percent have been demonstrated in concentrator solar cells in laboratory settings.[12] Twelve to eighteen percent is typical of non-concentrating solar PV silicon devices on the market today;[13] thin film solar cell efficiencies are typically several percent lower.

Unlike large-scale wind energy, solar PV is economical today in only some circumstances, but the economics of solar-generated electricity are improving rapidly. Typical retail costs for small-scale residential applications have been about \$5 per peak watt for the solar cell module itself, besides installation costs. Total installed costs are often in the \$8 to \$9 per peak watt range.[14] These prices reflect silicon solar cells with traditional manufacturing technologies on a relatively small-scale backfitted onto existing homes. Prices have come down significantly in the last few years and continue to drop. For instance, according to the National Renewable Energy Laboratory, in 2004, installed costs for small-scale applications of thin film solar cells were about \$6 per peak watt and up, of which about \$3 was the solar cell cost.[15]

While the cost of solar PV installations is declining, it is still rather high, especially when it concerns traditional silicon solar cells and small-scale installations:

- the high price of crystalline silicon due to rapidly rising demand
- the small-scale of manufacture in typical solar cell plants, typically 20 to 30 MW of solar PV cells per year
- the high cost of traditional crystalline silicon manufacturing techniques
- the slow emergence of thin film solar cells, which do not use crystalline silicon, in large-scale manufacturing
- the deployment of solar PV in small-scale residential applications which are backfitted onto existing structures.

A number of factors are bringing down the costs of solar PV significantly. In the past year or two there have been significant new developments that would set a course for solar cells to have deployed costs of \$2 or less per peak watt within a few years for intermediate- and large-scale applications (100 kw or more) and perhaps even for small-scale applications. It would take a considerable dissertation to go through the various developments, but the following list provides some indications of the basis for this conclusion:

- In June 2006, Nanosolar, a venture capital financed firm, secured $100 million in financing to build a 430 MW per year thin film solar PV factory in California. The scale of the manufacturing is large enough for the company to set a goal of competing with peak electricity generation costs. In a July 200 interview, the CEO of the company stated that volume manufacturing by 2008 would be the key to success in the industry and that Nanosolar would have certified solar panel "available in near-term 100MW volume at a fully-loaded cost point in the sixties [cents/Watt] or less so that one can profitably sell at a $.99/Watt wholesale price point.[16]
- First Solar, one of the larger solar PV manufacturers using thin film technology, announced that it had achieved a manufacturing cost as low as $1.25 per peak watt in its February 13, 2007, 8-K filing with the Securities and Exchange Commission. First Solar has signed contracts to supply 685 megawatts of solar PV to European clients for $1.28 billion, which is just under $1.90 per peak Watt. [17]
- A South African-German consortium that began building a thin film solar cell factory in Germany in 2006 announced anticipated costs of about one euro per peak watt[18] – about a factor of three to four less than present typical costs.
- A radically new manufacturing technique ("string-ribbon" technology) for polycrystalline silicon cells that draws strings of silicon through a silicon melt and produces very thin sheets cuts silicon requirements for solar cells by almost half, from over ten grams per watt for conventional ingot-based technology to six grams per watt. Further reductions in thickness are expected.[19]
- The first factory based on this technology, with a capacity of 15 MW of solar PV modules is operating in Marlboro, Massachusetts, and one with twice the capacity is operating in Thalheim, Germany.[20]
- The Department of Energy projects that annual manufacturing capacity of solar PV in the United States will increase almost twelve times in five years, from 240 megawatts per year in 2005 to 2,850 megawatts per year. It estimates that this expansion of capacity "put the U.S. industry on track to reduce the cost of electricity produced by PV from current levels of $0.18-$0.23 per kWh to $0.05 - $0.10 per kWh by 2015 – a price that is competitive in markets nationwide."[21]

To gain a perspective on these costs, the present electricity cost of new solar PV projects of intermediate or large-scale of about 20 cents per kWh about the same as that using a single stage natural gas turbine, which is a typical method of providing peak power to electricity grids. The natural gas peaking costs are far higher than those anticipated when these systems were installed because the fuel costs have gone up from $2 per million Btu to almost $8 per million Btu (see Figure 1-6, Chapter 1).[22]

At least some solar technologies are on the threshold of an installed cost of $2 per peak watt at intermediate- and large-scales. At $2 per peak watt, the cost of solar electricity would be about 12 cents per kilowatt hour, well under peak power costs, and not much different than the cost of electricity generated using a natural gas combined cycle plant at a fuel cost of $8 per million Btu and delivered to the residential sector. The DOE's projection for 2015 of solar PV competitive with present-day large-scale commercial power plants comes in the context of rapidly declining solar PV costs and rapidly expanding global manufacturing capacity. As noted, the scale of manufacturing plants is also increasing, which is a key to cost reduction

The technological developments to make solar PV economical to supply peak and intermediate-level power have largely been accomplished with both thin film cells made of materials other than silicon as well as silicon cells using new manufacturing techniques or Fresnel lens concentrators. The issues remaining are increasing the scale of manufacture, and developing a wider infrastructure for manufacturing of the associated components, such as inverters, at larger scales. An analysis of the effect of very large-scale manufacturing of thin film technology – 2,000 to 3,500 MW per year of solar PV modules – commissioned by the National Renewable Energy Laboratory indicated that economies of scale could bring the overall cost, including installation, down to about $1 per peak watt for a 6,000 watt roof installation, including manufacturer's and retailer's margins. The largest portions of the cost reductions estimated by the authors were by analogy with cost reductions due to increase in manufacturing scale achieved in the flat panel display industry. One key ingredient was mass manufacture of the machines that make solar cells. One hundred lines of such machines were envisioned for a single plant.[23] One dollar per peak watt appears too optimistic for a residential rooftop system, given that costs of the parts, other than the solar cells, and of installation are unlikely to decline as much as the cells themselves. However, it appears reasonable that, with improvements in manufacturing technology, installed costs of $1 to $1.50 can be achieved in systems of 100 kW and larger. We have assumed $1.50 per peak watt in the reference scenario, which relies mainly on such systems.

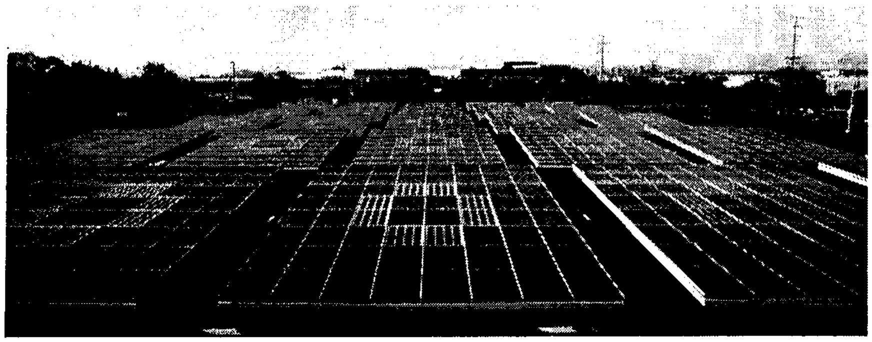
The next few years will likely see which of the competing technologies will be manufactured at a large enough scale that the machines for the manufacturing can be mass produced. At that stage, one can expect that the costs of large-scale installations should be $1 to $1.25 per peak watt or so – yielding a power cost of about 6 to 7.5 cents per kilowatt hour. In short, the solar PV industry appears to be at about the same stage as wind was in the early 1990s, when it began to change from an industry with custom manufacturing of a few large-scale installations to a relatively mature industry today that can out-compete new nuclear power plants.

In the reference scenario for this study, we will assume that large-scale deployment of solar cells (on the scale seen for wind energy today) will not take place until about 2015 or 2020, though it may well do so before that. We assume an intermediate-scale installation cost of $1.50 (reflecting a mix of large-scale, intermediate-scale, and a smaller component of small-scale installations). Costs of storage and added costs for distribution are added as well (see Chapter 5 for details). As we will discuss, time-of-use pricing is an important policy tool for a transition to a renewable electricity system. It also best reflects market considerations in terms of cost of supply. A lack of time-of-use pricing is a reflection of improper market signals and the cause of significant market failures in the electricity sector.

We will incorporate all levels of solar electricity – very local residential (up to a few kW), medium-scale commercial (100 kW to a few MW), as well as central station (100 MW or more) – in our approach to a zero-CO_2 economy.

It turns out that a considerable part of the potential for solar electricity generation can be achieved on an intermediate-scale at the point of use – on rooftops, over parking lots, and if thin films get thin enough and cheap enough, simply by covering south-facing walls of buildings with photocells. We consider parking lot solar PV because of the potential scale of this resource and its many advantages in medium-scale applications. Let us first consider actual examples. Figure 3-4 shows a 235 kW installation for a 186 vehicle parking lot – or more than one kW per vehicle.

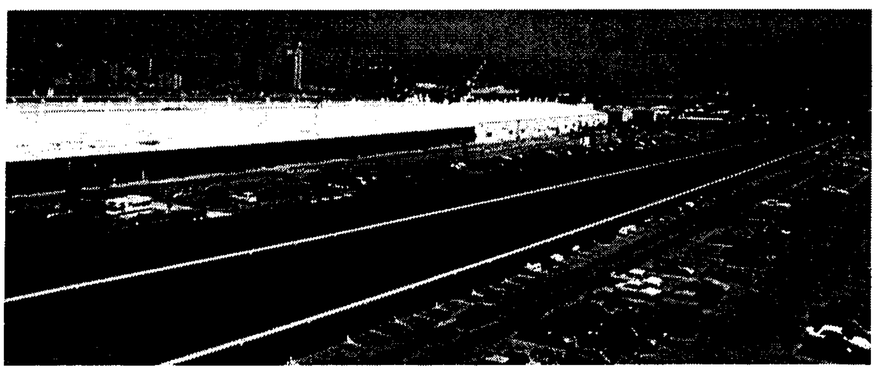
Figure 3-4: Kyocera "Solar Grove" – 25 Panels, 235 kW Total, 186 Vehicle Parking Lot.



Source: Copyright 2007 Kyocera Solar, Inc. All rights reserved

Figure 3-5 shows a larger, 750 kW, U.S. Navy system in San Diego installed in 2002. It is easy to see that there is plenty of room to install additional solar energy capacity in that parking lot.

Figure 3-5: U.S. Navy 750 kW Parking Lot Solar PV Installation Near San Diego



Source: Courtesy of PowerLight Corporation

According to PowerLight, this installation is expected to avoid nearly a quarter of a million dollars per year of peak electricity costs:

> The 750 kW solar electric system was implemented as part of an Energy Savings Performance Contract (ESPC) project developed by NORESCO of Westborough, MA. The photovoltaic system was designed, manufactured and installed by PowerLight Corporation of Berkeley, CA. This photovoltaic system will produce approximately 1,244,000 kWh per year and is expected to save over $228,000 in annual operating costs by avoiding purchases of expensive peak electricity.[24]

Google is planning an even larger installation – 1.6 megawatts – sufficient to supply its headquarters with a large part of its electricity, in a combination of parking lot and rooftop deployment.[25]

Parking lot solar PV makes a great deal of sense for several reasons. Among them:

1. It does not require roof penetrations, reducing maintenance and the risk of leaks.
2. It does not require any new dedicated land.
3. It can be implemented on a scale that provides significant economies in installation costs.
4. It provides shade to parked vehicles, increasing comfort and reducing the need for air-conditioning at full blast when vehicles are started after being parked on bright summer days.
5. It increases the value of the parking lot.
6. Not least, grid connections in large parking lots (and rooftops) can be made compatible with vehicle-to-grid storage systems, discussed below. In these systems, parked electric vehicles or plug-in hybrids can supply power to the grid during peak daytime hours (for instance, on hot summer days), having been charged during off-peak hours at night. They could also be charged in the workplace during off-peak hours (for instance during night shifts or the early morning hours), with the same result. This also increases the value of the vehicles parked in the lot.

The land area devoted to parking spaces in the United States is very large. It has been estimated by the Earth Policy Institute at about 1.9 million hectares, or 19 billion square meters.[26] Most of these are not multi-story parking lots, but rather vast expanses of asphalt at shopping centers, offices, high schools, universities, airports, strip malls, supermarkets and other large stores, and the like, as well as private parking spaces. At 15 percent conversion efficiency, available today, parking lot PV installations could supply more than the electricity generated in the United States today. Of course, it may not be practical to use much of the parking area; some of it may be shaded much of the day, for instance. But parking lot solar PV installations could play a large role in a future electricity grid especially in the context of vehicle-to-grid (V) applications. Parked cars could exchange power with the grid, both serving as storage devices for times when excess electricity capacity is available and supply devices when the grid requires more electricity than the generation system can supply. Similarly, large flat commercial rooftops can also be used.

The first test of a V2G system is being started by Google and Pacific Gas & Electric (PG&E), the electric utility in the area, with a single Toyota Prius that has been converted by the addition of batteries and electronics to a plug-in hybrid. PG&E will control the charge on the batteries remotely, to test the system of charging the batteries when they are low and taking power from them when needed by the grid. [27]

Solar electric systems can also be used in more centralized installations. At 15 percent efficiency, a 1,000 MW plant in the Southwest (that is, in a favorable area for solar) would occupy about 300 acres, including 70 acres or so between solar PV arrays. Plant buildings and roads would be in addition to this area. Figure 3-6 (see color insert) is a map of the continental United States, published by the National Renewable Energy Laboratory, showing annual average incident solar radiation on a device that turns to face the sun. Figure 3-6 shows that there are large areas in the Southwest which are favorable to solar energy (more than 6 kWh per square meter per day). Much of the rest of the United States has an insolation rate of 4 to 5 kWh per square meter per day. The insolation values have been averaged day and night, over the entire year. The semi-arid and desert areas in the Southwest and West not only have the greatest incident energy, but also the greatest number of cloudless days. Those regions are therefore excellent candidates for central station solar PV, especially since this technology, unlike fossil fuel and nuclear plants, does not require cooling water. At 15 percent efficiency, a square meter of land with insolation at about seven kilowatt hours per square meter would generate about 400 kilowatt hours per year. Hence, an amount equal to about a trillion kilowatt hours – one-fourth of today's annual electricity output – could be produced on about 650,000 acres – a square with a side of just over 30 miles. With ancillary facilities, it would be a square with a side of about 35 miles.

Solar energy, of course, has in some measure a problem of intermittency, but in arid and semi-arid climates, this is not a significant issue, especially if solar PV is integrated with other energy sources. Solar insolation is much more predictable than wind on a hour-ahead, day-ahead, and seasonal basis. Moreover, it does not have the same kinds of micro-fluctuations that can create regulation problems on a time scale of seconds or minutes that wind energy does. Finally, being available in the daytime, it covers many of the peak hours, notably in the summer.

However, there are also certain periods of no sunshine when solar PV output is zero. Hence the problem of storage occurs on a diurnal time scale. Seasonal variations can also be considerable, the more so at higher latitudes. Figure 3-7 (see color insert) shows seasonal solar insolation variations, each value being averaged over a month (diurnal variations are taken into account in these averages). At 30° latitude (which runs through Texas, southern Louisiana, and northern Florida), solar insolation varies by a factor of almost two between the summer peak and winter trough. But in the United States the location of central station solar PV installations (or other solar installations) in the West and Southwest, two regions that combine availability of land and sunshine, would be feasible, since for most of the country the peak of demand occurs in the summer. Still, seasonal variation will be something of an issue since most of the land area of the United States is above 30° N.

Figure 3-8 (see color insert) shows the effect of nighttime lack of solar energy according to season for a zero-net-energy solar home in Virginia. The net effect of the seasons in balancing generation and demand on how much electricity is purchased and how much is fed back (exported) into the grid is quite complex. The June insolation daytime peak generation results in a high net feedback into the grid; but the export of electricity is about as high in October, when both demand and insolation are lower.

The graph "shows that even in the winter months a solar home is net exporting to the electric grid during the day and importing electricity from the electric grid during the early morning and evening hours. The time between 1300 and 1600 is the traditional peak for electricity particularly during summer months." (ERT 2005 page 11)

A part of the problem of diurnal and seasonal variation in solar energy can be dealt with by combining solar thermal power plants with heat storage as well as supplemental fuel use with solar thermal generation. Central station solar thermal plants use concentrators to focus heat on long pipes (parabolic troughs) or on a small area ("power towers"). There are nine power plants of the former design, between 14 MW and 80 MW, totaling 354 MW, operating in California that were installed between 1984 and 1990 by Luz International.[28] A variety of heat storage devices ranging from concrete and bricks to molten salt are being investigated, but none have been demonstrated in conjunction with a commercial solar thermal power plant. Capital costs for heat storage are estimated to vary between $30 for concrete and $130 per kilowatt hour-thermal for some phase-change materials. Since thermal energy must be converted to electricity with significant loss of energy, the capital costs of capacity to store enough heat to generate one kilowatt hour of electricity are significantly higher.[29] At $30 capital cost per kilowatt hour for concrete, assuming that the storage is used once every-day, the storage cost per kilowatt hour of electricity generated would be about 4 cents plus the cost of the solar thermal plant itself. In addition, there would be the operating and maintenance costs of the equipment associated with storing the heat – piping, pumps, etc.

Every energy source has its environmental costs, but when all is said and done, those associated with solar energy, even at a very large-scale of deployment, would be small. At present, the main environmental problems associated with solar energy arise from the emissions from fossil fuel plants that provide the energy to make the photovoltaic cells. Since crystalline silicon cells are the most energy intensive, the largest emissions, whether of heavy metals or CO_2 are associated with them.[30] They are higher than with wind energy due to the greater energy intensity of silicon cells.[31] Fresnel lens concentrators, which reduce the amount of silicon needed per unit of power generation, as well as newer techniques for manufacturing the thin strips of silicon needed for solar cells, will significantly bring down the energy cost of these cells. The emissions are lower with thin film cells mainly due to the lower energy manufacturing use per cell, despite their lower efficiency.

The indirect energy impact of solar PV, notably silicon cells, is declining due to more efficient use of silicon. Further, the indirect pollutant emissions are expected to be small once fossil fuels are eliminated from the energy supply. However, there will remain some impacts of mining, notably mining elements that are present in ores in small concentrations, as, for instance, with cadmium. Fthenakis and Kim estimate that these emissions would be quite small – 23.3 milligrams per million kilowatt hours – for cadmium telluride thin film PV, with the main impact coming from the production processes (production of the alloy and the PV cell itself) rather than mining. They estimate that mining impact is ~0.1 percent of the total cadmium emissions. The small mining impact is mainly due to the fact that the cadmium is a by-product of zinc manufacturing, with the main emissions being attributed therefore to zinc.[32] How such allocations might change in the face of very large-scale deployment of thin film solar PV must be evaluated. Recovery and reuse of the materials would greatly reduce their ultimate impact.[33] We note here that lithium-ion batteries, which would be used for electricity storage in V2G systems, can be recycled.

C. Biomass – Introduction

Solid biomass in the form of wood, crop residues, and cow dung still provides the bulk of residential fuel use for many or most people in developing countries, as it has for centuries. Biomass also provides the food for animals that still provide the main source of draft power for agriculture in much of Asia.[34] However, the use of biomass fuels directly in the form of liquids and gases on a large-scale has drawn considerable interest since the first energy crisis in the West in 1973, when OPEC increased oil prices and the Arab members of OPEC imposed an oil embargo on the United States, Western Europe, and Japan. The initial flurry of interest in the United States faded to some extent in the 1980s and then more so in the 1990s, with only a modest amount of ethanol derived from corn finding a niche in the automotive fuel market. A number of initiatives, including the possible use of the most productive plants, measured in terms of their efficiency of capture of solar energy, were abandoned. At least one country took a different path. Brazil persisted with ethanol production from sugarcane. Dual fuel cars are the norm in Brazil. Ethanol now supplies about 40 percent of motor vehicle fuel in Brazil.[35]

In the last few years, a number of factors, including rising petroleum prices and political and military turbulence in critical oil exporting areas, notably (but not only) in the Persian Gulf region, have caused a dramatic change in U.S. biofuel policy and production, centered on the production of ethanol from corn. President Bush featured ethanol production in his State of the Union speech two years in a row.[36] At the end of 2006, the ethanol production capacity in the United States was more than five billion gallons per year.[37] In his 2007 State of the Union speech, President Bush set a production target date for "renewable and alternative fuels," including ethanol, of 35 billion gallons for the year 2017.[38]

Biofuels can be a significant part of the energy supply. However, there are a number of fundamental issues that must be addressed not only to ensure long-term reliable and economical supply but also to verify that other serious problems, such as food insecurity, indirect large CO_2 emissions, or major economic inequities within countries or internationally do not arise as a result of fuel production from biomass. This is a very complex topic. The present report cannot do full justice to it. However, in view of the critical nature of the issue to energy supply, greenhouse gas emissions, land use, environmental protection, and other areas, it is important to consider it here to the extent needed in the context of an overall roadmap for a zero-CO_2 economy, including research and development, as well as infrastructural needs.

Basic considerations of the efficiency of photosynthetic solar energy capture under various circumstances are a good place to start. Solar insolation at mid-temperate latitudes at midday on a clear day provides energy at the rate of 1,000 watts per square meter.[39] The average over 24 hours is, of course, considerably lower due to a variety of factors, mainly no sunshine at night, considerably reduced insolation in the early morning and late afternoon hours, cloud cover, seasonal variations, and precipitation. As a result, the average annual insolation across most of the contiguous United States and Hawaii ranges from about four to about eight kilowatt hours per day per square meter.[40]

For food crops, the capture efficiency of solar energy is typically a fraction of one percent. For instance, corn yields are typically 8,000 to 10,000 kilograms per hectare[41] in the Midwest. The solar energy capture efficiency for a yield of 8,000 kilograms per hectare is about one-quarter of one percent.[42] Converting corn to ethanol results in about half or just under half of the energy value being in the ethanol; the rest is accounted for by co-products, like animal feed, and losses.

Low solar energy capture even at high food crop yields is only a part of the difficulty with the use of corn as a feedstock for ethanol production. A considerable amount of energy is needed to convert corn to ethanol – for instance, large amounts of steam are required. As a result of low solar energy capture, heavy use of fertilizers, and other inputs that are energy intensive, the net energy balance is not very good, even when the energy value of the co-products like animal feed is taken into account. A careful assessment of various studies on a commensurate basis indicates a range from approximately zero gain (energy used about equal to the energy output) to a net energy output of about 29,000 Btu per gallon (8 megajoules per liter). The latter is only 0.035 percent of the incident solar energy on the land. The energy input was estimated at 76,000 Btu per gallon (21.2 megajoules per liter).[43] Since coal, natural gas, oil, and electricity (largely derived from fossil fuels) are all needed for ethanol production from corn, and since other greenhouse gas emissions, such as nitrous oxide emissions due to nitrogen fertilizer use, also result from corn production, the greenhouse gas balance compared to gasoline is also rather poor. Some estimates of greenhouse gas emissions are actually higher than for gasoline, while others are somewhat lower. However, ethanol production does have a significant positive effect in reducing petroleum consumption, since much of the energy used in its production is in the form of natural gas, coal, and electricity.[44]

It is being rapidly recognized that the use of corn (and other food crops) for fuel on a large-scale can create serious competition with food. This already appears to be occurring as a result of the rapid growth of U.S. ethanol production. For instance a combination of demand for corn for ethanol in the United States production as well as local problems in market structure in Mexico has already contributed to a serious escalation in tortilla prices in Mexico:

> ...Although Mr. Calderón [President of Mexico] moved quickly, announcing a pact on Jan. 18 [2007] to freeze prices, the problem has not been resolved. Even with the pact, the news reports focused on the fact that the price ceiling for the tortillas of about 35 cents a pound was about 40 percent higher than the price three months earlier and contrasted that with the 4 percent increase in the minimum wage, which is still less than $5 a day.
>
> But because fewer than 10 percent of tortilla producers signed on to the agreement, the government had little power over those who did not. In some areas, prices have risen to 45 cents a pound. There is little more that Mr. Calderón can do to contain prices without huge expenditures for subsidies. Most analysts agree that the main cause of the increase has been a spike in corn prices in the United States, as the demand for corn to produce ethanol has jumped.
>
> But the uneven structure of Mexico's corn and tortilla industry here has also generated accusations – none of them proved – of hoarding and profiteering. Mexico's corn flour industry is controlled by just two companies, Grupo Maseca and Minsa. Under the pack, Grupo Maseca agreed to keep the prices for corn flour at 21 cents a pound. The government has promised to crack down on profiteers.[45]

In effect, a part of the burden of reducing oil imports by substituting corn-derived ethanol is being paid by the poor in Mexico. The global effects of rapidly increasing the use of corn, and possibly other food crops, such as cassava, which is a subsistence crop in much of Africa, for fuel ethanol could be devastating to the world's poor. Runge and Senauer have done a policy review of the issue going back to the 1970s and concluded as follows:

> The enormous volume of corn required by the ethanol industry is sending shock waves through the food system. (The United States accounts for some 40 percent of the world's total corn production and over half of all corn exports.) In March 2007, corn futures rose to over $4.38 a bushel, the highest level in ten years. Wheat and rice prices have also surged to decade highs, because even as those grains are increasingly being used as substitutes for corn, farmers are planting more acres with corn and fewer acres with other crops.

> This might sound like nirvana to corn producers, but it is hardly that for consumers, especially in poor developing countries, who will be hit with a double shock if both food prices and oil prices stay high. The World Bank has estimated that in 2001, 2.7 billion people in the world were living on the equivalent of less than $2 a day; to them, even marginal increases in the cost of staple grains could be devastating. Filling the 25-gallon tank of an SUV with pure ethanol requires over 450 pounds of corn – which contains enough calories to feed one person for a year. By putting pressure on global supplies of edible crops, the surge in ethanol production will translate into higher prices for both processed and staple foods around the world. Biofuels have tied oil and food prices together in ways that could profoundly upset the relationships between food producers, consumers, and nations in the years ahead, with potentially devastating implications for both global poverty and food security.[46]

Runge and Senauer estimate that an additional 600 million people in developing countries could face malnutrition or starvation relative to trends in 2003, that is before the recent "biofuel mania."[47]

The integration of global markets and the rapid changes in production patterns and prices can result in serious problems in other areas as well. For instance, when the global balance of greenhouse gas emissions is taken into account, the use of food crops for fuel production can be much more damaging than revealed in an analysis focused at the national or regional level. One of the most dramatic examples in this arena is the increased emissions of carbon dioxide in Indonesia due to the export of palm oil to Europe for biodiesel production. When the per-acre yield of biodiesel alone is considered, palm oil appears to be one of the more attractive ways to produce biodiesel.[48] However, a recent detailed analysis shows that one metric ton of palm oil production on cleared and drained peatlands in Indonesia results in 10 to 30 metric tons of CO_2 emissions,[49] which is three to ten times more than the emissions from burning petroleum.

Ethanol from corn has provided two advantages so far in terms of guidance for policy. First, it has, after a considerable lull, re-focused attention on the potential large-scale use of biomass for fuel in the United States, which has the advantage of possessing a large, uncultivated land mass that is generally unsuitable for crops. Second, it has shown that an infrastructure for alternative fuels can be rapidly created, given the right policies. Of course those policies also need to focus on the appropriate technical, environmental, and economic choices. Producing fuel from food is already having deleterious effects and should not be encouraged by policy (see Chapter 7).[50]

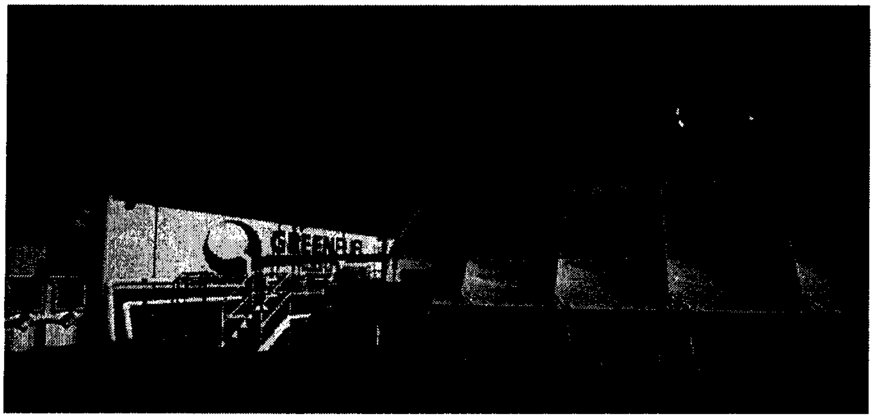
D. Microalgae

Corn stover and other crop residues can provide inputs for ethanol production that would avoid some of the difficulties that are associated with the use of corn. However, large-scale production of liquid fuels from biomass or, for that matter, of solid fuels for electricity production would require a resource base that is considerably larger than that available from crop residues.[51] This restraint is strengthened when appropriate consideration is given to land conservation issues, which are important, among other things, for maintaining the soil's ability to continue to fulfill its role as a large reservoir of CO_2. Hence, while crop residues can and will likely play some role in the context of an economy with a large biofuels sector, they cannot play a central role in a large-scale biofuel supply. For the purposes of this investigation, we focus therefore on new biomass that is not associated with food crops.

There are two broad categories of biomass that could be cultivated for producing biofuels: grasses of various types and high productivity plants that grow in aquatic environments. As an example of the second type, microalgae exhibit prolific growth in a CO_2-rich environment. Microalgal productivity in such an environment in a sunny climate could be as high as 250 metric tons of dry mass per hectare per year, without using any artificial fertilizer other than exhaust from a power plant using fossil fuels.[52] Other plants that grow in nutrient rich environments, notably wastewater, at very high productivity in the range of 100 to 250 metric tons per hectare are duckweed and water hyacinth. The highest productivities are achieved in tropical or semi-tropical zones, though duckweed will also flourish for part of the year in the temperate zone. At the high end of productivity, the efficiency of solar energy capture of these plants is about 5 percent or about ten times that of the entire corn plant. It is about 20 times the efficiency relative to the solar energy capture in corn alone.

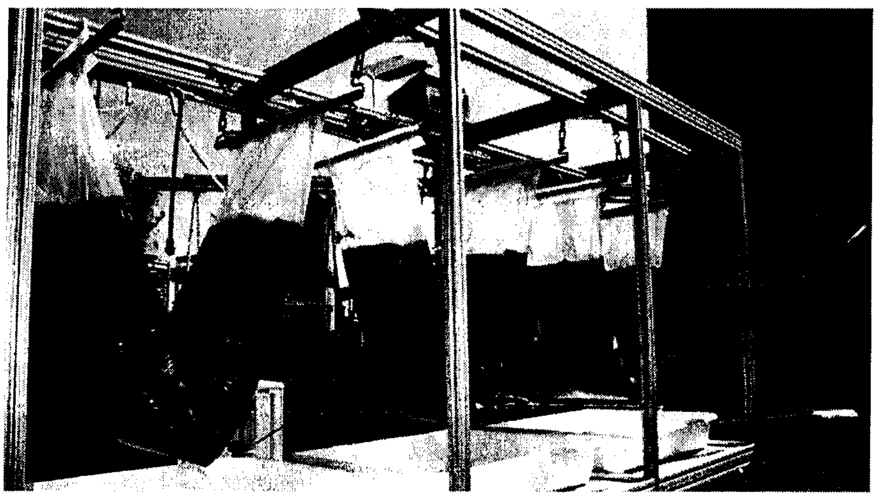
Demonstration-scale microalgae production using CO_2 from power plants has been carried out in two different contexts. The first used CO_2 from a 20 MW cogeneration plant at the Massachusetts Institute of Technology. The algae were not grown in open pools but rather in tubes slanted to face the sunlight.[53] The land area is minimized, the efficiency increased, and the quality of the algae is better controlled in this way. The algae apparently adapt to changing environmental conditions rapidly without a need for genetic engineering. The second is a small-scale bioreactor producing algae that has been operating in Arizona (Figure 3-9). A third demonstration plant has been installed at a coal-fired power plant in Louisiana (Figure 3-10).

Figure 3-9: Pilot Engineering-Scale Microalgae Plant at the Redhawk Gas-Fired Power Plant in Arizona



Source: Courtesy GreenFuel Technologies

Figure 3-10. Operating Demonstration Algae Bioreactor at a Coal-Fired Power Plant in Louisiana.



Source: Courtesy GreenFuel Technologies

It has been successfully tested using brackish and salt water. Isaac Berzin, who leads the research and development team for this technology for the company GreenFuel and also led the one for the MIT installation, has noted that the ability to use land of any quality and water of any quality are at least as important as the efficiency of solar energy capture. The target is a productivity of 100 metric tons per acre when the operation is commercialized (250 metric tons per hectare). The engineering-scale unit uses CO_2 from a combined cycle plant owned by Arizona Public Service, which is the largest electricity supplier in that state.[54]

A seven-day test at the MIT plant showed that daytime CO_2 removal was over 80 percent on sunny days and over 50 percent on cloudy and rainy days. Nitrogen oxide removal was in excess of 80 percent.[55] The engineering-scale unit in Arizona is on 0.3 acres of land. It operated in the spring and summer of 2007 in Arizona at the site of an Arizona power company's (APS) power plant. The expected breakeven price for a fully operational, large-scale plant is under $30 per barrel, without any subsidies or CO_2 credits.[56] Note that when the biomass is burned the CO_2 is released. Hence, microalgae, as a method of CO_2 capture from fossil fuel use, can result in large reductions in CO_2 emissions, but cannot by themselves result in a zero-CO_2 system. However, the same technology can also be used to capture CO_2 from electric power generating stations that use biomass as a fuel. Both uses of this technology are incorporated into the reference scenario (Chapter 5).

Since microalgae can be used to capture CO_2 from large-scale fossil fuel burning such as that in coal-fired and combined cycle power plants or cement plants and even combined heat and power systems, it can have medium-term impact in some major ways if it is sucessfully commercialized:

- Reduction of CO_2 (and NOx) emissions from existing fossil fuel power plants in the electric power sector.
- Reduction of industrial CO_2 emissions by CO_2 capture from cement plants, blast furnaces, and combined heat and power plants.
- Reduction of petroleum use (and hence oil imports) – in effect, CO_2 from coal, and natural gas combustion is combined with solar energy to produce petroleum substitutes. These substitutes could be various combinations of biodiesel and ethanol, depending on demand and the type of algae used.[57]

The very large capacity of coal-fired power plants, used to supply about half of the U.S. electricity, plus much smaller, but still important thermal uses of coal in cement and steel, are among the main reasons that the existing fossil fuel system has large economic inertia. In addition, natural gas use in central station power production, as a heat source in industry, and for combined heat and power production also results in considerable CO_2 emissions that could be captured in algae. The other very large sector of CO_2 emissions is, of course, the use of petroleum in transport, mainly land-transport, but also aircraft. While these emissions cannot be captured in biomass in any practical way, the fuel for them can be made from biomass, including algae production from the capture of power plant and industrial CO_2.

Algal bioreactors could capture most of the daytime emissions of CO_2 from large-scale sources. Nighttime emissions can only be captured if the CO_2 is stored and then passed through an additional bioreactor in the daytime. This necessitates local CO_2 storage in an underground reservoir. But the scale of the temporary sequestration is orders of magnitude lower than that required for long-term sequestration of CO_2, since storage capacity is needed for part of a day only, rather than for decades. Moreover, the risks that may arise from long-term storage are avoided.[58] The storage of nighttime CO_2 for daytime capture in algae would be akin to compressed air storage associated, say, with a wind farm, in which off-peak wind energy is stored at high pressure for generating electricity during peak and intermediate load hours. The technology of algae biomass production would likely first be commercialized for daytime capture, while the cost and technical issues associated with nighttime storage of CO_2 for daytime use are worked out. Overall, in sunny areas such as the Southwest, it may be possible to capture about 70 to 80 percent of the CO_2 in algae. The dry mass of algae is about double the captured mass of carbon, with the added weight being contributed by hydrogen, oxygen, nitrogen, and other elements.[59] With full implementation of CO_2 capture in algae, about seventy percent of the energy in coal could be captured in algae using bioreactors to convert CO_2, water, and other elements into biomass. [60] This can be converted into liquid biofuels, offsetting oil imports. The overall efficiency of liquid fuel production could be up to 10,000 gallons per acre per year.[61]

The carbon captured in the algae is emitted when the fuels are burned, for instance, in cars. The net effect is to reduce CO_2 emissions from the displaced petroleum consumption. Conversion of microalgae to liquid fuels at acceptable cost at or near the targeted efficiencies remains to be demonstrated. A commercial plant has not yet been built.

In the longer term, as fossil fuels are phased out, the approach of using CO_2 from fossil fuel combustion for algae production is not compatible with a zero-CO_2 economy, since the CO_2 will eventually be emitted from vehicles or other machinery. However, microalgae can also grow in saline, nutrient rich waters, such as run off flowing into the Salton Sea, as well as in ponds. In the long-term, transportation will be supplied by (i) electricity, (ii) hydrogen produced from wind or solar energy, or (iii) biofuels. Fuel can also be produced from landfill methane, forest wastes, food wastes and other similar sources of biomass.

E. Grasses

Switchgrass, a high-yield, perennial prairie grass that can be grown in a variety of circumstances, has been investigated recently as a prime candidate for anchoring the supply of biofuels to overcome the limitations of ethanol from corn. A seminal report was issued by the Natural Resources Defense Council in 2004, which estimated that by 2050 the United States could be producing 7.9 million barrels a day of biofuels (in petroleum equivalent) using this approach.[62] The report cautions that switchgrass is one good candidate for creating such a supply but that further work is needed. Switchgrass has some ancillary environmental advantages:

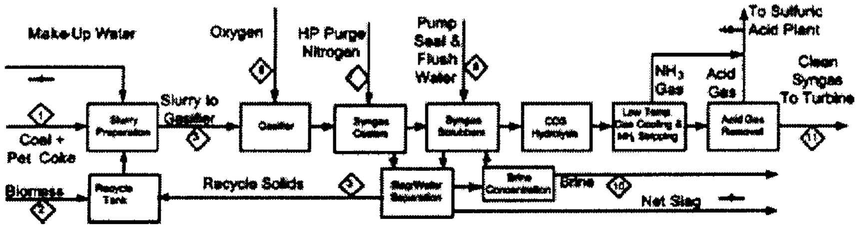
Switchgrass also offers low nitrogen runoff, very low erosion, and increased soil carbon–which is actually enhanced when the crop is harvested. Switchgrass also provides good wildlife habitat. It is likely that such benefits are not limited to switchgrass, although other crops were not investigated in any detail.[63]

The current productivity of switchgrass is estimated to be about 10 to 12 metric tons per hectare per year over a variety of growing regions and that by 2050 this could be about 25 to 30 metric tons per hectare per year by crop selection done without genetic engineering.[64] Farrell et al. have estimated that if current approaches to converting cellulosic material to liquid fuels can be made economical, that the energy and greenhouse balance of switchgrass would be very favorable.[65] The ratio of output energy to input energy is estimated at 8.2 and the emissions of greenhouse gases are estimated at 11 grams carbon equivalent per megajoule compared to 94 for gasoline.[66] Growing fuel crops on marginal lands is also possible and, done appropriately, it can provide measurable increase in carbon sequestration in the soil, without the use of expensive and energy intensive inputs such as fertilizers and pesticides. This approach would avoid the use of high quality land and inputs for biofuel production while providing larger collateral environmental benefits.[67] The cultivation and harvesting of biomass in such a way as to sequester carbon in the soil in measurable ways is a crucial part of the process of developing the large-scale use of cultivated biomass in the energy system. It is also important for other types of biomass in case net removal of CO_2, beyond zero-CO_2 emissions, is pursued.

The land requirements implicit in using grasses at productivities of 25 to 30 metric tons per hectare (10 to 12 metric tons per acre) as the mainstay for biofuel production would cause significant, possibly unacceptable, land use impacts (see Chapter 5). It is, therefore, crucial to tap into higher productivity biomass, including, but not only microalgae, to produce liquid fuels and industrial feedstocks. Alternatively, direct production of hydrogen from solar energy could replace a large portion of the biofuel requirements with much smaller land requirements, provided the methods can be made economical (Chapter 6).

The initial stage of development of the technology of the use of solid biomass as fuel is occurring in the context of co-firing biomass with coal. This can be done for power production only or for combined power and liquid fuel production. Co-firing in IGCC plants with coal and biomass has already been tested, for instance, by Tampa Electric. The flow diagram of the plant is shown in Figure 3-11.

Figure 3-11: Flow Diagram for the Tampa Electric Test of Co-firing Biomass with Coal and Petroleum Coke



Source: Tampa Electric, 2002, page 3. Reprinted with permission of Tampa Electric Company.

The proportion of biomass burned in the Tampa Electric test was very small – only one percent. It was to test whether there was an increase in sulfur dioxide or NOx emissions from the power plant due to an introduction of biomass feed. The proportion of biomass was kept high enough for the measurements of the pollutants of concern to be statistically significant.

It is important that IGCC technology, that can use mixtures of biomass and coal and that can run on biomass alone to produce power and liquid fuels, be developed. In the recommended scenarios in this report, we do not assume the use of coal. However, it is important to note that the requirement for liquid and gaseous fuels in transport and industry is likely to remain very large. Hydrogen produced from renewable electricity can be used in transportation, in whole or in part. However, portions of such use, notably for aircraft, require long-term development.

F. Other High Productivity Biomass

Even with substantial hydrogen and direct electricity use in transportation, there is still likely to be a large requirement for liquid and gaseous fuels for transport and industry in a zero-CO_2 economy. It is important to plan for about 15 to 20 quadrillion Btu per year of such fuels, even in an economy where efficiency increases result in a steady absolute decline in energy use (See Chapter 6).

Production of large amounts of biofuels using mainly switchgrass or other prairie grasses would likely create unacceptably high land requirements. It is important, therefore, to consider whether there are other sources of high productivity biomass, comparable to microalgae, which do not require an input of high CO_2 gases. The water hyacinth in semi-tropical (and tropical) climates is one such plant. (See Figure 3-12 in color insert.) Duckweed is another. The latter also grows well in temperate climates. Both of them grow prolifically in wastewater rich in nutrients. The productivity of water hyacinths in semi-tropical climates, if they are harvested regularly, is comparable to microalgae grown in tubes with CO_2-rich exhaust from power plants – that is, about 100 dry metric tons per acre. Indeed, at up to 17.5 wet tons per hectare per day, it may be the most productive plant on earth.[68] Under the right conditions, water hyacinths can produce as much dry matter in two weeks as switchgrass produces in one year. The high productivity depends on water that is rich in nutrients – nitrogen and phosphorous. These nutrients are, of course, present as pollutants in wastewater treatment plants and in run-off from agricultural lands.

In terms of the efficiency of solar energy capture, water hyacinths can achieve efficiencies up to 5 percent, which is several times the total biomass efficiency of most crops (which need energy inputs and artificial fertilizers) and two times or more than the biomass output of sugarcane.[69] In point of fact, without plant breeding or other intensive research to increase productivity, the efficiency of solar energy capture of water hyacinths is only about a factor of three lower than that of today's commercial solar PV cells. It is ten times higher than the entire corn plant.

In practice, the prolific productivity of water hyacinths has caused it to be regarded as a nuisance weed or worse, and for good reasons. It can choke waterways, requiring large expenditures for periodic removal. Mosquitoes may breed in infested waterways more easily, with attendant health risks. Further, the plants are killed by sustained temperatures (for about 12 to 24 hours) below about 24°F.[70] However, the ability of water hyacinths to soak up nutrients has also been seen as a potential boon in wastewater treatment and in treatment of natural ecosystems that have become seriously damaged by eutrophication due to nutrients in agricultural runoff. Hence, so far, experimental and demonstration projects with water hyacinths have centered on their effectiveness in wastewater treatment, both public and industrial, rather than as an energy source.

In the 1970s, the National Aeronautics and Space Administration initiated a project in Bay St. Louis, Mississippi, to try to address a problem of heavy metals in wastewater discharge for its National Space Technologies Laboratories (NSTL). Conventional treatment did not result in consistent compliance with EPA standards.[71] A lagoon of just over half-an-acre was constructed to receive and treat about 25,000 gallons per day of water, with a retention time of 20 days. Even with only chemical wastes from photography laboratories in the discharge water, the water hyacinths grew rapidly – by about five-fold, from an initial 20 percent stocking, in four weeks. Silver was the main metal pollutant in the effluent water. The results are worth quoting at length, not only because of the potential for wastewater treatment and energy, but for reducing heavy metals pollution and, indeed, their possible recovery and recycling.

> The water hyacinths proved to be a very effective filtration system for cleaning wastewater containing a complex chemical mixture. Organics, heavy metals and other elements were effectively removed from the wastewater by plant root sorption, concentration and/or metabolic breakdown... Trace elements entering the lagoon system were effectively removed to levels which comply with PHS [Public Health Service] recommendations.

> Even the hardy water hyacinth is not immune to heavy metal pollutants. Approximately every eight weeks during the summer, the leaf tips began to turn brown and curl, indicating that the plants had sustained permanent metabolic injury from the environmental pollutants....
>
> Since the plant stems and leaves, as well as its roots, were found to contain heavy metals, no part of the harvested plants can be used as feed or fertilizer. However, the harvested plants can be used safely for the production of biogas. Whole harvested plants (or remaining sludge, if biogas is produced) should be put in a pit especially designed to eliminate ground water infiltration. Such a pit is planned to be utilized at the NSTL zig-zag lagoon. Over a period of years, the heavy metals in the pit may accumulate to levels high enough that their extraction becomes economically feasible. Such small "mining" operations – particularly of silver – may prove to be an efficient method of recycling valuable metals for industrial use.[72]

There have been a number of demonstration projects using water hyacinths for public wastewater treatment.[73] Most of these were in small to medium systems where the biomass product was a liability, since it had to be composted or otherwise disposed of. Mosquito control was achieved partially through stocking of mosquito fish or completely through aeration, which also eliminates odors and allows high nutrient loading of the influent water. In colder climates, other very high productivity plants like duckweed and cattails have also been used. A mix of plants, using cold-resistant plants in the winter and water hyacinths in warmer seasons can also be used.

Experiments to produce biogas using water hyacinths have been conducted by NASA and others. The NASA research indicates that a mixture of plants, for instance, water hyacinths and duckweed, would produce better results, than either alone.[74] Using plants like duckweed may also be desirable in some areas for other reasons. Water hyacinths do not grow in brackish water, but other plants, such as duckweed, do.

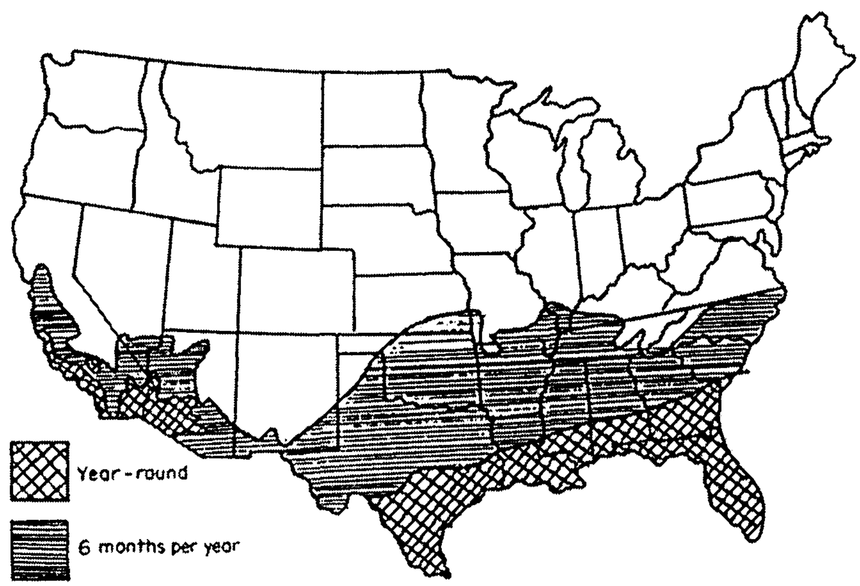
The amount of effort into actually demonstrating the use of high productivity plants has been minuscule – so tiny that it is not on the radar screen of energy policy. Yet, their basic biological and solar energy capture properties indicate that they have the potential to:

- Greatly reduce the land area needed to grow biomass,
- Combine water treatment with very efficient biomass production for use in IGCC systems to produce electricity, hydrogen, or liquid fuels,
- Combine biomass production of various kinds by using water hyacinths, duckweed, etc., in IGCC systems, with the CO_2 effluent being used to cultivate microalgae for liquid fuel production – probably the most efficient combination,
- Provide a source of animal feed, if grown in wastewater that is free of heavy metals,[75]
- Provide the possibility of CO_2 capture from the atmosphere and sequestration of a solid material rather than CO_2 gas, in case negative CO_2 emissions policies are required in the future, and

- Provide the potential in industrial and urban wastewater treatment systems of recovering heavy metals for reuse in the economy.

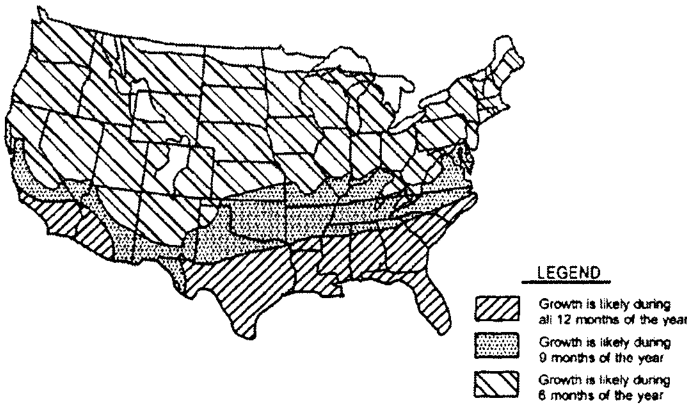
The above list is not presented with the idea that this is some kind of a silver bullet, but to indicate the possible potential of an area that has received almost no attention in energy policy. When properly situated, aquatic plants could, in combination with other approaches, provide a significant portion of the energy supply in environmentally sound ways. Figures 3-13 and 3-14 show the areas where two of the candidate plants can be grown and the length of the growing season.

Figure 3-13: Areas Suitable for Water Hyacinths Systems



Source: EPA 1988 page 50

Figure 3-14: Areas Suitable for Duckweed Systems



Source: Zirschky and Reed 1988. Copyright © 1988 Water Environment Federation: Alexandria, Virginia. Adapted with permission.

The approach needs to be implemented with the sophistication that is possible with large-scale application and with the specific aim of optimizing the various outputs that are possible. The optimization will be different in different areas of the country. In some areas, land use and climatic factors may make the approach unsuitable locally. At the same time, if compressing and piping CO_2 for a couple of hundred miles is seen as feasible or even necessary for climate protection policy, it is even more worthwhile to explore the piping of wastewater to warm areas to produce clean water and achieve high efficiency solar energy capture in biomass.

G. Some Conclusions about Biomass

Even the above brief survey demonstrates the complexities of biofuel production as well as its immense potential. Some principal conclusions are, however, clear in the context of this report examining the feasibility of a zero-CO_2 economy:

- Food crop based approaches to biofuels requiring heavy inputs are not suitable for large-scale biofuel production if the main aim is to reduce greenhouse gas emissions. They are also not a very good choice due to low net energy output. Moreover, they can and often do create other social and environmental damage that is difficult or impossible to remedy. We will not consider food crops as a source of biofuels for the United States in this book.
- Cellulosic biomass from crop residues may provide a modest fraction of U.S. biofuel requirements, with appropriate cautions, but is unlikely to be a major source, defined as a few million barrels of petroleum equivalent a day, or more.
- Microalgae, used to capture CO_2 from fossil fuel power plants, could make a significant contribution to liquid fuel supply. Microalgae can also be grown in CO_2 captured from solid biomass burning as fossil fuels are phased out.

This technology needs full-scale demonstration. Storage of nighttime CO_2 and additional production of microalgae in the daytime can also be accomplished.

- Grasses can be cultivated on marginal lands in a manner that would not put fuel in competition with food. Their productivity is lower than microalgae, but they have the merit of capturing atmospheric carbon dioxide and can therefore be used in the long-term as part of a negative CO_2 emissions scheme. That is, combustion of biomass can, in principle, be accompanied by CO_2 capture and sequestration. They do not need a special source of CO_2; with appropriate crop selection and rotation, inputs such as fertilizers can be avoided or minimized.
- Aquatic biomass varieties grown in nutrient-rich wastewater, such as water hyacinths and duckweed, have enormous potential due to their high yields (comparable to microalgae). The technologies have been tried but their application for energy production potential has not been demonstrated on a significant scale.

H. Solar Hydrogen

There are many ways to produce hydrogen from solar energy. Many of them involve production of some kind of feedstock, such as glucose or some form of biomass, produced using solar energy. The feedstock is then processed, in some cases with the use of solar energy, to produce hydrogen. Biomass, such as aquatic plants and microalgae, can also be converted into carbon monoxide and hydrogen in a gasification plant similar to those being used in the Integrated Gasification Combined Cycle technology that has been developed for coal. These can then be turned into CO_2, water, and hydrogen, after which the hydrogen is separated from the other gases. Overall, this method is a special application of biomass production for energy.

Hydrogen is produced commercially today for industrial applications from natural gas, of which methane is the principal component. Hence, the same can also be done using landfill gas, which also has methane as its principal constituent (though in lower concentrations than natural gas). However, this would remain a relatively small source of hydrogen, since the source material is not very plentiful relative to energy requirements.

Direct solar hydrogen production methods include:

- Biological hydrogen production, using algae (photolytic hydrogen production)
- Photoelectrochemical hydrogen production – where various inorganic materials are arranged into solar cell type of devices, but instead of producing electricity, they split water into hydrogen and oxygen
- High temperature, solar-energy-driven systems that split water into hydrogen and oxygen, using catalysts.

For the most part, using solar energy to produce hydrogen directly is still in the laboratory stage of study. For photolytic hydrogen production using algae (see Figure 3-15 in color inserts), high efficiencies have been achieved in turning incident light energy into chemical energy, but the hydrogen production rate is still low, making for low overall efficiency. Higher efficiencies have been achieved with photoelectrochemical production and high-temperature catalytic splitting of water.[76]

To compete with gasoline at $3 per gallon, the delivered cost of hydrogen should be about $3 per kilogram (since one kilogram of hydrogen is approximately equivalent in energy terms to a gallon of gasoline). Of the approaches mentioned here, the IGCC approach is perhaps closest to commercialization, since most of the technological development has already been completed. However, the economics of the process will depend in part on the efficiency with which the feedstock biomass captures solar energy. This is the principal determinant of land requirements. Biomass, such as prairie grasses, could be used on a modest scale to produce hydrogen, but the land use implications of growing prairie grasses would not be qualitatively different than producing liquid fuels. Significant work remains to be done in regard to technology development before reliable cost estimates can be made.

The Department of Energy's target efficiency for photoelectrochemical hydrogen for 2010 is 8 percent – that is, the energy content of the hydrogen would have eight percent of the energy content of the incident solar energy.[77] This is very high efficiency – higher than that of any type of biomass. Further, unlike solid biomass, hydrogen can be used directly in internal combustion engines. High temperatures generated by solar concentrators can also be used to produce hydrogen and show promise of high efficiency. The DOE's target for the year 2015 is a cost of $3 per kilogram, which would be competitive with gasoline at current prices (July 2007).[78]

Direct hydrogen production methods, notably the photoelectrochemical and high temperature splitting of water have the potential to greatly reduce land requirements for a renewable energy economy relative to the reference scenario. This is one reason that one or both of these methods, and possibly others that can have comparable efficiencies of hydrogen production (five percent or more) can provide the basis for a partial hydrogen economy.

A mixture of biofuels produced with high efficiency and direct solar hydrogen production, with as large a component of the latter as possible, would be a preferred way of achieving a renewable energy future with the low environmental impacts relative to other biofuel scenarios. This is because the composition of most liquid biofuels is similar to that of petroleum-based fuels in that they consist of hydrocarbons. Burning them therefore would still raise pollution issues of unburned hydrocarbons, carbon monoxide, nitrogen oxides, and in some cases particulates as well. While all of these have been and can be further reduced, the use of hydrogen completely eliminates all but some nitrogen oxide emissions. Further, direct solar hydrogen production does not involve such air emissions in its manufacture. Therefore, in terms of urban air quality and the reduction of emissions from industry, hydrogen made directly from solar energy is a preferred energy source and should be developed.

I. Wave Energy

While the potential for generating electricity from the motion of waves is nowhere near as large as that of wind or solar energy, it could be an important source in some coastal areas. In contrast to offshore wind, which has faced considerable opposition in some areas, such as Cape Cod, Massachusetts, due to the high visual profile of the towers, the profile of wave generators is very low – they float on the surface of the water. Another advantage is that wave energy is more steady and forecastable, so that there is less of an issue with intermittency than there is with wind energy.

A study by the Electric Power Research Institute concluded that Hawaii, Oregon, northern California, and Massachusetts would likely be the first areas that could achieve economics on a par with wind energy. In contrast to the latter, wave energy is still in the early stages of large-scale demonstration. The potential is considered to be in the tens of thousands of megawatts.[79] In this study we assume that it will be included under the rubric of "geothermal and other" energy supply estimates in the future.

J. Hot Rock Geothermal Energy[80]

After the 1973 energy crisis, many energy research projects were initiated at the national laboratories, besides the establishment of a dedicated laboratory, now known as the National Renewable Energy Laboratory.[81] One of the most important projects, potentially, was one to investigate the feasibility of tapping the heat in high temperature rocks in some geologic formations for generating electricity. The project was carried out at Los Alamos National Laboratory for about two decades but closed down in the 1990s.

Two great advantages of hot rock geothermal technology (known more formally as "Extended Geothermal Systems" (EGS)) are (i) that it can provide baseload power, and thus be a critical part of reducing reserve or storage requirements in a system with intermittent sources and (ii) that it is far more widely available than conventional hydrothermal geothermal energy. The latter consists of water that is heated deep in the earth that can be brought to the surface and flashed into steam to drive a turbine. It is an important regional resource, for instance, in California. But it is far more limited than the heat in rocks at depths of 3 to 5 kilometers (10,000 to 16,500 feet). If this heat can be tapped for power production, geothermal energy could become a much greater energy resource. The main idea behind hot rock geothermal energy is to inject fluids into fractures in the hot rock zone and then pump the heated fluids back to the surface where they are then used to generate electricity in a manner similar to the way hot geothermal water is used today.

Deep drilling technology, developed among other things for oil and gas production, can be used in producing hot rock geothermal energy. However, much research, development, and demonstration remains to be done in every area from drilling to reservoir management to power production. An expert panel reviewing the technology has recently (2006) concluded that

> A cumulative capacity of more than 100,000 MWe from EGS can be achieved in the United States within 50 years with a modest, multiyear federal investment for RD&D in several field projects in the United States.[82]

For reference, 100,000 MW is approximately equal to the installed capacity of nuclear power plants today. This is an especially significant amount of power in any context, including that of the present study due to its ability to provide baseload generation. IEER's reference scenario assumes that about one-fourth of this amount will be developed as baseload capacity by 2050, with the first large plants coming on line in the 2020-2030 decade.

K. Energy Storage Technologies

Given the large part that wind and solar energy will play in a renewable energy economy, storage technologies will be critical to the reliable functioning of the electricity system. At present, with low penetration of these two sources, no storage is necessary since reserve capacity can be supplied in other ways. For instance, as we have noted, the excess capacity of natural gas-fired power plants can serve as a standby for wind, and it can also serve the same purpose for central station solar power plants. The Luz International central station solar thermal power plants have the capacity to burn natural gas at night to supply around the clock energy.[83] A new installation of that type would likely not need such a capability. It would probably be cheaper to have a contractual arrangement with an existing natural gas fueled combined cycle power plant operator to provide the needed energy in the evening hours.

However, in the final analysis, natural gas cannot continue to serve this function (except as a contingency) if fossil fuels are to be phased out (leaving aside, for the moment, the potential for CO_2 sequestration). We have already mentioned the possibility of heat storage in various media, such as concrete, in the context of central station solar thermal generation. We will not discuss it further here. Rather, we take up three other storage technologies:

1. Batteries
2. Capacitors
3. Compressed air

In addition to these sources, we assume that existing reservoirs and hydropower stations can be managed to complement wind energy by limiting their use to periods when the wind is not blowing but the electricity demand is still present.[84] We recognize that there are considerations other than electricity generation in the management of dams and reservoirs, such as irrigation, flood control, or endangered species protection. Combining solar, wind, hydropower, and combined cycle natural gas-fired power plants into a single system that is optimized could provide the added flexibility that is needed for multiple uses of water in the reservoirs. With a combination of sources, existing reservoirs can also be used for pumped storage. Some storage issues are discussed in Chapter 5 in connection with demand-side management in the electricity sector.

1. Batteries

Storage of electricity in batteries has been traditionally associated with lead-acid batteries, which are inefficient and heavy, but which have long had the merit of being cheap compared to other batteries. Lead-acid batteries are used, among other things for Uninterruptible Power Supply (UPS) in applications where even small discontinuities in energy supply for a few seconds can be very expensive. Batteries can supply a large amount of power for short periods of time (a virtue that has made them ubiquitous for starting cars). But they are not durable enough to be charged and discharged repeatedly, which is a requirement for electricity storage in a renewable electricity system.

In recent years, a number of new candidates have come into the market, such as nickel-metal-hydride (NiMH) batteries that are used in hybrid cars (such as the Toyota Prius). But these, too, have a very limited storage capacity; moreover, they are expensive. The most promising candidates for large-scale energy storage are new designs of lithium-ion batteries. These are similar to other batteries used in cell phones and many other portable devices. The new varieties do not use carbon, a source of safety concerns (and a reason for the recalls of lithium-ion batteries used in many laptop computers). Lithium-ion batteries with lithium-iron oxide and lithium-titanium oxide electrodes have a number of properties that make them suitable for all-electric cars as well as plug-in hybrids:

1. High storage capacity per unit weight – at present about 100 to 120 watt-hours per kilogram and expected to go up to about 180 Wh/kg (about six times the energy density of a lead-acid battery)
2. Capacity to be charged and discharged 10,000 to 15,000 times without significant loss of performance (applicable to the Altairnano battery)
3. High efficiency of charging and discharging
4. Ability to withstand deep discharge repeatedly
5. Satisfactory performance on safety tests (Altairnano battery)
6. Ability to be charged in a relatively short period of time (10 to 15 minutes) with appropriate heavy-current equipment.[85]

Such batteries have the kind of performance that could make all-electric cars economical in the next decade. The main requirement is that the cost needs to be brought down by about a factor of 5 from the present $1,000 per kilowatt hour of storage to about $200 per kilowatt hour. At the former cost, a car with a range of 200 miles would incur $40,000 in battery cost alone. However, these are still more or less custom-made batteries that do not have high volume manufacturing. The processes to make them are new. It is anticipated that with the kind of process improvements that are normal in manufacturing for a maturing technology and with a large enough scale (tens or hundreds of thousands of cars per year), such a cost reduction should be achievable in the next decade.[86]

The possibility of using passenger and commercial vehicles to exchange power with the electricity grid, and hence for vehicles to serve as an energy storage medium, was first analyzed in a 1997 paper by Kempton and Letendre,[87] according to a University of Delaware research project.[88] Passenger vehicles are usually parked. They are used a very small proportion of the time – typically 5 to 7 percent – creating the possibility of a vehicle-to-grid (V2G) system. Further, utilities could also contract with corporate and governmental owners of fleets of vehicles. These institutions have reliable ways to estimate the patterns of usage of their vehicles, which can then be partly matched to the requirements of a utility.

The installed power of engines in cars and light trucks is well over an order of magnitude more than that of the entire U.S. electric power system. Therefore, only a small fraction of vehicles is needed for energy storage for a vehicle-to-grid system to function reliably. For instance, at 10 kW per vehicle, 10 million vehicles would supply a standby capacity of 100,000 megawatts, the equivalent of 100 large nuclear power plants. Yet, 10 million vehicles would be only about three percent of the total number of vehicles projected for 2050. With fully or partly electric vehicles, a V2G system could store energy during off-peak hours and supply it during peak hours.[89] Or it could supply standby capacity for wind-generation to compensate for its intermittency. As discussed in Chapter 2, the marginal cost, and the implicit CO_2 price, of such a system could be low, if the vehicles themselves are economical.

There are, of course, a number of issues associated with the development and reliable functioning of a V2G system:

1. Will the energy stored in mobile vehicle batteries be available to the grid when it is needed?
2. Is the electricity distribution system robust enough to handle the amount of power that would run through it in a system with a high proportion of intermittent renewable sources?
3. How will the Independent System Operator, who must ensure that the stability of the electricity grid and the demand and supply are matched, communicate with vehicles when they are plugged into the grid and manage the system to ensure the right amount of power exchange to keep the grid functioning at all times?
4. Will the batteries last?
5. How could vehicle users be assured of sufficient charge remaining in their vehicles to be able to use them when they are needed?
6. What about rush hour?

These are critical questions and the feasibility of V2G systems depends on the answers. Yet they are not as daunting as they seem at first. For instance, the kind of satellite communications that have made global positioning systems (GPS) cheap and reliable enough to be available in individual cars can also be used for communicating with vehicles. Cell phone towers could also be used. High frequency signals sent through the electricity grid are also a possibility.

So far as the distribution system is concerned, it may be impractical, at least in the initial stages, to use individual homes as hookup points for V2G systems, though this may not apply to certain kinds of residential developments. For instance, a development in Atlanta was created as a community, with open spaces, a large, leased vegetable plot where locally grown produce is supplied on a commercial basis to residents, etc. One feature of this development is that there are only walking lanes in the community and a parking lot at its entrance. This feature of the community was not created for energy purposes but to make the spaces in the community safe for children and free of cars. But with dozens of vehicles parking in a single area, it would be much more practical to consider installing an infrastructure for exchanging power with the grid or even just for quick charging of plug-in hybrids and all-electric vehicles.

As noted in the section on solar power above, one principal hub of a V2G system could be the parking-lot/rooftop solar system that has V2G infrastructure installed with it. The two can be developed independently, as well. The number of vehicles in such situations could be estimated relatively easily. This is a scale where the installation of the communication with the Independent System Operator could be economical. With a diversity factor between various building and parking lots across a region, planning of power system resources should be possible in a reliable manner. In other words, with sufficient parties participating, the minimum number of V2G vehicles plugged into the grid at any time can be computed with a higher degree of confidence.

As noted above, the first test of a V2G system will be carried out in a collaboration between Google, whose Silicon Valley headquarters has rooftop and parking lot solar PV, and PG&E, the electric utility that serves the area. Google has purchased a plug-in hybrid (a converted Toyota Prius) whose batteries will be controlled by PG&E when it is parked.[90]

The costs of the infrastructure, apart from the batteries, have been estimated for a 5,000 car system at about 0.5 cents per kilowatt hour.[91] There are different estimates of losses for a charging and discharging cycle, which the utility would experience. Tesla Motors cites a value of 86 percent for its battery pack, while Solion, which makes battery systems for racing cars, has stated that the charge discharge efficiency of a single cell is 99 percent. We will assume a 90 percent efficiency for a practical charge-discharge cycle in the year 2050.[92] Since the batteries would be charged off-peak, the cost of electricity losses is on the order of 0.5 cents per kWh or less (with an off-peak electricity cost of five cents per kWh or less). The overall cost of the V2G system would therefore be expected to be one cent or less per kWh plus the payment to the owner of the battery and the parking spot. Overall, the cost of V2G storage of electricity and re-supply to the grid at peak and intermediate load times would be expected to be a little over one cent per kWh if there is sufficient competition to supply the V2G service.

The cost of a V2G system with batteries would be quite large unless the batteries can withstand charging and discharging, without significant deterioration in performance, in excess of the number of times that such charging would be needed for the use of the vehicles themselves. For instance, if a car is charged every 100 miles, the annual number of charges would be typically 150 to 200, which gives a total of 1,500 to 2,000 charges over an expected ten-year life of the vehicle. Typical batteries today can withstand charging a few hundred to 1,000 or 1,500 times. With such batteries, a V2G system would impose battery depreciation costs, which would markedly affect the viability of the system. One reason that V2G has been considered to be feasible in this study is that newly designed lithium-ion batteries now being installed in vehicles have been successfully tested for their ability to endure over 10,000 charging cycles. For instance, the lithium-ion battery with a lithium-titanium oxide electrode manufactured by Altairnano in 2006 has been tested over 15,000 deep discharges with 85 percent capacity still remaining after the tests.[93] This is 15 to 20 times the number of times a typical battery can be discharged and recharged. With such performance, the marginal battery cost imposed by a V2G system is close to zero (though, of course, the owner of the battery would reasonably want compensation for the service provided to the grid). The batteries are being installed in all-electric pickup trucks made by Phoenix Motorcars in 2007.

Lithium-ion batteries, which can be recycled, have also begun to be used in custom conversions of hybrid cars into plug-in hybrids. Hybrid cars use batteries to store energy recovered from braking and deceleration. The batteries store sufficient energy to enable a car to run on electricity only for short distances.[94] The addition of batteries can extend the electricity-only range, which reduces the use of gasoline, increases overall efficiency (since the electric part of the car is more efficient than the gasoline part), and reduces CO_2 emissions. Google's plug-in hybrids have been instrumented for measuring the gasoline and electricity consumption. As of July 8, 2007, the average mileage per gallon of gasoline was 73.6; in addition, the cars used about 0.12 kWh per mile of electricity. Plug-in hybrids using lithium-ion batteries could provide an opportunity for widespread demonstration of V2G technology in the next five years, if governments and corporations decide to purchase them in large enough numbers. Major automobile manufacturers have expressed various levels of interest in plug-in hybrids; some have announced specific models that will be made, but none have announced plans for large-scale production.[95]

2. Capacitors

Like batteries, capacitors store electricity, but they do so differently. Batteries store charge chemically, while capacitors store electrical energy by storing an electric charge on electrodes separated by an insulating material. As with a battery, there is a voltage difference between the electrodes, and the stored energy can be recovered by discharging the capacitor through a load, like an electric light or an electronic circuit. The amount of energy stored is proportional to the square of the voltage difference and the area of the electrodes that store the charge.

Capacitors have some very distinct advantages and disadvantages as energy storage devices. They are very efficient (95 plus percent efficiency is possible) and hence expensive electricity is not wasted in charging and discharging the device. They are also the fastest devices. A capacitor can be charged and discharged in seconds or fractions of a second. Batteries take a long time to charge and even with the most recent advances in lithium-ion batteries, the charging is anticipated to be 10 to 15 minutes with special equipment and several hours when plugged into a residential outlet.

There are a number of reasons why capacitors have not become central features of renewable energy systems. The energy density of even the best capacitors, known as ultracapacitors (or ultracaps, for short) is only 4 to 6 watt-hours per kilogram, compared to five to seven times as much for a lead-acid battery and 30 times as much for a lithium-ion battery. They also use expensive materials. The combination, of course, makes ultracaps bulky and expensive, and therefore unsuitable as the main energy storage device in vehicles. However, the speed of charging and discharging enables such devices to be used where the quality of power is at a premium and space is not – for instance, as voltage stabilizers at times of peak power demand.[96]

Ultracaps can also serve a useful role in electric vehicles and plug-in hybrids. A small ultracap storage capacity can serve the function of storing the energy recovered during regenerative braking and provide the energy for quick starting from a stop. A combination of small capacitor storage and a main battery storage system may make for more durable electric vehicles and better performance; it is in the initial stages of commercial exploration today. One company, AFS Trinity, has announced that it will manufacture an "extreme hybrid" which is a plug-in hybrid that uses a combination of a gasoline engine, batteries, ultracapacitors, and a flywheel to optimize the operation of the car for getting better performance from the batteries and the entire electrical portion of the vehicle.[97] Where weight is not at a premium, as for instance, in stationary storage applications, ultracapacitors could be used in combination with V2G and/or advanced stationary batteries like sodium-sulfur batteries, provided there are significant reductions in cost.

New developments in capacitor technology indicate the potential for these devices to move from a niche role in the energy system to a bigger role in energy storage. Nanotechnology may enable a large increase in the area of electrical charge storage in capacitors without increasing their bulk. Such devices are still being researched in laboratories and it is by no means assured that the indicated promise can be realized technically or, if it is, that the economics will be favorable. But that promise is important in the context of a renewable energy system.

Specifically, nanocapacitors (also called supercapacitors) have the potential to increase the energy density of capacitors 30 to 60 watt hours per kilogram.[98] While such capacitors would still be too heavy for most vehicular applications, they could serve as the basis for energy storage in small-scale renewable systems or as complements to a V2G system if they were cheap enough. That is a lot of ifs, and the potential may not be realized. This report does not rely on this technology in its scenarios. However, we have identified this as a research and development priority because the characteristics of nanocapacitors could enable a more efficient functioning of electric power grids and small-scale renewable energy systems.

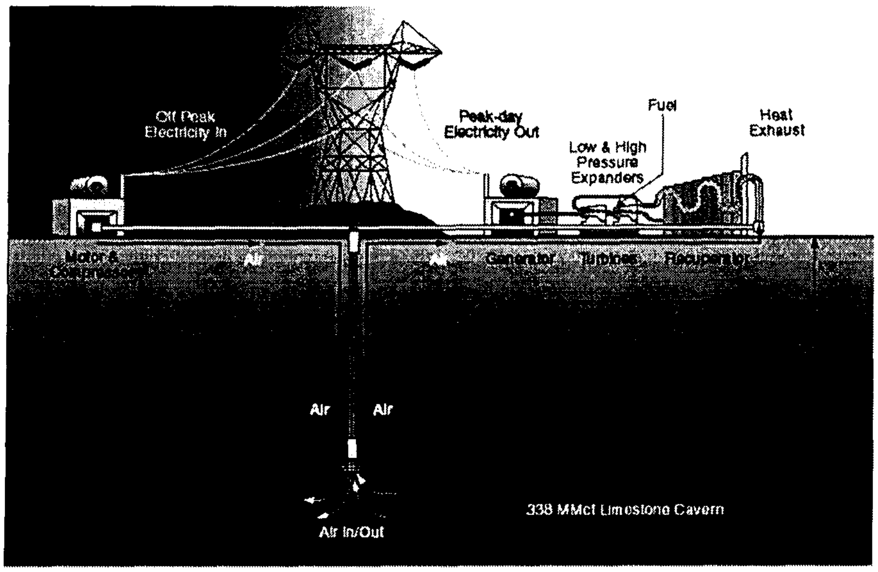
Batteries can also be used for stationary storage. Specifically, the sodium-sulfur battery, which is bulky and unsuitable for transportation applications, can be used to store off-peak power generated by wind turbines.

3. Compressed Air Storage

Compressed air storage involves using off-peak electricity to compress air and store it in a large underground cavern, which could be a pre-existing cavern or one mined specifically for the purpose. At times of peak demand, the compressed air is withdrawn from the cavern, heated using natural gas, and used to operate a combined cycle plant. The advantage of this technology within this framework is that it can reduce the amount of expensive natural gas used per kilowatt hour and, in its place, use whatever fuel is available more cheaply at off-peak times. Design storage pressure can range from 1,100 to 1,500 pounds per square inch.[99]

The usual context for the use of compressed air storage in electrical power applications has been when cheap coal-fired capacity is used in the off-peak hours to compress air, but the approach can equally well be used for large-scale wind energy applications. There is less merit in this technology for central station solar technology, because solar energy already generates energy during peak or intermediate times. However, it may be useful for some hours of storage to provide electricity during the immediate post-sunset hours when electricity demand is still relatively high. Figure 3-16 shows a schematic of a compressed air energy storage system described above.

Figure 3-16: Compressed Air Energy Storage Schematic



Source: Sandia National Laboratories

There are compressed air plants of medium size – one in Huntdorf, Germany (290 MW) and one in McIntosh, Alabama (110 MW). Both plants use salt caverns that were solution mined specifically for the purpose of providing compressed air storage for these facilities. The McIntosh plant has been in operation since 1991. It uses off-peak electricity to compress air and inject it into a compressed air storage cavern, and single stage natural gas turbines for on-peak power. Its cavern is 10 million cubic feet. Its nominal energy balance per kWh of peak output is as follows:[100]

- Off-peak use of 0.82 kWh of electricity from the grid to compress air – if this is coal-fired capacity, the fuel input would be 8,200 Btu.
- On-peak recovery of compressed air which is heated with 4,600 Btu of natural gas
- The combined result is 1 kilowatt hour of electricity during times of peak load takes 12,800 Btu of energy but 8,200 of that is cheap coal.

The overall energy balance is about the same as generating peak power with a single stage gas turbine. The result in the Alabama case is lower fuel cost but larger CO_2 emissions. At $7 per million Btu for natural gas and $1.25 per million Btu for coal, the cost of fuel is reduced by about 4.7 cents per kilowatt hour overall with the compressed air system. But the CO_2 emissions increase from about 680 grams per kilowatt hour for the single stage turbine to about 1,030 grams per kilowatt hour, an increase of about 350 grams emissions per kilowatt hour.

However, the same system can be deployed quite differently in the context of a goal of reducing CO_2 emissions. Specifically, compressed air storage can be used to store off-peak wind energy and displace single stage turbine use of natural gas. Since wind energy has essentially zero-CO_2 emissions (to a first approximation), the use of compressed air to displace single stage turbine use of natural gas with the same parameters as above (0.82 kilowatt hour of off-peak electricity and 4,600 Btu of on-peak natural gas) results in a net reduction of about 440 grams of CO_2 per kilowatt hour generated at peak, compared to using a single stage gas turbine without compressed air storage. A wind energy power plant combined with compressed air storage is being planned in Iowa.[101] In the long-term, that is, beyond 2030 or 2040, the natural gas can be replaced by methane made from biomass.

A great deal of optimization of large-scale wind, solar, and storage systems, including, possibly, compressed air systems would be necessary to arrive at a sound estimate of an economical combination of generation capacity (assuming only wind and solar were available) and compressed air storage. When one considers that baseload capacity in the form of geothermal energy and biomass fueled power plants will be part of the generating system in a zero-CO_2 economy, the scale, or even the necessity of compressed air systems that would be needed, is not clear. Since it is desirable for the electricity supply system to evolve as rapidly as possible in the direction of a reliable system based on renewable energy sources, further development of compressed air storage provides an important element of flexibility in actually achieving the goal.

L. Long-term Sequestration of CO_2

Coal used for electricity generation accounts for about one-third of U.S. energy sector emissions of CO_2.[102] The gravity of the global warming crisis has caused a considerable study of the technologies for capturing and sequestering CO_2 in underground or undersea geologic formations. A brief overview description of the approach is provided by Wilson, Johnson, and Keith:

> Geologic sequestration is accomplished by injecting CO_2 at depths greater than ~1 km into porous sedimentary formations using drilling and injection technologies derived from the oil and gas industry. The technology required to inject large quantities of CO_2 into geological formations is well-established. Industrial experience with CO_2-enhanced oil recovery (EOR), disposal of CO_2-rich acid gas streams, natural gas storage, and underground disposal of other wastes allows confidence in predictions about the cost of CO_2 injection and suggests that the risks will be low. Once injected, evidence from natural CO_2 reservoirs and from numerical models suggests that CO_2 can – in principle – be confined in geological reservoirs for time scales well in excess of 1000 yr and that the risks of geological storage can be small.[103]

The caveat "in principle" is important. As is generally recognized, a considerable amount of field research and development has to be done before the caveat can be removed and sequestration pursued with the necessary confidence that almost all of the confined CO_2 will remain confined for the long-term and that the potential for accidental large releases is acceptably small. A broad debate on the levels of demonstration that would be needed for widespread deployment has not yet happened.

In general, the types of geologic media that could hold large amounts of CO_2 are understood from prior experience, much of which derives from knowledge accumulated in the course of more than a century of oil and gas development and production. But it is necessary to have extensive measurements of leakage rates and rates of reactions of gaseous CO_2 with the surrounding geologic media to form solids in order to develop reliable models of long-term performance and estimate uncertainties. Figure 3-17 shows various methods of CO_2 sequestration (see color insert).

Saline reservoirs where CO_2 can form carbonates are considered to be among the most promising sequestration media. Such reservoirs also happen to be present in coal rich areas in the West, for instance, in Utah. A recent study by the Utah Geological Survey mapped the potential reservoirs in relation to existing sources of power plant CO_2 emissions. According to this study, the geologic formations "indicate [that] natural, long-term storage of carbon has occurred as precipitated carbonate minerals (mineral trapping) as well as by hydrodynamic trapping of gas and dissolved CO_2 in the pore water."[104] The potential for sequestration is indicated by the fact that about 100 million tons of CO_2 are generated by power plants close enough for the CO_2 to be piped into available geologic formations.

Modeling found that storage occurred in the gaseous, liquid, and solid phases. However, the solid precipitate is slow to form, so that containment of gaseous storage for several hundred years must be assured:

> The modeling suggests that there is ample storage in geologic structures beneath the Colorado Plateau, but a critical factor is whether the reactions that precipitate CO_2 have time to occur.
>
> These reactions typically require time scales of hundreds of years, so subsurface trapping for at least 500 years is essential. If major, high permeability faults are present, then loss of CO_2 to the surface could make the injection site unsuitable for CO_2 sequestration.[105]

The Utah Geological Survey model indicates that even after 1,000 years, the CO_2 would be well contained.

Much work remains to be done both in terms of commercialization of CO_2 capture and sequestration. The demonstration that the degree of containment required will endure for long periods of time will take considerable effort. At present not enough data are available for a confident conclusion. Yet, the scale of the use of coal in the United States and abroad is such that the development of the technologies and their demonstration is critically important.

In this study, the development of CO_2 sequestration is regarded mainly as a hedge – an element of flexibility that should be developed because:

- Coal is in widespread use and its use is likely to continue for some time
- Sequestration of CO_2 from biomass burning can provide for the negative CO_2 emissions that may become necessary if the actual impact of greenhouse gas emissions is greater than now projected
- Our approach to zero-CO_2 without nuclear power requires many different new technologies to work together and difficulties that are hard to foresee may arise, for instance, in the large-scale use of biomass or in the development of hot rock geothermal technology.
- Sequestration may also become very important if it is found necessary to remove CO_2 from the atmosphere beyond zero-CO_2 emissions. In view of these considerations, the vigorous development of IGCC technology, CO_2 capture and sequestration is part of our recommendations, but actual continued reliance on coal and large-scale use of sequestration is not.

CHAPTER 4: TECHNOLOGIES—DEMAND-SIDE SECTORS

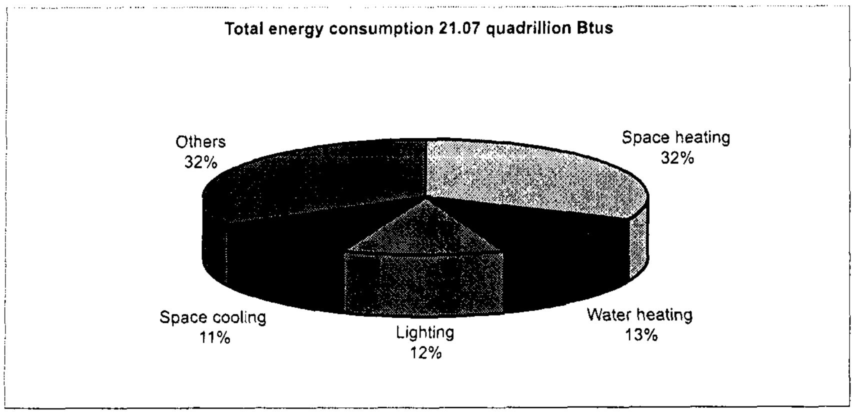
Here we take up the technologies and approaches in the energy consuming sectors – residential and commercial (considered together, since they are dominated by similar end uses), transportation, and industrial. Our analysis on the demand-side is first on the basis of delivered energy – that is energy that is actually used at the consuming site or in the consuming sector. The energy losses in electricity generation are separately considered.

A. Residential and Commercial Sectors

Residential use of energy is dominated by space heating, water heating, and space cooling (air conditioning). Figure 4-1 shows the energy use in the residential sector in 2004 – and these three end uses accounted for 56 percent of the total. But 46 percent of the total use of 21.07 quadrillion Btu was actually lost, discharged as waste heat at power plants, leaving just over half, 11.46 quadrillion Btu delivered to end users (Figure 4-2). On the basis of delivered energy, space heating, water heating, and space cooling combined dominate residential energy use, accounting for 71 percent of it.

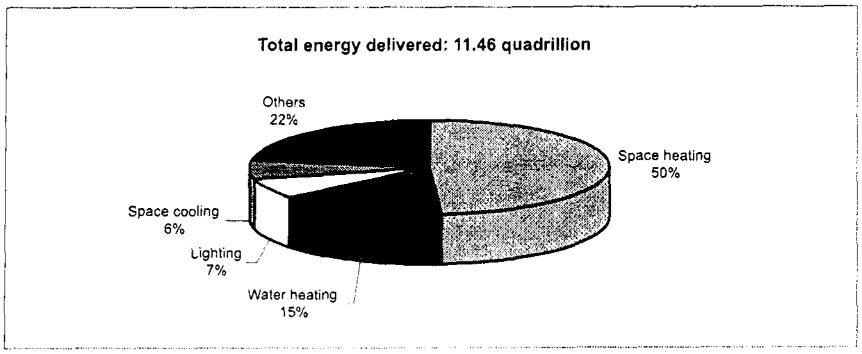
Actually, a great deal of the delivered energy used for space heating is also wasted due to poor design of buildings and inefficient space heating systems. Therefore, most of the delivered energy used for space heating is wasted at the point of use. The same is true of water heating, since very high quality sources of energy, like natural gas and electricity, are used to produce hot water at very low temperatures. Most of the potential of the energy to do work is wasted when it is used for low temperature applications, for which other approaches such as solar water heating, are much more efficient.

Figure 4-1: Residential Sector Energy By End Use: Total Energy, Including Electricity Sector Losses, 2004.



Source: EERE 2006 Table 1.2.3 (page 1-6)

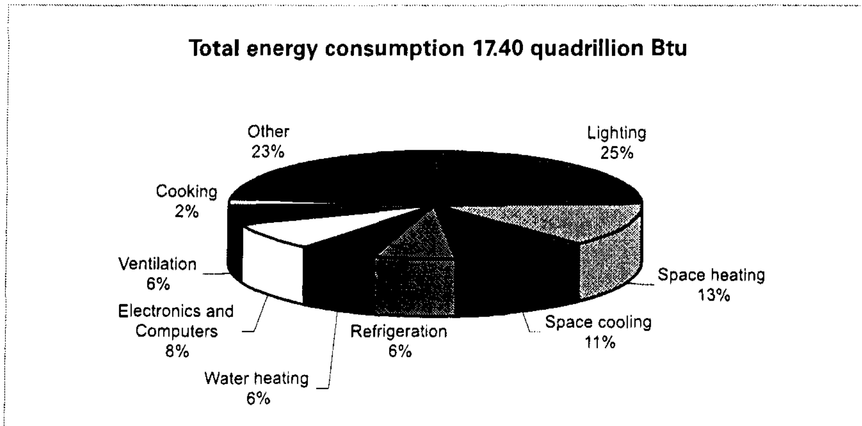
Figure 4-2: Residential Sector Energy By End Use: Delivered Energy, 2004



Source: EERE 2006 Table 1.2.3 (page 1-6)

The pattern is somewhat different in the commercial sector in that lighting is the largest single end use and water heating is not as important when losses in electricity generation are included (see Figure 4-3). This is, of course, to be understood in the context of offices, shops, etc., having a large lighting demand. Lights also heat up the air, increasing air-conditioning demand in the summer. In the winter, lighting reduces heating demand for the same reason. As a result of these factors, electricity use is high in the commercial sector and more than half (52 percent) of the energy use of 17.4 quadrillion Btu is discharged as waste heat at power plants. When only delivered energy is considered, space heating is the largest end user (Figure 4-4), but, as in the residential sector, a lot of that delivered energy is wasted in inefficient building design and heating systems.

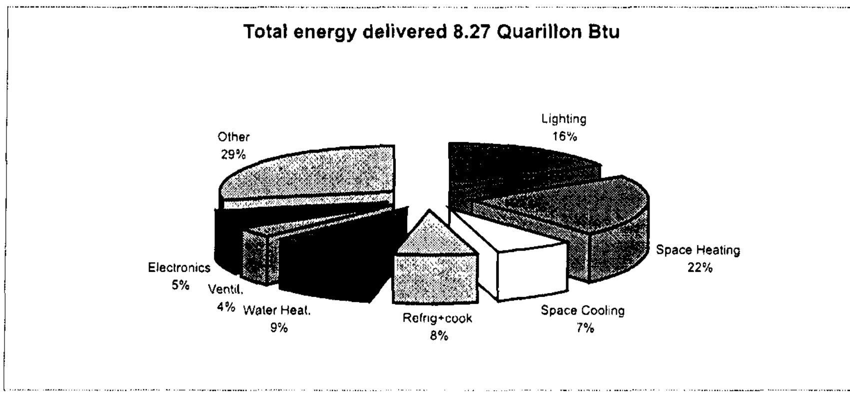
Figure 4-3: Commercial Sector Energy By End Use: Total Energy, Including Electricity Generation Losses, 2004



Source: EERE 2006 Table 1.3.3 (page 1-10)

Efficiency in lighting is critical to the performance of the commercial sector. Including delivered energy plus waste heat in electricity generation, lighting is 25 percent of the total commercial sector energy use. When only the delivered energy is counted, lighting is only about 16 percent of the total.

Figure 4-4: Commercial Sector Energy By End Use: Delivered Energy 2004



Source: EERE 2006 Table 1.3.3 (page 1-10)

The performance of the average building in the residential and commercial sector can be classified as dismal compared to available technology and design concepts, even leaving aside use of renewable energy sources. The main design components and concepts have been known for some time:

- Excellent insulation
- Optimal thermal mass, designed for the climate – that is, a building that can

store sufficient heat on sunny winter days to be able to keep the home warm at night and on the next day if it is cloudy, but not so large that it would become too hot on consecutive sunny days
- Windows of sufficient area that let in heat and light in the winter – for starters, preferentially south facing (in the United States) – and can be shaded in the summer if necessary
- Very efficient lighting, appliances, and space heating and cooling systems.

If a solar water heating system is added to such features, most of the fuel requirements of residential buildings can be eliminated. The rest can be supplied in a variety of ways, depending on the overall cost of various energy sources and the policies in place at any time. Increasing lighting efficiency and use of sunlight directly and via special luminaires are especially important in the commercial sector. The actual achievement of excellent performance, within the parameters of a given set of energy prices and policies, will not always be reached, but it is worthwhile to examine what has been accomplished by sound design across the United States.

Below we describe two kinds of newly built residences, in two different climates. We compare the level of energy used in each of these buildings to the U.S. averages. One is a single family home in New Hampshire (Hanover House). The other is a multi-family apartment building with 43 units in Washington, D.C. (Takoma Village).[1]

The Hanover House in New Hampshire has a solar thermal water heater that provides both space heating and water heating. It has an electric hot water heater element that supplements the solar heat. There is a large storage tank. The use of solar heat keeps the electricity requirements for heating to a minimum. (Passive solar design by contrast uses the structure of the house to absorb heat, special windows, etc.). Its energy design features are as follows:

- **"Wall Insulation**
  Achieve a whole-wall R-value greater than 25
- **Solar Cooling Loads**
  Orient the building properly
  Locate garages and porches on the east and west sides of the building
- **Heating Loads**
  Site the building for southern exposure
- **High-performance Windows and Doors**
  Use superwindows with a whole-unit U-factor less than
  0.25 (greater than R-4.0)
  Avoid divided-lite windows to reduce edge losses
- **Heating Systems**
  Use active solar heating

- **Air Infiltration**
  - Use continuous air barriers
  - Seal all penetrations through the building envelope
- **Computers and Office Equipment**
  - Use Energy Star computer equipment"[2]

The only purchased energy input is electricity. Over a three year period, electricity consumption ranged from 4,250 to 5,560 kilowatt hours per year. The overall use of delivered energy was only about 8,300 Btu per square foot compared to about 58,000 Btu per square foot for the U.S. average in 2004.[3] The total energy, including electricity losses, was about 25,000 Btu per square foot for Hanover House compared to 109,000 Btu per square foot for the U.S. average. Overall there is about a factor of seven difference in the end use energy and more than a factor of four difference in the total energy.

Note that a 3 kilowatt solar PV system would be sufficient to convert this house to a zero net energy system. In that case, total energy would be reduced by a factor of 13 compared to the present residential average. Zero net energy homes with very low energy use have been built. An example in Arcata, California uses a geothermal heat pump, efficient building design and appliances, solar cooking (for 1/3 of the total cooking), and a 3 kW peak solar PV system.[4] Measured data over a four-year period show a small net electricity output (generation greater than consumption by 0.05%). Total electricity usage, including heating and appliances averaged only about 3,400 kWh per year.

A similar pattern emerges for multifamily housing. Note that Takoma Village Cohousing was a nearly completely commercial project, other than a $5,000 tax credit for first time home buyers among the residents. Washington, D.C. is hot and humid in the summer and moderately cold in the winter. Heating and cooling is provided by an earth-source heat pump (also called a geothermal heat pump). This gathers energy from the ground in a fluid that circulates in a buried pipe, which greatly increases the efficiency of the heat pump. A simple payback time of 9.5 years was estimated for the heat pump system.

The energy design features are:

- **"Wall Insulation**
  - Minimize wall area through proper building massing
  - Achieve a whole-wall R-value of 15 or greater
  - Use spray-applied insulation in cavities with many obstacles or irregularities
- **Ground-coupled Systems**
  - Use ground-source heat pumps as a source for heating and cooling
- **Solar Cooling Loads**
  - Use light-colored exterior walls and roofs
  - Minimize number of east and west windows
  - Shade south windows with overhangs

- **Daylighting for Energy Efficiency**
  Use light pipes and/or active tracking skylights for daylighting

- **Non-Solar Cooling Loads**
  Reduce internal heat gains by improving lighting and appliance efficiency

- **Cooling Systems**
  Size cooling equipment appropriately
  Keep cooling equipment, especially air handlers and coils, in conditioned space

- **Foundation Insulation**
  Use slab perimeter insulation with an insulating value of R-11 or greater

- **High-performance Windows and Doors**
  Use windows with a whole-unit U-factor less than 0.49 (greater than R-2.1)

- **Heating Systems**
  Keep heating equipment in conditioned space

- **Luminaires**
  Use high-efficiency luminaires

- **Air Infiltration**
  Keep all mechanical, electrical and plumbing systems within the air and vapor barriers
  Perform blower door testing

- **HVAC Distribution Systems**
  Seal ducts
  Keep duct work out of unconditioned space

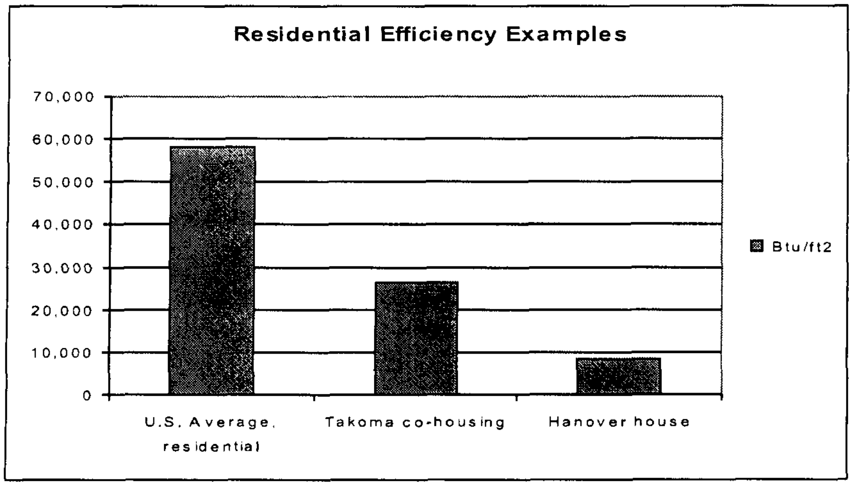
- **HVAC Controls and Zoning**
  Use seven-day programmable thermostats"[5]

The total end use energy was 26,300 Btu per square foot, with 21,100 of that being purchased electricity and the rest natural gas, compared to 58,000 Btu per square foot for the national average in 2004. Total energy use including electricity losses was 69,000 Btu per square foot, compared to the national average of 109,000 Btu per square foot.

A reduction of 60 to 80 percent in delivered energy (which is the point of reference here since the electricity supply system can change substantially) is easily possible in new construction. The technologies are well established.

Figure 4-5 compares the delivered energy use per square foot for the average U.S. house with the two examples discussed above.

Figure 4-5: Comparison of Two Efficient Homes with the U.S. Average Residential Energy Use (2004), Delivered Energy, Btu per Square Foot



Source: IEER

The inefficiencies in the commercial sector are similar. For instance, the end use energy at the Durant Road Middle School in Raleigh, North Carolina, is about 25,000 Btu per square foot, and the total including thermal losses in electricity generation is 42,000 Btu per square foot. The comparable national averages are 103,000 Btu per square foot and 217,000 Btu per square foot respectively – differences of about a factor of four and five respectively. The design features responsible for the better energy efficiency were:

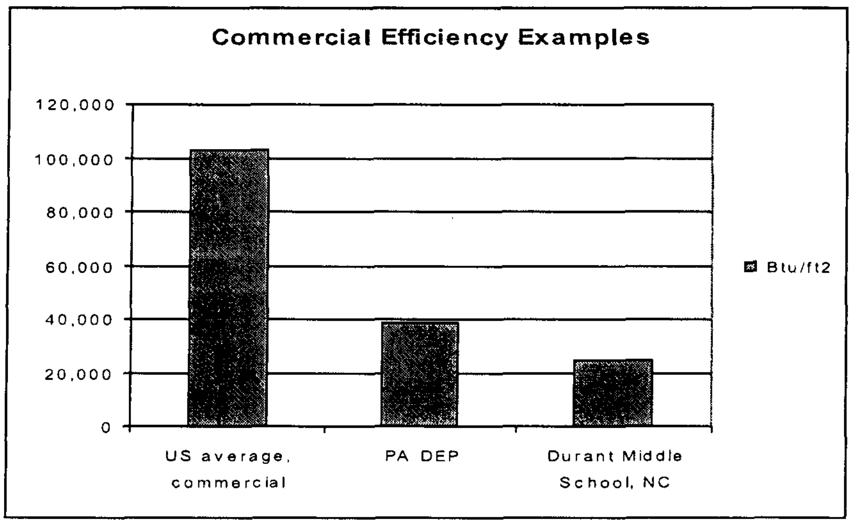
- "**Solar Cooling Loads**
  Orient the building properly
- **Daylighting for Energy Efficiency**
  Use south-facing windows for daylighting
  Orient the floor plan on an east-west axis for best use of daylighting
  Use north/south roof monitors and/or clerestories for daylighting
- **Interior Design for Light**
  Use light colors for surfaces and finishes
- **Light Levels**
  Use light levels appropriate for different tasks
- **Light Sources**
  Use high-efficacy T8 fluorescent lamps
- **Lamp Ballasts**
  Use automatic-dimming electronic fluorescent lamp ballasts in conjunction with daylighting

- **Luminaires**
  Use high-efficiency luminaires
- **Lighting Controls**
  Use on/off photoelectric daylight sensors"[6]

It is interesting to note that nearly all of the above features relate to lighting. Indirectly this would also reduce cooling loads and improve efficiency in the summer.

Consider an office building as another example: the Pennsylvania Department of Environmental Protection's Cambria Office Building in Ebensburg. It is an all-electric building with an earth-source heat pump. The end use energy is about 40,000 Btu per square foot, including 1,610 Btu per square foot of solar PV. In addition to its efficient heat pump and active solar energy, its design features include efficient lighting, insulation, high performance windows, etc.[7] For the commercial sector, it also appears possible, with existing design features, to reduce energy end use per square foot by three to four times compared to the present average. And neither example we have cited includes the use of combined heat and power. As with the residential sector, the technologies are well established. Figure 4-6 compares average energy use per unit area in the commercial sector with the examples discussed above, based on delivered energy.

Figure 4-6: Comparison of Two Efficient Commercial Buildings with U.S. Average Commercial Energy Use (2004), Delivered Energy, Btu per Square Foot



Source: IEER

The inefficiencies in the residential and commercial sectors provide key examples of the large-scale failure of the market and the resultant excess greenhouse gas emissions. A principal problem is that the developers generally do not pay the energy bills. This is called a "split incentive" barrier. The developer has an interest in the lowest capital cost possible compatible with building codes and sales strategy, while the occupants paying the bills have an interest, at least in theory, in the lowest overall annual operating cost (capital and energy bills combined). We will address this problem for new and existing buildings in Chapter 7.

It is worthwhile to mention some potential savings in appliances besides the well known potential in refrigerators and lighting. For instance, standby power consumption in a variety of devices like TVs and DVD players has grown to 600 kilowatt hours per household per year. These could be reduced to 200 kilowatt hours using 1 W or less standby systems.[8]

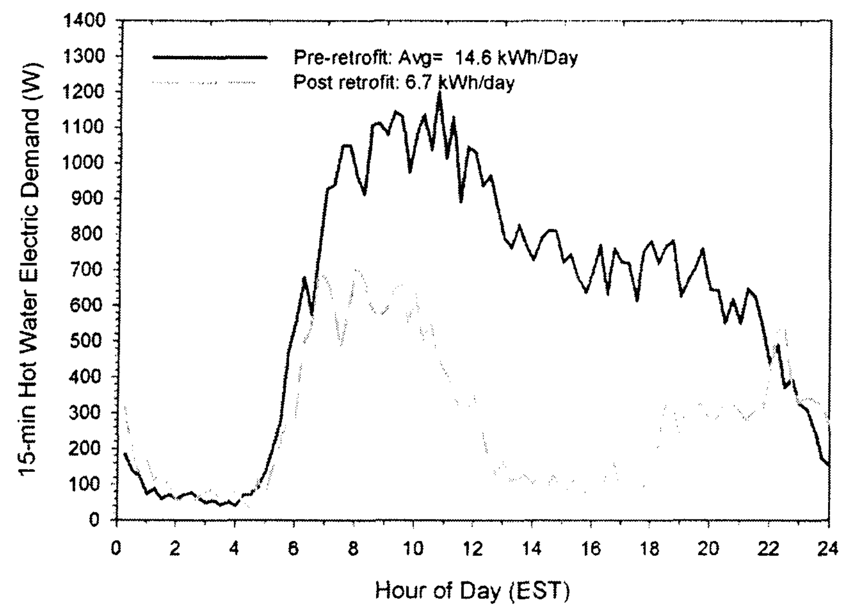
Backfitting, or retrofitting, existing homes is generally more complex than incorporating energy efficiencies in new buildings at the time of construction. Nonetheless it has been shown that many backfits can save energy and money when carried out properly. Consider, for instance, the case of a housing project of single-family houses for low-income households where backfits, such as better insulation and windows, were installed. There are measured data for this case, so that both energy performance and cost effectiveness were verified. The eight houses in this case study were in Florida.[9]

Backfits had short payback times. The shortest was one year – associated with cleaning refrigerator coils. Other measures – low flow showers, compact fluorescent lighting, and return duct sealing had payback times between 3.3 and 3.7 years. One house was backfitted with a solar water heater. This yielded the largest energy savings – 1,960 kilowatt hours per year. The payback time was estimated at 10.2 years. The electricity price used was a fixed rate of 8 cents per kilowatt hour.

A look at the change in the load profile, which is variation in the electricity demand over time, due to the solar hot water heater indicates that the economics would be dramatically different. Figure 4-7 shows the change in the load profile of the house backfitted with a solar water heater as measured between 1996 and 1998. There was a drop of about 500 watts in the peak load of the water heater. The solar water heater actually resulted in a reduction in load at most times of the day except for the period between 10 p.m. and 6 a.m. These are not the times of peak load for the utility, which are normally in the middle of the day or the early evening hours. Hence, there is a net benefit to the overall system that should be reflected in the costing of the program.

Another important result of the case study was that the payback time for the solar water heater installation in a new home was about the same as backfitting an existing home. However, the payback time was generally much lower for other devices if they were installed at the time of house construction. The biggest difference was the case of taping the duct system, which is much more laborious to backfit. Still, the payback time for a backfit was a respectable 3.6 years. When done properly in the first place, the payback time was only 0.7 years. These measured data, while sparse, are quite consistent with policies of building low-income housing to stringent efficiency standards and of backfitting existing housing so as to improve efficiency.

Figure 4-7: Load Profile of a Electric Water Heating System Without and With a Solar Water Heating Supplement



Courtesy of Florida Solar Energy Center. Source: Parker, Sherwin, and Floyd 1998

Lighting

Incandescent bulbs, which are still by far the most common type, typically convert two to three percent of the electrical energy input into visible light. This means that their efficiency on the basis of fuel input for electricity production is about 1 percent. This is because about two-thirds of the fuel input to coal and nuclear plants is discharged as waste heat at the power plant and the other one-third is converted to electricity and transmitted to the user. Compact fluorescent bulbs, which have been commercially available for some time, are about three to four times as efficient as incandescent bulbs and last much longer. One disadvantage is that, like other fluorescent bulbs, they contain mercury and the disposal problem has yet to be systematically addressed.

Emerging technologies beyond the compact fluorescent lamp have the potential to further reduce lighting energy use. Two examples are:

- Hybrid solar lighting: This technology uses optical fibers, which transmit sunlight from the outdoors to the insides of a building. They are in effect solar light pipes and conduct light much as a copper wire conducts electricity along its length with little leakage out the sides. A four-foot diameter solar concentrator on a rooftop that focuses light on a bundle of optical fibers is sufficient to provide light to about 1,000 square feet of indoor space at the height of a sunny day. The light pipes are part of lighting fixtures that also have electric lamps. As available sunlight increases or decreases, electronic sensors automatically adjust the light output of the electric lamps so as to keep overall light intensity constant.[10] The system was developed at Oak Ridge National Laboratory. It is being field tested in offices and large retail stores.[11]
- New LED lighting has an efficiency of 80 lumens per watt,[12] which is double that of compact fluorescent lamps.

One can anticipate that with such technologies, combined with motion detectors and photoelectric switches, electricity demand for lighting per unit area in many parts of the commercial sector might be reduced by about 80 percent (possibly more in some cases) in the next two decades. Electricity for residential lighting could be similarly impacted, notably since incandescent bulbs are still by far the most common in this sector.

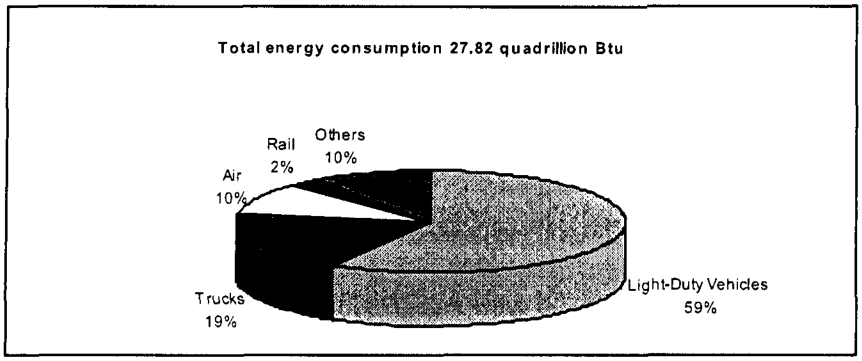
B. Transportation

Figure 4-8 shows the end use pattern in transportation for 2004. Personal (light duty) vehicles and trucks are nearly four-fifths of the total and aircraft represent another 10 percent. The remaining ten percent miscellaneous set of items, while small, is critically important, since it includes everything from pipelines that transport oil and gas to barges that transport food grains to intra- and inter-city buses. Almost all the energy use in the transportation sector is supplied by petroleum. A tiny amount consists of electricity.

The problem of poor efficiency of personal passenger vehicles is well known – it arises from a combination of preferences for large vehicles on the part of consumers and aggressive marketing of such vehicles by manufacturers. While gasoline and diesel prices have fluctuated a great deal, the peaks that cause consistently high consumer demand for more efficient vehicles have not been sustained in the past.

We have already discussed electric cars and plug-in hybrids in the review of batteries, notably lithium-ion batteries (Chapter 3). The main problem at this stage appears to be large-scale manufacture and process improvements within the framework of the innovations that have already been tested and used in new vehicles, such as the Tesla Motors racing car, 0 to 60 in four seconds, the Phoenix Motorcars' pickup truck and planned SUV, as well as plug-in hybrids.[13] We assume that, with the right incentives, electric cars will become the norm in a reasonable time – twenty to thirty years. In the interim, we assume that plug-in hybrids will take a significant share of the institutional and then commercial markets, due to rising efficiency requirements, cost of fuels, and government and corporate procurement of advanced vehicles.

Figure 4-8: Transportation Sector Energy By End Use, 2004



Source: EIA AEO 2006 Table A7 (page 145)

In this section on transportation technologies, we focus on fuels for jet aircraft (the predominant type of aircraft) and on the efficiency of public transportation.

1. Fuel for Jet Aircraft

For a zero-CO_2 economy, there are two basic approaches for replacing specially formulated kerosene (JP-8), which is the present fuel for jet aircraft. One can use biofuel feedstock to produce liquid biofuels, like biodiesel or ethanol or biofuel equivalents of liquid petroleum gases. Aircraft can also use fuels that are gases at room temperature provided they are liquefied. This requires cooling them to cryogenic temperatures. The fuels that have been studied are liquefied natural gas (LNG) and liquefied hydrogen. LNG can be replaced by methane made from biofuels.

Biodiesel and possibly some other liquid biofuels can, with some processing, be used in existing aircraft, though there remains considerable work to be done before a fuel has satisfactory performance and can be made at an acceptable cost. To use hydrogen fuel, aircraft would have to be redesigned to accommodate storage, because, for the same amount of energy, four gallons of hydrogen are necessary to replace one gallon of kerosene.[14] The issues relating to liquefied methane are on the one hand similar to biofuels, in that methane must be made from biofuel feedstock in a zero-CO_2 economy, and to hydrogen on the other, because a cryogenic fuel must be carried aboard aircraft. For simplicity, we discuss only liquid biofuels and hydrogen here, with the understanding that events may show cryogenic methane to be a preferable fuel. For instance, it has a higher volume energy density than hydrogen.

Biodiesel has some disadvantages as a fuel. The main one is that it freezes at a higher temperature than kerosene. Attempts to address this issue result in other problems, such as increased costs and lower fuel density. If a recent solicitation of bids by the Defense Advanced Research Projects Agency (DARPA) is any indication, it will take considerable time, effort, and money to produce biofuels suitable for jet aircraft at an acceptable price. The solicitation is quoted at length, since it provides many insights into the nature of the obstacles to be overcome:

> The Defense Department has been directed to explore a wide range of energy alternatives and fuel efficiency efforts in a bid to reduce the military's reliance on oil to power its aircraft, ground vehicles and non-nuclear ships. DARPA is interested in proposals for research and development efforts to develop a process that efficiently produces a surrogate for petroleum based military jet fuel (JP-8) from oil-rich crops produced by either agriculture or aquaculture (including but not limited to plants, algae, fungi, and bacteria) and which ultimately can be an affordable alternative to petroleum-derived JP-8. Current commercial processes for producing biodiesel yield a fuel that is unsuitable for military applications, which require higher energy density and a wide operating temperature range.... Subsequent secondary processing of biodiesel is currently inefficient and results in bio-fuel JP-8 being prohibitively expensive.
>
> The goal of the BioFuels program is to enable an affordable alternative to petroleum-derived JP-8. The primary technical objective of the BioFuels program is to achieve a 60% (or greater) conversion efficiency, by energy content, of crop oil to JP-8 surrogate and elucidate a path to 90% conversion. Proposers are encouraged to consider process paths that minimize the use of external energy sources, which are adaptable to a range or blend of feedstock crop oils, and which produce process by-products that have ancillary manufacturing or industrial value. Current biodiesel alternative fuels are produced by transesterification of triglycerides extracted from agricultural crop oils. This process, while highly efficient, yields a blend of methyl esters (biodiesel) that is 25% lower in energy density than JP-8 and exhibits unacceptable cold-flow features at the lower extreme of the required JP-8 operating regime (-50F). The focus of this program is to develop alternative or additional process technologies to efficiently produce an acceptable JP-8 surrogate fuel. Potential approaches may include thermal, catalytic, or enzymatic technologies or combinations of these. It is anticipated that the key technology developments needed to obtain the program goal will result from a cross-disciplinary approach spanning the fields of process chemistry and engineering, materials engineering, biotechnology, and propulsion system engineering. The key challenges are to develop and optimize process technologies to obtain a maximum conversion of crop oil to fuel....
>
> While the efficiency of the oil to JP-8 conversion process is the primary objective of this solicitation, the cost and availability of the necessary feedstock materials should also be considered. The development of conversion process technologies compatible with oils from a broad range of crops, potentially including new crop stocks selected specifically for their oil harvest, is preferred. Proposers will be required to provide a production cost model supporting their assertions of affordability.

> It has been demonstrated that oil-producing crops (seeds and algae for example) can be genetically modified or selected to have certain desired agronomic characteristics, such as a higher yield of specific triglycerides. Proposers to the BioFuels program are encouraged to consider the use of selected crop oils (or mixtures) including specific cultivars, strains, etc., to maximize the conversion energy efficiency (crop oil to fuel)....
>
> The program will be an exploratory evaluation of processing crop oils into a JP-8 surrogate biofuel, resulting in a laboratory scale production to be tested at a suitable DOD test facility. The successful proposer is expected to deliver a minimum of 100 liters of JP-8 surrogate biofuel for initial government laboratory qualification....[15]

Since a fuel that is not far from possessing the desired properties can be produced today, we have used jet fuel derived from biomass in the reference scenario. Hydrogen is also a possibility.

The commercialization of hydrogen fuel for aircraft will take considerable time and faces many uncertainties. Despite that, there are sound reasons to pursue research and development and further demonstration of the use of hydrogen as the standard aircraft fuel of the future. First, its technical feasibility has already been established in a commercial passenger jet. In 1988, the Soviet Union successfully demonstrated in flight a Tu-155 commercial aircraft that had been converted to use liquid hydrogen. It was also tested with liquefied natural gas in 1989.[16]

There are also strong arguments that, despite its poor reputation, hydrogen is a safer jet fuel than kerosene, though, of course, any accident containing a large amount of any flammable fuel is, by its nature, very dangerous.[17] Since hydrogen is a gas at quite low temperatures, it evaporates very rapidly upon release and, being much lighter than air, it disperses very fast. While liquid hydrogen needs a larger volume than jet fuel for the same amount of energy, it has a higher density per unit mass. The lower weight of fuel that would have to be carried could provide a significant boost in energy efficiency.

The European Aeronautic Defence and Space Company (EADS N.V.) has studied the feasibility, environmental impact, safety, and economics of liquid hydrogen powered aircraft.[18] A study by Airbus Deutschland in 2003 evaluated the prospects for hydrogen fuel in considerable detail. We use it here as a basis for the analysis of the prospects for hydrogen, especially as it is supported by other investigations. According to the study, which was based in part on a study of the performance characteristics of four conventional jet aircraft engines tested with hydrogen fuel:

> This CRYOPLANE System Analysis has shown that hydrogen could be a suitable alternative fuel for the future aviation. Nevertheless, due to the missing materials, parts, components and engines further R&D work has to be performed until hydrogen can be used as an aircraft fuel. According to estimations made during this project the earliest implementation of this technology could be expected in 15 to 20 years, provided that research work will continue on an adequate level.

> From the operating cost point of view hydrogen remains unattractive under today's condition, with kerosene is much cheaper as hydrogen and production/infrastructure is completely missing.
>
> Assessments based on conservative calculations and today's understanding have confirmed that the use of hydrogen would reduce aircraft emissions to a minimum. It needs to be validated that the water emission of hydrogen-fuelled aircraft has low impact to the atmosphere as predicted.[19]

Airbus also estimated that "no technology leap is required" for hydrogen fueled aircraft.[20] In fact, according to Airbus Deutschland:

> This system analysis on components has demonstrated sufficiently that technology and design principles for H_2 fuel tank and H_2 fuel systems are available today....No showstopper for the further development of the CRYOPLANE has been found. However technical work has to be done in order to adapt and optimise the existing materials, components and modules to the needs of an aircraft design.[21]

The overall conclusions of the Airbus Deutschland study regarding a "realistic" time frame for commercialization of hydrogen fuel is surprisingly short – 15 years:

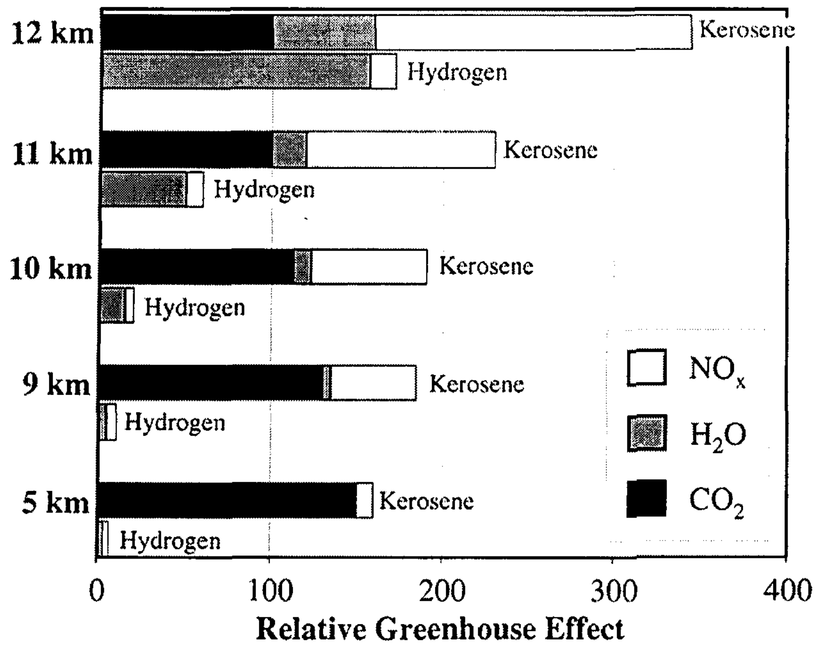
> Taking into consideration uncertainties both on the aircraft as well as on the infrastructure side a time schedule for having the first cryoplanes in regular airline operation can be estimated at approximately 10 (very ambitious) to 15 years (realistic).[22]

The main change in the aircraft would be in the configuration of the fuselage to accommodate the larger volume of fuel. The large volume of hydrogen fuel makes fuel tanks in the wings, which are used in kerosene-fueled aircraft, impractical.

Hydrogen-fueled aircraft would have lower environmental impacts overall than those fueled with petroleum-derived jet fuel. Large reductions in nitrogen oxide (NO_X) levels are possible; emissions of carbon monoxide and unburned hydrocarbons would be eliminated.[23] These advantages also hold for hydrogen relative to biofuels. There is one potential major problem relating to hydrogen, which is that it would produce more water vapor than jet fuel (and, in the future, biofuels).

Water vapor in the stratosphere is a greenhouse gas of some concern. Therefore the greenhouse gas emissions impact of a switch to hydrogen fuel depends strongly on the altitudes at which the aircraft would fly. Figure 4-9 shows a comparative evaluation of the overall greenhouse gas emissions of hydrogen and kerosene. At a 12-kilometer altitude (about 40,000 feet), hydrogen has about half the greenhouse gas impact of kerosene, but this is reduced to a very small fraction at 9 kilometers,[24] (about 30,000 feet). However, there is a fuel penalty, since the efficiency of jet aircraft increases with altitude.

Figure 4-9: Comparative Greenhouse Gas Impact of Hydrogen and Kerosene Aircraft Fuel



Source: IPCC 1999, Figure 7-37 (Section 7.8.1) Used with permission.

As regards efficiency of aircraft, Airbus projects that jet fuel consumption as low as 1.5 liters or even 1 liter per 100 seat kilometers can be achieved.[25] The latter figure corresponds to over 230 seat miles per gallon. In this study we have assumed an average fuel efficiency of 150 seat miles per gallon by 2050.

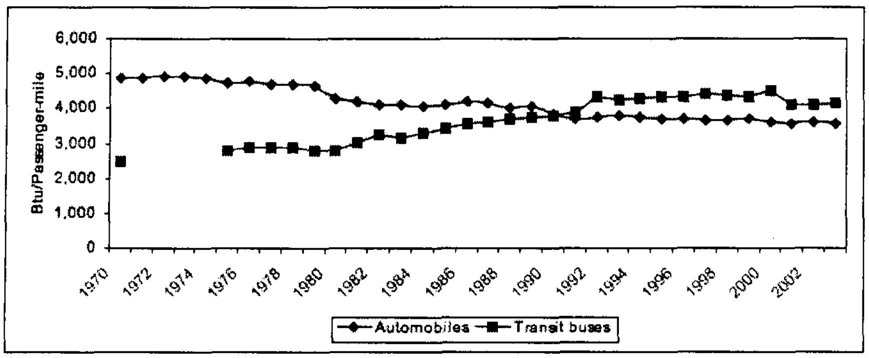
2. Public Transportation

Excellent public transportation in cities is often one of the central features of making living in them convenient, and attractive. Paris and London and San Francisco are examples. Especially in cities with high traffic congestion on the roads, like Washington, D.C. or Los Angeles, with its attendant economic, environmental, and health impacts, there is a strong argument that people using public transport are subsidizing those using private cars, especially at times of peak travel, in more ways than one.

A good public transportation system is not only an important ingredient of livable cities, but it can save energy indirectly since fewer people choose to use their cars routinely in such cities. In many instances, they may own fewer cars or even forgo them. New York City is a prime example. It has the most diverse and efficient public transport in the country. It also has the lowest rate of vehicle ownership. As of the 2000 U.S. Census, less than 50 percent of households owned a car (all five boroughs). In Manhattan, fewer than one in four households had a car.[26] While this is to some extent a function of income (owner occupied households have greater vehicle ownership than renter occupied households), the existence of a diverse public transportation system is one critical element in overall low car ownership. Not coincidentally, New York City also has one of the lowest per-capita energy use rates in the United States, less than one-third of the U.S. average.[27]

The evidence on the energy efficiency of public transport is, as a general matter, more mixed. It is not a given that public transport is generally more efficient than personal cars. The efficiency of public transport is highly dependent on ridership. That in turn is dependent on density of cities, and the density and availability of public transport. Figure 4-10 shows the contrarian evolution of the efficiency of public transport buses compared to personal cars since 1970. The energy use per mile of cars has declined, while that of buses has increased.

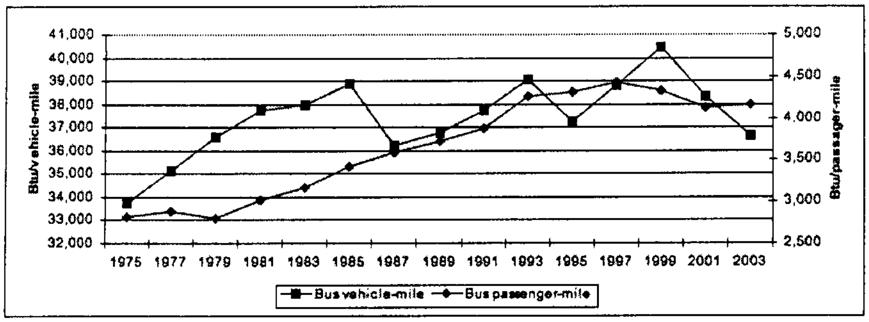
Figure 4-10: Evolution of the Energy Use per Mile Versus Transit Buses Since 1970



Source: TEDB 2006, Table 2-11

The reasons are not far to seek. First, personal passenger vehicles have had to comply with efficiency standards (known as CAFE or "Corporate Average Fuel Economy" standards). Despite the slippage in recent years, the improvement since the early 1970s, when car efficiency was typically in the 12 to 15 miles per gallon range, has been very large. Buses have not had to comply with such standards, and their fuel efficiency per vehicle mile has zig-zagged over the years rather than improved, while the efficiency per passenger mile has declined. Figure 4-11 shows the fuel consumption of transit buses per vehicle mile and per passenger mile (the inverse of efficiency).

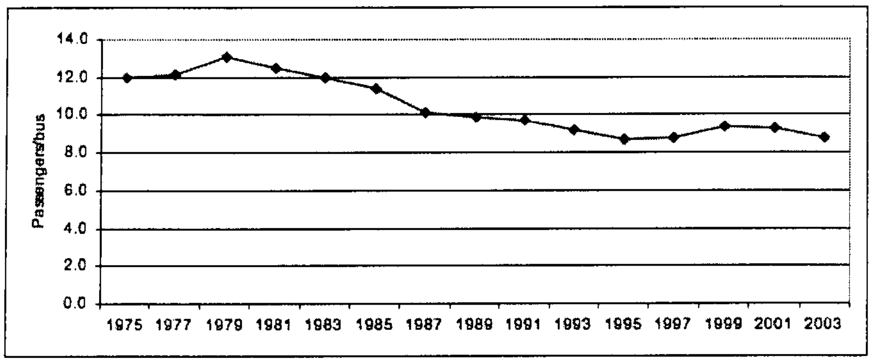
Figure 4-11: Transit Bus Fuel Use per Mile: 1975 to 2003



Source: TEDB 2006 Table 2-11[

The data in Figure 4-11 allow the computation of average ridership in a bus for a typical mile of its route. Figure 4-12 shows that ridership has declined since 1975 by about 25 percent.

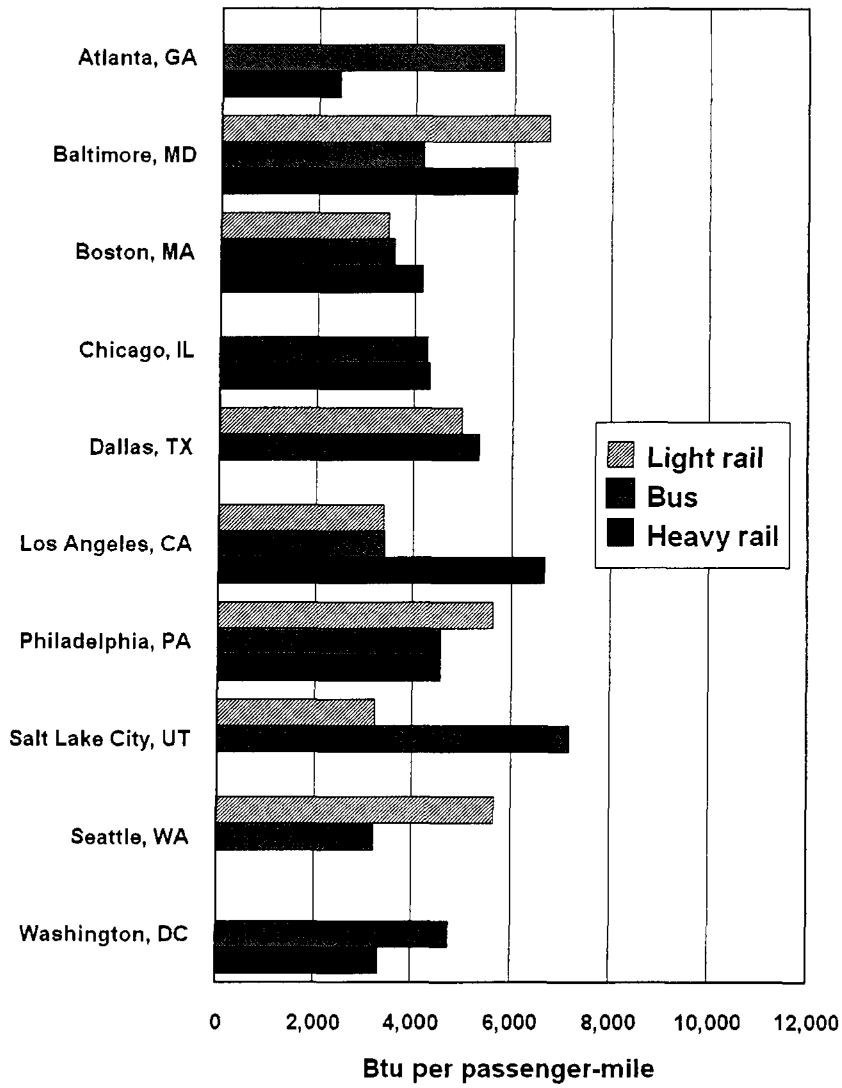
Figure 4-12: Evolution of Transit Bus Ridership, 1975 to 2003



Source: TEDB 2006 Table 2-11

Declines in ridership, of course, make transit buses more expensive per mile to operate, creating a vicious circle of increasing cost, declining ridership and decreasing efficiency. A detailed investigation of the history of public transportation infrastructure is beyond the scope of this book. We only note here that the data indicate that the energy efficiency of public transport depends on whether and how well the system serves the public, whether it is affordable, and so on. A city that is well-served with public transportation will tend to have a more dense population, with lower car use and lower per person energy use. Figure 4-13 shows the estimated fuel consumption per passenger mile of three kinds of public transportation systems – light rail, buses, and heavy rail – in various cities.

Figure 4-13: Comparative Efficiencies of Urban Public Transport Systems



Courtesy of Oak Ridge National Laboratory. Source: TEDB 2006 Figure 2.2 (page 2-15)

Efficiency does not appear to be a characteristic of the technical mode, but rather of other characteristics that are particular to the public's use of the system (including population density, service in the areas needed, etc.). The relatively high efficiency of the transit bus system in Los Angeles is perhaps one of the most interesting features of this chart. A demand for better public transport by the public of Los Angeles, notably its lower income public, and for economic and environmental justice were joined together in a long struggle that has resulted in Los Angeles becoming a surprising success story, still developing, in public transport.[28]

As a final note, we might consider the health benefits of living in a city in which walking, bicycling and greenways, public transport, mixed zoning and other considerations, are larger features than they typically are today in most U.S. cities and suburbs with segregation of housing, recreation, shopping, etc. An epidemiological study recently completed in New York City indicated that people living in neighborhoods where walking was easy and purposeful – such as stepping out to buy groceries or to go to a restaurant – had a lower body mass index than people in areas of New York City without easy access to public transport, mixed zoning, etc.[29] Public transport should be considered as a public utility in large cities, much like water and electricity supply and sewage systems.

Of course, living in densely populated communities is not everyone's cup of tea, and perhaps may be preferable at certain times of life than at others. The observation is offered here as an example of the kinds of considerations that should go into public policy decisions about public transport and its real benefits to the public. They in turn should help determine how public transport should be developed and costed. We have not quantitatively factored in public transportation changes into the scenarios in this study because of the complex nature of the problem. However, we do assume that the vehicular efficiency of transit buses will improve and that policies will be put into place towards that end.

C. The Industrial Sector

The industrial sector is the most complex of all the demand sectors due to the huge number of different industries and the diverse characteristics of energy use in them. For instance, mining, heavy manufacturing, metals production, chemicals, light industry, textiles, paper, and glass are all in one large energy sector. More detailed breakdowns are available, but an end use analysis from the point of technology and efficiency would take a multivolume treatise.

Fortunately, such an analysis is not necessary in the context of this study for two reasons. First, it is possible to aggregate the data by the major processes and end uses typical of broad classes of industry. Second, the policy approach chosen here, which is basically to make large users of fossil fuels pay for emitting CO_2 while reducing the total amount of emissions allowed each year, would automatically encourage industry to seek both ways to increase energy efficiency and to increase use of renewable energy. Hence, this sector does not require a detailed analysis. If the emission allowances are reasonable and decline in a predictable manner, the innovation and investment will shift towards reducing CO_2 emissions.

We briefly consider the kinds of areas in which industry will likely reduce CO_2 emissions. We include the use of feedstocks in industry, even though they are non-fuel uses of fossil fuels, for two reasons. First, many of the feedstocks eventually result in greenhouse gas emissions. Second, replacement of fossil fuels in all sectors, including industry, is an important part of ensuring that zero-CO_2 emissions are realized.

Among the uses of energy (including electricity) in industry are:

- Process heating, whereby the materials being worked on are heated, as for instance in the recycling of scrap iron and aluminum, the rolling of steel, and heating of chemicals to achieve the correct temperature for reactions.
- Production of steam for process purposes, which requires use of fuel in boilers.
- Electricity for driving machines, typically electric motors, but also diesel pumps and the like.
- Petroleum, liquid petroleum gases, and natural gas for feedstock uses.
- Reduction of ores to metal, as for instance reduction of bauxite to aluminum metal.
- Distillation.
- Heating, air conditioning, and lighting of buildings.
- Fuel for onsite generation of steam and electricity (combined heat and power).
- Lighting.

As noted in Chapter 1, there has already been a remarkable shift in industrial energy use patterns since 1973 due to a variety of factors, including fluctuating prices of energy, which have risen to quite high levels in some periods, innovations in processes, and the changing composition of industry. A cap on CO_2 emissions, if it is stringent enough, will convert the current trend of flat energy use in industry with rising production into a trend of declining energy use with increasing production. There are still many opportunities in industry for improving efficiency within the framework of available technology, such as efficient lighting and motors. But innovation will also play a role.

Industries and companies that have taken early action for a variety of reasons, including environmental protection, improving profitability, reducing uncertainties, and anticipating restrictions on greenhouse gas emissions, already indicate the large potential. We took a look at DuPont as a brief case study both because it has taken (and is taking) early action and because DuPont's Director of Sustainability, Dawn Rittenhouse, arranged for me to interview her and her colleague, John Carberry, for this report. A summary of that interview is in Appendix B.

In 1999, DuPont set a goal of reducing greenhouse gas emissions by 65 percent and actually achieved 72 percent by 2003. Most of this was in the form of reductions of halocarbon process emissions in manufacturing. DuPont has a target of further reduction of 15 percent based on 2004 emissions, with halocarbon and energy-related emissions being part of the achievement of the goal. In other words, DuPont is already accomplishing a major reduction in greenhouse gas emissions and a significant reduction in CO_2 emissions even without legislated restrictions.

In the interview, John Carberry discussed a few of the kinds of steps that would be taken in the context of a global goal of 60 to 80 percent reductions of greenhouse gas emissions:

> In the chemical industry CHP [Combined Heat and Power] is a big one.
>
> Another is replacing distillation – one alternative is modernization of processes so you don't have so many operations that involve distillation. Or it could be replaced by crystallization or membrane separation technologies, for example. Other areas are steam system management, insulation, powerhouse modernization, steam trap management. Optimization for first pass first quality yield is a big one – that is, make it correctly the first time. If you don't make it correctly, you have to recycle the product and make it again and you have wasted all the energy that was used the first time.
>
> Optimizing the manufacturing efficiency of your facility is another one. If you are in a standby hot mode, you use 60 or 70% of the energy anyway. So you want to run 100% of capacity 100% of the time. Then there is optimized process control and finding alternatives to grinding of solid materials – grinding is highly energy intensive.[30]

Further discussion on industry-related energy policy is in Chapter 7. In the reference scenario we assume that there will be approximately a one percent decline per year in absolute terms in U.S. industrial energy use between 2010 and 2050. The use of fuels for industrial feedstocks is assumed to be constant.

CHAPTER 5: A REFERENCE ZERO-CO_2 SCENARIO

In this chapter, we set forth a reference zero-CO_2 scenario going to 2050, at which time there would be no fossil fuels consumed and no nuclear power generated in the United States. Variations upon this reference case are considered in Chapter 6.

Zero-CO_2 emissions without nuclear power is an admittedly ambitious goal that would do nothing less than revolutionize the energy supply in the same way that petroleum and electricity did in the last century. There would also be considerable changes on the demand-side in that economic growth would be accompanied by slowly declining energy demand. However, the precedent of zero energy growth with significant economic growth already exists in the United States; it occurred in the 1973-1985 period (Chapter 1). It is also noteworthy that energy use declined slightly between 2004 and 2006, while GDP continued to grow at 3 percent per year.

The reference scenario also serves to illuminate constraints on renewable energy supplies, such as land for biofuels and the need for additional reserve capacity in the electricity sector in the case of wind and solar energy. The possible different time-scales for transitions are discussed in Chapter 6. The recommendations of the study are developed once the reference scenario and potential alternatives are discussed.

The reference scenario also serves to set forth the assumptions underlying the projected demand that serve to demonstrate the reasonableness of a delivered energy use of about 45 to 50 quadrillion Btu by 2050. (Electricity and biofuels production losses are separately considered.) One goal of the eventual set of recommendations is that there must be sufficient flexibility on the supply-side to meet a contingency of a somewhat higher or lower demand than forms the basis of the supply estimates here. The possible variation in the total energy figure is likely greater than that of delivered energy, since energy losses depend a good deal on the specific mix of types of electrical generation assumed and the extent of the role of liquid and gaseous biofuels and how they are produced.

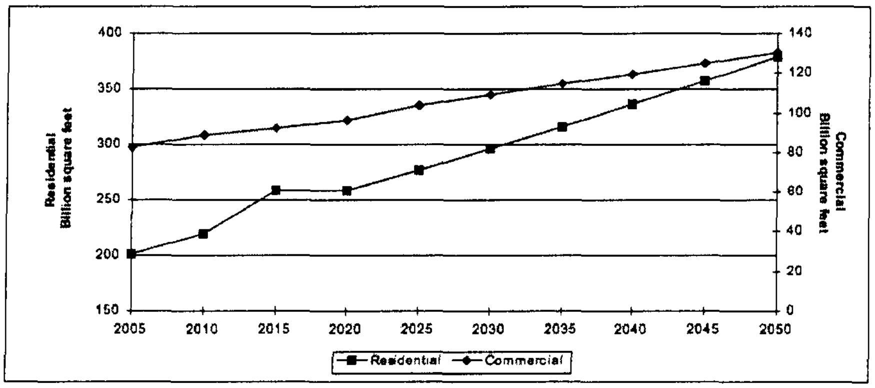
A. Residential and Commercial Energy Use

The economic assumptions underlying the reference scenario and its derivatives are in the category of "business-as-usual." Some of the specific figures that are very important in analyzing the demand-side are set forth in Figure 5-1 for the residential and commercial sectors. The residential area is projected to grow from about 200 billion square feet in 2004 (the base year for these projections) to about 380 billion square feet in 2050. The number of households will increase from about 113.6 million in 2004 to 175 million in 2050.[1] This means an increase in the area per household of about 25 percent.

Commercial space is projected to grow as well. It is shown in Figure 5-1, but to a different scale (on the right of the graph). It is expected to increase by about two-thirds between 2004 and 2050.

The main loads – heating, cooling, and lighting – scale approximately as area. Others, such as hot water, would scale more according to population, whose rate of increase is slower. We do not scale the use of energy services by population, but do it rather by area, since this leaves room for new appliances and uses that would not be accommodated by a straight population-based projection.

Figure 5-1: Residential and Commercial Sectors, Projections of Floorspace, in Billion Square Feet



Sources: Commercial: DOE 2006 Table 2.2.1 (page 2-5) up to 2025. Residential: EIA AEO Assumptions 2006 page 23 and DOE 2006 Table 2.1.1 (page 2-1) EIA AEO gives an average square footage for 2001 and 2030. We have interpolated the values for the years in between and multiplied them with the number of households listed in DOE 2006. The values after 2025 for commercial area and after 2030 for residential area were extrapolated.

In estimating residential and commercial energy use and the efficiencies that can be achieved (using the approaches discussed in Chapter 4), we first calculate the energy actually used in the specific application. For instance, we derive a cooling load based on business-as-usual projections of efficiency and electricity use. These projections assume slow increases in efficiency not only for heating and cooling but for other appliances in the aggregate as well. For instance, the total heating load grows by only 10 percent and the cooling load by 40 percent, though the area almost doubles.

In the reference scenario the efficiency improvements are larger. There is a decline in delivered energy use from about 58,000 Btu per square foot per year in 2004 to about 21,000 Btu per square foot. In other words, delivered energy use per square foot would be about 37 percent of what it is today in the residential sector. We have shown by a few examples (and there are many more) that it is possible to design and build homes (single family and multi-family) that use between 8,300 and 26,000 Btu per square foot at reasonable cost in areas that are quite representative of conditions in large areas of the United States. Examples of even lower specific energy use can be found. Overall energy use on the basis of delivered energy would decline only about 30 percent, since the number of houses and the area per house are both expected to increase. Technology and efficiency assumptions are specified in the following endnote.[2]

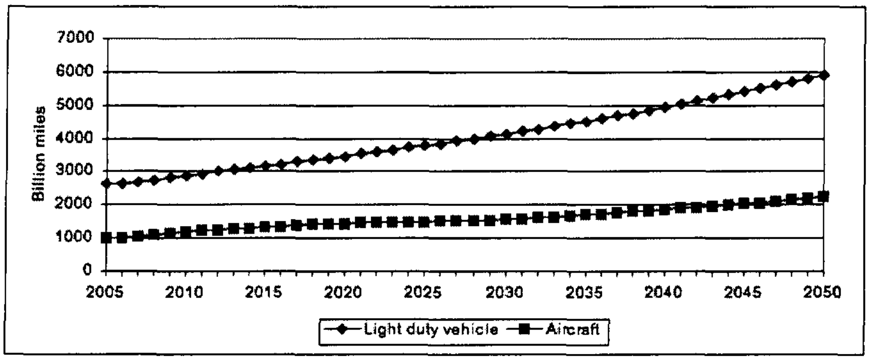
Business-as-usual projections in the commercial sector actually assume an increase in delivered energy use per unit area, despite great potential for efficiency in new buildings. We have assumed that new space will be much more efficient beginning in 2015, but that existing space will achieve only modest energy efficiency increases by 2050. This recognizes that it is often more expensive to retrofit existing commercial buildings. Overall, energy use per square foot in 2050 would be about 58 percent of that in 2004, while total energy use in the commercial sector would stay about the same, due to increasing area. The technology and efficiency assumptions for the commercial sector are specified in the following endnote.[3]

Changes have also been assumed in the fuel supply of the residential and commercial sectors. We assume that most existing homes with natural gas as a heating fuel will convert to methane derived from biofuel, ordinary heat pumps, geothermal heat pumps, or resistance heating assisted by a solar thermal system (as in the Hanover House discussed in Chapter 4). Figure 5-2 (see color insert) shows the evolution of fuel and electricity use in the residential and commercial sectors combined, on a delivered energy basis. The transition from natural gas to methane can be expected to be smooth, since no changes in fuel transportation (pipelines) or infrastructure at the point of end use are involved. The efficiency slice is the avoided energy use due to increases in efficiency relative to the business-as-usual scenario.

B. Transportation and Industry

The personal passenger vehicle miles and aircraft vehicle miles in the business-as-usual projection are shown in Figure 5-3.

Figure 5-3: Business-as-usual Projections for Light Duty Vehicles (Vehicle-Miles Traveled) and Aircraft (Seat Miles Available)



Source: EIA AEO 2006 Table A7 (pages 145-146) up to 2030, projected thereafter by IEER.
Note: Light duty vehicles are defined as weighing less than 8,500 pounds.

Cars that run on gasoline or diesel alone (including hybrid vehicles that cannot be plugged in) with efficiencies up to 60 miles per gallon that meet other safety and environmental standards, are available on the market today. Eighty-mile-per-gallon vehicles have also been manufactured. Plug-in hybrids can get 70 to 100 miles per gallon of liquid fuel; in addition, they use 0.1 to 0.15 kWh of electricity per mile. As is well recognized, much of the problem in the lack of use of highly fuel efficient vehicles has been the absence of stringent mandated efficiency standards, aggressive marketing of highly profitable SUVs, and customer preferences for the latter.

We assume gradual changes in new vehicle efficiency to 40 miles per gallon by 2020 and continued steady improvements after that to just under 75 miles per gallon by 2050, for liquid-fuelled vehicles. This yields an average fuel economy of about 65 miles per gallon in 2050.

The bigger change that is assumed here is a transition to steadily increasing use of electricity in light duty vehicles, until electricity dominates the energy input in this sector in about three decades. We envision that plug-in hybrids will first be introduced on a large-scale, followed by all-electric vehicles in about 20 years. These assumptions apply to the reference scenario. It is also possible that if direct production of hydrogen from solar energy and/or electrolytic hydrogen from wind energy become economical then a combination of hydrogen and electricity would be the mainstays for land transport. This possibility is discussed in Chapter 6.

Based on interviews and an examination of presently available data, which is scant, the present efficiencies of lithium-ion all-electric vehicles are in the 0.2 to 0.3 kilowatt hour per mile range (3.3 to 5 miles per kilowatt hour).[4] While there is an expectation that this will improve to 10 miles per kilowatt hour in the next several years, this appears rather optimistic. We have assumed an efficiency of 6 miles per kilowatt hour (delivered electricity at the plug) in 2015, slowly increasing to 10 or 11 miles per kilowatt hour in the 2040 to 2050 period for new vehicles made in that decade.

Partial use of electricity, in a mixture of plug-in-hybrid and all-electric modes is also assumed in commercial light trucks (50 percent by 2050), but the proportion of electricity for large trucks is small, 10 percent. This would account for a portion of the metropolitan area truck transport. We assume that developments in batteries will not be significant enough to allow long distance truck freight to be electrified.

There are fundamental reasons for seeking such a major transition in transportation technology and putting policies into place to ensure that it will occur:

- Electricity provides the greatest flexibility in energy supply.
- Use of solar and wind energy to charge plug-in hybrids and all-electric vehicles will greatly reduce waste of energy and increase transportation efficiency. With an efficiency of 5 miles per kWh, which is possible today, the use of solar or wind energy would yield an equivalent "well-to-wheels" efficiency of about 150 miles per gallon. This can be doubled in the coming decades.
- Making the transition to electric vehicles, for the most part, eases the pressure on other, more difficult, sectors, like aircraft and feedstocks in industry. The requirements of other sectors, combined with continued use of liquid fuels in industry, could put intolerable pressures on land for producing biofuels if passenger vehicles continue using liquid fuels.
- Electricity for transportation greatly reduces fuel cost, especially if the charging is mostly done off-peak. Hence, a greater investment in the vehicle itself is possible, for the same per mile transportation cost.
- The change would make the air in cities dramatically cleaner than it is today, since petroleum-fueled vehicles are the largest source of air pollution in many urban areas and, as such, are a principal contributor to respiratory diseases, like asthma, especially among children and the elderly.[5]
- New battery technology permits vehicle-to-grid support for renewable energy sources at nearly zero-marginal cost in terms of battery wear. This makes a V2G supported grid much more feasible and obviates the need for costly storage technologies. It also provides some insurance against difficulties in large-scale development of hot rock geothermal technology and other baseload sources to support a wind and solar PV system. Lithium-ion batteries can be recycled.

Figure 5-4 (see color insert) shows the evolution of the transportation fuel mix in the reference scenario. Initial uses of electricity are mainly for plug-in hybrids. The high efficiency of electric cars means that a relatively small amount of electricity can replace a much larger amount of gasoline. The energy use is shown on the basis of delivered energy; neither electricity production losses nor biofuel production losses are shown. They are discussed in Section C.

It is possible that technological developments in areas such as solar hydrogen production or hydrogen production from high-yield biomass, could turn out to be more economical than electricity. These possibilities are discussed in Chapter 6 as variants of the reference scenario. Rapid and large-scale introduction of plug-in hybrids into the marketplace could probably be achieved if they became a significant part of governmental and corporate fleets.

Tesla Motors is founded on the idea that initial market breakthroughs occur at the high-end of the market, since the wealthy are willing to pay more for an avant-garde, attractive all-electric car that is also environmentally friendly. At about $100,000 per car, the Tesla Roadster is already sold out for the 2007 model year and more than half of the 2008 model year has been reserved.[6] By design, the approach is similar to the introduction of new appliances and gadgets, such as digital TVs and cameras, DVD players, or, long ago, color TV, where the initial buyers were people willing to pay high prices, opening the way for cheaper mass manufactured products that displaced the prior standard ones.

Finally, as noted in Chapter 4, the reference technology for aircraft is continued use of the present type of jets with biofuels, with incremental efficiency improvements to 150 seat miles per gallon by 2050. Today's most advanced passenger commercial aircraft perform at about 100 seat miles per gallon.[7] The main technology and efficiency assumptions for the transportation sector in the year 2050 are discussed in the following endnote.[8]

Even with a very fundamental transition to electric vehicles for passenger vehicles and light duty trucks, transportation fuel requirements for aircraft and internal combustion engines remain very large – about 6 million barrels a day of oil equivalent in 2050. These requirements would by themselves be well within reasonable land requirements for production of liquid biofuels.[9] However, the industrial biofuel requirements must also be taken into account. They increase land requirements considerably.

We have assumed that energy use in industry for fuel uses will decline by 1 percent per year and still sustain business-as-usual growth in output. Feedstock uses of fuels would remain constant over time. Overall, this requires only a modest change from no-growth in energy use that has prevailed on average since 1973. The net result is that industrial energy use in 2050 would be about 70 percent of that in 2004 (delivered energy basis). This is a reasonable concomitant of an assumption of a CO_2 emission reduction regulation system in which emission allowances for large users will be fixed ("capped"), with the limit declining each year until it reaches zero by mid-century (see Chapter 7). An interview with DuPont officials on industrial energy use in a world with CO_2 emission restrictions is in Appendix B. DuPont is one of the corporations that is part of the U.S. Climate Action Partnership (USCAP),[10] which advocates, among other things, a target of 60 to 80 percent reductions in U.S. greenhouse gas emissions by the year 2050.

C. Electricity Production

About half the electricity production in the United States in 2005 was fueled by coal. About 19 percent came from nuclear energy and 19 percent from natural gas (including combined heat and power generation in industry). The balance came from hydroelectricity, petroleum, and renewable sources such as wood waste and wind. Solar-generated electricity was not yet a significant component of the supply.

Since over 90 percent of the generation came from thermal power plants, mainly coal and nuclear, the losses of energy were considerable. The overall generation efficiency of these two types of power generation, on average, is about one-third, which means that about two-thirds of the energy input winds up as waste heat. Since this waste heat component is a very large part of total energy use, it important to consider how it is actually accounted for in energy data. Without a careful consideration of this issue, energy data over time could be rendered non-comparable.

1. Methodological Note on Thermal and Other Losses in Electricity Production

Electricity by its nature is thermodynamically different than fuels that are burned to produce heat. In theory, electricity can be converted with 100 percent efficiency into mechanical energy (or work). The same is true of converting the mechanical energy in the flow of water into electricity. Heat energy conversion to mechanical energy (or electricity) is restricted to an upper limit less than 100 percent, determined by the temperature of the combustion relative to ambient temperature. The efficiency of thermal power plants is highly variable in practice. It ranges from a low of 15 or 20 percent for geothermal energy to about 33 percent for nuclear power plants, about 40 percent for new coal-fired power plants, and 55 percent for natural-gas-fired combined cycle plants. This has created a methodological problem. Electricity from all of these sources is equivalent, and after it enters the grid, its source cannot be determined. But hydropower needs no fuel. So how is the mechanical energy input to a hydropower plant to be added to the fuel input to a coal-fired or nuclear power plant? Assuming a unit of hydroelectricity is equivalent to a unit of coal used in a coal-fired power plant would be adding up incommensurate kinds of energy in terms of the useful work that can be extracted from them.

Traditionally, a fictitious heat loss, typical of thermal electricity generation, is added to hydroelectricity generation to make its contribution commensurate with fossil fuels. This creates an artificial inflation of energy use in an economy that does not correspond to actual energy use, since hydropower plants do not have such thermal losses. However, the practice does not result in a large distortion of energy data so long as non-thermal electricity generation sources are a small part of the total, as they are today in the United States. However, in a transition to an economy where wind and solar photovoltaic electricity would play a major role and where the efficiencies of thermal generation could range from 15 percent to 55 percent combined cycle plants, the traditional approach is quite unsuitable since it would greatly distort the actual energy inputs into the economy.

In this book, we have projected delivered energy, including electricity consumed at the point of delivery. That is, the basic analysis on the demand-side discussed above is done according to the evaluation of energy used at the point of use – homes, office buildings, cars, factories. On the supply-side, a variety of choices can be made for electricity generation, some of which would involve thermal losses, while others would not. For instance, a large role for biomass combustion would mean greater thermal losses than if some of that role were taken up by solar PV. The approach, therefore, is to produce scenarios of electricity supply that would meet the criteria of reliability, resource availability, and constraints (such as land), and then estimate the actual thermal losses that would result from the specific mix of sources.

These considerations are quite important in comparing different supply scenarios. The delivered energy remains the same in all cases.

In addition to thermal losses at the power plant, all centralized electricity generation entails losses of electricity between the point of generation and the point of use. These are called "transmission and distribution" losses. The term "transmission losses" applies to high-voltage electricity transmission from the generation plant to intermediate voltage points of use for large-scale industrial and commercial users or to substations where the electricity is converted to the low voltages that are typically used in homes, office buildings, schools, shops, etc. Distribution losses are from these intermediate points to residences and other small-scale uses. Large industries often take their electricity at higher voltages and do not have distribution losses. Overall transmission and distribution losses amount to about eight percent of electricity generation, with most of that being distribution losses. In the reference scenario, we have assumed that electricity losses go up slightly (from eight percent to ten percent) due to a greater use of the distribution system and lower use of the high-voltage transmission system. The losses could be reduced if generation at the point of use is increased.

2. Electricity in the Reference Scenario

The demand sector projections discussed above show electricity as part of the delivered energy to each sector. A transition to an electricity sector based on renewable energy sources requires a complex set of considerations. The first is reliability. The present electricity sector is highly centralized, apart from a modest amount of combined heat and power generation in the industrial sector (about 4 percent of the total). By and large, this provides a reliable supply, though its vulnerabilities have been apparent in various major blackouts in the past several decades, including the major Northeast blackout in 1965 and the most recent one in 2003.

These vulnerabilities stem from the potential for disturbances created by the removal of a major generating station or an important segment of the transmission grid at a time of heavy load. This can cause temporary disturbances in the grid, called transients, that cause more and more generating stations and/or sections of transmission lines to shut down for safety reasons (to protect against overloads). Blackouts can spread with great speed. It is a complex and difficult exercise to turn the entire grid back on after a widespread blackout. Many types of institutions, from hospitals to banks, have emergency power supplies that allow them to keep operating at minimal levels during blackouts. Nonetheless, prolonged blackouts lasting a few days cause immense economic damage and create health risks as well.

In addition to the risks of blackouts due to natural disasters (such as hurricanes and lightening strikes), excessively centralized systems are also vulnerable to terrorism, for the same reason. An attack on critical sections of the system could cause the same types of dislocation and damage as a prolonged blackout due to other causes.

On the other hand, a purely decentralized system also has its problems of reliability. A breakdown could cause a prolonged period without electricity, though the damage is restricted to a local area. For that very reason, a decentralized system presents a far less attractive target for terrorist attack than a centralized system. However, a purely decentralized system that is also reliable is generally expensive because extensive back up is required in case the main system is down for maintenance or due to accidents or natural disasters.

A mix of the two approaches with decentralized sources providing a large fraction of electricity connected into a grid that also has centralized sources can overcome most of the vulnerabilities of each approach. In fact, it can provide a more reliable system. A grid within which small-, intermediate-, and large-scale generating stations all play significant roles is called a "distributed grid." Distributed grids can also bring dispersed wind resources into the energy system in a much more cost effective way than a purely decentralized system, especially in the United States, where the best land-based wind energy resources are concentrated mainly across a swath through the middle of the country and offshore.

The total electricity requirements under the reference scenario remain about the same throughout the period under consideration (to 2050). Efficiency improvements reduce demand; this is offset by loads growing due to increasing economic output, greater numbers of homes and businesses, and new uses of electricity (such as plug-in hybrids and all-electric vehicles). But the fuel mix of electricity would have to change almost completely, except for the eight percent or so that comes from hydroelectricity, wind, wood wastes, and geothermal energy.

As we have discussed in Chapter 3, solar and wind energy are each plentiful enough to supply the entire electricity requirement of the United States. We have also discussed various ways in which the intermittency of these two resources can be addressed by optimizing their contribution to electricity generation based on overall cost for a given reliability.[11]

Besides combining wind, solar, standby natural gas/bio-methane, and hydropower to overcome the effects of intermittency, the reference scenario assumes the use of a V2G system after 2030 or 2035; in the alternative, stationary storage in advanced batteries, possibly in combination with ultracapacitors, can also perform the same function.

In order to provide baseload power, we assume a significant use of solid biofuels for electricity production, about 9 quadrillion Btu per year, generating over one-fifth of the total electricity requirement in the year 2050. The use of solid biomass is coupled to the production of microalgae from the CO_2 exhaust. This forms the feedstock for producing liquid fuels for transportation. In addition, methane derived from biomass would be used in combined cycle plants in place of natural gas in order to provide reserve capacity in the system. Hot rock geothermal power is also assumed to be deployed on a significant scale after 2030. This technology is important since it can provide baseload generation in areas that have relatively low solar energy availability and relatively low potential for large-scale biomass production at high efficiency, as for instance the Northeast.

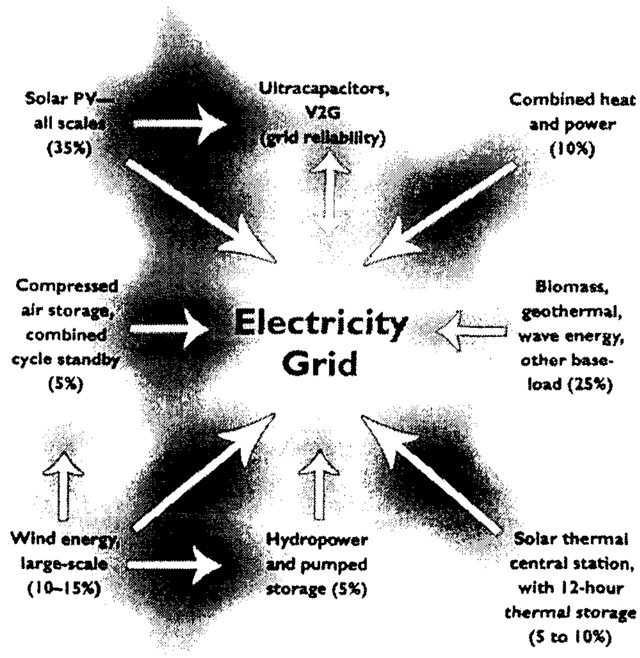
Finally, the number of combined heat and power systems would grow in the industrial and also the commercial sector (with more modest use in the residential sector, for instance in multi-family housing). Natural gas is the main fuel for such systems today; it is assumed that this will be gradually replaced by methane made from biofuels.

Figure 5-5 (see color insert) shows the evolution of the electricity sector in the reference scenario. Solar energy consists mainly of solar PV, but also includes 150 gigawatts of solar thermal with heat storage for 12 hours. In this arrangement, solar thermal can serve as a kind of quasi-baseload generating system if built in very sunny areas such as the Southwest. The preferred technology for solid biofuels would be IGCC because of its efficiency and the relative efficiency with which CO_2 can be captured in this system. In the initial 2010-2020 period, a larger part of the renewable expansion is due to an increase in supply from wind energy. Of course, in this period, most of the present baseload capacity would continue to be available. We also assume that the use of CO_2 capture in microalgae would be implemented at existing fossil fuel power plants, so as to minimize emissions and create an industrial base for biofuel production that does not rely on food crops.

Much of the solid biomass would likely be prairie grasses or switchgrass. We will explore various alternatives for biomass production for electricity generation and of the use of solar energy for producing transportation fuels (other than electricity) in Chapter 6.

Figure 5-6 is a schematic diagram of the electricity system in the reference scenario. The numbers are similar to those in the reference scenario, but ranges are shown in some cases, for purposes of illustration. Other combinations are possible with this same set of technologies. The actual evolution of electricity supply will depend on relative costs, the state of transmission and distribution, infrastructure, and other factors.

Figure 5-6. One Possible Future U.S. Electric Grid Configuration Without Coal or Nuclear Power in the Year 2050



Source: IEER

In the scheme shown in Figure 5-6, about 45 to 50 percent of the electricity supply would be from intermittent renewables, not including solar thermal power plants. This would require a considerable standby capacity, but not equal to the peak demand. A coordination of wind, solar PV, and solar thermal in a way that takes advantage of the diversity of times when they are available would reduce standby requirements. A large portion of the standby would be supplied by combined cycle plants operating first on natural gas and then on methane derived from biomass. There is ample spare capacity available and a good portion of that would be maintained. Some standby capacity would be provided by hydropower. Solar thermal power plants would be provided with 12-hour heat storage, so that they could provide power through much of the time when bright sunshine is not available. Further, about 25 percent of the capacity would consist of central station baseload or quasi-baseload capacity.

A combination of a V2G system and stationary storage, for instance, in advanced batteries, would provide the rest of the backup. It is difficult to estimate what this amount would be without developing detailed load profiles, which is far beyond the scope of this study. It would be less than and probably much less than a quarter of the peak demand in the configuration shown in Figure 5-6.

We assume for the sake of estimation that the standby capacity required to be supplied by a combination of V2G, advanced battery, and ultracapacitor storage in the year 2050 would be on the order of 100 gigawatts, which is about equal to the installed capacity of all U.S. nuclear power plants. This seems rather large, but a very small fraction of the light duty vehicles would be able to meet it. At 10 kilowatts per vehicle,[12] the number of vehicles required would be 10 million. This is about three percent of the fleet of light duty vehicles in the United States projected for the year 2050. Typically, vehicles are used much less than 10 percent of the time, so that on average over 90 percent of the vehicles would in principle be available. However, a far smaller number of vehicles would be available at peak vehicle use times. This will likely not have a significant effect since only a few percent of vehicles would be required, at most. Hence, arrangements made with businesses that have large numbers of vehicles in their parking lots at the time of peak load would be sufficient to provide adequate standby capacity. Vehicles parked at airports could also play a role.

Storage of electricity on the supply end can be combined with storage equipment at the demand end. For instance, an air-conditioning system that is equipped with an ice-making machine can shift air conditioning load from on-peak times in the middle of the day to off-peak hours. It is commercially available from Ice Energy for both residential and commercial buildings.[13]

Such a system can complement renewable energy storage systems by shifting the load to times when renewable energy is available. For instance, ice can be made at night when wind energy is typically more available and used for air conditioning during the daytime. Similarly, the peak of solar energy availability is in the middle of the day, while the peak of the air-conditioning load often occurs in the late afternoon.[14] Michael Winkler has proposed a "smart grid" system in which thermal storage (of both heat and coldness) is controlled by the utility to some extent so as to match available supply. In this concept, renewable energy sources, geothermal heat pumps, storage of heat and coldness, and electricity storage are combined so as to optimize the generation capacity and make the best use of available intermittent resources. A smart grid would allow greater use of intermediate- and small-scale solar energy with greater reliability per unit investment and potentially at lower cost.[15]

D. Overall Results

A series of graphs illustrate the results of this analysis. Note that generally we have assumed that major changes will begin between 2015 and 2030 depending on the state of the technology. Figure 5-7 (see color insert) shows the delivered energy in the reference scenario. The electricity shown in the chart is that actually consumed at the point of end use (rather than at the point of transformation to another energy source). Similarly, thermal losses and biofuel production losses are not shown. The increases in efficiency incorporated into the scenario result in a decline of delivered energy use from about 74 quadrillion Btu in 2004 to about 48 quadrillion Btu, a reduction of about 35 percent.

Figure 5-8 (see color insert) shows the total energy input into the system including electricity transmission and distribution losses, thermal losses in electricity production, and biomass losses in liquid and gaseous biofuels production. The total energy use declines from almost 100 quadrillion Btu in 2005 to about 76 quadrillion Btu. The losses in the present system are concentrated in the electricity generation sector. By contrast, in the reference scenario in 2050, the electricity system losses would be cut by more than half. However, the losses in production of liquid and gaseous biofuels for all end-use sectors will likely be large; as a result, the overall losses do not change significantly when comparing the energy system in 2004 to the reference scenario in 2050. The proportional role of losses in the renewable energy system in the reference scenario is actually greater than at present (almost 37 percent compared to 25 percent). This is undesirable. Alternative approaches are discussed in Chapter 6. These are used to develop a preferred renewable energy scenario (Chapter 8, Section A).

Land Use Considerations

Wind energy takes up relatively little land. Crops can be cultivated and cattle can graze right up to the towers of wind turbines, whose footprint is small. The area requirements for wind energy are determined by the swept area of the turbine blades, which does not significantly impact the footprint of the installation. For instance, the total footprint of 15 wind turbines, 2 megawatts each, in a Polish wind farm was only 0.5 hectares (1.25 acres). The project was built on an area totaling 225 hectares of farms. Almost all the land between the wind turbine tower foundations will be farmed.[16]

The largest area requirements are for the service roads associated with the construction and maintenance of wind farms. Other service facilities, such as an electrical substation, would also be required. The actual area required is site dependent, since the length of the roads would depend on topography, existing land uses, and other factors. An analysis by the New York State Energy Research and Development Authority concluded that five percent of the total land area of the project might be considered as rule of thumb for planning wind power projects. The total land-area requirements per unit of installed capacity themselves vary from project to project, and depend largely on the wind speed characteristics and topography of the site. Assuming a total project area of about 12 hectares per megawatt, the land-area requirements would be about 0.6 hectares per megawatt.[17] On this basis, the total land-area requirements for wind energy in the reference scenario would be about 490 square miles, which is equal to a square about 22 miles on the side.

Solar photovoltaic cells also do not take up much land. In fact, installations on rooftops and parking lots take up no additional land. Assuming that half of the large- and intermediate-scale installations are associated with commercial parking lots and rooftops, the land-area requirements for solar PV in the reference scenario are rather modest – about 860 square miles, which is equal to a square about 29 miles on the side, assuming the central station installations are in sunny areas. This includes a 30 percent allowance for roads, space between the PV arrays, and infrastructure.

We estimate solar thermal electric power production land requirements would be about 210 square miles. The trough or parabolic reflectors that track the sun in such power plants capture solar energy much more efficiently than solar PV, though much of that advantage is lost in the thermal electricity production cycle as waste heat.

Overall, the total land-area requirements in the reference scenario for wind and solar energy (other than parking lots and rooftops) would be about 1,560 square miles, which is a square almost 40 miles to the side.

Liquid and gaseous biofuels, derived from solid biomass grown for the purpose, play a very large role in the reference scenario. In fact, their role in the energy sector would be somewhat greater (proportionally speaking) than that played by oil and natural gas in the United States economy today. This is mainly because there is a very large component of industrial demand and a significant component of demand in each of the other sectors that cannot easily be met by electricity at reasonable cost, given present technology. The overall requirement for liquid and gaseous biofuels in the reference scenario is about 35 quadrillion Btu of delivered energy. This does not include solid biomass requirements for baseload electricity production or the losses associated with production of liquid and gaseous fuels from solid biomass. As can be seen from Figure 5-8, these losses are substantial. The total solid biomass production requirements for all uses in the reference scenario are about 60 quadrillion Btu. We have assumed an efficiency of 70 percent for liquid and gaseous fuels production from solid biomass by the year 2050.

A part of this requirement can be met by recovering landfill gas, which has a significant amount of methane (the principal constituent of natural gas). Gasification of household waste, use of waste cooking oils, and other sources can also provide some sources of fuel. However, a complete elimination of fossil fuels would create very large requirements for liquid and gaseous fuels, unless there is a transition to a hydrogen economy and/or a far greater use of solar thermal energy and/or electricity for a variety of purposes including space heating and industrial process heat. That is the case in the reference scenario. For purposes of illustration of land requirements in the reference scenario, we will ignore the relatively modest contributions that landfill gas and household garbage and trash could make to total biofuel requirements. In practice such sources can often be used to good effect.

The productivity of land and the efficiency with which the biomass is converted into liquid and gaseous fuels (mainly methane to replace natural gas) and feedstocks determine the land area that will be needed. The use of prairie grasses and switchgrass for producing the entire projected amount would require 12 to 15 percent of the land area of the United States, which is an unrealistic requirement. Even if it were feasible, devoting such a large land area to commercial crops would require the creation of a vast new infrastructure of roads and industries in many areas that are now unspoiled or nearly so. For reference, the land area harvested in 2005 was 321 million acres,[18] which is about 14 percent of the U.S. land area.

The reference scenario, therefore, requires the inclusion of a substantial portion of high productivity biomass to reduce the land-area requirement to about 5 to 6 percent. The latter figure is the upper limit of what would be feasible (though not necessarily desirable). Six percent of the land area of the United States is about equal to the land area of Montana and North Dakota combined.

The principal ways to reduce land-area requirements while still relying on liquid and gaseous biofuels derived from biomass is to maximize the use of landfill gas and other waste biomass and to rely on biomass that has high efficiency of solar energy capture (~ 5 percent). The approaches are discussed in Chapter 3 and can be summarized in the context of the reference scenario as follows:

- Capture of CO_2, notably in microalgae, in the short and intermediate (5 to 30 years) term from fossil fuel combustion at power plants and in industry.
- Capture of CO_2, notably in microalgae, in the intermediate and long term (from about 2020 onwards) from biomass and liquid and gaseous biofuel combustion at power plants and in industry.
- Cultivate high productivity biomass, including microalgae and aquatic plants, such as water hyacinths and duckweed, for instance, in constructed wetlands associated with wastewater treatment systems and in areas with runoff that have high nutrient content.

The following approach has been used in the reference scenario regarding capture of CO_2 in the biomass/biofuels sector for the year 2050:

1. Twenty percent in industry
2. Fifty percent in production of liquid and gaseous biofuels from biomass
3. Eighty percent in central station electricity production.

The low percentage of CO_2 capture assumed for industry is due to siting issues, since land availability would likely be a problem for a large number of industries. This would be the smallest constraint for power plants, since these would be sited close to the location of biomass production, with due consideration given for land requirements of CO_2 capture in microalgae. The percentage of CO_2 captured from the liquid and gaseous biofuels production sector is assumed to be in between the industrial and power generation sector. In most of these cases, facilities for one-to-two-day storage of CO_2 would be required in order to capture the CO_2 generated at night on the following day or two. This would be required to accomplish the targeted capture fraction.

The productivity of microalgae and aquatic plants is assumed to increase from 150 metric tons per hectare (60 metric tons per acre) in the year 2020 to 250 metric tons per hectare in the year 2050. As noted in Chapter 3, the largest productivity that has been observed to date has been 250 metric tons per hectare under optimum climatic conditions.

With these assumptions and a productivity of switchgrass or prairie grasses of 30 metric tons per hectare by 2050, the land-area requirements for all biofuel requirements, including those for electricity generation come to about 184,000 square miles, which is just over 5 percent of the land area of the United States. It should be noted that these calculations of land area are very approximate and depend greatly on a variety of assumptions about the kinds of plants that would be grown, and the regions where the biomass would be grown.

Table 5-1 summarizes the main land-area requirements for the reference scenario:

Table 5-1: Land-Area Requirements for the IEER Reference Scenario (rounded)

Energy source	Land area, square miles	Side of a square	Comments
Wind	490	22	Mainly infrastructure, including roads
Centralized Solar PV	860	29	PV area + 30% infrastructure
Solar thermal (central station)	210	15	Collector area + 30% infrastructure
Biofuels (solid and liquid)	184,000	429	About five-sixths of the area is harvested area for biomass; rest is microalgae and aquatic plants
Total	**185,360**	**431**	**About 5.2 percent of U.S. land area**

Notes: 1. Wind capacity factor = 30% and land per megawatt = 0.6 hectares.
2. Solar PV efficiency 15%; average annual insolation 250 W/m^2.
3. Solar thermal efficiency 20%; average (tracking) insolation 300 W/m^2.

It is easy to see that the land-area requirements are dominated by biofuel production. This is because:

(i) the amount of biofuel requirements are very large, since biofuels supplant coal, oil, and natural gas combined, albeit in a more efficient economy,
(ii) the losses involved in the production of liquid and gaseous biofuels are significant even with overall 70 percent efficiency,
(iii) a significant amount of biomass production is assumed to occur at a rather low solar energy capture efficiency of 30 metric tons per hectare, which is an efficiency of solar energy capture of less than one percent at typical average levels of insolation.

Cultivation and harvesting of biomass must be done in ways that do not decrease the carbon stored in the soil (a minimal requirement) or, preferably, it should increase carbon stored in the soil. In this analysis it is assumed that biomass cultivation will not change soil CO_2 storage.

The reference scenario incorporates features that would allow land currently not deemed fit for cultivation and, potentially, as well as, areas such as the Salton Sea in California for most biomass cultivation. The land-area requirements are still very large. Cultivation of prairie grasses, switchgrass, etc., would require an expansion of harvested area in the United States by about 30 percent. If sufficient high productivity biomass is not available, the land-area requirements could increase beyond 6 percent. It is therefore important to consider ways to reduce the land-area requirements, including increasing biomass production efficiency and direct solar hydrogen production. We note here, in closing, that the reference scenario is designed mainly to illustrate one path to a zero-CO_2 emissions economy without nuclear power. It is not necessarily the most desirable way to get there. We explore the options in Chapter 6.

CHAPTER 6: OPTIONS FOR THE ROADMAP TO ZERO-CO_2

The reference scenario provides one plausible way to achieve a U.S. economy without CO_2 emissions or nuclear power by about 2050. However, on the basis of the technical framework in that scenario alone, there are a number of uncertainties that may prevent its achievement. It may also not be the most effective or environmentally sound way to a renewable energy economy. We have already noted the rather large land requirements (over 5 percent of the U.S. land area) for biofuels as well as the large energy losses associated with the production of liquid and gaseous biofuels in the reference scenario. Further, the continued use of carbon-based fuels also implies the continuation of some level of air pollution, including unburned hydrocarbons, carbon monoxide, and nitrogen oxides.

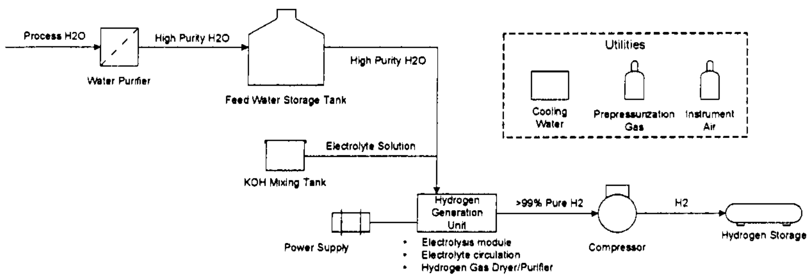
Further, several of the key technologies in the reference scenario are leading-edge technologies that are still in the demonstration stage, as for instance, is the case with capture of CO_2 from power plants using microalgae. Other technologies are in the marketplace, but are not yet commercial and require subsidies or cater to niche markets. This is the case with lithium-ion electric cars/SUVs, for instance. Lithium-ion batteries must come down in cost by a factor of about five before they can be used on a large-scale to transform the energy system. This is also a requisite for their use in an effective vehicle-to-grid system. The path to the zero-CO_2 emissions goal would be quite uncertain unless there is a systematic technological redundancy built into energy policy so that roadblocks in one or a few areas do not prevent overall progress towards eliminating CO_2 emissions.

A. Hydrogen Production from Solar and Wind Energy

It is possible today to produce hydrogen on a large-scale from renewable energy sources by electrolysis of water.[1] Hydrogen can be produced on a distributed basis, that is, near the point of use, or on a centralized basis. In the latter case, a hydrogen infrastructure, notably long-distance pipelines are needed. We will focus on distributed generation in this brief examination in order to illustrate the potential of hydrogen to displace biofuels.[2]

Figure 6-1 shows a flow diagram of a distributed hydrogen production system. It consists of an electrolyzer, water supply, a water purifier (since high purity water is needed), a compressor, a storage tank, and ancillary facilities. Vehicles can be refueled from the storage tanks. The overall efficiency of present-day systems was estimated to be about 60 percent as of 2005.

Figure 6-1: Schematic Diagram of Compressed Hydrogen Production by Electrolysis



Source: Ivy 2004 Figure 1 (page 6)[3]

While a considerable amount of attention has been devoted to cars with fuel cells that use hydrogen as a fuel, this is not necessary for using hydrogen in motor vehicles. It can be used in present-day internal combustion engines. Pound for pound, hydrogen carries about 2.7 times as much energy as gasoline. However, since it is very light, its volume energy density is correspondingly low. Hence for cars to have a reasonable range, it must be compressed to 10,000 pounds per square inch or be used in the form of liquid hydrogen. The latter carries significant cost penalties.

A BMW luxury car prototype, with a 260-horsepower engine, that is fueled by liquid hydrogen, is being made in a limited edition, to be driven by selected users, on lease or loan in Europe, Asia, and the United States. A few liquid hydrogen refueling stations will be open to serve the drivers. The range of the car on hydrogen fuel will be limited to 125 miles. It is a dual-fuel car, with a supplementary gasoline fuel tank, which extends its range to 425 miles.[4]

The Department of Energy's program plan for hydrogen estimates the cost of distributed hydrogen production using electrolysis at about $4.80 per kilogram. The DOE cost estimate assumes an electricity cost of 3.9 cents per kWh, which is a low off-peak cost. This is a cost estimate not for wind-generated electricity, but rather among the lowest prevailing prices available on U.S. electricity grid.[5] Were the analysis done for wind-generated electricity, the cost of hydrogen would be higher – closer to about $6 per kilogram. This is double the average price of gasoline in the United States as of early July 2007 (energy content comparison). However, it is typical of the price of gasoline in much of Western Europe, since gasoline is highly taxed there.

The DOE estimates that in order to bring the cost of hydrogen to about \$2.80 per kilogram, electrolyzer costs per kilogram of hydrogen would have to decline by about a factor of four from \$1.20 in 2006 to 30 cents. Operating and maintenance costs, other than electricity, would have to decline from \$1.40 to \$0.70 per kilogram of hydrogen. A modest reduction in electricity costs from \$2.20 to \$1.80, mainly attributable to increases in electrolyzer efficiency, is also assumed to occur within a decade. With typical wind energy costs, these figures would imply a cost of about \$4 per kilogram of distributed hydrogen production.

The above comparisons have treated hydrogen and gasoline on a par for the purposes of fuel cost evaluation. However, tests on prototype hydrogen cars using internal combustion engines indicate that their efficiency will be higher than the same cars using gasoline. A Ford 350-Series pickup truck using hydrogen was "up to 25 percent" more efficient than its gasoline counterpart according to a Ford hydrogen vehicle technical leader.[6] If a hydrogen car is significantly more efficient than a gasoline car, all other things being equal, then the break-even price of a kilogram of hydrogen can be that much higher than a gallon of gasoline. For instance, if hydrogen is 25 percent more efficient than gasoline, then hydrogen at \$4 per kilogram is equivalent to gasoline at about \$3.20 per gallon, if the pickup truck has a gasoline fuel efficiency of 15 miles per gallon. Further, hydrogen from renewable energy would have no CO_2 emissions and it would also have lower emissions of other pollutants than gasoline-fueled cars. The significant health benefits from reduced urban air pollution by switching to hydrogen fuel are not easy to quantify but very real.

As an aside, it is worth noting that electrolysis of water also generates pure oxygen ($2H_2O \rightarrow 2H_2 + O_2$), which could in some cases be marketed. If the electrolysis facilities are near a coal-fired power plant, the oxygen could be used instead of air for the combustion of coal. This would reduce nitrogen oxide emissions and enable capture of CO_2 for sequestration. We have not explored the possible implications of this, since it would require site-specific study, but considerations relating to the use of oxygen should be part of any optimization strategy for producing electrolytic hydrogen.

The Department of Energy's cost goals for electrolytic hydrogen discussed above are for the year 2017. If they are met, it may be possible to avoid much of the use of biofuels assumed in the reference scenario, since hydrogen could be used in its stead, possibly from 2025 onward. The reference scenario use of biofuels in the year 2050 for transportation excluding aircraft is about 9 quadrillion Btu. If half of this is replaced by distributed hydrogen, the land-area requirements could be reduced by 10 to 15 percent.[7] However, this would require quadrupling of wind energy requirements compared to the reference scenario.

The transmission infrastructure requirements would be very large and present a significant obstacle. Were wind-derived hydrogen to become economical, it would be possible to consider special pipelines for hydrogen. As an alternative, wind-derived hydrogen could be used to a more modest extent and coupled with direct solar hydrogen production. A mixture of wind-derived hydrogen and centralized direct solar hydrogen production could be considered. This would make the hydrogen infrastructure more economical, since it would be shared between wind and solar hydrogen production. This would improve the capacity utilization by reducing the impact of intermittency of either source alone.

Centralized hydrogen production would require a pipeline infrastructure, which could at least in part follow existing electricity transmission corridors. Such corridors already exist from the Midwest eastward and from the Rocky Mountain states westward. In addition or as a substitute, offshore wind farms could be used to create onshore distributed hydrogen infrastructure. Offshore wind farms may be the best approach in many cases to combining large-scale wind energy with distributed hydrogen production, since the wind farms could be built within a few dozen miles from the points of hydrogen production on land.

Hydrogen could also be used for residential and commercial applications in place of biomass-derived liquid fuels or methane. In an economy in which most biofuels are replaced with hydrogen produced at 10 percent efficiency from solar energy, the land requirements for a renewable economy could be reduced to ~2 to 3 percent of the US land area – or about half that of the reference scenario. Wind-derived hydrogen would take even less land. We note that 10 percent is currently the DOE target efficiency for photoelectrochemical hydrogen production for the year 2018. This is a method of producing hydrogen directly from solar energy (see Chapter 3).

B. Efficiency and Electricity

It is possible to reduce biofuel requirements in the residential and commercial sector by increasing efficiency relative to the reference scenario and, in that context, also increasing the use of electricity.

In the reference scenario, the average residential energy use per square foot is about 38 percent of the average in 2004. For the commercial sector the value is about 58 percent. There are a many energy efficient buildings being built today, some of which are not much different in cost than less efficient ones that have energy use significantly less than the projected average. The Hanover House, a single family home already discussed in Chapter 4, is an example. The delivered energy in 2004 on average was 58,000 Btu per square foot in the residential sector and that in the Hanover House was only 8,300 Btu per square foot. A combination of advanced design features and active solar thermal hot water and space heating minimize the purchased energy. One of the most interesting results of this design is that the house uses no liquid or gaseous fuels at all. The supplemental heating is provided by electric resistance heat. The combination of active solar thermal heating and design features means that even a rather inefficient use of electricity – resistance heating – is in a context where the inefficiency of the method is rendered more or less irrelevant due to the small demand. As noted in Chapter 4, the house could achieve net zero energy with about a 3 kilowatt peak solar PV installation.

While it is not possible to backfit existing homes with all the features of the Hanover House, it is possible to backfit many more existing homes with space solar heating and possibly solar thermal cooling as well.[8] One of the principal advantages would be to largely eliminate methane derived from biomass. A detailed evaluation of the potential for residential and commercial use of such technologies both in existing and new buildings would provide a guide as to the amount of methane replacement for natural gas that can be eliminated.

As another example, we have used an average coefficient of performance of six for air conditioners in the year 2050 and of four for heating for geothermal heat pumps in that year. The best current commercially available equipment using geothermal heat pumps has a coefficient of performance for cooling of about eight (Energy Efficiency Ratio or EER of 27) and heating of about four.[9] A gradual increase in standards to a cooling COP of eight or ten and a heating COP of five or six is likely possible, with the right incentives and regulations.

In the transportation sector, efficiency of liquid fuel use can be pushed considerably beyond that assumed in the reference scenario. For instance, the efficiency of light-use vehicles (personal cars and SUVs) is assumed to increase gradually to 50 miles per gallon by 2027. By contrast, the European Union has a target of 52 miles per gallon by 2012. Of course, the United States is far behind the EU currently, so that it will take time to catch up. But there is little reason, other than political resistance by the automobile industry in the United States, that the efficiency schedule in the reference scenario cannot be accelerated to 50 miles per gallon by 2020 and 100 miles per gallon by 2050. The increases in efficiency of trucks can be similarly accelerated.

Aircraft in the reference scenario also have slow improvement in efficiency, which on average would reach about 100 seat miles per gallon by about 2035. This efficiency has already been achieved by current generation of new aircraft. With an average life of aircraft in service at any time of ten years, a much greater improvement in efficiency is possible and perhaps likely, given current high fuel costs.

Finally, it is also possible that reduction in battery cost and weight would allow electrification of long distance truck transport. This is a matter whose evaluation can properly be done in a few years, when battery technology is more mature and prototypes have been built as they have been for cars and light trucks.

Overall, the liquid and gaseous biofuels requirement could be cut possibly by roughly a third, possibly more, with present and easily foreseeable efficiency standards and incentives as well as greater orientation towards electrical and solar thermal heating technology.

C. Stationary Storage of Electricity

It is possible that vehicle-to-grid approaches would not work as well in practice as the promise indicated on paper. In some circumstances, combinations of high peak loads and low availability of vehicles at the right locations may make reliable operation difficult. It is appropriate therefore to consider the cost of stationary storage. This can be done using advanced batteries (lithium-ion, sodium sulfur) possibly with ultracapacitors.[10] The latter can be considered for supporting the electricity grid but not for cars (so far as can be foreseen) because they store much less energy per unit weight than do lithium-ion batteries or even lead acid batteries. Since weight is at a premium in vehicles, batteries are to be preferred for electric cars. That is not a critical constraint for stationary applications.

Lithium-ion or other advanced batteries, possibly in combination with ultracapacitors, could be used to provide storage for solar PV systems as a complement to or in place of V2G if the overall capital cost of storage is reduced to $200 per kWh or less. The added capital cost of one day's storage, including ancillary equipment, would be about $1,200 per installed peak kW of solar PV capacity.[11] At $1,500 per peak installed kilowatt for solar PV, the overall cost of electricity provided at peak and intermediate times works out to about 16 cents per kWh. Distribution costs for electricity generated on an intermediate-scale in commercial parking lots or on commercial rooftops might be on the order of 2 cents per kWh. With a more efficient use of electricity, the overall cost of electricity services (lighting, refrigeration, air conditioning, etc.) would not be significantly different than at present (see Chapter 8). It appears worthwhile therefore to place a significant emphasis on developing stationary storage methods for electric power with a cost goal of $200 per kWh or less.

D. Feedstocks and Industrial Energy

A very large use of liquid and gaseous fuels (at present oil and natural gas and, in the reference scenario, liquid and gaseous biofuels) is for use as industrial feedstocks, as for instance for plastics, lubricating oils, synthetic textiles, and other products, such as vehicle tires, made from synthetic fibers. Feedstock uses of energy-containing materials are projected to remain constant at somewhat over 7 quadrillion Btu per year through to the middle of the century. This is about one-fifth the estimated use of liquid and gaseous biofuels in 2050 in the reference scenario – about the same as the entire use of these fuels in the residential and commercial sectors combined.

Recovery of materials for reuse where they may be burned or discarded today would be a much more powerful incentive in the context of policies designed to eliminate CO_2 emissions. Fossil fuel feedstocks would be treated on a par with fuels since most such materials eventually degrade and produce greenhouse gases, including CO_2. While some do so slowly – others, such as plastics and tires – are often incinerated. For instance, if a technology for devulcanizing rubber **can be commercialized** – that is the process that removes sulfur from rubber – then most raw material for new tires could come from discarded existing ones.[12]

In some cases, plastics can be recovered for replacing new feedstock. New materials can be designed that would ease such recovery. It is difficult to estimate the impact that such approaches would have cumulatively without a detailed study devoted to this subject alone. That is one of the reasons that they have not been included in the reference scenario. However, it would be highly desirable to reduce the use of feedstocks as much as possible so as to reduce the requirements for biofuels.

E. Natural Gas Combined Cycle and Coal as Contingencies for the Electric Grid

The electricity sector discussed in Chapter 5 relies a good deal on advanced technology such as lithium-ion batteries, the vehicle-to-grid system, and hot rock geothermal that are on the cutting edge of new developments in energy today. Technical assessments available today indicate that all of these technologies can be made economical within ten to fifteen years or less in the context of policies designed to achieve a zero-CO_2 economy (that is policies that increase the price of fossil fuel use and encourage the use of renewable energy and higher efficiency). But that is by no means assured. It is prudent therefore to make a contingency plan in case some of these approaches do not work. Direct solar hydrogen production as well as electrolytic production of hydrogen from wind are two such technologies. The latter is well in hand and requires a cost reduction of about a factor of two (compared to a factor of five for lithium-ion batteries). But it also requires the creation of a hydrogen-using infrastructure.

If zero-CO_2 by 2050 is defined as being within 5 percent of present CO_2 emissions, about 20 percent of electricity generation could come from natural gas combined cycle plants in that year. This would be a more than sufficient contingency for the failure of one or more of the advanced technologies that are part of the electricity sector in the reference scenario (V2G, hot rock geothermal, and biomass derived methane all put together, for instance). Further, the CO_2 from combined cycle plants can be captured and sequestered. As discussed in Chapter 3, carbon sequestration technology needs to be developed in any case as a prudent measure in case we need to recover some of the already emitted CO_2 from the atmosphere. Finally, sequestering 250 to 300 million metric tons of CO_2 would be qualitatively less problematic than attempting to find sound locations for disposal of amounts that would be several times larger, were coal to continue as a major energy source.

If such a contingency were to be put into action, alternatives for the remaining natural gas would have to be researched, developed and put into place for a complete elimination of fossil fuels. As discussed, such alternatives do exist, but it is difficult to estimate their commercialization prospects at present. Given that, it is possible that even with a vigorous and ongoing program of evaluation, research, development, and demonstration, achieving zero-CO_2 emissions in the literal sense could take a decade or so longer than in the reference scenario.

For coal to remain as a contingency in an economy with zero-CO_2 emissions, it will be essential to first demonstrate that carbon sequestration is a reliable technology that will contain CO_2 underground for thousands of years. The specific geologic settings and circumstances in which such performance can be expected will have to be specified. As noted in Chapter 3, the development of carbon sequestration technology is important in any case as a contingency in case the extraction of CO_2 already emitted to the atmosphere is needed. Such an eventuality may arise if climate change is far more severe than now anticipated in models that call for a 50 to 85 percent reduction in CO_2 emissions by 2050.

Some effort at developing approaches for removing CO_2 from the atmosphere at modest energy cost is also warranted. However, we note that resorting to this will increase energy use and complicate and possibly lengthen the schedule for eliminating CO_2 emissions.

In sum, natural gas combined cycle could be used as a contingency source of electricity power supply for up to 20 percent of generation in the reference scenario even if sequestration does not prove to be viable. For coal to serve as a contingency fuel in a zero-CO_2 economy, a prior demonstration that carbon sequestration would be feasible is necessary.

F. Structural Changes in the Economy

It is environmentally desirable to have many other changes in the structure of the U.S. economy that have not been factored into the reference scenario or any of the technical alternatives considered in this chapter. These do not relate to energy conservation as such, but rather to broader decisions about the pattern of economic development that could have significant implications for energy demand, and for the pace and the nature of the transition to a renewable energy economy.

For instance, in Chapter 4, we considered the issue of public transportation and showed that the energy efficiency and overall energy use in personal transportation (including cars) and even the number of cars owned varies according to the quality of the public transportation infrastructure. Were high quality public transportation to be treated as a public utility, a necessity for cities, much like electricity supply from a grid or sewage treatment systems or public water supply, the structure of cities would tend more toward being like San Francisco or New York or London or Paris. The mix of walking, public transport, bicycling, and automobile use would change, not because of energy considerations, but because it was more convenient and healthy, as well as less polluting. There is no evidence that such changes would decrease wealth or the GDP, but they would shift it toward greater public infrastructure investments and less energy production and consumption investments. The structure of the energy investments would also be different.

As another example, there are many reasons to consider greatly reducing the use of water sold in plastic bottles. Some leading brands of bottled water are just treated tap water. Transport of water over long distances contributes to water and air pollution needlessly. Despite recycling efforts, most plastic bottles are discarded. Finally, there is the question of the use of petroleum to make the plastic.

Much tap water, like that in New York City, is famously pure. Pollutants can be removed from tap water with commercially available filters at a small fraction of the cost of bottled water. A significant reduction of bottled water use would have modest implications for energy, but were it accompanied by similar changes in food and beverage consumption patterns, the implications for energy demand in the agricultural and industrial sectors could be significant.

One would not advocate a change were bottled water essential to health. But, arguably, it is not, as a general matter. Similarly, changes in where we live, what modes of transportation are available to us, and what we choose to eat and drink can have important effects on the shape of a renewable energy economy. This report shows that they are not essential to achieving it. However, a change towards a less energy intensive economic structure, because it is healthier and more desirable for other reasons, could accelerate the transition to a renewable energy economy much in the same way as increasing the efficiency of energy use. This topic is vast and complex in its own right. Moreover, it is not essential to the core investigation as to whether a zero-CO_2 emissions economy without nuclear power is feasible; hence, we have not attempted to quantify the effects of structural changes in the patterns of production, trade, and consumption. However, this omission should not be construed as an indication of a lack of importance of structural changes that improve quality of life, health, and reduce energy use.

G. Some Considerations in Setting Target Dates for Zero-CO_2 Emissions

We selected 2050 as a reference date for a zero-CO_2 economy for several reasons:

- The amount of installed coal and nuclear electric capacity in the United States is very large and it will take time to phase it out.
- It will be difficult to substitute liquid and gaseous fuels in the residential, commercial, and industrial sectors quickly and it will become more economical as equipment depreciates, new buildings are built, and existing buildings are sold.
- A number of the technologies that are needed are not yet fully commercial and some have not been fully demonstrated (such as using V2G to enable efficient use of renewable resources).
- The sunk investments in the fossil fuel sector would be largely lost if the equipment is retired prematurely.
- Rapid increases in the price of CO_2 allowances, for instance, by sharp reduction in CO_2 caps for the industrial and electricity production sectors, may cause a large-scale migration of industry offshore. Though this study has been done only in the U.S. context, it is recognized that there are limitations to actions in one country alone in terms of implications for global CO_2 emissions.

This is a powerful set of reasons. But at least as powerful is the quickly developing climate crisis, whose presence is clear but whose dimensions are as yet emerging. Adverse changes are occurring much faster than estimated even a few years ago. Hence the case for more rapid action is persuasive, at least to this author.

1. Historical Examples

Large transitions in the energy sector are nothing new. There was a huge transition from wood and animal power to coal in the nineteenth century. But it was still partial. Animals were still the main source of energy on farms, and the use of wood was still widespread a hundred years ago. Three other examples are more indicative of the potential for rapid transitions.

We have already discussed the first, which occurred in the United States after 1973. Within a couple of years, a relationship of lock-step growth between the economy and energy use that had been considered almost a law of modern economic development was broken. For over a decade, economic growth occurred without energy growth (on average). Industrial growth continued after that without energy growth. Hence, it appears possible to move the economy in a direction of more efficient energy use in a very short time. In this example it took an external shock. But there is no inherent reason why policies related to climate change cannot propel a similar change. We have already taken this into account to some extent in our demand scenario, though there is still ample room beyond that for energy efficiency, as noted above.

A more rapid transition can also be achieved if there are breakthroughs in supply and conversion technology. Let us first briefly consider some recent historical examples of major energy transitions.

The energy economy of the United States was thoroughly transformed in the first four decades of the twentieth century from horses and coal-fired trains to electricity and oil-fueled cars and tractors. The evolution since World War II has been of growth, not of structure. Nuclear power has not changed this fundamentally, since it supplies only about eight percent of U.S. energy and about 20 percent of U.S. electricity. Seen in this context, a time scale of about forty years appears to be reasonable and practical. The evolution of the energy economy was driven by a mix of laissez-faire, government policy, cheap oil, and two world wars.

The transitions in the electricity sector in France since World War II are even more interesting. There were two major ones between about 1960 and the 1990s. Table 6-1, taken from an earlier IEER report on the French energy sector, summarizes those transitions.

Table 6-1: French electricity sector transitions energy supply, in percent

	1960	1973	1996	2001
Coal [1]	~35	16	5	6
Hydro	56	27	14	14
Oil	7	39	Included in "other thermal"	2
Other thermal [1]	2?	10	3.6	1.4
Nuclear fuels	Negligible[2]	8	77	76

[1] We do not have exact coal and "other thermal" data for 1960.

[2] The initial sources of nuclear electricity in France were the plutonium production reactors in the nuclear weapons sector.

Source: Based on Makhijani and Makhijani 2006 Table IV.1 (page 27)

In 1960, the French electricity sector was dominated by hydropower and coal – they were over 90 percent of the total supply. In an era of rapid electricity growth and cheap oil France made a major electricity sector transition in only 13 years. By 1973, coal was on its way out, hydropower made half the percentage contribution it did in 1960, and oil had risen from 7 percent to 39 percent. Natural gas went from essentially zero to nearly ten percent. These rapid changes should be seen both as a result of national policy (France's electricity sector was

100 percent nationally owned) and rapid growth. Hydropower output did not decline. Rather, electricity use grew – and the growth was taken up by cheap oil and natural gas.

The second transition was more complete. Essentially the entire electricity sector, except for a more or less constant total contribution from hydro (and hence declining share), was supplied by nuclear power. This was not the result primarily of economics. France could have imported coal from the United States, for instance. It was the result of an "energy independence" decision taken to reduce France's dependence on petroleum, since almost its entire supply was (and continues to be) imported. While France is still dependent almost entirely on oil imports for its transportation sector, oil was nearly eliminated from the electricity sector.[13]

France's electricity sector transition shows that a nearly complete transition in a large sector can occur in less than 25 years, given determined government policy. It must be noted here that there was precious little consultation with the public on the transition to nuclear power, which has created its own problems, for instance, in terms of finding a site for disposal of high-level nuclear waste. The French government also owned the sector it transformed. But we see no fundamental reason why, with the right policies and incentives in place, a transformation of the U.S. energy economy to one that has very low CO_2 emissions cannot be achieved in 30 years, that is, before 2040. The French example shows that a transformation to a proliferation prone and costly technology that did not even solve the oil import problem in France was possible in the name of energy independence. The same could surely be done in making the change to an efficient, renewable energy economy given that, according to the Stern Review, climate change represents "the greatest and widest-ranging market failure ever seen."[14] The uncertainties largely lie, perhaps, in the last 10 or 15 percent of energy supply requirements.

2. Demand Sector Considerations for a Target Phase-out Date

Two complementary approaches to energy supply and to CO_2 emissions reduction could greatly accelerate the process. First, the residential and commercial sector should be considered together in terms of policy for encouraging renewable energy sources. The scale of residential solar PV is so small that custom backfitting will likely continue to be expensive even with cheaper solar cells, since the balance of the costs, including retail price markups, costs of inverters, connections to the grid, and labor, would not diminish very much. By contrast, medium-scale commercial installations in parking lots and on roof tops – 100 kW to a few MW – can be envisioned in the coming years at installed costs as low as $1.25 per peak watt. At the present time, the cheapest solar cell manufacturing is $1.25 per peak watt and installation costs are in addition to that.

As noted, bringing installed costs down to such a low level requires process improvements for solar cells that are already in the manufacturing and commercialization stages. But it does not require fundamental new technical breakthroughs. Broadening the concept of "zero net energy" could help. The term is usually defined in the context of a single building; it is taken to mean that the energy produced within the premises of the building (including its grounds and structure) is, on an annual average basis, equal to the energy consumed. On a day-to-day basis, energy may be imported or exported from the building, usually from and to the electric grid (respectively).

Contracts to sell electricity from commercial-scale installations to private residences and to other buildings in the commercial sector itself could be included in a community concept of zero net energy. This "community zero net energy" or "area zero net energy" could accelerate the transition to renewables by allowing development of lower cost resources first and making them available to a larger population.

There are already examples of institutional arrangements for contracts between commercial institutions. For instance, specialized companies are installing medium-scale solar PV on roofs and parking lots and selling the electricity to the corporations that own the buildings at their existing cost of electricity. The solar energy companies themselves make money from the electricity sales revenues and state, local, and federal rebates and incentives for solar PV.

Parking lot and rooftop area in the commercial sector is sufficient to supply both the residential and commercial sectors.[15] We estimate that, with time-of-use pricing, such contracts would not require incentives at $2 per peak watt or less (installed). One important constraint could be the quality of local distribution systems, which would need to be improved in many cases. Transmission costs are avoided. Equally important, if intermediate-scale systems form a principal source of supply, then the need for new transmission corridors can be reduced, and, in some cases, eliminated.

Local storage of electricity could also make the transition more rapid. As noted above, V2G systems and/or stationary electricity storage would allow a higher fraction of installed renewable capacity at the local level without placing large demands on the grid for providing reserve capacity. Either V2G or storage technologies are critical. If both can be successfully developed in a decade, the CO_2 emissions due to personal vehicles and residential and commercial electricity consumption, about 45 percent of the total, could be eliminated in about 30 years, possibly less.[16]

Michael Winkler has proposed an integrated electricity and thermal storage system. That storage can be accomplished using hot water. Storage of cold is accomplished with a specially designed ice-maker. Such a system could reduce the costs of a renewable energy system by minimizing installed capacity requirements. For instance, night-time wind-generated electricity could be used to make ice which would provide cool air during the day-time.[17]

H. Estimating a Phase-out Schedule

We will first consider a recent historical parallel to the complete elimination of a class of industrial materials due to environmental concerns and then summarize the possible range of dates by which CO_2 emissions could be eliminated without the use of nuclear power.

1. Ozone-depleting Chlorofluorocarbons (CFCs)[18]

The history of the complete elimination of CFCs, which were almost as ubiquitous as fossil fuels, though in more subtle ways, is instructive. In the mid-1970s, CFCs were used in everything from refrigerators and car air conditioners to the foam used for flower arrangements and insulation to solvents for cleaning electronic circuit boards to spray cans. In the 1970s, in a bow to initial scientific concern and findings and popular sentiment, the use of CFCs in aerosol spray cans was banned in the United States. There was as yet no detected large-scale depletion of the ozone layer.

In 1985, the existence of the Antarctic Ozone Hole was confirmed. By 1987, other trends in ozone layer depletion also showed themselves to be worse than previously estimated. In 1985, only the Vienna Convention for the Protection of the Ozone Layer was in place as an international treaty. It asked its members to take action to protect the ozone layer, but placed no numerical limits on emissions and had no phase-out date for CFCs.[19] There was widespread sentiment in the two to three years that followed for a complete phase-out of CFCs, but there was also much industry resistance and alarms about potential drastic economic and social results if CFCs were phased out.

Yet alternatives were available or nearly so. A report done by the present author with two other colleagues showed that alternatives existed in every sector where significant amounts of CFCs were used.[20] Some were not as economical as CFCs but others turned out to be cheaper. Some were in the pilot plant stage. Some were well developed. By 1987, when the Montreal Protocol to protect the ozone layer was signed, there was agreement to reduce CFCs production by 50 percent by 1998. But the crisis clearly demanded more. In 1988, DuPont, the largest manufacturer of CFCs, announced it would stop making them by the year 2000. In the same year, Sweden announced it would phase out CFCs by January 1, 1995. The 1990 revision of the Montreal Protocol, signed in London, set the year 2000 as the target date for a complete phase-out of CFCs by the developed countries. At the Copenhagen meeting of the parties to the treaty in 1992, the CFCs complete phase-out date was moved up to 1996. It was achieved. The developing countries were given an extra ten years.

The phase-out of CFCs was not without its bumps and problems. Some of the substitute compounds also caused depletion of the ozone layer, though not as powerfully. Some were greenhouse gases. At least some of these problems could have been avoided by a more thoroughgoing early elimination of ozone-depleting compounds than was agreed.[21]

The situation in the energy sector is similar, not only as a broad analogy but also in many details, such as the various stages of the development of the required technologies, the conflicts between partial reduction of CO_2 emissions versus a complete or near-complete elimination. Further, there are multiple goals to be achieved – in climate change, foreign policy as it relates to oil imports, and nuclear non-proliferation. A bold approach to eliminate CO_2 emissions, adopted early, with frequent and careful reconsideration of the potential for accelerating the schedule and also taking into account unanticipated problems, is indicated by the experience with ozone layer protection.

2. A Range of Dates for Zero-CO_2 Emissions

The energy sector is far larger and more complex than the use of CFCs. It will take investments and changes on a longer time frame, if only because the stock of existing capital – buildings, vehicles, aircraft, and industrial equipment – is so much larger. The main lesson of the rapid CFC phase-out was that with a firm target date that all parties knew would be enforced, CFCs were actually rapidly phased out at modest cost and little economic dislocation.

As noted above, there is no real technical obstacle to an elimination of the CO_2 emissions associated with personal vehicles and the residential and commercial sector within about 30 years. (We assume a starting date for serious action by 2010, since the enactment of legislation and the promulgation of regulations is likely to take about two years). By extension, it should also be possible to significantly reduce the use of petroleum across a broader swath of the transportation sector in that time. If the distributed generation of hydrogen and its use in internal combustion engines is put on the front burner of technology and infrastructure development, the whole land-based transportation sector could end petroleum use and move to a combination of electricity, hydrogen, and liquid biofuels. Each might be used alone, or two might be used in combination, as with plug-in hybrids for electricity and liquid biofuels, or dual-fuel internal combustion engines that use hydrogen and biofuels. If hydrogen can be economically compressed to 10,000 psi or more, it would be possible to have vehicles with reasonable range running only on hydrogen or a combination of hydrogen and electricity.

While hydrogen-fueled aircraft have been demonstrated, it is unlikely to contribute to a faster elimination of petroleum from that sector. The development of biofuels that resemble the properties of kerosene is more important for the air transportation sector.

One of the principal issues associated with biofuels is the amount of land that is likely to be needed for a complete transformation to a renewable energy economy if direct production hydrogen from solar energy is not developed and electrolytic hydrogen from wind energy is not made more economical. This throws some light on the importance of the development of the corresponding technologies for a more rapid phase-out. [22]

As discussed, all of the difficulties associated with the transition to renewable energy become more manageable if the efficiency of its use is increased to maximum feasible extent.

In sum, an elimination of fossil fuel use and nuclear power by about 2040 seems feasible if most of the following technical conditions can be met (policies are discussed in Chapter 7):

1. V2G technology is developed rapidly and/or stationary technology for electricity storage is developed rapidly so as to come down in cost to $200 per kWh or less. The main aim would be to make intermediate-scale solar PV supply most or all community electricity requirements. Investment in strengthening distribution systems would likely be required in some or many areas.
2. Greater use is made of solar thermal technology for heating and cooling in the residential, commercial, and industrial sectors, as well as for process heat in the industrial sector.
3. Efficiency is increased over that projected in the reference scenario, using technologies that are available today, along with greater electrification in the residential, commercial, and transportation sectors.
4. Wind-generated electricity is used to produce hydrogen on a large-scale, possibly using existing transmission corridors for creating a pipeline infrastructure. Alternatively, offshore wind development could be coupled with onshore distributed hydrogen infrastructure.
5. Greater use is made of hydrogen produced from wind energy in industry to produce feedstocks.
6. Direct solar production of hydrogen becomes economical within the next 15 years at efficiencies of ~10 percent, especially if such production can occur on an intermediate-scale, sufficient to serve single large factories or a few thousand automobiles. This allows faster incorporation of a significant amount of hydrogen into the fuel mix in place of liquid or gaseous biofuels.

The last item is, at present, in the stage of research. The other items in the list involve technologies that are already known and economical under some circumstances, or are within a factor of five of becoming economical. This last applies to ultracapacitors for large-scale stationary electricity storage and to lithium-ion batteries for electric vehicles. The cost of electrolytic hydrogen production is currently about a factor of two higher than the cost of gasoline, without taking into account any of the external health and security costs associated with oil.

The above list is not meant to be exhaustive of the possibilities that could result in an earlier elimination of CO_2 emissions from the U.S. energy sector. Rather, it is envisioned that a regular process of evaluation will take place to gauge the effectiveness of the policies, to assess new technologies, and to consider unanticipated problems.

As a final note on the feasibility of creating an efficient economy based on renewable fuels by about 2040, we note that the depreciation of most of the energy production, conversion, and utilization equipment occurs over the 10-to-40 year range. A modest acceleration of this, induced by a price paid for CO_2 emissions allowances, could produce a more rapid replacement of existing infrastructure, provided the technologies were available at reasonable cost. This puts a significant burden on government to get its policies right, to have a system for making mid-course corrections, and to shape the market by performance-based procurement policies that will enable needed technologies to be commercialized faster.

Prolonged difficulties, for instance, in commercializing liquid biofuels from high productivity biomass or failure to achieve significant cost reductions in lithium-ion batteries, would make some of the technologies not now in the reference scenario necessary for a zero-CO_2 emissions economy. Greater use of other technologies such as thermal storage for large-scale solar thermal power plants and solar heating would also be necessary. In turn, such a turn of events would tend to focus on power development in the Southwest where the number of sunny days is high. This would raise transmission issues.

One important contingency plan to prevent delays beyond 2050 is to maintain a significant portion of the natural gas combined cycle infrastructure for generating electricity. This would provide a margin for error and failure in other areas that could help prevent a slippage of the 2050 target. As noted, if natural gas combined cycle were used for 20 percent of the electricity generation in the reference scenario, the total CO_2 emissions would be less than five percent of the level in 2004.

Carbon sequestration technology would provide some redundancy, but it could be limited if there are significant problems in finding geologic sites for reliable, long-term disposal of CO_2. Finally, vigorous development of solar hydrogen production and development of hydrogen-fueled aircraft would also provide redundancy in case of problems with large-scale hydrocarbon biofuels production.

CHAPTER 7: POLICY CONSIDERATIONS

The atmosphere, and specifically, its role in regulating the Earth's climate has been treated with disregard – or in economists' parlance, it has been treated as a "free good." This disregard creates many problems, including market decisions not to make investments in reducing CO_2 emissions. In the absence of economic incentives or penalties for reducing emissions, incurring expenses to reduce emissions puts the good environmental actor at a disadvantage in the marketplace under many circumstances. But the problem goes far beyond that. For instance, when energy is a modest or small part of a company's or individual's budget, they may pay little attention to opportunities to save money even at existing energy prices. For instance, it is economical to change from incandescent to compact fluorescent lamps, but the former still continue to dominate the lighting market. Corporations have been more responsive to opportunities to reduce energy consumption because saving energy often increases profits. In the residential and commercial sectors, the market failure is structural. Developers of residential and commercial properties generally do not pay the energy bills, so that there is actually a built-in incentive to skimp on items that are not uppermost in the buyers' or renters' minds, such as energy efficiency investments. In this case, there are actually built-in incentives for inefficiency (the technical term is "split incentive").

A number of approaches can, in theory, be used to reduce and eliminate CO_2 emissions:

1. Fossil fuels can be taxed according to their carbon content.
2. Emissions of CO_2 can be taxed.
3. A cap can be placed on CO_2 emissions, with the total amount being periodically reduced so as to ensure that emissions are declining with time. This system was first introduced on a large-scale as part of the 1990 Clean Air Act for reducing power plant emissions of sulfur dioxide (SO_2).[1]
4. A cap can be put on total production and import of fossil fuels, with a total ban going into effect in a pre-designated year.

5. Certain uses of fossil fuels could be banned. For instance, there have been proposals to ban new coal-fired power plants.
6. Indirect methods, such as efficiency standards for buildings, appliances, and vehicles can be used to reduce the total amount of energy needed for a given level of economic activity.

These methods are not mutually exclusive. For instance, at the present time, the United States has both gasoline taxes and fuel efficiency standards, though both are quite low. The European Union has high gasoline taxes as well as manufacturers' agreement to meet efficiency targets.[2] As another example, the problem of ozone-depleting chlorofluorocarbon emissions was addressed by simply banning production of CFCs and importation into developed countries by a certain date (1995) and in developing countries ten years later. And appliance standards without significant electricity taxes have helped greatly reduce electricity consumption for the same levels of air-conditioning, refrigeration, etc.

Some economists prefer taxes as the most efficient way of internalizing the costs of pollution and hence, reducing it. If the level of tax is not high enough to achieve the goal, it can be increased until alternative fuels and efficiency become sufficiently economical to do the job. However, taxes would pose significant problems for large portions of the energy sector of the United States, notably in the personal transportation sector. The level of taxes needed to reduce gasoline consumption significantly is quite high, since gasoline is typically only about one-fourth or one-fifth of the operating expense of a personal vehicle (unlike, say, a taxi). In Europe, where gasoline taxes run to several dollars per gallon, the efficiency of cars is still far below what it could be with available technology. In the United States, gasoline prices have doubled in the past few years, without a significant reduction in demand. In the economists' jargon, gasoline demand for personal vehicles is rather inelastic – that is, its sensitivity to price is rather low in practice (though its political sensitivity is higher). Second, low-income people tend to have the oldest and most inefficient vehicles; that makes a high gasoline tax (or tax on petroleum) very regressive. In theory, the income derived from a tax could be redistributed to low-income households, but this redistribution would be complex and difficult to achieve in a fair manner, even if it were politically possible to actually put an adequate redistributive law in place. Third, a tax on one fossil fuel alone would distort the energy marketplace. For instance, a tax of petroleum would encourage investment in technology for turning coal into liquid fuels. A tax on vehicles that fall significantly below specified efficiency standards may be an effective complement to CAFE standards. The revenues could be used to provide incentives for vehicles with efficiencies far higher than the CAFE standards.

There is a better case for a carbon tax on all fossil fuels – it would be set according to the amount of carbon dioxide that would be emitted per million Btu of energy derived from burning that fuel. However, the level of this tax would have to be very high in order to affect the use of petroleum. A tax of one hundred dollars per metric ton of CO_2 corresponds to a less than one dollar per gallon of gasoline. While people would buy more efficient cars, the European experience makes it clear that it would be not adequate to reduce gasoline consumption sufficient to address global warming concerns. Yet a tax of $100 per metric ton of CO_2 is greatly in excess of what is needed for reducing and even eliminating CO_2 emissions from the electricity and buildings sectors. A carbon tax is a rather indiscriminate instrument that does not take into account the varying costs of reducing CO_2 emissions in different sectors of the economy. However, taxes may have a limited role in some circumstances as noted above.

We focus on the following policies as the main instruments for achieving a zero-CO_2 economy without nuclear power in the United States:

1. A combined fixed limit on CO_2 emissions per year for large fossil fuel users that would decline to zero in 30 to 50 years and sale of emissions allowances by the government corresponding to each annual cap.
2. Efficiency standards for vehicles, residential and commercial buildings, and appliances.
3. A shaping of the energy supply and demand marketplace through government procurement, research, development and demonstration, as well as preferences for government contracts to corporations that have relatively low CO_2 emissions for their sectors compared to prevailing norms.
4. Appropriate electricity rate structures at the state and local level.
5. A ban on new coal-fired power plants without CO_2 storage.
6. Elimination of subsidies for fossil fuels and nuclear power.

A. A CO_2 Emissions Cap Declining to Zero

The first large-scale implementation of a cap on emissions of a pollutant that would decline over time was for sulfur dioxide. It was enacted into law in the 1990 Clean Air Act. It applied to large electric power plants and then to power plants over 25 megawatts. Free emissions allowances were allocated to power plants in operation before 1995. Power plants that came on line in 1996 and after had to purchase allowances on the market or from the government. Trading in allowances is permitted. The Environmental Protection Agency administers the program. Any registered individual or institution can purchase or sell allowances. The cap is tightened periodically (in 2000 and 2010).[3] The program is important for the lessons it holds for CO_2 emissions. Its success in reducing SO_2 emissions in the United States made it a model for the European Union's CO_2 cap and trade program.

The European experience in CO_2 caps is the most extensive so far. The program is similar to the U.S. SO_2 program in that it applies only to large users, but it covers many more types of emitters than just power plants. The definition of large energy users adopted in the EU was quite complex, because caps were set for individual sectors:

> Large point sources were defined as power plants with thermal capacity of greater than 300MW, all refineries, sulphuric acid production plants and nitric acid production plants, iron and steel plants producing more than three million tonnes per year, pulp and paper plants producing more than one million tonnes per year, vehicle painting units painting more than one million vehicles per year, airports with greater than one million LTO [landing and takeoff] cycles per year, and any other activity producing more than one thousand tonnes of SO_2, NOx or NMVOCs [non-methane volatile organic compounds] or three million tonnes of CO_2 per year. [4]

Like the U.S. SO_2 program, free emissions allowances were granted to existing emitters of CO_2. However, since the varieties of emitters was much more complex, the problem of allocating emissions also was correspondingly complex. Further, giving free allowances based on prevailing use of fossil fuels tended to reward the most inefficient, since they got larger amounts of a marketable commodity, CO_2 emissions allowances, compared to more efficient companies.

Analyses of early results indicate that, in terms of reducing CO_2 emissions, it fell far short of what was anticipated. A study by the Öko-Institut of Germany examined the system, known as the European Union Emissions Trading Scheme (ETS), in some detail. Some of its main conclusions were:

> 1. Auctioning remains the most efficient allocation approach. All approaches based on free allocation of allowances to existing or new installations will face major problems in ensuring comprehensive and non-distorting incentive structures of the ETS (i.e. the full and comprehensive pricing of carbon). No Member State was successful in sufficiently balancing all different incentives (for existing installations, new entrants, plant closure and replacement) against each other, although some (e.g. the UK) did much better than others.
>
> ...
>
> 3. The criterion of economic efficiency should be seen as the most important especially with regard to existing installations in the power sector. Fairness problems mostly arise for the allocation to new entrants.
>
> ...
>
> 6. The full costs of carbon create the key incentive for the operation of existing power plants and the implementation of emission abatement measures in existing plants. Ex-post adjustments eliminate these incentives (see the German example). [5]

Many of the problems arose in relation to new entrants. With free and generous allowances for existing users, new entrants would be at a competitive disadvantage if they were not given free allowances. But if new entrants were given free allowances, the cap would have to be increased each time there was a new entrant into the market. Continual adjustments in the cap and issuance of allowances created a situation of an oversupply of CO_2 credits and a collapse of the market for CO_2.

A U.S. evaluation of the EU system concluded that for industries with large CO_2 emissions, caps at the point of fossil fuel combustion were effective. Such a cap is called a "downstream cap" because it is at the point of end use of the fuel, which is "downstream" of the fuel production, processing, and transportation system.

> A downstream system that focused on large energy users only would be more feasible [than one with universal coverage]. The number of regulated entities would be quite small: Per CORINAIR [European air pollutant emissions inventory] data, the number of large point sources in the fifteen EU Member States totaled only 1,652 in 1990. Further, the carbon embodied in fuel combusted would be easy to estimate based on existing fuel use records, and the regulated facilities would be experienced in reporting environmental data. Accordingly, much of the analysis in Section IV [of CCAP 1999] relates to a "limited" downstream system that covers large point sources only.[6]

For small users, imposing individual caps and attempting to enforce them would involve the creation of huge bureaucracies to administer the program. Small users number in the hundreds of millions. In 2004 there were about 230 million personal cars, SUVs, and light trucks and 113 million residences in the United States. In such a circumstance, some, including the Electric Power Research Institute, have advocated an "upstream" cap for small users:

> An upstream market-based system, one that requires fuel producers to surrender allowances or pay a tax for emissions attributable to their products would cover 90 percent or more of these emissions.[7]

According to this proposal, natural gas pipeline operators and/or natural gas producers would have emissions allowances and would pay a tax for continuing to sell natural gas to homes and businesses if they did not want to surrender their allowances. The same would apply to petroleum refiners who make gasoline and diesel. They would be paying a tax even though they do not actually use the fuel. Since they have huge investments in the existing fossil fuel infrastructure, they would have every incentive to pass on the costs.

On the other hand, developers, who make the basic decisions about the energy consumption structure of buildings, would receive only an indirect and weak signal regarding fossil fuel use, since they don't pay the energy bills. Moreover, for residential purchases, energy bills are generally a minor consideration in the purchase. Schools, safety, transportation infrastructure, and design features of the buildings are more central. And, as every real estate agent knows, the emotional factor – a house that a customer loves for its particular features – is often critical. Similarly, gasoline is only on the order of one-fourth the cost of operating a personal vehicle. As discussed above, taxes would have to be very high to have a significant effect on gasoline consumption. Moreover, there is no clear path to essentially eliminating CO_2 emissions, unless very high levels of taxation are imposed. A hybrid system proposed here would avoid the creation of a large bureaucracy while creating a framework within which almost all of the elimination of CO_2 emissions can occur (see Section B below).

Some lessons can be drawn from the European experience:

1. Free emissions allowances to existing users reward inefficiency, create inequities between new and existing users of fuels, and penalize those who have taken early action to reduce emissions.
2. Free allowances are relatively ineffective in reducing CO_2 emissions, especially in a context of trying to create a level playing field for new users of fossil fuels.
3. It is difficult to create a system covering all users when it comes to fossil fuels because of the very large number of consumers.
4. Auctioning allowances from the start is much more efficient than "grandfathering in" existing emitters and trying to add charges for new users only.

In light of the above, we propose the following policies to reduce and eliminate CO_2 emissions for large users:

1. A single "hard cap" – an absolute quantitative limit – would be set for all large users of fossil fuels together. It would be reduced every year and go to zero, by 2060 at the latest, with periodic evaluations to try to achieve it earlier. The term "users" includes electric utilities, since they burn the fuel in producing the commodity they sell. The definition of a "user" would be at the level of the holding company. The fossil fuel use of all subsidiaries would be added to determine whether the entity meets the definition of a "large" user.
2. The federal government would auction CO_2 emissions allowances to large users on a single open market, much like the sale of Treasury bills. However, in this case the number of CO_2 allowances would decrease each year until it reaches zero and the market would be national rather than global.
3. A penalty for fossil fuel use without allowances would be maintained at about ten times the average sale price of CO_2 allowances realized by the government in the prior year. This would discourage emissions without allowances.
4. Resale of unused allowances would be permitted.
5. Offsets would not be allowed – emissions would be allowed only against purchased allowances. In other words, fossil fuel users would not be permitted to emit CO_2 because they claimed that they have financed a reduction in emissions by a third party or planted trees somewhere that would supposedly capture the emitted CO_2.

This system incorporates market features in that it would allow holders of emissions allowances to use or sell them, since they have, after all, paid for them. But the more general "cap and trade" system that includes offsets and trading across borders would not be permitted. It is particularly important to avoid international offsets between countries that have set enforceable legal limits on emissions (whether by treaty or not) and those that have no such obligations. At present, CO_2 emissions' offsets purchased from developing countries create perverse incentives that could, and sometimes do, aggravate global warming problems. In the absence of a limit on CO_2 emissions, developing countries have an incentive to add to them if they can subsequently turn around and get paid for eliminating those same emissions.

It is not that the theory of offsets is without merit. Offsets, done within the framework of limits on emissions that are being tightened each year and enforced honestly, both within and across national boundaries, could produce more economical reductions in CO_2 emissions if they are measurable by strict criteria. *However, none of these basic conditions necessary for success is currently in place.* When an equitable and enforceable path to 50 to 85 percent reduction in global CO_2 emissions is worked out, offsets and international trading might be reconsidered. Until then, a national system without offsets is the surest way for the United States to proceed, especially as it is exceedingly well endowed with renewable energy resources and the opportunities for economical improvements in energy efficiency are great.

1. Early Action Rewards

A system of allowances in which all large users bid for them in a single market would also reward the companies that have invested early in CO_2 reductions as part of their corporate strategy, in anticipation of restrictions on emissions or as measures to save money or both. The United States Climate Action Partnership of corporations and private environmental organizations has made a particular point of the issue of providing appropriate recognition in practical, bottom line, terms to those who take early action:

> Prior to the effective date of mandatory emission limits, every reasonable effort should be made to reduce emissions. Those companies that take early action should be given appropriate credit or otherwise be rewarded for their early reductions in GHG emissions.[8]

An auction system would put those who take early action at a competitive advantage since they would have to purchase fewer CO_2 emission allowances. Another way that local, state, and federal governments could encourage action beyond the norm would be to award extra points, when evaluating government contract proposals, to those companies which excelled in performance on reducing CO_2 emissions. Companies could similarly adopt green purchasing policies; some already have such policies in place to varying extents.[9]

2. Defining "Large Users" of Fossil Fuels

Since it would be impractical, intrusive, and onerous to try to impose caps on small fossil fuel users, it is necessary to define the term "large user." We consider each of the two components of the term: "large" and "user."

Besides the practicality of enforcement, the term "large" must also be considered from the users' point of view. It would take some effort, experience, and expertise for a company to keep track of the CO_2 allowances market and determine whether it should invest to avoid emissions or purchase allowances for some more time. Such decisions would depend on the state of a company's finances and equipment at any given time and also on its view of its own future evolution. A company may decide to invest in energy efficiency after the purchase of allowances and sell the excess if the price of allowances goes up. The time and expertise invested in these decisions represent transactional costs of reducing CO_2 emissions, which should be kept well below the cost of the avoided fuel purchases.

A large user might be defined as one purchasing 100 billion Btu of fossil fuels or more. For an average future price of fossil fuels of $10 per million Btu, the threshold for fossil fuel expenditures would be $1 million per year. One hundred billion Btu is about equal to the delivered energy annually used by 1,000 households. A single 1,000 megawatt coal-fired power plant consumes about 700 times this threshold definition of large users. As another example, the definition would cover all large industries and corporations holding on the order of one million square feet of office space. It would also generally cover medium-scale industries and many small-scale industries. While there would be some paperwork requirements for all the entities defined as "large users," these would be kept to a minimum by having a single market for the CO_2 allowances and a single reporting time to the EPA each year (see below and also the interview with Dawn Rittenhouse and John Carberry of DuPont in Appendix B).

Electric utilities and independent merchant generators would be subject to the caps. Airline companies and large trucking companies would also be included in the caps. Fuel purchases for vehicle fleets owned by corporations would be included, but not personal vehicles owned by employees.

The term "user" would aggregate all the fossil fuel purchases of all subsidiaries of a corporation. Any other definition may encourage the formation of small subsidiaries that would each have fossil fuel purchases under the limit, giving such users an unfair advantage and also creating obstacles in reducing CO_2 emissions. In the commercial sector the definition would apply to the owners of the property.

The term "fossil fuel use" also needs definition. It is clear that it should include actual burning of fossil fuels because that is the activity that generates CO_2 emissions. Industries like oil refineries would be included only insofar as their own consumption of fuels was more than 100 billion Btu per year (which it generally is). Allowances would be needed only for the net amount of fuel they consume.

An important definitional problem relates to feedstocks. Over seven quadrillion Btu of fossil fuels, mainly petroleum and natural gas, are used as feedstocks for the production of a variety of goods, including basic chemicals, lubricating oil, pesticides, synthetic textiles and fibers, and plastics. These are not burned by the industries purchasing the fuels. However, much of the feedstock eventually degrade into CO_2, as for instance, when trash is burned in municipal incinerators. Keeping track of the fate of the materials made out of feedstocks could be even more onerous than creating caps for all users of fossil fuels. It is suggested therefore that feedstock uses of fossil fuels be included within the definition of fossil fuel "use." The use of fossil fuels in large amounts for feedstocks would fall under the cap, according to this definition.

In 2004, electric utilities and industries accounted for about 54 percent of total fossil fuel use. In addition a large portion of the transportation sector, such as airline companies, large trucking companies, and corporate vehicle fleets, as well as a significant part of the commercial sector, would fall in the large user category. An additional few percent would be represented by large truck and light vehicle fleets. However, not all commercial buildings or industries would fall under the term "large users." Overall, about two-thirds to three-fourths of total fossil fuel use would be covered by the cap. Residential sector purchases of fossil fuels, which consist mainly of natural gas and heating oil, and purchases of vehicular fuel for personal use and by small businesses would not be covered. But residential and commercial purchases of electricity from the grid would be affected by the cap so long as electric utilities are still using fossil fuels for electricity generation.

We reemphasize that the system is envisioned as a pure CO_2 permit system, with declining caps. Those who emit CO_2 would actually have to hold the allowances to do so, purchased at auction from the government or on the open market. CO_2 offsets, such as emitting CO_2 and claiming CO_2 capture in tree farms, etc., would not be permitted. The complexities of measurement of CO_2 balance in the soil, for instance, would create enforcement nightmares. Offset schemes tend to undermine the CO_2 market. Further, as noted, international offset schemes would face problems of huge loopholes and verification, notably in the absence of a binding global treaty with intra- and trans-national enforcement provisions to greatly reduce CO_2 emissions. Biofuels would be exempt from the cap. However, use of fossil fuels on a large-scale in producing biofuels would be included.

A modification of the system above can be considered to include emissions of greenhouse gases other than CO_2 that occur in the energy sector. For instance, there are emissions of methane associated with pipelines and emissions of certain other gases such as HFCs from industry. A total CO_2 equivalent cap corresponding to emissions from the covered entities (large users of fossil fuels) could be set. This would likely be more desirable since companies would have the flexibility to reduce those emissions that are the cheapest to eliminate first. But it should be done with some rigor – and with measurability, enforcement, and verification as key considerations.

3. Penalties

Enforcement of the CO_2 cap for large users requires that they face some penalties for emitting CO_2 without holding an allowance to do so. The successful enforcement of SO_2 caps provides a useful guide. A penalty of $2,000 per ton is imposed for emitting SO_2 without holding an allowance. The level of the penalty is much more than the cost of reducing SO_2 emissions:

The SO_2 program has also brought home the importance of monitoring and enforcement provisions. In 1990, environmental advocates insisted on continuous emissions monitoring, which helps build market confidence. The costs of such monitoring, however, are significant. On the enforcement side, the Act's stiff penalties – $2,000 per ton of excess emissions, a value more than 10 times that of marginal abatement costs – have provided sufficient incentive for the very high degree of compliance that has been achieved.[10]

The same approach can be used for CO_2. The costs of reducing CO_2 emissions are expected to range from negative up to perhaps $40 per metric ton. A reasonable starting value of penalty would be about $100 per metric ton of CO_2, since the typical cost of abatement of CO_2 emissions in the early stages would likely be on the order of $10 per metric ton. A policy to maintain the penalty at about ten times the average sale price of CO_2 emissions in the prior year would serve as an effective enforcement tool. It would be expected to increase from the initial value of $100 per metric ton to several hundred dollars per metric ton as the use of fossil fuels declines, the cap is reduced, and allowances become more expensive.

In the SO_2 reduction system, the EPA requires electric utilities (only utilities are covered) to submit both the emission allowances and emission measurements for the preceding year. This system allows companies to adjust their operations during the year. They can purchase additional allowances, sell some of the ones they hold, and/or install pollution control equipment to reduce them, according to their estimate of the profitability of these measures. A similar system can be put in place for fossil fuels. The allowances would correspond in this case for fossil fuel purchases unless the user can show measurements that CO_2 has been captured, resulting in avoided emissions.

4. Revenues

Important practical economic goals are served by auctioning all allowances and setting an initial cap that is stringent enough to yield a non-negligible price but not so high that it would cause large business dislocations in the short-term. For instance, if the auction price averaged $10 a metric ton of CO_2 emissions,[11] a cap covering large users' emissions of about 4 billion metric tons of CO_2 would result in a total revenue of $40 billion per year. Four billion metric tons corresponds to about two-thirds of CO_2 emissions in 2005. As the cap is reduced each year, the price of each allowance would tend to rise. While it is difficult to estimate revenues over the long-term from such a scheme, one might anticipate that revenues would remain in the $30 to $50 billion per year, provided technological breakthroughs do not reduce the cost of eliminating CO_2 well below current estimates (see Table 2-1, Chapter 2). Breakthroughs are to be desired of course, since they would reduce the time required for a transition to renewables. They would also reduce the scale of government expenditures and investments in research, development, and demonstration plants, as well as added procurement expenditures required to shape the market along more efficient, renewable lines.

If there are too many allowances on the market, it would depress the price of a CO_2 allowance that the federal government gets at auction. This would indicate that the there is a greater potential for reducing CO_2 emissions at a given cost than anticipated. A falling price could therefore be a signal to the federal government to reduce the allowances for sale in future years, thereby accelerating the transition to a zero-CO_2 economy.

B. Small Users of Fossil Fuels

As discussed above, the imposition of caps on small users is impractical and would create inequities. But small consumers must also be brought into the overall scheme, since the required reductions on CO_2 emissions cannot be achieved unless they are. It is important to take into account the fact that individuals and very small businesses simply do not have the wherewithal to assess energy and environmental questions on a day-to-day basis. Further, the individual's control of the market is weak, though collective consumer preferences, such as for types of vehicles and homes purchases, do have a profound effect. Further, as noted above, developers and manufacturers of appliances and vehicles are small enough in number that efficiency standards can be enforced. Finally, efficiency standards on new equipment and buildings solves the problem of the "split incentive"– that is, the lack of incentive on the part of developers to invest in efficiency beyond required codes since energy bills are paid by owners or renters.

Standards for appliances and new buildings are easier to conceive and implement than standards for existing buildings. There is ample precedent for incremental tightening of efficiency standards for new equipment. Limits on Btu of externally delivered energy per square foot can be made part of state and local building codes and incentives can be provided for exceeding the standards. This is a performance-based approach, which allows the builder to decide what mix of passive features (such as building thermal mass and insulation) and active features (such as solar water heating or solar PV) to use to meet the code's requirements. The added costs, if any, become part of the mortgage payment. This is also the simplest way to finance the transition in the building sector. Gradually a zero net energy goal can be created – that is, imports of energy into areas and communities (purchased fuels and electricity) would equal exports when averaged over two or three years.

Similarly, costs of vehicle efficiency improvements become part of the cost of the vehicle. Any added costs for more efficient vehicles would become part of loans, if they are taken, to finance cars. The added cost would be largely or fully offset by reduced energy costs.

For existing buildings, the time of application of standards would be when they are sold. That way, the financing of the changes becomes a part of the mortgage taken by the new owner. Since it is more difficult and expensive to improve the efficiency of existing homes, the standards of existing buildings would be tightened more gradually and remain less stringent than those for new buildings.

1. Time-of-use Rates

We have discussed the importance of time-of-use (TOU) rates in the context of the economics of solar energy during peak hours. A transition to a renewable economy would be greatly aided by more general adoption of time-of-use rates, especially since it would encourage investment in small- and intermediate-scale solar PV systems. TOU rates require a change of metering arrangements, since special meters are needed to measure electricity use according to the time of day. Net metering is a natural complement to time-of-use rates, since it both charges consumers at the rate then prevalent and also gives the consumers the corresponding rate when they supply electricity back to the system.

The oil and natural gas peaking systems operating for a few hours a day are the most costly. If the natural gas systems are single-stage gas turbines, which have very low capital costs but high fuel requirements, peak electricity costs, delivered to residential customers, can be as high as 20 cents per kWh (for natural gas costs of $8 per million Btu and single stage turbine capacity use of 300 hours per year). Costs of oil-fired peak generation would be similar or higher.

A flat rate for electricity grossly distorts the actual costs incurred and cannot be justified on market-based considerations. Since solar energy provides most of its generation during peak hours (and the rest during intermediate load hours) time-of-use metering is an action that corrects a large market distortion and promotes solar PV at the same time.

In a distributed grid supplied mainly by solar and wind energy, lower rates may not necessarily be at night, as is the case at present. Rather, rates would be high at the time of lowest supply in relation to demand. Flexibility would be introduced into the system through electricity and thermal storage and possibly a "smart grid."

2. *Incentives and Rebates*

In the initial stages of development of renewable energy sources and the encouragement of their use, rebates and tax incentives have been critical to their rapid growth. The Western Governors' Association has a goal "30,000 MW of clean, diversified energy" of which 4,000 MW will be solar PV (3,000 of it in California alone). Half-a-million solar thermal systems are also planned.[12] California has provided high incentives to early adopters (Table 7-1). The incentives are expected to decline significantly as more and more capacity is added. For instance, the incentive payment per kWh for the third tranche (MW Step 3) is 34 cents per kWh, if the capacity is in the residential or commercial sector. For the tenth step, the corresponding payment is only 3 cents per kWh. Payments are higher if the capacity is added by non-profits or the government. The California Public Utilities Commission had extensive public hearings and consultation with producers, consumers, and manufacturers in arriving at these incentives. These were accompanied by extensive analysis.[13]

Table 7-1: California Payment Scheme for Solar PV

Levelized PBI Monthly Payment Amounts at 8% Discount Rate			
MW Step	MW in step	PBI payments (per kWh)	
		Residential/Commercial	Government/Non-Profit
1	50	n/a	n/a
2	70	$0.39	$0.50
3	100	$0.34	$0.46
4	130	$0.26	$0.37
5	170	$0.22	$0.32
6	230	$0.15	$0.26
7	300	$0.09	$0.19
8	400	$0.05	$0.15
9	500	$0.03	$0.12
10	650	$0.03	$0.10

Source: CPUC 2006 Table 5, (pages 37-38)

Notes: 1. PBI = Performance Based Incentives

2. The increments in capacity are divided into ten steps. Each increment represents a total addition to capacity. The additions in each step are larger than in the prior ones. The earlier steps get higher rebates than subsequent additions.

California plans to spend \$2.5 billion to \$3 billion in implementing its 3,000 MW "Million Solar Roofs" program. This will be paid for by a charge of about 0.1 cents per kWh on electricity over a ten year period.[14] California also has rebate programs for zero-emission vehicles, which are helping to establish an initial market for electric cars.

Rebate programs are also important for encouraging the use of technologies that are very efficient but are marginally economical due to high first cost, such as earth-source heat pumps. There are many examples of incentives in essentially every state. They include residential and commercial installations.[15]

3. Achieving Zero-CO_2 Emissions for Small Users

The policies discussed above would result in large reductions in CO_2 emissions by smaller users, but would not guarantee zero-CO_2 emissions. Some individuals may want to continue using fossil fuels. Further, most large users, as defined above, would fall into the small user category at some stage as they reduce their fossil fuel consumption. The absence of carbon taxes would create the potential for fossil fuel prices to decline below the prices of renewable fuels as large users become more efficient and switch to renewable fuels. Such a situation would likely not occur for a considerable time (at least two decades). But, in the long-term, supplementary policies may therefore be necessary to ensure a continued transition to a fully renewable energy economy, including

1. Zero-CO_2 emissions requirements for developers of new buildings.
2. Zero net energy goals for areas and communities (in combination with a grid consisting of renewable electricity only).
3. Emissions or fuel type requirements for new vehicles.
4. A ban on fossil fuel production and imports by a certain date, similar to the CFC ban.

It is possible that some combination of the first three policies would be required unless the fourth is used.[16]

C. Government Actions

A shaping of the energy supply and demand marketplace through government procurement, research, development and demonstration is part of the solution for achieving a more rapid transition to a zero-CO_2 emissions economy. Some of the estimated \$30 billion to \$50 billion in annual revenues derived from the sale of CO_2 emission could be transferred to state and local governments for supporting programs analogous to those in California and other states that have already taken the leadership in promoting efficiency and renewable energy sources.

Plug-in hybrids could become the standard issue government car by 2015.

Large-scale central station solar energy plants to stimulate investment in large-scale solar PV manufacturing and in solar thermal technology are needed. Lack of sufficient demand is the central obstacle that is preventing economies of scale from being achieved in critical technologies. Demonstration of V2G technology on a scale that would test its viability for creating a reliable grid is also needed. A more detailed list is specified in a timeline in Chapter 8. Taxi commissions in cities can allow (or require) taxis to be hybrid cars. Federal, state, and local governments could set zero net energy, or at least zero net electricity goals, to be achieved in about 20 to 25 years.

The federal, state, and local governments can also give preferences in contracts to corporations that have relatively low CO_2 emissions for their sectors compared to prevailing norms. Some corporations have already adopted such policies in their own purchasing decisions (see Appendix B).

One important initiative would require collaboration between the federal, state, and local governments. Aquatic plants can be grown in the effluent of waste water treatment systems, particularly if these are combined with constructed wetlands. There are a host of regulations that already cover wastewater treatment. Integrating biomass production with them would be a complex regulatory question. However, given that (i) plants like water hyacinths have been shown to improve water quality (see Chapter 3), and (ii) they have the potential to contribute significantly to energy supply, a joint exploration of the ways to accomplish that along with demonstration projects in various climates should be an important funding priority A demonstration of offshore wind energy, coupled with onshore electrolytic hydrogen production, is also desirable.

Finally, a fundamental change in the sources of energy supply in the U.S. economy will no doubt affect large numbers of workers, from coal mining and petroleum to suppliers of automobile parts. Fossil fuels are mainly produced today in the Appalachian region, in the Southwest and West and some parts of the Midwest and Rocky Mountain states. For the most part, these areas are also well-endowed with the main renewable energy resources – solar and wind. In the East and Southeast, offshore wind is a significant resource. Distributed hydrogen production and utilization infrastructure could be a major new industry. Federal, state, and regional policies, designed to help workers and communities transition to new industries, therefore appear to be possible without more major physical movement or disruption of populations than has occurred in post-World War II United States. It is recognized that much of that movement has been due to dislocation and shutdown of industries, which causes significant hardship to communities and workers. Some of the resources raised by the sale of CO_2 allowances should be devoted to reducing this disruption. For instance, the use of CO_2 capture technologies, notably microalgae CO_2 capture from existing fossil fuel plants, can create new industries and jobs in the very regions where the phase-out of fossil fuels would have the greatest negative economic impact. Public policy and direction of financial resources can help ensure that new energy sector jobs that pay well are created in those communities.

D. New Coal-fired Power Plants

New coal-fired power plants that do not have provisions for capture and sequestration of CO_2 should be prohibited. New pulverized coal-fired power plants would have a life of about 40 years or more. Since these plants are now quite expensive, the owners of new ones would constitute a formidable lobby to advocate slowing down, diluting, or stopping mandatory reductions in CO_2 emissions. Since wind-generated electricity is already economical relative to coal with sequestration, there is no reason to allow the building of new power plants that would emit large amounts of CO_2 for decades.

E. Ending Subsidies for Nuclear Power and Fossil Fuels

Nuclear power still gets a significant subsidy in the form of government-provided accident insurance. Further, despite all the talk of a nuclear power renaissance, not a single new nuclear power plant has been ordered as of this writing (July 2007), despite added subsidies for license application and other costs that were enacted into law as part of the Energy Policy Act of 2005. Congress is considering 80 to 100 percent loan guarantees for new power plants, that may extend to as many as 28 plants, at $4 billion to $5 billion each.[17] Even so, Standard & Poor's, the well-known Wall Street credit rating agency, has stated that:

> ...an electric utility with a nuclear exposure has weaker credit than one without and can expect to pay more on the margin for credit. Federal support of construction costs will do little to change that reality.[18]

This means that Wall Street, or at least an influential portion of it, considers nuclear power such a high risk that the credit rating of a utility ordering it would be likely to suffer, even if the federal government provides subsidies. The result of an order would, therefore, likely increase the costs of electricity across the board, making any utility that ordered a nuclear plant less competitive.

The escalating costs of finding, characterizing and developing a deep geologic repository program for nuclear waste provide an added element of risk. Expanding nuclear power plant capacity significantly will likely require a second repository, when it is already unclear whether the proposed Yucca Mountain repository for disposing of spent fuel can ever be licensed. The site's deficiencies have been extensively written about, including by the present author.[19] Adding more nuclear power plants risks more repositories, higher costs for repositories, or higher costs for reprocessing, or all three. Further, heat waves and droughts may cause nuclear power plants to be shutdown for extended periods at times of peak demand. Since such events are expected more frequently in a warming world, an element of intermittency may be introduced into nuclear energy.

Massive subsidies should not be sustained indefinitely for any source of energy, and especially not one that carries significant nuclear proliferation, waste, and severe accident risks. Nuclear power advocates claim that it could be part of the solution of the climate change problem. CO_2 emission caps will cause the costs of fossil-fuel-related generation to increase. Nuclear power should be able to compete with that in the marketplace. There is no sign that it will be able to do so. Nuclear power should be eliminated from the U.S. economy as the current plants reach the end of their licensed lives.[20] Specifically, the following policies should be adopted:

1. All subsidies for new nuclear power plants, including government-supplied and guaranteed insurance, tax credits, and licensing subsidies should be ended.
2. Government should explicitly declare that it will not take responsibility for nuclear waste disposal from new nuclear power plants and that its responsibility extends only to existing power plants for their licensed lifetimes.
3. A regulatory infrastructure for reactor safety for existing reactors and for waste management and disposal should be maintained.
4. Onsite storage of spent fuel should be hardened against terrorist attack.
5. The insurance provisions for present plants should more realistically reflect the estimated damages from worst-case accidents that are estimated to be part of the plants' design vulnerabilities.
6. The ban on reprocessing spent fuel enacted under President Carter should be re-imposed.

Fossil fuels have been around far longer than nuclear power. Subsidies and tax breaks or loan guarantees for new applications, such as processing coal to produce liquid fuels, are especially counterproductive at a time when public policy needs to focus on achieving CO_2 emission reductions in ways that will not aggravate other problems. The exception that we would make to this policy is the full commercialization of IGCC technology, because essentially the same technology that is now proposed for coal would also be useful for electricity generation using biomass as a fuel. Carbon sequestration should also be developed for the reasons that have been discussed in Chapters 3 and 6.

F. Corporate and NGO Actions

The potential for a regulatory zero-CO_2 goal to achieve change is being illustrated in the marketplace, even from consideration of goals that are far short of this plan. For instance, the U.S. Climate Action Partnership (USCAP), which consists of corporations and large environmental non-government organizations, published a report advocating a U.S. target of 60 to 80 percent absolute reduction in greenhouse gas emissions by 2050.[21] This goal is reminiscent of major industries agreeing to the 1987 Montreal Protocol to protect the ozone layer, which required a 50 percent reduction of CFC emissions in about ten years. Eventually more was required, and developed countries phased out CFC production by 1996.

In February 2007, after the publication of USCAP's recommendations, a private group sought to complete the largest corporate buyout in history, that of TXU, which was planning to build 11 coal-fired power plants. The private group consulted with large environmental groups who were certain to oppose the deal. The cancellation of eight of the power plants and a plan to increase the building of renewable energy sources was the result.[22]

These actions, which have commanded a great deal of media attention, are only the most recent and most visible phase of a quieter but nonetheless important change that has been occurring. Insurance companies and some banking sectors of Wall Street have had practical concerns about global warming for some time. Multinational corporations that operate in scores of countries now have to deal with vastly differing rules in different places. Oil and gas companies face massive disruption in the case of more frequent and/or more severe loss of offshore production capability due to storms. Wild gyrations in natural gas prices like those that have occurred since 1999 make corporate planning much more difficult at higher levels of energy use. Turbulence in key oil and gas producing parts of the world has made planning for higher energy productivity a much higher priority in many boardrooms. A part of the result can be seen in the fact that energy use in the United Stated declined in 2006 to below the 2004 level.

Some corporations have been willing to be more open to outside advice and to analyses by nongovernmental organizations (NGOs), who may have been regarded not too long ago as adversaries. Tough negotiations were involved in achieving the cancellation of eight TXU coal-fired power plants. But the remarkable thing is that they took place at all and achieved a significant result.

CHAPTER 8: ROADMAP FOR A ZERO-CO_2 ECONOMY

It is technologically and economically feasible to phase out CO_2 emissions and nuclear power at the same time. The analysis in this report indicates that it can be done at reasonable cost by 2050. The goal could be achieved about one decade earlier, if biomass and hydrogen can be produced with high efficiency of solar energy capture and if greater efforts at energy efficiency are made. As discussed in Chapter 6, it is also possible that addressing some issues, such as creating a distributed grid with several new technologies, may take longer. The most important step at the present time to ensure the phase-out happens is to set a mandatory goal of a zero-CO_2 emissions U.S. economy as much before 2060 as possible. We first set forth a preferred renewable energy scenario to frame the detailed timeline. The action plan in the timeline also contains the contingency elements that provide redundancy in case the preferred approach cannot be realized to its fullest.

A. A Preferred Renewable Energy Scenario

Various possible components of an approach that would be preferable to the reference scenario were discussed in Chapter 6. This roadmap stresses a renewable energy economy based on a desired outcome rather than in the reference scenario. The main problem in the reference scenario is the relatively large area of land that would be required to cultivate the biomass needed mainly for liquid and gaseous biofuels that would replace fossil fuels in all sectors of the economy. Another problem is that the large amount of liquid and gaseous biofuels results in large energy losses. Five to six percent of the land area of the United States (and possibly more) would be needed. Impacts in particular regions would be considerably greater. While this is within the realm of feasibility, setting a course for a more efficient economy, with a component of hydrogen derived from wind and solar energy would be preferable.

Besides considerations of land area, there may also be issues of water use both in biomass crop production and in their processing into fuels. In view of these considerations, policy should seek to have considerably greater efficiency in all areas where liquid or gaseous biofuels are involved. The following appears to be a reasonable approach for that portion of energy demand relative to the reference scenario (electricity use and use of solid biomass for electricity generation remain unchanged):

- A significant reduction in use of gaseous biofuels in the residential and commercial sectors, for instance through greater efficiency and greater use of solar thermal heating. This applies mainly to space and water heating.
- A significant reduction in use of liquid biofuels in transportation through greater efficiency than in the reference scenario. As discussed in Chapter 6, the reference scenario assumptions are not very ambitious in relation to presently available and foreseeable technology.
- A reduction in biofuel requirements for feedstocks and fuel uses in industry though greater efficiency and greater use of solar thermal energy.

Some of the remaining hydrocarbon biofuel demand could be met using hydrogen in industrial combustion engines, greater use of electricity in the residential, commercial, and transportation sectors, and in industry. We assume that aircraft, much industry and most long-distance road transport will still use liquid biofuel hydrocarbons.

If these technological goals were realized, the overall biomass requirements would be significantly reduced. Electricity production would increase somewhat. And there would be a role for hydrogen in transportation (probably in internal combustion engines) and a greater role for hydrogen in industry. Hydrogen would be produced by a combination of electrolysis using wind energy and by one or more direct solar hydrogen production methods. In this preferred scenario, the land requirements for biofuels could be reduced to 2 to 3 percent of the U.S. land area (compared to 5 to 6 percent in the reference scenario).

Realizing this preferred renewable energy scenario would require:

- More stringent standards for buildings and vehicles compared to the reference scenario.
- Extended adoption of the concept of zero net energy beyond buildings to areas, communities, and institutions.
- Greater emphasis on research, development, and demonstration of electrolytic hydrogen from wind energy.
- Full commercialization of at least one technology for direct hydrogen production from solar energy in the next twenty years.
- Ensuring through government procurement and other incentives that, once the hydrogen production and use technologies are close to commercializa-

tion, that the infrastructure for its use will be created. Distributed hydrogen infrastructure – that is, infrastructure close to the point of use can probably be realized more expeditiously than a centralized system.

B. Timeline for Transformation

The following is a brief timeline based on the analysis in this report. The list is not comprehensive but indicative and based on the technologies that appear to be important at this time.

2007

1. Enact a physical limit of CO_2 emissions for all large users of fossil fuels (a "hard cap") that steadily declines to zero prior to 2060, with the time schedule being assessed periodically for tightening according to climate, technological, and economic developments. The cap should be set at the level of some year prior to 2007, so that early implementers of CO_2 reductions benefit from the setting of the cap. Emission allowances would be sold by the U.S. government for use in the United States only. There would be no free allowances, no offsets, and no international sale or purchase of CO_2 allowances. The estimated revenues – approximately \$30 to \$50 billion per year – would be used for demonstration plants, research and development, and worker and community transition.
2. Eliminate all subsidies and tax breaks for fossil fuels and nuclear power (including guarantees for nuclear waste disposal from new power plants, loan guarantees, and subsidized insurance).
3. Ban new coal-fired power plants that do not have carbon storage.
4. Enact high efficiency standards for appliances at the federal level.
5. Enact stringent building efficiency standards at the state and local levels, with federal incentives to adopt them.
6. Enact stringent efficiency standards for vehicles and announce the intention of making plug-in hybrids the standard U.S. government vehicle by 2015.
7. Put in place regulations requiring the recycling of batteries used in plug-in hybrids and electric cars.[1]
8. Put in place federal contracting procedures to reward early adopters of CO_2 reductions.
9. Establish a standing committee on Energy and Climate under the U.S. Environmental Protection Agency's Science Advisory Board.

2008–2009

1. Publish draft regulations and their finalization for treating CO_2 as a pollutant, cap and trade, etc.
2. Publish and finalize governmental purchase rules for biofuels to include liquid fuels made from microalgae .
3. Begin government purchase of plug-in hybrids.

4. Increase funding for the National Renewable Energy Laboratory (NREL), including an acceleration of the solar hydrogen and electrolytic hydrogen program.
5. Commission an evaluation of programs and policies (such as rebates, rate structures, etc.) in California and other states for applicability across the country.
6. Create an NREL program to evaluate and develop the uses of aquatic plants as energy sources.
7. Create a joint federal-state-local government task force on growing biomass for energy on constructed wetlands and begin planning pilot and demonstration projects.
8. Fund the following in collaboration with industry:
   - Design of Integrated Gas-Turbine Combined Cycle plant for biomass, especially for high productivity biomass.
   - Research on and development of nanocapacitor (supercapacitor) storage.
   - Large-scale demonstration plant for the production of liquid fuels and methane from microalgae.
9. Commission a thorough optimization for integrating wind and solar electricity with hydropower and combined cycle natural gas standby into a distributed electric grid. The study should also explore the concept of a "smart grid," which integrates electrical and thermal storage components.[2]
10. Commission an economic impact study for areas with high fossil fuel production to devise policies for a just transition to a renewable energy system.

Also in this period a number of actions would be needed to prepare for a first test of a vehicle-to-grid system. A V2G Task Force – a joint federal effort with Independent System Operators in cooperation with one state (such as California) where the institutional infrastructure is already in place – would be created to carry out and evaluate such a test.

2010–2020

1. Begin implementation of the hard cap for large fossil fuel users at about the 2005 level of CO_2 emissions. It would be set to decline by 3 percent per year relative to the base year in the first ten years, and adjusted thereafter.
2. Begin a policy of installing roof-top and parking lot solar PV installations at federal facilities with a goal of making the federal government buildings a zero-net energy institution by 2030 or 2035 and begin revenue sharing with the state and local governments for the same purpose.
3. Build and test 5,000- to 10,000-vehicle V2G systems in three different regions.
4. Build several demonstration plants, from small to large, for growing high productivity plants (microalgae, water hyacinths, duckweed, etc.), in conjunction with wastewater treatment plants or in areas where runoff that is

high in nutrients is creating ecological problems. Build at least one plant where wastewater is piped out of metropolitan areas to areas with degraded land for biomass and biofuels production.

5. Continue development of fuel cells, especially for stationary applications.
6. Construct an electrolytic hydrogen plant for testing and demonstrating infrastructure for hydrogen for internal combustion engine vehicles.
7. Begin building pilot plants for promising solar hydrogen technologies.
8. Begin and complete construction of a 1,000 MW solar thermal plant with twelve-hour energy storage.
9. Enact building standards at the state and local level for residential and commercial buildings.
10. Begin designing and building an IGCC plant using biomass with no coal or other fossil fuels.
11. Complete evaluation of liquid and gaseous fuel production from microalgae, prairie grasses.
12. Design and build a pilot plant for liquid and gaseous fuels from aquatic plants.
13. Design and build a demonstration plant for nighttime storage of carbon dioxide emitted from fossil fuel plants with the aim of using the CO_2 to grow microalgae in the daytime.
14. Begin using liquid fuels from microalgae on a commercial scale in the 2015 to 2020 period.
15. Design and build a demonstration hot rock geothermal plant.
16. Ensure that all housing subsidized by the federal government, including housing provided with government-subsidized loans or insurance, is built to at least Gold LEED standards. (LEED stands for Leadership in Energy and Environmental Design; it is a building certification program.)
17. Conduct a study evaluating the amounts by which public transit riders subsidize automobile users in high traffic cities.
18. Complete an evaluation of the wind farm with compressed energy storage planned for Iowa and commission second generation demonstrations.[3]
19. Build an offshore wind-energy-based electrolytic hydrogen demonstration plant for distributed onshore hydrogen production
20. Begin design and construction of demonstrations of CO_2 sequestration, with a research design that will allow evaluation of the risks of leaks and the potential for sudden releases of CO_2 after disposal.
21. Build a large-scale Fresnel lens solar concentrator solar photovoltaic power plant.
22. Evaluate and put in place a program for hydrogen-fueled commercial aircraft, including a demonstration project.
23. Issue biennial reports from the EPA's Energy and Climate Committee, which would allow updating of the program for eliminating CO_2 emissions.

2020–2030

Toward the end of this period, the backbone of the energy system is transformed. At this stage, about half of the electricity and half of the total energy inputs would come from renewable sources. Major changes in the efficiency of the U.S. economy will have become institutionalized. Different ways of doing business will have become the norm. The CO_2 cap will have declined to about half of the base level in the 2025-2030 period, possibly lower. A mix of storage technologies, solar thermal power stations, solar PV, wind farms, and other technologies would be in place. Electricity storage technologies, V2G, and the construction of regional distributed electricity grids would be well underway. Aircraft would begin using biofuels on a significant scale. The transformation of vehicles to using electricity would be well advanced. Plug-in hybrids and all-electric vehicles would be the standard new vehicles being purchased in the latter part of this period.

A decision on whether hydrogen would be a major energy carrier would also be made in this period, after evaluation of the technologies and costs of its production and use based on pilot and large-scale demonstrations. Zero net energy would be achieved for state, local, and federal buildings and by many commercial, residential and industrial buildings and in many communities and areas. Efficiency standards would have been upgraded. It would be routine to make energy-related upgrades to buildings prior to sale.

Other expected features of this period:

- The personal vehicle sector begins a major transformation to electric and plug-in hybrid vehicles as the standard production vehicles.
- Use of IGCC plants running on biomass begins. If not, other modes of deployment of biomass, such as methane production, are put into place.
- Hot rock geothermal energy, wave energy, and other technologies, possibly including carbon sequestration, transition to the commercial stage.

If solar hydrogen or electrolytic hydrogen from wind energy transition to the commercial scale by about 2025, an earlier elimination of CO_2 emissions would be possible. If, on the other hand, some technologies, such as electricity storage from intermediate-scale solar PV, compressed air storage, and V2G do not become commercial, the transition could be delayed. It is not necessary for all these technologies to be commercial, but a combination that would provide for electricity grid reliability on renewable energy alone should exist and be commercial by about 2030. The term "commercial" in this context includes the price that large users of fossil fuels must pay for scarcer CO_2 emission allowances.

Table 8-1 shows the technologies for supply, storage, and conversion, their current status, and the dates when they might come into use in a renewable energy economy, up to about 2025. Table 8-2 shows the same for demand-side technologies.

Table 8-1: Roadmap – Supply and Storage Technologies

Technology	Status	Deployable for large-scale use	Next steps	CO_2 abatement cost; obstacles; comments
Solar PV intermediate-scale	Near commercial with time-of-use pricing	2010 to 2015	Orders from industry and government; time-of-use electricity pricing	\$10 to \$30 per metric ton; no storage; lack of large-scale PV manufacturing (~1 GW/yr/plant); some manufacturing technology development needed.
Solar PV – large-scale	Near commercial	2015 to 2020	Large-scale demonstration with transmission infrastructure, ~5,000 MW by 2015-2020	\$20 to \$50 per metric ton; no storage; transmission infrastructure may be needed in some cases
Concentrating solar thermal power plants	Near commercial; storage demonstration needed	2015 to 2020	~3,000 to 5,000 MW needed to stimulate demand and demonstrate 12 hour storage, by 2020	\$20 to \$30 per metric ton in the Southwest. Lack of demand main problem.
Microalgae CO_2 capture and liquid fuel production	Technology developed, pilot-scale plants being built	2015	Large-scale demonstrations – 1,000 to 2,000 MW by 2012; nighttime CO_2 storage and daytime CO_2 capture pilot plants by 2012. Large-scale implementation thereafter. Demonstration plants for liquid fuel production: 2008-2015	Zero to negative at oil prices above \$30 per metric ton or so for daytime capture; nighttime capture remains to be characterized. Liquid fuel potential: 5,000 to 10,000 gallons per acre (compared to 650 for palm oil).
Wind power – Large-scale, land-based	Commercial	Already being used	Transmission infrastructure and rules need to be addressed; optimize operation with existing natural gas combined cycle and hydropower plants	Negative to \$46 per metric ton for operation with combined cycle standby. Areas of high wind are not near populations. Transmission development needed
Solar PV intermediate storage	Advanced batteries and ultracapacitors are still high cost	~2020	Demonstration of vehicle-to-grid using stationary storage (ultracapacitors and advanced batteries) – several ~1 MW-scale parking lot installations	Five fold cost reduction in stationary storage and lithium-ion batteries needed. Main problems: lack of large-scale manufacturing and some manufacturing technology development needed

Table 8-1 (continued): Roadmap – Supply and Storage Technologies

Technology	Status	Deployable for large-scale use	Next Steps	CO_2 abatement cost obstacles; comments
Solar PV intermediate-scale with Vehicle-to-Grid	Planning stage only. Technology components available. Integration needed.	~2020 to 2025	By 2015, several 5,000 to 10,000 vehicle demonstrations of V2G technology	V2G could reduce the cost of solar PV electricity storage from several cents to possibly ~1 cent per kWh
Biomass IGCC	Early demonstration stage	~2020	Pilot- and intermediate-scale plants (few MW to 100 MW) with various kinds of biomass (microalgae, aquatic plants), 2015 to 2020	Baseload power
High solar energy capture aquatic biomass	Experience largely in the context of wastewater treatment; some laboratory and pilot plant data	~2020	2010 to 2015 pilot plant evaluations for liquid fuel and methane production with and without connection to wastewater treatment	May be comparable to microalgae biofuels production. 50 to 100 metric tons per acre
Hot rock geothermal energy	Concept demonstrated; technology development remains	2025?	Build pilot and demonstration plants: 2015-2020 period	Baseload power
Wave energy	Concepts demonstrated	2020 or 2025?	Pilot and demonstration plants needed	Possible baseload power
Photolytic hydrogen	Laboratory development	Unknown – possibly 2020 or 2025	Significantly increased R&D funding, with goal of 2015 pilot plants	Potential for high solar energy capture. Could be a key to overcoming high land-area requirements of most biofuels
Photoelectrochemical hydrogen	Concept demonstrated; technology development remains	Possibly 2020 or 2025	Significantly increased R&D funding, with goal of 2015 pilot plants	High solar energy capture. Could be a key to overcoming problems posed by agricultural biofuels (including crop residues)

Table 8-1 (continued): Roadmap – Supply and Storage Technologies

Technology	Status	Deployable for large-scale use	Next Steps	CO_2 abatement cost obstacles; comments
Advanced batteries	Nanotechnology lithium-ion batteries; early commercial stage with subsidies	2015	Independent safety certification (2007?); large-scale manufacturing plants	Large-scale manufacturing to reduce costs. Could be the key to low cost V2G technology
Carbon sequestration	Technology demonstrated in context other than power plants	Unknown. Possibly 15 to 20 years.	Long-term leakage tests. Demonstration project ~2015-2020	For use with biomass, plus back up, if coal is needed
Ultracapacitors	Commercial in certain applications but not for large-scale energy storage	2015 to 2020?	Demonstration test with intermediate-scale solar PV. Demonstrate with plug-in hybrid as a complement to battery operation for stop-and-start power	Complements and tests V2G technology. Significant cost reduction needed for cost to be ~\$50/metric ton CO_2. Lower CO_2 price with time-of-use rates
Nanocapacitors	Laboratory testing of the concepts	Unknown.	Complete laboratory work and demonstrate the approach	Has the potential to reduce costs of stationary electricity storage and take ultracapacitor technology to the next step
Electrolytic hydrogen production	Technology demonstrated	Depends on efficiency improvements and infrastructure development	Demonstration plant with compressed hydrogen vehicles needed ~2015-2020	Could be used in conjunction with off-peak wind power

Table 8-2: Roadmap – Demand-Side Technologies, 2008-2020

Technology	Status	Deployable for large-scale use	Next steps	CO_2 price; obstacles; comments
Efficient gasoline and diesel passenger vehicles	Commercial to ~40 miles per gallon or more	Being used	Efficiency standards needed	Efficiency depends on the vehicle. Can be much higher.
Plug-in hybrid vehicles	Technology has been demonstrated	2010	Efficiency standards, government and corporate orders for vehicles	Large-scale battery manufacturing needed to reduce lithium-ion battery cost by about a factor of five.
Electric cars	Technology with ~200 mile range has been demonstrated; low volume commercial production in 2007 (sports car and pickup truck)	2015 to 2020	Safety testing, recycling infrastructure for battery materials, large-scale orders, solar PV-V2G demonstration	One of the keys to reducing the need for biofuels and increasing solar and wind power components.
Internal combustion hydrogen vehicles	Technology demonstrated	Depends on infrastructure development	10,000 psi cylinder development and testing of vehicles. Demonstration project	
Biofuels for aircraft	Various fuels being tested	2020?	Fuel development, safety testing, emissions testing	
Hydrogen-fuel aircraft	Technology has been demonstrated	2030?	Aircraft design, safety testing, infrastructure demonstration	In combination with solar hydrogen production, could reduce need for liquid biofuels.
Building design	Commercial, well known	Already being used	Building standards, dissemination of knowledge, elimination of economic disconnect between building developers and users	Residential and commercial building energy use per square foot can be reduced 60 to 80 percent with existing technology and known approaches. CO_2 price, negative to $50 per metric ton.
Geothermal heat pumps	Commercial	Already being used	Building standards that specify performance will increase its use	Suitable in many areas; mainly for new construction.

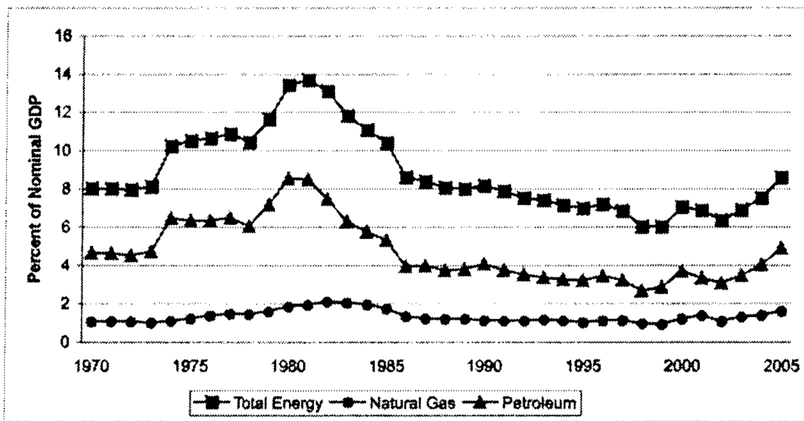
Table 8-2 (continued): Roadmap – Demand-Side Technologies, 2008-2020

Technology	Status	Deployable for large-scale use	Next steps	CO_2 price; obstacles; comments
Combined heat and power (CHP), commercial buildings and industry	Commercial	Already being used	Building performance standards and CO_2 cap will increase use	CO_2 price negative to <$30 per metric ton in many circumstances.
Micro-CHP	Semi-commercial	Already being used	Building performance standards will increase use	
Compact fluorescent lighting (CFL)	Commercial	Being used currently	Appliance and building regulations needed	Negative CO_2 price. Mercury impact of disposal needs to be addressed.
Hybrid solar light-pipe and CFL	Technology demonstrated; beta-testing being done in commercial establishments	2012 to 2015?	Government and commercial sector orders	Solar concentrators focus light indoors; work in conjunction with CFL. Five-fold cost reduction needed.
Industrial sector: examples of technologies and management approaches: alternatives to distillation, steam system management, CHP, new materials, improved proportion of first pass production	Constant development of processes	Various	Hard cap for CO_2 with annual assured decreases and no free allowances will lead to increase in efficiency	Variable. Negative to possibly $50 per metric ton, possibly more in some cases. Great potential for economical increases in efficiency exists at present costs, since energy costs have gone up suddenly. Successful reductions of energy use indicate that overall cost will be modest, with possible reduction in net cost of energy services.

C. Macroeconomics of the Transition

In the three decades following 1970, U.S. energy expenditures fluctuated from a low of about six percent (very briefly when prices collapsed in the late 1990s) to about 14 percent of the GDP. About 8 percent has been more typical, leaving aside the fluctuations caused by the turbulence immediately following the crises of 1973 and 1979. The proportion fell briefly to about 6 percent in the late 1990s, when oil prices declined steeply, dipping to a low of $12 per barrel.

Figure 8-1: Proportion of GDP Spent on Energy



Source: Courtesy of the Energy Information Administration of the United States Department of Energy

By 2050 the GDP will be nearly $40 trillion (constant 2004 dollars) under business-as-usual economic growth.[4] The energy use projected under the business-as-usual scenario is 160 quadrillion Btu, while that estimated for the reference scenario for the present analysis is about 76 quadrillion Btu. Both figures include losses in electricity production; the latter also includes losses in biofuels production. (The energy consumption in 2005 was about 100 quadrillion Btu.)

We have estimated the proportion of GDP that would be devoted to the energy services, such as transportation and heating and cooling in buildings. One overall criterion for an economical transition to a renewable energy economy is that the proportion of GDP devoted to energy services be no different than has been typical in recent decades, apart from the brief extreme swings occasioned by very rapid increases and decreases of oil prices. It is more difficult to compare this macroeconomic estimate for the reference scenario with the proportion of GDP that would be devoted to energy under the business-as-usual scenario. For the purposes of comparison, we use present prices, though this represents a rather unrealistic picture. The reason is that such a projection is built into a business-as-usual scenario, which is less a projection than an estimate of energy use in the future in the absence of major changes in the global economic, political, security, and resource picture. We chose a benchmark eight percent of GDP for energy expenses as a figure of merit for the reference scenario. A comparison with business-as-usual is made under assumption of present energy prices.[5] We address issues connected with business-as-usual projections separately (see Section C below).

1. The Residential and Commercial Sectors

A computation of the future cost of energy services under the reference scenario requires estimates of energy supply costs (fuel and electricity) and of additional investments that will be necessary to achieve the higher efficiency relative to the business-as-usual scenario.

Present costs of ethanol, hydrogen from electrolysis, and other biofuels indicate that the costs of biofuel supply for the residential and commercial sectors may be somewhat higher in the future than that of fossil fuels in 2005. We have assumed a delivered cost of $20 per million Btu, which is rather on the pessimistic side, in order not to underestimate the future fuel cost in a reusable energy economy.

For electricity, we assume a delivered cost to residential and commercial customers of about 12 cents per kWh for two-thirds of the supply, based on IGCC technology with sequestration and coal as a fuel, with which much of the future renewable electric supply system would have to compete in the absence of subsidies. For the rest, we have assumed that the cost would be typical of an intermediate-level solar PV system. We also assume that storage corresponding to one day's average output would be part of such a system. Storage capacity costs are taken to be $200 per kWh, which is about one-fifth the present price of ultra-capacitors.[6] The installed cost of solar PV systems is assumed to average $1.50 per peak watt, without storage. The generation per peak installed kW is taken as 1,800 kWh per year for a non-tracking system. A two-cent charge for distribution is added, since distribution systems will likely have to be strengthened for widespread use of intermediate-scale solar PV systems. The overall cost for such a system comes to about 18.2 cents per kWh. Combining the two estimates yields an average electricity cost for the residential and commercial sectors of 14.1 cents per kWh. Other forms of storage could be used instead or as complements in a "smart grid" system that combines supply-side and demand-side storage.[7]

For the business-as-usual scenario, we have used January 2006 costs: $12 and $10 per million Btu for the residential and commercial sectors respectively for fuel, and 9.57 cents and 8.81 cents per kWh for electricity. As discussed above, these are only notional costs used here to represent an unchanged and smooth business-as-usual energy future.[8] They are unlikely to be representative of actual future costs if energy demand grows as estimated in the business-as-usual scenario. Increasing fuel consumption implies growing imports of oil and natural gas (See Section C below), which will likely affect market and geopolitical conditions adversely.

We also assume that additional investments will be needed relative to business-as-usual to achieve the efficiencies that are built into the demand structure in the reference scenario. It is more difficult to make reliable estimates of such investments far into the future in part because there are fewer generally applicable examples.

1. For new commercial buildings, the added investment assumed is $10 per square foot, which is greater than examples of platinum level LEED-certified buildings. LEED (Leadership in Energy and Environmental Design) is a building certification program that evaluates not only energy efficiency but also other environmental aspects such as water use and the nature of the materials used on construction. We have not attributed any of the costs to aspects of environmental design other than energy use.

2. Residential building costs are much more variable, varying from $70 to over $200 per square foot for environmentally advanced buildings. There is no discernible pattern, except that buildings that include solar PV, solar thermal space or water heating, or geothermal heat pumps would cost somewhat more. (see Table 8-3). We assumed that the higher efficiency in the reference scenario would add about 10 percent per square foot to the cost of advanced buildings being built at present, as illustrated in Table 8-3. Only costs for efficiency improvements are included. The costs for solar PV, solar thermal installations, and combined heat and power systems were added separately.

3. For existing buildings, we assumed an investment at the time of sale of the homes and a turn over rate of a little over 5 percent per year. The total sales of existing homes between 2010 and 2050 would be about 300 million (since existing homes would be sold more than once in the period). We assumed that there would be an investment of $20,000 in one-third of these transactions.

Table 8-3: Examples of Cost of Green Building Award-Winning Homes for Efficiency Improvements Only

Climate/State	cost/sq. ft.	area, sq. ft.	Cost $
Moderate/MD or VA	100	1900	190000
Cold/WI	76	2728	207328
Hot/TX	115	1994	224310
Moderate/CA	70	2543	163610
Cold/CO	98	2864	280672
Cold/MI	198	3453	676194
Cold/ID	75	2653	198975
Moderate/MD	58	3716	192128
Moderate/OR	235	2544	565540
Total		24395	2698757
Average	111		

Source: Energy Value Housing Awards at http://www.nahbrc.org/evha/winners.html (EVHA 2007) and, for the first building in the list at PRSEA 2003.

Note: The additional costs of solar thermal installations over and above those of conventional systems are taken to be: solar PV at $6,000 per peak watt, solar thermal water heating systems at $5,000, and geothermal heat pumps at $7,500 for those homes that have them. These costs have been subtracted from the building cost and separately accounted for in the reference scenario and Table 8-4 below.

Table 8-4 shows the results for the residential and commercial sectors. The total estimated annual energy and investment costs for the residential and commercial sectors in terms of GDP impact are about the same as energy costs in the business-as-usual scenario. The lower per house and per square foot, higher needed investment, and higher anticipated per unit costs of electricity and fuels under the IEER reference scenario are taken into account. The net estimated GDP impact of reducing residential and commercial sector energy use by efficiency improvements and converting entirely to renewable energy sources is small and well within the range of the uncertainties in the calculations.

Table 8-4: Annual Residential (R) and Commercial (C) Energy and Investment Costs in 2050, in Billions of Constant 2005 Dollars

Item	IEER Reference Scenario	Business-as-Usual Scenario
R + C Electricity	$326	$442
R + C Fuel	$150	$247
Sub-total energy cost	$476	$689
Added annual investment for efficiency (Notes 2 and 3)	$205	$0
Total GDP-basis amount (rounded)	***$681***	***$689***
GDP in 2050 (Note 4)	$40,000	$40,000
GDP fraction: residential and commercial energy services	***1.70%***	***1.72%***

Notes:

1. Business-as-usual (BAU) fuel and electricity prices: about $12 per million Btu and 9.6 cents per kWh. Reference Scenario prices: $20 per million Btu and 14.1 cents per kWh respectively. BAU electricity price is from January 2006.
2. Added efficiency investments: existing residences: $20,000 per residence each time, assumed to occur in one of every three sales of existing buildings between 2010 and 2050; new = $10 per square foot (about $20,000 per house, approximate LEED-certified house added cost); plus cost of replacing appliances every 15 years with then-prevailing advanced appliances. Investments for solar thermal heating, combined heat and power, and geothermal heat pumps added to these figures for the proportion of residential area using them. LEED stands for Leadership in Energy and Environmental Design; it is a building certification program.
3. Commercial efficiency investments: $10 per square foot; this is more than examples of platinum level LEED investment. Investments for solar thermal heating, combined heat and power, and geothermal heat pumps have been added to these figures.
4. GDP = consumption expenditures + investment + government spending (on goods and services) + exports – imports.

Under the stated assumptions, the costs in the residential sector are somewhat higher than business-as-usual and those in the commercial sector are somewhat lower. A calculation for an average individual homeowner who purchases a new, detached home in the year 2050, with features weighted by the proportion in which they are used in the reference scenario indicates that the added cost would be $20 to $100 per month. An interest rate of 7 percent and a 30-year mortgage has been assumed. The latter figure is less than 0.7 percent of median household income in 2050. The range reflects uncertainties as to the marginal increased cost of efficiency based on estimated added costs of efficient homes over typical homes at present of 3 to 8 percent.[9]

2. Transportation

Estimating the costs of the transformation of the vehicular sector for the technologies in the reference scenario is rather difficult and relies on a projection of the costs of plug-in hybrids and electric vehicles. The most important uncertainty is the cost of batteries. At present the cost is around $1,000 per kWh. This is too expensive to compete with gasoline cars at $3 per gallon. However, as noted, present battery costs are dominated by low volume of manufacture and the nascent nature of the industry. We assume battery costs of $200 per kWh, which are anticipated in less than a decade (see Chapters 3 and 5). We also assume that the entire cost of the battery needed for a 200-mile range would be additional cost over a gasoline car. Efficiency assumptions for the year 2050 for personal vehicles are as follows:

- Business-as-usual: about 40 miles per gallon.
- IEER reference scenario: 10 miles per kWh
- An average electricity cost of 14.1 cents per kWh, assuming that partial off-peak and partial on-peak charging will result in average electricity rates for vehicle charging. This assumption may appear rather adverse for electric cars. However, it is realistic to assume that facilities similar to gas stations would be commonly used for quick charging of vehicles in addition to off-peak charging in a context where electric vehicles and/ or plug-in hybrids with high capacity for running on electricity only would be the standard vehicles on the market.

The reduced costs of maintenance (no oil changes, no tune-ups, lower brake replacement rate, etc.) of electric vehicles are not taken into account. With these assumptions, the proportion of GDP devoted to fuel cost for personal vehicles would be about 0.9 percent for the business-as-usual scenario and 0.5 to 0.6 percent for the reference scenario. Another way to look at these numbers is that personal and small business transportation in the reference scenario would be comparable to the business-as-usual scenario with present achievable electric vehicle efficiency and battery cost of $200 per kWh. At future efficiency of 10 miles per kWh, the battery cost could be about $400 per kWh. Hence, improvements in vehicle efficiency and reductions in battery costs can go hand-in-hand in improving electric vehicle economics.

Personal transportation fuel use represents only about half the fuel consumption in transportation. The proportion of energy costs in the transportation sector would therefore be 2 to 3 percent, possibly less, under these assumptions in the year 2050.

D. Projecting Business-as-usual

A business-as-usual future would be characterized by a lack of restrictions on fossil fuel consumption and hence most likely growing oil and natural gas imports. Such an energy future may be characterized by economic turbulence and higher prices that are not captured by the notional prices used in the comparisons above. Business-as-usual is an historical construct that facilitates technical calculations, but should not be regarded as an estimate of the evolution of the energy future of the United States or the world.

An energy future that follows the past pattern of increasing oil imports would likely be wracked by volatility in oil prices. Disruptions in supply, such as those caused by Hurricane Katrina, may also be more frequent due to the increasing effects of severe climate change. If the United States does not commit to serious reductions in oil consumption, there would be no prospect that China, India, and other developing countries would do so. The overall global economic and political environment in which these and other countries, including the European Union and Japan, compete for oil and gas would be very likely to deteriorate. This problem of resource competition would likely be much worse in areas where production costs are very low, at present mainly the Persian Gulf region, where costs are less than $3 per barrel, but also in other areas, where production costs are moderate.

Another way of saying the same thing is that business-as-usual projections of energy use are unlikely, in the same way that projections made before 1973 became unlikely in the face of the political, military, and economic crisis represented by the events of 1973 and 1979. They changed the energy picture in the United States profoundly (see Chapter 1). The main choice is whether energy use will become more efficient and more oriented towards domestic renewable resources by deliberate policy or whether it will be driven there willy-nilly by recurrent global crises.

CHAPTER 9: SUMMARY

A three-fold global energy crisis has emerged since the 1970s; it is now acute on all three fronts:

1. **Climate disruption**: Carbon dioxide (CO_2) emissions due to fossil fuel combustion are the main anthropogenic cause of severe climate disruption, whose continuation portends grievous, irreparable harm to the global economy, society, and current ecosystems.
2. **Insecurity of oil supply**: Rapid increases in global oil consumption and conflict in and about oil exporting regions make prices volatile and supplies insecure.
3. **Nuclear proliferation:** Non-proliferation of nuclear weapons is being undermined in part by the spread of commercial nuclear power technology, which is being put forth as a major solution for reducing CO_2 emissions.

This book examines the technical and economic feasibility of achieving a U.S. economy with zero-CO_2 emissions without nuclear power. This is interpreted as an elimination of all but a few percent of CO_2 emissions or complete elimination with the possibility of removing from the atmosphere some CO_2 that has already been emitted. We set out to answer three questions:

- Is it possible to physically eliminate CO_2 emissions from the U.S. energy sector without resort to nuclear power, which has serious security and other vulnerabilities?
- Is a zero-CO_2 economy possible without purchasing offsets from other countries – that is, without purchasing from other countries the right to continue emitting CO_2 in the United States?
- Is it possible to accomplish the above at reasonable cost?

The overarching finding of this study is that a zero-CO_2 U.S. economy can be achieved within the next thirty to fifty years without the use of nuclear power and without acquiring carbon credits from other countries. In other words, actual physical emissions of CO_2 from the energy sector can be eliminated with technologies that are now available or foreseeable. This can be done at reasonable cost while creating a much more secure energy supply than at present. Net U.S. oil imports can be eliminated in about 25 years. All three insecurities – severe climate disruption, oil supply and price insecurity, and nuclear proliferation via commercial nuclear energy – will thereby be addressed. In addition, there will be large ancillary health benefits from the elimination of most regional and local air pollution, such as high ozone and particulate levels in cities, which is due to fossil fuel combustion.

The achievement of a zero-CO_2 economy without nuclear power will require unprecedented foresight and coordination in policies from the local to the national, across all sectors of the energy system. Much of the ferment at the state and local level, as well as some of the proposals in Congress, is already pointed in the right direction. But a clear long-term goal is necessary to provide overall policy coherence and establish a yardstick against which progress can be measured.

A zero-CO_2 U.S. economy without nuclear power is not only achievable – it is necessary for environmental protection and security. *Even the process of the United States setting a goal of a zero-CO_2, nuclear-free economy and taking initial firm steps towards it will transform global energy politics in the immediate future and establish the United States as a country that leads by example, rather than one that preaches temperance from a barstool, especially in the matter of nuclear power and the technologies that are associated with it, some of which are directly relevant to nuclear weapons production.*

A. Findings

Finding 1: A goal of a zero-CO_2 economy is necessary to minimize harm related to climate change.

According to the Intergovernmental Panel on Climate Change, global CO_2 emissions would need to be reduced by 50 to 85 percent relative to the year 2000 in order to limit average global temperature increase to 2 to 2.4 degrees Celsius relative to pre-industrial times. A reduction of 80 percent in total U.S. CO_2 emissions by 2050 would be entirely inadequate to meet this goal. It implies annual U.S. emissions of about 2.8 metric tons per person.

A global norm of emissions at this rate would leave worldwide CO_2 emissions almost as high as in the year 2000.[1] In contrast, if a global norm of approximately equal per person emissions by 2050 is created along with a 50 percent global reduction in emissions, it would require an approximately 88 percent reduction in U.S. emissions. An 85 percent global reduction in CO_2 emissions corresponds to a 96 percent reduction for the United States. An allocation of emissions by the standard of cumulative historical contributions would be even more stringent.

A U.S. goal of zero-CO_2, defined as being a few percent on either side of zero relative to 2000, is both necessary and prudent for the protection of global climate. It is also implied by the United Nations Framework Convention on Climate Change. That treaty, to which the United States is a party, requires that the burden of reducing emissions of greenhouse gases be shared equitably, with due consideration to the historical fact and current reality that developed countries have been and are responsible for most emissions. A per-capita norm is a minimal interpretation of this treaty. When joined to the goal of being reasonably sure to limit temperature rise to the range of 2 to 2.4 degrees Celsius by 2050, the UNFCCC implies a zero-CO_2 economy for the United States.

Finding 2: A hard cap on CO_2 emissions – that is, a fixed emissions limit that declines year by year until it reaches zero – would provide large users of fossil fuels with a flexible way to phase out CO_2 emissions. However, free allowances, offsets that permit emissions by third party reductions,[2] or international trading of allowances, notably with developing countries that have no CO_2 cap, would undermine and defeat the purpose of the system. A measurement-based physical limit, with appropriate enforcement, should be put into place.

A hard cap on CO_2 emissions is recommended for large users of fossil fuels, defined as an annual use of 100 billion British thermal units (Btu) or more – equal to the delivered energy use of about 1,000 households. At this level, users have the financial resources to be able to track the market, make purchases and sales, and evaluate when it is most beneficial to invest in CO_2 reduction technologies relative to purchasing credits. This would cover about two-thirds of fossil fuel use. Private vehicles, residential and small commercial use of natural gas and oil for heating, and other similar small-scale uses would not be covered by the cap. The transition in these areas would be achieved through efficiency standards, tailpipe emissions standards, and other standards set and enforced by federal, state, and local governments. Taxes are not envisaged in this study, except possibly on new vehicles that fall far below the average efficiency or emissions standards. The hard cap would decline annually and be set to go to zero before 2060. Acceleration of the schedule would be possible, based on developments in climate impacts and technology.

The annual revenues that would be generated by the government from the sale of allowances would be on the order of \$30 billion to \$50 billion per year through most of the period, since the price of CO_2 emission allowances would tend to increase as supply goes down. These revenues would be devoted to ease the transition at all levels – local, state, and federal – as well as for demonstration projects and research and development.

Finding 3: A reliable U.S. electricity sector with zero-CO_2 emissions can be achieved without the use of nuclear power or fossil fuels.

The U.S. renewable energy resource base is vast and practically untapped. Available wind energy resources in 12 Midwestern and Rocky Mountain states equal about 2.5 times the entire electricity production of the United States. North Dakota, Texas, Kansas, South Dakota, Montana, and Nebraska each have wind energy potential greater than the electricity produced by all 103 U.S. nuclear power plants. Solar energy resources on just one percent of the area of the United States are about three times as large as wind energy, if production is focused in the high insolation areas in the Southwest and West.

Just the parking lots and rooftops in the United States could provide most of the U.S. electricity supply. This also has the advantage of avoiding the need for transmission line expansion, though some strengthening of the distribution infrastructure may be needed. Wind energy is already more economical than nuclear power. In the past two years, the costs of solar cells have come down to the point that medium-scale installations, such as the ones shown in Chapter 3, are economical in sunny areas, since they supply electricity mainly during peak hours.

The main problem with wind and solar energy is intermittency. This can be reduced by integrating wind and solar energy together into the grid – for instance, wind energy is often more plentiful at night. Geographic diversity also reduces the intermittency of each source and for both combined. Integration into the grid of these two sources up to about 15 percent of total generation (not far short of the contribution of nuclear electricity today) can be done without serious cost or technical difficulty with available technology, provided appropriate optimization steps are taken.

Solar and wind should also be combined with hydropower – with the latter being used when the wind generation is low or zero. This is already being done in the Northwest. Conflicts with water releases for fish management can be addressed by combining these three sources with natural gas standby. The high cost of natural gas makes it economical to use combined cycle power plants as standby capacity and spinning reserve for wind rather than for intermediate or baseload generation. In other words, given the high price of natural gas, these plants could be economically idled for some of the time and be available as a complement to wind power. Compressed air can also be used for energy storage in combination with these sources. No new technologies are required for any of these generation or storage methods.

Baseload power can be provided by geothermal and biomass-fueled generating stations. Intermediate loads in the evening can be powered by solar thermal power plants which have a few hours of thermal energy storage built in.

Finally, new batteries can enable plug-in hybrids and electric vehicles owned by fleets or parked in large parking lots to provide relatively cheap storage. Nanotechnology-based lithium-ion batteries, which Altairnano has begun to produce, can be deep discharged far more times than needed simply to operate the vehicle over its lifetime (10,000 to 15,000 times compared to about 2,000 times respectively).

Since the performance of the battery is far in excess of the cycles of charging and discharging needed for the vehicle itself, vehicular batteries could become a very low-cost source of electricity storage that can be used in a vehicle-to-grid (V2G) system. In such a system, parked cars would be connected to the grid and charged and discharged according to the state of the requirements of the grid and the charge of the battery in the vehicle. Communications technology to accomplish this via wires or wireless means is already commercial. A small fraction of the total number of road vehicles (several percent) could provide sufficient backup capacity to stabilize a well designed electricity grid based on renewable energy sources (including biomass and geothermal).

One possible configuration of the electric power grid is shown in Figure 5-6 in Chapter 5. A large amount of standby power is made available. This allows a combination of wind and solar electricity to supply half or more of the electricity without affecting reliability. Most of the standby power would be supplied by stationary storage and/or V2G and by combined cycle power plants for which the fuel is derived from biomass. Additional storage would be provided by thermal storage associated with central station solar thermal plants. Hydropower use would be optimized with the other sources of storage and standby capacity. Wind energy can also be complemented by compressed air storage, with the compressed air being used to reduce methane consumption in combined cycle power plants. Storage on the energy supply-side can be combined with storage on the demand-side and a smart grid approach in which demand can be adjusted to more closely match renewable energy supply.

With the right combination of technologies, it is likely that even the use of coal can be phased out, along with nuclear electricity. However, we recognize that the particular technologies that are on the cutting edge today may not develop as now appears likely. It therefore appears prudent to have a backup strategy. The carbon dioxide from coal-fired power plants can be captured at moderate cost if the plants are used with a technology called integrated gasification combined cycle (IGCC). Carbon capture and sequestration may also be needed for removing CO_2 from the atmosphere via biomass.

Finding 4: The use of nuclear power entails risks of nuclear proliferation, terrorism, and serious accidents. It exacerbates the problem of nuclear waste and perpetuates vulnerabilities and insecurities in the energy system that are avoidable.

Commercial nuclear technology is being promoted as a way to reduce CO_2 emissions, including by the U.S. government. With Russia, the United States has also been promoting a scheme to restrict commercial uranium enrichment and plutonium separation (reprocessing) to the countries that already have it. (These are both processes that can produce nuclear-weapons-usable materials.) This is a transparent attempt to change the Nuclear Non-Proliferation Treaty (NPT) without going through the process of working with the signatories to amend it. The effort will undermine the treaty, which gives non-nuclear parties an "inalienable right" to commercial nuclear technology. In any case, non-nuclear-weapon states are unlikely to go along with the proposed restrictions.

It is not hard to discern that the increasing interest in nuclear power is at least partly as a route to acquiring nuclear weapons capability. For instance, the Gulf Cooperation Council (Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates), pointing to Iran and Israel, has stated that it will openly acquire civilian nuclear power technology. In making the announcement, the Saudi Foreign Minister Prince Saud Al-Faisal was quoted in the press as saying "It is not a threat….We are doing it openly." He also pointed to Israel's nuclear reactor, used for making plutonium for its nuclear arsenal, as the "original sin." At the same time, he urged that the region be free of nuclear weapons.[3]

Interest in commercial reprocessing may grow as a result of U.S. government policies. The problems of reprocessing are already daunting. For instance, North Korea used a commercial sector power plant and a reprocessing plant to get the plutonium for its nuclear arsenal. Besides the nuclear weapon states, about three dozen countries, including Iran, Japan, Brazil, Argentina, Egypt, Taiwan, South Korea, and Turkey, have the technological capacity to make nuclear weapons. It is critical for the United States to lead by example and achieve the necessary reductions in CO_2 emissions without resorting to nuclear power. Greater use of nuclear power would convert the problem of nuclear proliferation from one that is difficult today to one that is practically intractable.

Even the present number of nuclear power plants and infrastructure has created tensions between non-proliferation and the rights countries have under the NPT to acquire commercial nuclear technology. Increasing their number would require more uranium enrichment plants, when just one such plant in Iran has stoked global political-security tensions to a point that it is a major driver in spot market oil price fluctuations. In addition, there are terrorism risks, since power plants are announced terrorist targets. It hardly appears advisable to increase the number of targets.

The nuclear waste problem has resisted solution. Increasing the number of power plants would only compound the problem. In the United States, it would likely create the need for a second repository, and possibly a third, even though the first, at Yucca Mountain in Nevada, is in deep trouble. No country has so far been able to address the significant long-term health, environmental and safety problems associated with spent fuel or high level waste disposal, even as official assessments of the risk of harm from exposure to radiation continue to increase.

Finally, since the early 1980s, Wall Street has been, and remains, skeptical of nuclear power due to its expense and risk. That is why, more than half a century after then-Chairman of the Atomic Energy Commission, Lewis Strauss, proclaimed that nuclear power would be "too cheap to meter," the industry is still turning to the government for loan guarantees and other subsidies. The insurance side is no better. The very limited insurance that does exist is far short of official estimates of damage that would result from the most serious accidents; it is almost all government-provided.

Finding 5: The use of highly efficient energy technologies and building design, generally available today, can greatly ease the transition to a zero-CO_2 economy and reduce its cost. A two percent annual increase in efficiency per unit of Gross Domestic Product relative to recent trends would result in a one percent decline in energy use per year, while providing three percent GDP annual growth. This is well within the capacity of available technological performance.

Before the first energy crisis in 1973, it was generally accepted that growth in energy use and economic growth, as expressed by Gross Domestic Product (GDP), went hand in hand. But soon after, the U.S. energy picture changed radically and economic growth was achieved for a decade without energy growth.

Since the mid-1990s, the rate of energy growth has been about two percent less than the rate of GDP growth, despite the lack of national policies to greatly increase energy efficiency. For instance, residential and commercial buildings can be built with just one-third to one-tenth of the present-day average energy use per square foot with existing technology. As another example, we note that industrial energy use in the United States has stayed about the same since the mid-1970s, even as production has increased.

Our research indicates that annual use of delivered energy (that is, excluding energy losses in electricity and biofuels production) can be reduced by about one percent per year while maintaining the economic growth assumed in official energy projections.

Finding 6: Biofuels, broadly defined, could be crucial to the transition to a zero-CO_2 economy without serious environmental side effects or, alternatively, they could produce considerable collateral damage or even be very harmful to the environment and increase greenhouse gas emissions. The outcome will depend essentially on policy choices, incentives, and research and development, both public and private.

Food crop-based biodiesel and ethanol can create and are creating social, economic, and environmental harm, including high food prices, pressure on land used by the poor in developing countries for subsistence farming or grazing, and emissions of greenhouse gases that largely or completely negate the effect of using the solar energy embodied in the biofuels. While they can reduce imports of petroleum, ethanol from corn and biodiesel from palm oil are two prominent examples of damaging biofuel approaches that have already created such problems even at moderate levels of production.

For instance, in the name of renewable energy, the use of palm oil production for European biodiesel use has worsened the problem of CO_2 emissions due to fires in peat bogs that are being destroyed in Indonesia, where much of the palm oil is produced. Rapid increases in ethanol from corn are already partly responsible for fueling increases in tortilla prices in Mexico. Further, while ethanol from corn would reduce petroleum imports, its impact on reducing greenhouse gas emissions would be small at best due to the energy intensity of both corn and ethanol production, as well as the use of large amounts of artificial fertilizers, which also result in emissions of other greenhouse gases (notably nitrous oxide). All subsidies for fuels derived from food crops should be eliminated.

In contrast, biomass that has high efficiency solar energy capture (~five percent), such as microalgae grown in a high-CO_2 environment, can form a large part of the energy supply both for electricity production and for providing liquid and gaseous fuels for transport and industry. Microalgae have been demonstrated to capture over 80 percent of the daytime CO_2 emissions from power plants and can be used to produce up to 10,000 gallons of liquid fuel per acre per year. Some aquatic plants, such as water hyacinths, have similar efficiency of solar energy capture and can be grown in wastewater as part of combined water treatment and energy production systems.

Water hyacinths have been used to clean up wastewater because they grow rapidly and absorb large amounts of nutrients. Their productivity in tropical and subtropical climates is comparable to microalgae – up to 250 metric tons per hectare per year. They can be used as the biomass feedstock for producing liquid and gaseous fuels. There are also other high productivity aquatic plants, such as duckweed, that grow in a wider range of climates that can be used for producing biofuels.

Prairie grasses have medium productivity, but can be grown on marginal lands in ways that allow carbon storage in the soil. This approach can therefore be used both to produce fuel renewably and to remove CO_2 from the atmosphere.

Finally, solar energy can be used to produce hydrogen; this could be very promising for a transition to hydrogen as a major energy source. Techniques include photoelectrochemical hydrogen production using devices much like solar cells, high-temperature, solar-energy-driven splitting of water into hydrogen and oxygen, and conversion of biomass into carbon monoxide and hydrogen in a gasification plant.

Finding 7: Much of the reduction in CO_2 emissions can be achieved without incurring any cost penalties (as, for instance, with efficient lighting and refrigerators). The cost of eliminating the rest of CO_2 emissions due to fossil fuel use is likely to be in the range of \$10 to \$30 per metric ton of CO_2.

Table 9-1 shows the estimated costs of eliminating CO_2 from the electricity sector using various approaches.

Table 9-1: Summary of costs for CO_2 abatement (and implicit price of CO_2 emission allowances) – Electricity sector (based on 2004 costs of energy)

CO_2 source	Abatement method	Phasing	Cost per metric ton CO_2, \$	Comments
Pulverized coal	Off-peak wind energy	Short-term	A few dollars to \$15	Based on off-peak marginal cost of coal.
Pulverized coal	Capture in micro-algae	Short- and medium-term	Zero to negative	Assuming price of petroleum is >\$30 per barrel.
Pulverized coal	Wind power with natural gas standby	Medium- and long-term	Negative to \$46	Combined cycle plant idled to provide standby. Highest cost at lowest gas price: \$4/mn Btu
Pulverized coal	Nuclear power	Medium- to long-term	\$20 to \$50	Unlikely to be economical compared to wind with natural gas standby.
Pulverized coal	Integrated Gasification Combined Cycle (IGCC) with sequestration	Long-term	\$10 to \$40 or more	Many uncertainties in the estimate at present. Technology development remains.
Natural gas standby component of wind	Electric vehicle-to-grid	Long-term	Less than \$26	Technology development remains. Estimate uncertain. Long-term-natural gas price: \$6.50 per million Btu or more.

Notes:

1. Heat rate for pulverized coal = 10,000 Btu/kWh; for natural gas combined cycle = 7,000 Btu/kWh.
2. Wind-generated electricity costs = 5 cents per kWh; pulverized coal = 4 cents per kWh; nuclear = 6 to 9 cents per kWh.
3. Petroleum costs \$30 per barrel or more.
4. CO_2 costs associated with wind energy related items can be reduced by optimized deployment of solar and wind together.

Further, the impact of increases in costs of CO_2 abatement on the total cost of energy services is low enough that the overall share of GDP devoted to such services would remain at about the present level of about 8 percent or perhaps decline. It has varied mainly between 8 and 14 percent since 1970, hitting a peak in 1980. It dropped briefly to about 6 percent in the late 1990s when oil prices tumbled steeply, hitting a low of about $12 per barrel in 1998.

Finding 8: The potential for energy efficiency is considerably greater than assumed in the reference scenario in many areas. Greater efficiency, greater use of electricity, and use of hydrogen derived from wind (and possibly solar) energy would greatly reduce the land impacts associated with large-scale biofuel production.

The opportunities for greater efficiency beyond the reference scenario discussed in Chapter 6 help reduce the requirement for liquid and gaseous biofuels in 2050 from about 35 quadrillion Btu to 20 to 25 quadrillion Btu. A significant fraction of this fuel requirement can be met by electrolytic hydrogen from wind and possibly direct solar hydrogen production, provided there is adequate early emphasis on commercialization of hydrogen. Distributed hydrogen production and use of hydrogen in internal combustion engines are the closest to practical application. Reducing liquid and gaseous biofuels requirements to the 10 to 15 quadrillion Btu range would largely resolve the most important anticipated environmental impact of the reference scenario – land use for biofuels. In the preferred renewable future, only about 2 to 3 percent of the land area of the U.S. would be needed for energy supply.

Finding 9: The transition to a zero-CO_2 system can be made in a manner compatible with local economic development in areas that now produce fossil fuels.

Fossil fuels are mainly produced today in the Appalachian region, in the Southwest and West and some parts of the Midwest and Rocky Mountain states. These areas are also well-endowed with the main renewable energy resources – solar and wind. Federal, state and regional policies, designed to help workers and communities transition to new industries, therefore appear to be possible without more major physical movement or disruption of populations than has occurred in post-World War II United States. It is recognized that much of that movement has been due to dislocation and shutdown of industries, which causes significant hardship to communities and workers. Some of the resources raised by the sale of CO_2 allowances should be devoted to reducing this disruption. For instance, the use of CO_2 capture technologies, notably microalgae CO_2 capture from existing fossil fuel plants, can create new industries and jobs in the very regions where the phase-out of fossil fuels would have the greatest negative economic impact. Public policy and direction of financial resources can help ensure that new energy sector jobs that pay well are created in those communities.

B. Recommendations: The Clean Dozen

The 12 most critical policies that need to be enacted as urgently as possible for achieving a zero-CO_2 economy without nuclear power are as follows.

1. Enact a physical limit of CO_2 emissions for all large users of fossil fuels (a "hard cap") that steadily declines to zero prior to 2060, with the time schedule being assessed periodically for tightening according to climate, technological, and economic developments. The cap should be set at the level of some year prior to 2007, so that early implementers of CO_2 reductions benefit from the setting of the cap. Emission allowances would be sold by the U.S. government for use in the United States only. There would be no free allowances, no offsets and no international sale or purchase of CO_2 allowances. The estimated revenues – approximately \$30 to \$50 billion per year – would be used for demonstration plants, research and development, and worker and community transition.
2. Eliminate all subsidies and tax breaks for fossil fuels and nuclear power (including guarantees for nuclear waste disposal from new power plants, loan guarantees, and subsidized insurance).
3. Eliminate subsidies for biofuels from food crops.
4. Build demonstration plants for key supply technologies, including central station solar thermal with heat storage, large- and intermediate-scale solar photovoltaics, and CO_2 capture in microalgae for liquid fuel production (and production of a high solar energy capture aquatic plants, for instance in wetlands constructed at municipal wastewater systems).
5. Leverage federal, state and local purchasing power to create markets for critical advanced technologies, including plug-in hybrids.
6. Ban new coal-fired power plants that do not have carbon storage.
7. Enact at the federal level high efficiency standards for appliances.
8. Enact stringent building efficiency standards at the state and local levels, with federal incentives to adopt them.
9. Enact stringent efficiency standards for vehicles and make plug-in hybrids the standard U.S. government vehicle by 2015.
10. Put in place federal contracting procedures to reward early adopters of CO_2 reductions.
11. Adopt vigorous research, development, and pilot plant construction programs for technologies that could accelerate the elimination of CO_2, such as direct electrolytic hydrogen production, solar hydrogen production (photolytic, photoelectrochemical, and other approaches), hot rock geothermal power, and integrated gasification combined cycle plants using biomass with a capacity to sequester the CO_2.
12. Establish a standing committee on Energy and Climate under the U.S. Environmental Protection Agency's Science Advisory Board.

AFTERWORD

by Dr. Helen Caldicott

The climate crisis has put the Earth in the intensive care unit. In the past few years I have experienced an acute sense of urgency to do my part to set it on the road to recovery. I have not felt such urgency since the threat of nuclear war between United States and the Soviet Union hung over the planet in the early 1980s, a threat incidentally that has not diminished, with thousands of Russian and US .nuclear warheads still on high alert, ready to be fired in minutes.

The Nuclear Policy Research Institute sponsored an energy conference in 2006 to which I invited some of the world's most experienced and able people in the energy field to ascertain whether they shared my sense of urgency about the state of the planet. This two day discussion dissected out the ecological and medical dangers of a fossil-fueled, nuclear-fueled energy system and explored the possibilities of a vibrant renewable energy economy.

Among the speakers were S. David Freeman and Arjun Makhijani. David's speech was extraordinarily inspiring as he raised the distinct possibility that all energy could be obtained from present-day technology without the use of fossil fuel or nuclear power. I could hardly believe my ears. This was an entirely new scenario that had never before been seriously entertained.

Dr. Makhijani agreed that the world was facing an ecological crisis and that the scale of the problem was escalating rapidly as grim news about climate alterations continued unabated. But was a renewable energy policy technically and economy feasible without nuclear power?

Arjun, one of the most capable scientists in environmental work, did not want to advocate something that he thought would only be feasible at an unbearably high cost. In his view, cost was part of the feasibility equation.

Several months of discussions took place before a plan of action eventuated. We agreed to initiate a comprehensive in-depth study to examine these questions. Dave Freeman and I would serve on an Advisory Board, along with other members from academia, industry, and the economic justice movement. To enable Arjun to focus entirely on the study, I agreed to accept the task of fundraising.

Arjun and I had many arguments as we discussed the conflicting goals which entailed urgency on the one hand and feasibility on the other. I reminded him that the patient had to survive at all costs and that from a medical perspective, the economy was secondary. He insisted that if we pushed things beyond what was economically feasible even with sensible policies, we would achieve nothing. We were not the captains of industry. We did not have our hands on serious capital to invest to help save the planet. The plan had to be within the realm of economic reality. It should frankly assess the current state of the technologies that were needed, how close they were to economical reality, and how these existing technologies could be marketed. We also needed a backup strategy if the main approach could not yield desired results.

The Roadmap meets all these requirements. Arjun has produced a study which fulfills my greatest hopes – an urgent action plan to move the Earth in a dignified way out of intensive care. This is a benign and efficient proposal to save the planet without the cancerous, radioactive, proliferation-prone side effects which current energy policy will inevitably bestow upon future generations. My message to all members of society, including local legislators, captains of industry, members of Congress, and presidential candidates is simple: read this book and act upon it.

Helen Caldicott, M.D.
Founding President, Nuclear Policy Research Institute

GLOSSARY

Baseload generation: Electricity generation on a continuous basis by large-scale power plants.

Biofuel: Fuel derived from biomass.

Biomass: Organic material produced by photosynthesis.

Cap: A limit on emissions.

Capacitors: Devices that store electric charge.

Carbon capture: Capture of carbon dioxide when fuels containing carbon are burned for their energy.

Carbon sequestration: Deep geologic storage of carbon for long periods (thousands of years) to prevent it from entering the atmosphere.

CFL: Compact fluorescent lamp, which is a high-efficiency light bulb.

CHP: Combined heat and power. In this arrangement, some of the energy derived from burning a fuel is used as heat (as for instance in heating buildings or for industrial processes), and some is used for generating electricity.

Combined cycle power plant: Power plant in which the hot gases from the burning of a fuel (usually natural gas) are used to run a gas turbine for generating electricity. The exhaust gas from the turbine is still hot and is used to make steam, which is used to drive a steam turbine, which in turn drives an electric generator.

Distributed grid: An electricity grid that combines significant portions of small-scale and intermediate-scale generation with centralized generation.

Earth-source heat pump: See geothermal heat pump.

Electrolytic hydrogen production: The use of electricity to separate the hydrogen and oxygen in water.

Geothermal heat pump: A heat pump that uses the relatively constant temperature a few feet below the earth's surface in order to increase the efficiency of the heat pump.

Ground source heat pump: See geothermal heat pump.

Hard cap: An absolute limit on annual emissions.

HFCs: Halogenated fluorocarbons. Could also apply to partially halogenated compounds.

IGCC: Integrated Gasification Combined Cycle plant. This plant gasifies coal or biomass and then uses the gases in a combined cycle power plant.

LEED: Leadership in Energy and Environmental Design – a rating system used for building efficiency. The platinum level is the highest rating.

Microalgae: Tiny algae that grow in a variety of environments, including salty water.

Nanocapacitor: Capacitors made using a nanotechnology that can store a very large amount of charge per unit volume. This technology is still in the laboratory stage.

Photoelectrochemical hydrogen: Hydrogen produced directly using devices similar to some solar photovoltaic cells that generate electricity. In this arrangement, hydrogen is produced instead of electricity.

Photolytic hydrogen: Hydrogen produced by plants, for instance, algae, in the presence of sunlight.

Pumped storage: Using electricity at off-peak times to pump water into a reservoir and then using a hydroelectric power plant to generate electricity with the stored water during peak times (or, when used with wind energy, when the wind is not blowing).

Smart grid: A distributed electricity grid in which electricity supply, electricity storage, and thermal storage (heat and coldness) are integrated with time-of-use controls of end-use equipment. It would enable real-time management of the electricity system so as to match electricity demand with the supply of intermittent renewable energy sources and reduce the total investment needed for a given level of energy services and reliability.

Solar light pipe: A fiber optic cable that conveys light from the sun along its length without leaking it out of the sides, much like a wire carries electricity. It can be used to light the interiors of buildings during the daytime.

Solar PV: Solar photovoltaic cells: Devices that turn incident sunlight into electricity.

Solar thermal power plant: A power plant that uses reflectors to concentrate solar energy and heat liquids that are then used to produce steam and generate electricity.

Spinning reserve: The capacity of electric power plants that are kept switched on ("spinning") but idle in order to be able to meet sudden increases in electricity demand.

Standby capacity: Power plants that are kept on standby to meet increases in electric demand.

Supercapacitors: See nanocapacitors.

Time-of-use rates: Electricity rates that vary according to the time-of-use relative to the availability supply and the types of electricity supply.

Ultracapacitor: A capacitor that can store much more electricity per unit volume than normal capacitors.

UNFCCC: United Nations Framework Conversion on Climate Change

V2G: Vehicle to grid system. Parked cars are connected to the grid. When the charge on the batteries is low, the grid recharges them. When the charge is sufficient and the grid requires electricity, a signal from the grid enables the battery to supply electricity to the grid.

APPENDIX A: NUCLEAR POWER

Uranium enrichment and reprocessing, once terms reserved for eggheads dealing in nuclear esoterica, are in the headlines everyday. Politicians and diplomats argue about them and the proliferation threats arising from the spread of commercial nuclear power technology.[1]

Yet, strangely, in a parallel universe also being played out on the public stage, fans of nuclear energy are proclaiming a "nuclear renaissance." The nuclear industry's claim, amplified by the megaphones of the media, is that nuclear power can play a vital role in saving the Earth from another peril – severe climate disruption caused by the anthropogenic emissions of greenhouse gases, particularly CO_2.

Could nuclear power really help save the world from what could be the worst environmental scourge ever to confront humanity? History would suggest two things: caution about the nuclear industry's messianic proclamations and careful analysis of the problem.

A. History

The early promises of the fervent advocates of nuclear energy were of an economic paradise that nuclear energy would usher in for everyone from the needy to the greedy. No whim or need would go unfulfilled. But it was mainly fantasy and propaganda.

Studies of the 1940s and 1950s showed that the public proclamations that nuclear power would soon to "too cheap to meter" were known then to be wrong. For instance, a 1950 article written by Ward Davidson, a research engineer with Consolidated Edison Company of New York, published in an industry journal, *Atomics*, concluded that the technical problems facing nuclear power were daunting. For example, the materials requirements would be stringent, given the high temperatures and damage from high neutron fluxes. Testing of the alloys to ensure the quality and uniformity needed would be difficult. All this meant, of course, that nuclear power would be expensive.

"Too cheap to meter" was part self-delusion, as shown by the florid and fantastic statements made by the most serious people, such as Glenn Seaborg, who led the team that first isolated plutonium, and Robert Hutchins, the President of the University of Chicago during the Manhattan Project. And it was in part organized propaganda designed to hide the horror of the hydrogen bomb. The statement itself was made in 1954, by the then-Chairman of the U.S. Atomic Energy Commission, Lewis Strauss. It was part of a campaign to convince the world that the American atom was a peaceful one. There was fear that the Soviets would do that first.

In September of 1953, less than a month after the detonation of the Soviet's first hydrogen bomb, AEC Commissioner Thomas Murray wrote to the commission's chairman that the U.S. could derive "propaganda capital" from a publicity campaign surrounding their recent decision to construct the Shippingport nuclear power plant.[2] Sterling Cole, the chairman of the Joint Committee on Atomic Energy in the U.S. Congress, reached a similar conclusion regarding the importance of demonstrating the "benefits" of nuclear power as a counterbalance to the immense destructive force of the hydrogen bomb. This conclusion, in fact, led Cole to worry that the Soviets might beat the U.S. to a functional nuclear power plant, and thus steal the claim to being the true promoters of the "peaceful" atom. In a letter to a fellow Congressman, Sterling Cole wrote

> It is possible that the relations of the United States with every other country in the world could be seriously damaged if Russia were to build an atomic power plant for peacetime use ahead of us. The possibility that Russia might actually demonstrate her "peaceful" intentions in the field of atomic energy while we are still concentrating on atomic weapons could be a major blow to our position in the world.[3]

As early as 1948, the Atomic Energy Commission reported to Congress that "the cost of a nuclear-fuel power plant will be substantially greater than that of a coal-burning plant of similar capacity."[4] In the January 1949 issue of *Science*, Robert Bacher, one of the original members of the AEC and a member of the scientific team at Los Alamos during World War II, cautioned that despite the progress that was being made, it was "far too early to make any predictions about the economic feasibility of atomic power."[5]

One of the most direct of the early critiques of the economics of nuclear power came in a December 1950 speech before the American Association for the Advancement of Science by C.G. Suits. At the time, Suits was the Vice-President and Director of Research at General Electric which was then operating the Hanford plutonium production reactors in Washington State and was one of the principal companies developing nuclear reactors for the production of electricity. In his speech, which was reprinted in the industry journal *Nucleonics*, Suits stated bluntly that:

> It is safe to say... that atomic power is not the means by which man will for the first time emancipate himself economically, whatever that may mean; or forever throw off his mantle of toil, whatever that may mean. Loud guffaws could be heard from some of the laboratories working on this problem if anyone should in an unfortunate moment refer to the atom as the means for throwing off man's mantle of toil. It is certainly not that!
>
> ... At present, atomic power presents an exceptionally costly and inconvenient means of obtaining energy which can be extracted more economically from conventional fuels... The economics of atomic power are not attractive at present, nor are they likely to be for a long time in the future. This is expensive power, not cheap power as the public has been led to believe.[6]

In 1953, an official AEC study concluded that "no reactor could be constructed in the very near future which would be economic on the basis of power generation alone." Significantly, this language was identical to that in a study published by industrial companies and major utilities including Bechtel, Monsanto, Dow Chemical, Pacific Gas and Electric, Detroit Edison, and Commonwealth Edison.[7]

The dismal assessment of the prospects of nuclear went back to the Manhattan Project. In a star-studded 1948 report, authored by Enrico Fermi, Glenn Seaborg, and J. Robert Oppenheimer, the authors concluded that there was "unwarranted optimism" about the speed with which the technical difficulties facing nuclear power could be overcome. Ironically, the self-same Glenn Seaborg waxed eloquent about how plutonium fuel could transport everyone into a technical wonderland of "planetary engineering" – which, of course, could only be done if energy were actually very cheap.

A large part of the idea that nuclear energy would be a wondrous energy source was based on the idea that some kinds of nuclear reactors, called breeder reactors, could make more fuel than they consumed. Uraniun-238, not a reactor fuel, would be turned into fuel in breeder reactors, even as those same reactors consumed plutonium fuel. The net result would be more fuel at the end of the cycle. Since uranium-238 is a plentiful isotope in nature, the fantasy was only slightly exaggerated from a pure physics point of view.

But experience has shown that physics is not enough. An energy source must still meet the tests of safety, reliability, and cost. In the case of nuclear energy, there is also the unique problem of nuclear proliferation, in part hidden in the form of the plutonium content of the spent fuel and in part in the form of the spread of know-how. Taken together, these factors made the physics "magic" evaporate the first time around. Breeder reactors and the associated reprocessing have yet to be commercialized after over $100 billion in expenditures worldwide (constant 1996 dollars) and more than fifty years of effort. France, which has the most experience in the use of plutonium as an energy source as well as the largest commercial infrastructure for that purpose, has spent an extra 2 cents per kWh on electricity generation from plutonium fuel used in its light water reactors. The main breeder reactor that has been used in commercialization efforts has used liquid sodium as a coolant. It has a very mixed history, from reasonably good performance to utterly dismal. The largest such reactor, Superphénix, a 1,250 megawatt machine, was built in France. It operated for 14 years at an overall capacity factor of less than seven percent. Even if poor performance is discounted, breeder reactors remain far too expensive relative to light water reactors, the main design in use today. And since they would use plutonium (mixed with uranium) as the fuel, they pose greater proliferation risks.[8]

Half a century of efforts to commercialize thorium breeders – reactors that make fissile uranium-233 out of non-fissile thorium-232 – have not yielded a single commercial machine.

We have commented on some current proliferation issues in the preface and would not repeat that analysis here. But it is worth noting that the potential of nuclear power to provide a hidden infrastructure for nuclear weapons has long been known. In fact, that very possibility was entertained for the United States in 1946 by none other than J. Robert Oppenheimer, who was then the chairman of the General Advisory Committee of the Atomic Energy Commission. He did so in the context of the possibility that there would be a convention on international control of nuclear weapons that would result in nuclear disarmament:

> We know very well what we would do if we signed such a convention: we would not make atomic weapons, at least not to start with, but we would build enormous plants, and we would call them power plants – maybe they would produce power: we would design these plants in such a way that they could be converted with the maximum ease and the minimum time delay to the production of atomic weapons, saying, this is just in case somebody two-times us; we would stockpile uranium; we would keep as many of our developments secret as possible; we would locate our plants, not where they would do the most good for the production of power, but where they would do the most good for protection against enemy attack.[9]

Six decades later, quite a few countries may be taking a leaf from this book, or at least considering it.

B. Nuclear Waste

Even though efforts to commercialize plutonium have failed miserably, proposals to reprocess spent fuel, which contains about 1 percent plutonium (total content of all plutonium isotopes), are being revived. A central claim made now is that reprocessing will reduce the problem of disposal of spent fuel, which contains over 99 percent of the radioactivity associated with commercial nuclear power.

The vast majority of nuclear reactors in the world today are light water reactors, which use low-enriched uranium as a fuel. This fuel contains three to five percent uranium-235, which is the fissile isotope of uranium that can sustain a chain reaction. Almost all the rest is uranium-238. Once a reactor is fueled, U-235 atoms are bombarded with neutrons and they split, liberating energy and more neutrons. Some neutrons split more U-235 and some are absorbed in the more plentiful U-238, converting it into plutonium-239. Some of this plutonium fissions also yielding energy, and some remains until the fuel must be removed from the reactor. The typical composition of fresh fuel and spent fuel are shown in Table A-1.

Table A-1: Pressurized Water Reactor Fresh and Spent Fuel Composition (rounded)

Material	Fresh Fuel (weight percent)	Spent fuel (weight percent)	Comments
Uranium-235	4	1	Each kilogram of enriched fuel creates about seven kilograms of depleted uranium in the course of enrichment.
Uranium-238	96	94	
Plutonium (+ smaller amounts of other transuranic radionuclides)	0	1	Mixture of various isotopes from Pu-238 to Pu-242. Can be used to make nuclear weapons if separated from the rest of spent fuel. Predetonation is more likely for bombs made with reactor-grade plutonium than with weapon-grade plutonium.
Fission products	0	4	Fission products contain the vast majority of the radioactivity in the spent fuel.

Note: Trace quantities of U-234 and activation products are not shown.

In the early days of nuclear power, it was assumed that scarcity of uranium would lead to plutonium becoming the main fuel for nuclear power plants. But uranium was more plentiful than thought and reprocessing and plutonium fuel (which generally consists of mixed plutonium dioxide and uranium dioxide) turned out to be costly. The proliferation risks of reprocessing also became more clear after India exploded its "nuclear device" in 1974. Presidents Ford and Carter took steps to end the development of the plutonium economy in the United States. President Reagan tried to revive reprocessing in the early 1980s, but there were no commercial takers. To President Reagan's credit he did not propose massive new subsidies or that the U.S. government should enter the plutonium commercialization business.

In order to relieve utilities of the burden of spent fuel that now had no place to go and to reduce long-term proliferation risks arising from spent fuel sitting around at dozens of sites, a deep geologic repository program was created in 1982 pursuant to the Nuclear Waste Policy Act. Its history is a long and tangled one, but soon (1987) all resources were focused on just one site – Yucca

Mountain, Nevada. This is, in my opinion, the worst repository site that has been investigated in the United States. Indeed, the DOE's own assessment of the merits of the geologic setting in containing the radioactive waste, should they leak out of the containers, is that it would add almost nothing to the site's performance. Essentially the entire burden of performance, that is, keeping doses low enough to meet standards, would be on the packaging. Even so, the rules and standards have been changed numerous times, since Yucca Mountain has had serial difficulties in meeting proposed radiation exposure limits and engineering performance standards. For instance, Yucca Mountain was originally supposed to meet the 1989 EPA regulations that apply to all deep geologic repositories. Subsequently, the EPA Science Advisory Board found that Yucca Mountain may not meet the carbon-14 emissions standard.[10] Instead of looking for a new repository, Congress mandated that a new set of standards specific to Yucca Mountain should be created. A quarter century after the passage of the Nuclear Waste Policy Act, a new EPA standard for the Yucca Mountain repository has yet to be finalized.

As another example, the Nuclear Regulatory Commission published the criteria for performance of a geologic isolation system in 1985. These criteria placed primary emphasis on the properties of the geologic setting to prevent significant amounts of radionuclides from reaching the human environment. Only secondary reliance was placed on the disposal containers and associated engineered barriers in the containment of the pollution. But Yucca Mountain is made of a rock known as volcanic tuff, which turned out to be a poor candidate by these criteria, so the criteria were scrapped. The new criteria stressed "total system performance"; in effect, the performance criteria for the geologic system were scrapped. DOE's own estimates show that it is now placing primary reliance on the container. Moreover, the canisters are made of metal and their susceptibility to corrosion is highly variable, depending on the environmental conditions in the rock.[11]

Reprocessing only makes the problem worse, even though it is promoted as "recycling." The "recycling" portion generally applies to just that one percent of spent fuel that consists of plutonium isotopes. In the absence of economical breeder reactors (which still remain a nuclear pipe dream), the plutonium would be used as mixed oxide fuel in light water reactors at considerable expense. The current commercial reprocessing technology, PUREX (for plutonium-uranium-extraction) is huge and polluting. The largest such installation in the world is located on the Normandy peninsula in France. The radioactive liquid waste discharges from that and the similar facility in northwestern England, have polluted the seas all the way to the Arctic Ocean. Ten of the twelve parties to the Oslo-Paris accords (OSPAR) have asked the French and British to stop the discharge, but they have not done so. (The other two parties are France and Britain; they abstained and hence are not bound by the vote.)[12]

The fission product stream, which has most of the radioactivity, would still need to be disposed of in a deep geologic repository. Most of the long-lived radioactivity in this stream consists of cesium-137 and strontium-90, with half-lives of about 30 and 29 years respectively. But there are also significant amounts of iodine-129 and cesium-135, which have half-lives in the millions of years. While the volume of high-level waste is reduced after it is solidified in a glass matrix, reprocessing creates additional streams of waste besides the liquid discharges noted above. Specifically, intermediate-level waste, a waste classification used in France and other European countries, would be created in significant amounts. This waste must be disposed of in a geologic repository as well. Overall, reprocessing increases the volume of radioactive waste greatly when all waste streams are taken into account and does not eliminate the need for a deep geologic repository.[13]

The uranium stream that results from reprocessing consists of 95 percent of the nuclear material weight of spent fuel (U-238 plus U-235). It becomes contaminated with traces of fission products, notably technetium-99, as well as plutonium and neptunium-237. The contamination with these materials, which are much more radioactive than the uranium itself, creates considerable problems for the re-use of the uranium. Before it can be used again, it must be chemically processed and re-enriched to 3 to 5 percent U-235 content. The trace contamination results in contamination of the enrichment plant and creates additional radioactive exposure hazards for workers. For instance, in 1999, the Paducah uranium enrichment plant in Kentucky became notorious for not having warned its workers adequately about these trace contaminants in the uranium.[14] A subsequent analysis determined that plutonium and neptunium were concentrated in certain process streams at the plant and created the potential for high worker doses.[15] Trace contamination with plutonium and other radionuclides at Paducah was an important factor in the legislation that Congress passed in the year 2000, setting up a compensation program for nuclear weapons workers made sick by exposure to radiation and chemicals. The Paducah plant belongs to the U.S. Department of Energy; it is currently used only for commercial uranium enrichment. In the past it was used both for military and commercial purposes.[16]

While public information is scarce, it is interesting to note that France sends at least some of the contaminated uranium recovered at its La Hague reprocessing plant to Russia rather than re-enriching at home. If reprocessed uranium were to be disposed of as a waste instead of being re-enriched, this would also pose considerable problems. They would be more difficult than those faced by depleted uranium because the specific activity of the reprocessed uranium is roughly double that of depleted uranium; in addition it contains transuranic and fission product contaminants

Finally, all uranium enrichment results in a stream of depleted uranium, which is uranium depleted in the fissile isotope U-235. Depleted uranium consists mainly of the non-fissile isotope uranium-238 (99.7 to 99.8 percent usually). Some of this depleted uranium has been used for a variety of commercial and military purposes, the latter including tank armor and shells that have spread contamination on battlefields and testing areas in several countries. But the vast majority of it still remains as an orphan waste of the commercial and military nuclear enterprise. There is at present no place to dispose of depleted uranium in a way that would conform to prevailing radiological safety and health norms. Nor is there any program in place find one. It will not be easy. The characteristics of the waste make it akin to what is called transuranic waste (or Greater than Class C waste) and it should be handled accordingly – that is disposed of in a deep geologic repository.[17] But the depleted uranium sits at various sites in nuclear states, including three in the United States – Oak Ridge, Tennessee, Paducah, Kentucky, and Portsmouth, Ohio.

The Global Nuclear Energy Partnership

Based on a U.S. initiative, the United States and Russian governments launched a collaborative effort in 2006, called the Global Nuclear Energy Partnership (GNEP).[18] According to this proposal, countries that currently have reprocessing or uranium enrichment capacity would be allowed to possess it and, if they wish, expand it, while those that do not, would be prohibited from acquiring it. In return, the reprocessing-enrichment haves would supply the have-nots with prepackaged reactors and fuel. The spent fuel would be returned to the haves.

GNEP is a transparent attempt to rewrite Article IV of the NPT, which guarantees an "inalienable right" to acquire commercial nuclear technology to the non-nuclear weapons states that are parties to it. The inclusion of Article IV was unfortunate, but it was a fundamental part of the bargain. Nuclear energy had been romanticized and politicized at least since President Eisenhower's famous "Atoms for Peace" speech at the United Nations in December 1953. Article IV was a direct descendant of the U.S. Atoms for Peace program that followed that speech.

The second part of the NPT bargain was that nuclear weapons states would eliminate their nuclear arsenals.[19] The latter now recedes into the far future – all five nuclear weapon states parties to it are modernizing their arsenals. What India used to call "nuclear apartheid" before it detonated its own nuclear weapons in 1998, is being perpetuated. GNEP would extend that to nuclear energy. There are unlikely to be any serious takers. On the contrary, more and more countries are expressing interest in nuclear power, with the not too hidden agenda of acquiring much of the nuclear infrastructure and most of the knowledge that would enable them to make nuclear weapons in the future. There is even an active debate in Japan today about whether it should become a nuclear weapon state. Should it decide to do so, its reprocessing capability, its stocks of commercial plutonium, and other technological infrastructure would probably enable it to become a nuclear weapon state in six months.[20]

There are other potential components in GNEP, including a reprocessing technology called "electrometallurgical processing." Despite the fact that it would not separate pure plutonium, it would create material that non-nuclear states or terrorist groups could use to make nuclear bombs. Moreover, being more compact than PUREX, it would be far easier to hide the separation facilities, making them more proliferation prone, not less.

The costs of GNEP are likely to be huge. GNEP is not going to solve the problem of nuclear waste. However, it may be a new source of funds for that part of the nuclear power establishment that is closest to the weapons bureaucracy or is part of it. GNEP is centered in the Department of Energy, which owns the nuclear weapons complex.

There is no really good solution to the problem of spent fuel and high-level waste disposal. It is very difficult to compute the impacts on generations far into the future. Is it sensible to go on creating wastes that risks contamination of water, with its attendant radiation health damage, far into the future? Yet the problem of leaving it on the surface indefinitely is even more difficult. It entails the risks of proliferation (via reprocessing), terrorism, and accidents. Hardened On-Site Storage of spent fuel – that is, storage that could withstand severe attacks without dispersal of huge amounts of radioactivity – for a few decades followed by disposal in a deep geologic repository are the "least bad solution." But that "solution" makes sense only if we limit the creation of waste in the future.

C. Cost

The history of cost overruns at nuclear plants in the United States is well known.[21] Significantly, in a review of historical experience with nuclear plant construction, the DOE's Energy Information Administration noted explicitly that

> … although the utilities did increase their lead-time and cost estimates as work on the plants proceeded, they still tended to underestimate real overnight costs (i.e., quantities of land, labor, material, and equipment) and lead-times even when the plants were 90 percent complete.[22]
>
> In this review, the Energy Information Administration found that, for those plants that began construction between 1966 and 1969, the utilities were underestimating the final cost of the nuclear plants by an average of 63 percent prior to construction beginning and were still underestimating their final cost by 22 percent when the plants were three-quarters complete. Surprisingly, for those plants that began construction between 1974 and 1977, the nuclear industry actually grew slightly worse at estimating the final plant cost despite its increase in experience. Specifically, the utilities underestimated the costs of these plants by 72 percent prior to construction and, even when past plants were three-fourths complete, they were still underestimating the final construction cost by roughly 23 percent.[23]

One reactor that is being commonly considered in cost studies is Westinghouse's AP-1000.[24] An AP-1000 has never been built anywhere in the world, not to mention anywhere in the United States, so no real world experience is available from which to draw a direct comparison. While it is the same overall concept as the pressurized water reactor, the many new design features, some added for safety, add to the uncertainty in cost estimates.[25] As noted by analysts at Standard & Poor's in their 2006 assessment of nuclear power generally, "given that construction would entail using new designs and technology, cost overruns are highly probable."[26]

In recent regulatory actions in North Carolina, where Duke Power has proposed to build new coal plants at the existing Cliffside power plant, the doubts about nuclear power's cost-effectiveness and viability were voiced. Jim Rogers, CEO of Duke Power, which has expressed serious interest in pursuing nuclear power stated in his testimony:

> Here's my judgment. We put 1800 [dollars] in because it's what Westinghouse has told us the number is. We are in negotiations with Westinghouse. My personal – and we modeled – what if it was 2200 and under 2200 Cliffside and Gas would be the least cost alternative in every scenario almost. And the reality is, my personal belief about nuclear, I don't think it comes on in 2016. I'm not a true believer. And secondly, I don't believe – I believe it comes closer to 2500 or 2600. And if you look at the testimony of Judah Rose, it's pretty close to 2500. So my personal judgment is, is that nuclear comes in at a much higher price, and it comes – and we are actually able to build it, it's going to be delayed beyond 2016. That would be my bet if I had to make the bet today.[27]

Coming from the CEO of Duke Power, this is an especially interesting statement. Duke Power is a member of the U.S. Climate Action Partnership (USCAP) of some corporations and large environmental groups that has endorsed the concept of a 60 to 80 percent reduction in U.S. greenhouse gas emissions by 2050.

The U.S. Congress is considering ever more massive subsidies for nuclear power plants in the form of loan guarantees – possibly as much as $4 billion to $5 billion per reactor for as many as 28 reactors.[28] The reason is clear: the economic risks of nuclear power plants are just too large. In the words of Michael J. Wallace, who co-heads UniStar Nuclear, a company that wants to build nuclear power plants: "Without loan guarantees we will not build nuclear power plants."[29] We have already noted the opinion of a leading credit rating company, Standard & Poor's, that the credit standing of a company ordering a nuclear power plant would weaken if it ordered a nuclear power plant, even if it did so with government support (see Chapter 7).

D. Nuclear Power and Global Climate Change

There are two schools of thought among proponents of nuclear power and climate change. One is that a large number of reactors would be built to reduce the need for more coal-fired power plants. The other school advocates that nuclear power should be kept in the mix since all available energy sources that could help reduce CO_2 emissions should be considered as options.

If nuclear power is used as a principal element of future electricity generation worldwide, a very large number of reactors would have to be built in the coming decades. Brice Smith has estimated that for nuclear power to contribute about 20 percent of the global electricity supply by mid-century, about 1,000 reactors of 1,000 megawatts each would have to be built. For nuclear power to play a role comparable to coal today – about half of total generation – 2,500 reactors would have to be built in the same time. This is a rate of one reactor every six days.[30]

Such a massive system would require a new repository every few years, two or three new enrichment plants every year. It would greatly increase pressures for reprocessing. The risks of accidents would increase, even disregarding the potential for sloppy construction if the number of reactors is increased rapidly. Brice Smith has estimated that if 2,500 reactors are actually built in forty years, there would be a sixty percent chance of a Three-Mile-Island type of meltdown even if the safety of reactors were increased by a factor of ten compared to the present.[31]

But even far less serious events can trigger doubts about the nuclear industry as a whole, making it an unstable way to plan for future electricity generation. The July 16, 2007 earthquake in Japan under Tokyo Electric Power Company's 8,000 megawatt, seven-reactor nuclear power plant is a case in point. The leak of radioactivity into the sea was not large. *Nature*, a journal of science that has editorialized on nuclear power, noted its vulnerabilities after the earthquake and the poor public communications by Tokyo Electric that followed:

> Global warming and high energy prices have put nuclear power firmly back in the picture around the world. Plans are afoot to build new plants in Britain and the United States, and China and India look set to press ahead with nuclear power on a significant scale.
>
> Investors in planned nuclear plants continue to worry about waste disposal and liability issues, and look to sympathetic governments to provide assurance regarding these. Lurking in the back of their minds, however, is the ever-present risk of accidents of the sort that played havoc with the global industry at Three Mile Island, Pennsylvania, in 1979 and at Chernobyl in 1986. Another such event could undermine political support for nuclear power and so up-end their planned investments altogether, possibly before a single megawatt of power is generated and sold.[32]

How much can one rely on an energy source whose acceptability may depend on whether there is a severe earthquake or accident somewhere in the world and on the care with which geologic faults have been studied and incorporated into the design? Nuclear power is unique in having this vulnerability. No coal mine accident, oil tanker spill, or natural gas explosion puts the whole industry into question. Only climate change, which is being created by the global use of fossil fuels, has done that. But the nuclear industry could be derailed by a single local event – a severe accident, or possibly even by a single earthquake, to say nothing of a serious terrorist attack. More power plants would simply multiply the risks. Finally, the heat waves and regional droughts that are likely to accompany rising global temperatures threaten to make nuclear power into an intermittent source in the summers. For instance, one of the three nuclear reactors at Browns Ferry, belonging to the Tennessee Valley Authority, was temporarily shut down in August 2007 because the river water used to cool it was too hot. Sufficient cooling water was available for only two of the reactors.[33] Similar problems were experienced in France in 2006 when reactor power output was reduced[34] and in 2003.[35]

Those who have advocated that nuclear power should be kept in the mix have not really addressed the risks of doing so versus the option of simply omitting it from the energy picture and creating a reliable grid without it.

APPENDIX B: INTERVIEW REGARDING INDUSTRIAL GREENHOUSE GAS EMISSIONS

Final Summary of telephone conversation with Dawn Rittenhouse and John Carberry, both of DuPont, with Arjun Makhijani, 14 February 2007.

Reviewed and corrected by Dawn and John. Edits accepted and document cleaned up by Arjun. Notes are not verbatim, but a summary that reflects the substance of the conversation.

1.*What procedures do you have for GHG [greenhouse gas] emissions accounting in DuPont? Are there plant level measurements and reporting procedures so that HQ can compile company -wide data?*

Dawn and John: We use WRI's [World Resource Institute's] GHG protocol to calculate emissions. We use a control approach – that is accounting for 100% emissions of operations over which we have control. Scope 1 accounts are associated with direct use of fuel; Scope 2 is purchased electricity and steam. We don't do supply-chain-related emissions. Our corporate plan includes all environmental goals. Each site in May and June enters information into that plan and then it is pulled together at the corporate level to provide the overview.

Arjun: So basically you account for GHG emissions from fuel and energy purchases?

John: Yes. We don't do personal commuting and business travel. I did a check once and found that it would not change things significantly to include this. It would be 3 or 4 percent increase. However, for some businesses, like pharmaceuticals, travel by employees can be large.

Dawn: We have a new goal on our marketing fleet. It's not a big fleet. We are working with PHH, who is our fleet provider, and Environmental Defense, to do calculations on GHG emissions of our fleet. So we are reducing GHG based on using leading technology. That is associated with our fleet goal for 2015 – all of our fleet will be using a leading technology by that date. We did not define what that technology would be.
As for GHG emissions, our plan is to reduce emissions a further 15% off the 2004 base.

2. *Do large plants have energy managers whose responsibilities include ensuring that decisions such as replacement of motors and lighting are made with energy efficiency in mind?*

John and Dawn: We have a corporate energy competence center network – it is a formal network of energy professionals around the company. It is their responsibility to implement the energy efficiency programs of the company. The network is to share expertise and learning. If you recall the Pew Case study – there was a write up on the energy leader for the titanium technologies business, I sent you – that is an example. Craig Heinrich leads the energy work for the titanium technologies.

Each manager at the larger sites (20 plus largest sites) has goals and targets. And they go after those by addressing a wide range things. Their efforts are not limited to lighting and motors, but also go to areas like steam management and process changes.

We are committed to corporate leadership for manufacturing excellence. There is a corporate leadership process for manufacturing excellence. Energy efficiency is one of their top priority initiatives. They assign energy efficiency goals, monitor the progress of the site energy managers, and provide assistance where appropriate.

Arjun: Is a one or two percent [energy use] reduction per year reasonable as an energy efficiency goal across industry?

John: On an absolute basis, yes. Not if it is indexed to GNP. 1-2% in excess of GNP growth rate will probably be needed.

Probably the most important thing is to recognize that the four segments of the energy economy – residential, commercial, transportation, and industrial – have different marginal prices for energy. There have been different arguments about how to control different sectors. You have to take into account the differences between the sectors. But any one of the approaches would be suitable provided that it translates effectively into an effective market mechanism and gives credit for early action.

Arjun: I think cap and trade may be better in industry than standards, which I think would be better for appliances and the residential sector. What do you think?

John: The EU is experimenting with efficiency standards and cap and trade. The Dutch are making a good run at efficiency standards for industry. Big problem with cap and trade is adjusting for the evolution of industry.

Arjun: I propose that there be caps for an entire sector or industry segment and auction off the allowances on the market. Then the cap can be reduced every one to two years. That way you automatically get credit for early action because you don't have to buy so many allowances. An extra benefit could be given to companies that take early action by giving extra points in the federal contracting score for lower GHG emissions per dollar, for example.

Dawn: Your cap and trade proposals are way too complex in their details to comment on, briefly here. In short, an economic driver by industry sector, and as broad an application to that sector as reasonable, should be guiding principle.

John: I agree with concept of government leading the development of a market and taking into account the efficiency or GHG emissions of the suppliers. But there is no reason why companies should not also lead in the same way. They too could select suppliers based on their GHG performance and in fact some companies already do this.

Arjun: The concept of capping a segment of industry would be to limit it to large industry. I am leaning to a hybrid approach with cap and trade for larger users of fossil fuels and efficiency standards for smaller users, for instance in the residential and small business sector. The paperwork would be too much for small business.

John: This is a sore point for large businesses as well. No one wants paperwork – it is a burden on all. But I agree that large business can be more efficient in doing that paperwork. If there are ten major paperwork requirements, then in a large company each single requirement can be done by one individual, totaling ten people because there is enough work in each area. In a small company, the same person has to do all of them and so specialization is not possible. Although there is some efficiency gain, the cost (per unit of sales) is still about the same.

3. *What are the main areas in which DuPont seeks to achieve its reduction in energy use from its 2004 base? I am not looking for specific numbers and plans, but the areas of priority according to economic opportunity and to get some sense as to whether the same may apply to the rest of the chemical/biotechnology industry.*

Dawn: I want to make sure that we get clear as to what DuPont is doing. In 1999, we had a goal to reduce GHG emissions by 65%. By 2003 we had reduced by 72%. In 2004 we sold off our fibers unit- Invista, which produced nylon, PET and Lycra fibers etc. So we re-baselined the GHG goals to 2004 so there would not be GHG accounting problems due to the sale. We will reduce GHG emissions by an additional 15% by 2015 compared to 2004. The targeted areas are HFCs as well as energy projects.

We also set a goal in 1999 of holding energy use flat, based on the 1990 level. We were actually 6% lower than that in 2005 which is the last year we have the data collected. Then we reset the base to 2004, no we did not reset that base line- we just subtracted the energy from the 1990 number that was associated with Invista so that we can still use the 1990 as the baseline so it would be based on energy consumed by companies we are actually operating. We continue to monitor that. We continue to work on energy efficiency. On top of that we have a goal of getting 10% energy from renewable sources.

There is no single answer, nor even just a few. In broad terms major improvements come from:

- Improvements in first-pass, first-quality yield
- Maximization of process through-put and process up-time
- Combined heat and power generation (CHP)
- Changes to processing equipment
- Improved process control
- Powerhouse generation and distribution systems (steam traps, insulation, motor efficiency, etc.)

4. *In the USCAP paper, the coalition recommended a goal of reducing GHG emissions by 60 to 80% by 2050. Is DuPont or USCAP developing active plans for the 60 to 80 percent reductions in GHG emissions? What priority areas of research should the federal government undertake that would help achieve that goal?*

Dawn: That goal for 60-80% is for 2050 and it is not for one company. We are talking about expectations of energy efficiency and new forms of economically efficient energy supply, as well wind and solar energy. Through the next 45 years that will allow us to get to that goal. USCAP did not get into any kind of detail as to how one would get there [to a 60 to 80% GHG emissions reduction]. This is a man-on-the-moon type of thing – set a big goal and get people focused on meeting the big goal.

John: OK, what is that 60 to 80% reduction going to look like? If you got it down to a specific level – for instance, it would be how much energy is used in housing or different sectors? But in all cases, it is going to be the sum of a huge number of things that will need to be done. There is an overarching set of things-say renewable or passively safe nuclear energy or clean coal – those have applications across all segments. But as soon as you say a specific industry like the chemical industry, you have a lot of details that go into it – alternatives to distillation, for instance. Then there are the other GHGs besides CO_2 – capture of methane from offshore platforms, coal mines, and landfills. If you got 20 or 30 techies spread broadly across disciplines into a conversation, you would get 200 to 300 good ideas. There is the green building initiative. They have a whole bunch of things on HVAC design and passive heating and cooling. "There ain't no silver bullet and we don't want any lone rangers," as one of our engineers says. I could come up with 50 items if you gave me an hour. Take just the chemical industry or a segment of that, you'd have a host of specific things. The answers would be markedly different than in the aluminum industry. We'd have the big four [supply options] across the board – passively safe nuclear with acceptable waste management, clean coal with CO_2 sequestration, environmentally sound biomass, and reliable wind power with real solutions for managing the storage and distribution.

In the chemical industry CHP [combined heat and power] is a big one.

Another is replacing distillation – one alternative is modernization of processes so you don't have so many operations that involve distillation. Or it could be replaced by crystallization or membrane separation technologies, for example. Other areas are steam system management, insulation, powerhouse modernization, steam trap management. Optimization for first pass first quality yield is a big one – that is, make it correctly the first time. If you don't make it correctly, you have to recycle the product and make it again and you have waste all the energy that was used the first time.

Optimizing the manufacturing efficiency of your facility is another one. If you are in a standby hot mode, you use 60 or 70% of the energy anyway. So you want to run 100% of capacity 100% of the time. Then there is optimized process control and finding alternatives to grinding of solid materials – grinding is highly energy intensive.

The kind of question you are asking how are you going to get there [to 60 to 80 percent reductions], I probably would have to have a list of 10 to 20 big ones if I could get together the technical people from various areas.

One thing that we could have mentioned is the work on industrial biotech – for instance, the production of PDO from a bio route versus a chemical route is allowing us to save considerable energy – LCA [life-cycle analysis] results demonstrate that Bio-PDO™ requires 40-50 % less total energy to make that chemically derived PDO [polyester monomer propanediol].

Arjun: How about more waste heat recovery? It seems to me that developing new heat exchange materials that allow for more efficient transfer across small temperature differences – a few tens of degrees – would be helpful.

John : Improved waste heat recovery could come in at least two ways:

- Significant improvements in creating heat transfer surface area without an excessive capital cost or pressure drop penalty
- Significant increase in the minimum operating temperature for equipment that converts waste heat to electrical energy without an excessive capital cost or pressure drop penalty, or some other operational problem such as sensitivity to corrosion or fouling.

Arjun: How about using nanotechnology to increase the heat transfer surface area? They are attempting that in nanocapacitors to increase storage of charge per unit weight dramatically.

John: I have not seen anything that will say nanotechnology will give a big area without a bigger pressure drop. This a large dynamic world that is very complex that is set up that allows for innovation. I will go along with a cheap way to get a lot bigger area. That would make a lower delta-T [temperature difference] practical.

5. *What part of steam generation is done by combined heat and power and what part by boilers alone? In other words, is there a large or small scope for DuPont to increase efficiency by going to CHP?*

John: Most large manufacturing facilities already utilize CHP either onsite or through purchase of steam (and electricity where permitted) from a third party that owns the CHP facility itself. Some additional potential CHP capability exists, but current energy, electricity, and equipment prices are such that economic justification is difficult.

6. *Has DuPont considered going to CHP plus carbon capture in algae and then production of fuels from algae. This system has been developed at MIT and used in their 20 MW CHP. See http://www.greenfuelonline.com/technology.htm. How would you rate this system compared to your recent biobutanol project?*

John and Dawn: I am not aware of us doing anything in that specific area. The whole point is – let's make sure we promote those technologies that convert biomass into high value products. Where the biomass comes from – there are a lot of options for that. The two issues are not necessarily connected. Algae farming has been mentioned as a source of carbon. Others emphasize maximizing carbon capture in the farming industry. For instance, they burn rice hulls in the open air today. There are lots of potential sources of carbon – food industry, animal farming, algae – you've go to create a world that permits the best of them to emerge, There could be algae farming in the Gulf Mexico, but there are environmental arguments against it.

But if algae farming became a big industry, DuPont would probably be interested in it. And DuPont would be interested not only for fuel but also up the value chain.

7. *Can DuPont's petroleum and natural gas feedstock requirements be met nearly fully with biomass-derived hydrocarbons?*

Dawn: The question is not whether DuPont can meet its own requirements that way. We are working to get the raw materials that we need from biomass. The question is as a whole society can and if we do that, whether we will have any ecosystems left.

Arjun: I think that ethanol from food is not a good idea – turning fuel into food and food back into fuel is going to be inefficient especially when the solar energy capture is low. Biofuels have to be done much more efficiently.

John: I agree that the idea that you are going to grow wheat for methane is not good. First maximize the carbon capture rate of the farm and make the maximum use of the highest value carbon. Then collect the waste carbon for fuel but in a way that we don't deplete the soil. The grain can be used for food and the residues for other things.

John: We have looked at the question of feedstocks from biomass for DuPont some. There is enough for DuPont – but that is not the issue – because DuPont is not the only one competing for it. The power industry is willing to pay a higher price for natural gas than the chemical industry. Their supply and demand is here, but we have to compete with lower price of natural gas in other countries. There is a huge difference in that issue again. Presently, the molecular structure of biomass carbon is not quite right for many applications. Or we have to come up with alternative products. But Mother Nature doesn't give us [the chemical industry] the exactly correct molecules. We have to learn to adapt our supply needs to what is provided, and to modify what nature provides.

Dawn: But if you think back to the corn biorefinery, our goal is to get the raw materials from that.

John: Yes, that is the ultimate goal. It is a matter of timescale and costs.

8. *What are the current prevailing industry assumptions about the price of natural gas and of the cost of hydrogen derived from it? I am not asking for DuPont-specific assumptions, which I presume would be confidential, but for your sense of the general thinking in the industry about natural gas prices and hydrogen costs.*

John: Steam reforming of methane is the preferred way of coming up with H. This is used for hydrogenating chemicals, but we could not use it as fuel.

What is the price of hydrogen for this high value H? We will need to contact Air Products. It is higher than the fuel value.

Let me go to the making H – using H as form of energy storage. Make sure that you have properly considered capital cost. You have a large amount of capital that you are using only part of the time. So electrolysis you only use for a third of the day. So your capital effectiveness factor is only 0.3, not counting anything else. Then there are the fuel cells, which you only use for 5 or 6 hours. So when you include the capital cost penalty, the cost increases. So be careful about that.

9. *What kinds of federal research would help industry in changing processes so that they become far more efficient (for instance by requiring far less process heat), or should the federal government leave such end-use research to industry?*

There is lots of room for research priorities for industry. The federal research priorities in the U.S. energy plan suffer from a lack of focus. Understanding the fundamentals and improving the efficiency of those are good areas for government research. Maximizing carbon capture in algae is also a possibility. The key point probably is that Federal R&D is most appropriate in the areas of basic research and early development of new technology that would not otherwise be developed by private companies.

The federal research priorities should not be in efficiency of existing technologies, but on the fundamentals of the energy production industry. Efficiency ideas will come from innovation in industry.

Arjun: In your comments on the outline of my report, you were not warm to the idea of government procurement of key technologies as a way of stimulating the market.

John: Procurement – it never seems to work – it gets spent in politically correct ways or on socially wishful thinking. If there are state programs to recycle material that should not be recycled, that should be done. If it is done correctly, using the federal dollar to prime the market would be a good idea.

Arjun: What about the a commission like the military bases commission as a way of priming the market and avoiding earmarks and pork barrel type of procurement?

Dawn: Well, the base closing decisions aren't just accepted. They also get politically changed.

Arjun: I see the point of your objections more clearly. The problem of politicization of procurement seems difficult to overcome.

John: No one can disagree with [the idea of] federal leadership – but federal leadership always gets misguided due to being politicized.

10. *Does DuPont have any project that would grow biomass as part of wastewater treatment, thus helping clean the water as well as producing fuel?*

John and Dawn: Our waste disposal facilities are very small compared to municipal waste water treatment – they will do it before we do it. Also their wastewater is much richer in nutrients. You can see a living example of that – with City of Philadelphia – the discharge to the Delaware River – there are now wetlands there that have grown up around the treatment plant. It is a rich and green and wonderful nature sanctuary. Your point about using wastewater to grow biomass seems something like that. But would a municipal waste facility be better than the mouth of the Mississippi? Those are technologies that would demonstrate effectiveness in certain kinds of weather, etc. If it is not effective at municipal waste treatment plants, then there is no hope that it would be effective in industry. A city in the south should have a great advantage over any industry for trying this out. Here some combination of federal and city or state projects is a leadership that could be done. Florida would be a good place to do it.

11. *I noted in the USCAP report that there should be mechanisms for credit for those who take early action, that is before caps are imposed. I agree. The framework I am thinking of is somewhat different initially from the report, which proposes some free CO_2 (equivalent) allowances. Free allowances have created lots of problems in Europe, including issues relating to new entrants into the marketplace. I suggest: auction all CO_2 (or CO_2-equivalent) allowances for large users, including large electricity generators, for two-year periods at a time, with caps going down every two years. This will automatically benefit those who have taken early action and the new entrants with low-CO_2 footprints. For an additional benefit, I suggest that a part of the score assigned for federal and state contracting (perhaps 10%) be assigned according to the projected CO_2 emissions for the job, based on company documentation, so that all those who have a low CO_2 footprint will have a leg up. Do you have any more comment though we've covered this some already?*

John: The auction system would work in the industrial sector, small or large – it could be applied across the whole sector. But efficiency standards would work better in residential and transportation. In automobiles, I am fan of efficiency standards. I am not in favor saying John Q Public is exempt from them [standards] but business has to comply.

Arjun: Thanks so much. I'll send you these draft notes for review and correction.

[The notes were sent to Dawn Rittenhouse and John Carberry and the corrections were incorporated. This is the corrected and approved record representing the substance of the conversation.]

APPENDIX C: JAPAN FOCUS INTERVIEW ON CARBON-FREE AND NUCLEAR-FREE

Note: Mark Selden, Editor of *Japan Focus* interviewed Arjun Makhijani about this book. The interview sets the work in an international context. It is reproduced here, slightly edited, with permission. *Japan Focus* is a web-based journal, located at www.japanfocus.org.

Why zero carbon emissions? Not even the boldest proposals have called for zero emissions, even defined as you do as a few percentage points of CO_2 emissions on either side of zero. We understand the necessity to sharply reduce carbon emissions to safe limits and to reverse the carbon excess in the environment. Still, why zero emissions? Is this simply a means to draw attention to the problem where substantial reductions rather than zero emissions would solve the multiple problems associated with the present profligate fossil fuel and other nonrenewable energy consumption? Does the demand for zero emissions not risk alienating potential support for a feasible program of sharp reductions?

The United Nations Framework Convention on Climate Change requires the burden of reductions to be borne with present and past inequities taken into account. At the very least, this will mean that any CO_2 emissions that are allowed would be allocated on a per person basis.

At the same time, the Intergovernmental Panel on Climate Change has estimated that if temperature rise by mid-century is to be limited to less than 2 to 2.4 degrees Celsius, it will be necessary to reduce global CO_2 emissions by 50 to 85 percent. The former number (a 50 percent reduction in emissions) corresponds to a 15 percent chance that the temperature rise will be limited to that range; the latter (an 85 percent reduction in emissions) an 85 percent chance. If the remaining CO_2 emissions are allocated on a per person basis, and we assume that we will need a reduction of 50 percent in CO_2 emissions, the United States will have to reduce its emissions by 88 percent. At this level, it will still be very likely that we will not be able to meet the temperature rise limit. For that we must reduce global emissions by 85 percent. The U.S. goal, given its world-leading position in CO_2 emissions, would then have to be 96 percent. This is operationally the same as zero-CO_2 emissions. (I assume a global population of 9.1 billion and a U.S. population of 420 million in the year 2050).

The other reason to actually go to 100 percent elimination is that climate change is shaping up to be more severe than estimated by models. We may have to remove CO_2 from the atmosphere that has already been emitted to try to mitigate the severity. It makes no sense to remove CO_2 at great expense while emitting more. So I studied the technical feasibility of achieving an energy economy actually eliminating all fossil fuels. Some coal and natural gas infrastructure would be maintained as a contingency, but not used unless there is a major technical failure. Even then coal would only be used with carbon sequestration.

Finally, the solution to other problems, notably oil-related insecurities accompanies a zero-CO_2 economy. It is not necessary to have a zero-CO_2 economy in the United States to accomplish a reduction of oil-related insecurities. There are a variety of ways to do that, such as turning coal to liquid fuels. But such choices would aggravate CO_2 emissions.

You focus on the U.S. Could you locate the U.S. within the global framework of energy consumption, showing the critical dimensions of U.S. reduction of carbon emissions to the overall future of humanity? In particular, could you locate the U.S. problem within the framework of the Asia Pacific region?

I focus on the U.S. because it is the largest emitter of CO_2 as of 2004, the reference year for this study. But obviously it makes no sense for the U.S. to eliminate all its CO_2 emissions, while others are doing business-as-usual and continuing fossil fuel use.

A U.S. direction of significantly reducing petroleum consumption would have a major positive effect on global politics, including in the Asia Pacific region. Much geopolitical competition, including between China and Japan, is over oil. This is exemplified in their dispute over rights to oil resources in the Sea of Japan, in competing plans for the location of Russia's oil pipeline, and in territorial conflicts over the Spratly Islands involving several Asian countries. Some U.S.-Chinese tensions are also related to oil, including their competition in Africa and their differing stance toward Iran. If there is less reason for Japan and China to compete over petroleum, the drift towards a more active military posture by Japan may also be halted.

I am not saying that a gradual U.S. withdrawal from the oil market would solve most or all major geopolitical problems, but it could contribute to a different setting in which other problems are addressed. New problems may also emerge. For instance, oil exporting countries may want to be compensated for not producing oil.

Finally, a U.S. goal of zero-CO_2 emissions would bring China and India to the table of climate change discussions in more positive ways, which would benefit the whole Asian Pacific region and the world.

One notable omission from your recommendations concerns the vast global oil and energy uses of the Pentagon, by far the largest U.S. energy consumer. Please comment on the reasons for the omission, and suggest how you would approach this important element in any emissions reduction program.

The Pentagon's oil consumption is quite high. Direct Pentagon oil demand was about 320,000 barrels of oil a day in 2006.[1] But this is mainly a reflection of the Pentagon budget, which is now about $650 billion per year. This amounts to about 5 percent of the U.S. Gross Domestic Product. The U.S. consumes about 20 million barrels of oil a day; five percent of that is 1 million barrels a day. So, while 320,000 barrels a day looks large, it is a smaller proportion of oil than the Pentagon budget is of U.S. GDP. Actually, it does not include all Pentagon oil consumption because it takes no account of the oil used by Pentagon contractors and the companies that build U.S. military equipment.

The underlying problem is not really high oil consumption, though there are probably inefficiencies in the Pentagon as in most other sectors of the economy. The real issue is high military spending. Oil consumption is a reflection of that. The issue of military spending is important, but it is not within the scope of the zero-CO_2 emissions book that I have just finished.

A vigorous carbon emissions reduction program on even a fraction of the scale your report envisages would enable the U.S. to lead the international drive to overcome global warming, reversing its present position as a laggard in this arena. I understand the necessity to issue a wakeup call to the U.S. Nevertheless, what considerations led you to focus exclusively on the U.S. rather than locating the problem in interactive terms involving other nations and international organizations?

I think that without US action, there can be no US leadership, and without such leadership, global efforts to curb emissions will be gravely weakened. At this stage, preaching temperance from the barstool is not an option for the U.S., if it ever was. As I have already explained, a zero-CO_2 emissions goal is not only desirable for protecting the environment, it is also implied by U.S. treaty commitments. It will be impossible to bring China and India and Brazil and other developing countries to the table for really serious reductions in CO_2 emissions, unless the US abides by the spirit of the United Nations Framework Convention on Climate Change. And that needs to happen soon. I believe that is why former Vice-President Gore has called on the developed countries to reduce their greenhouse gas emissions by 90 percent by 2050.[2] It will be interesting to see how President Bush's climate change summit at the end of September develops, and what India and China will have to say.

There are technical imperatives if we are to save the earth, but there are also political imperatives. How can we frame a series of proposals that will be taken seriously by political actors? Recently, Australian environmentalist, Clive Hamilton, critiqued George Monbiot's call for Britain to reduce carbon emissions by 90 percent by 2030 as politically unrealizable, however praiseworthy. In the US, a nation with no serious debate about a feasible emissions reduction program, is your call merely a wakeup call drawing attention to the disasters that await us? Under what circumstances could it become a rallying cry for political forces in the US and internationally? All the more so with neoliberal thinking so powerfully in the ascendant, what would be required to contemplate the unthinkable proposal you have formulated?

My proposal should be distinguished from Monbiot's 90 percent reduction by 2030. That seems much too short a time for the immense investment and infrastructural change that will be needed for a 90 percent CO_2 reduction. I think it will take about 40 years to do the job. If there are several new technological breakthroughs in the next decade, it could possibly be done by 2040. Even then, I recognize that the political hurdles are immense. There is a huge lobby for fossil fuels; solar energy and efficiency are puny by comparison.

Even though President Bush has promised to "consider seriously decisions made by the European Union..." which imply global reductions in CO_2 of 50 to 85 percent,[3] were he confronted with a bill that required corresponding U.S. action (88 to 96 percent reductions by 2050), he would be likely to veto it.

The most leverage, politically and economically, is at the state and city level and with the corporations that stand to lose a lot through inaction. Cities are where much of the action needs to take place anyway. They can require the conversion of their taxis to hybrids and purchase plug-in hybrids. They can follow the lead of New York City in encouraging bicycling and car-free greenways[4] and promoting public transportation or London in restricting traffic to and from the core of the city.[5] They can lobby Congress for grants for renewable energy infrastructure. They can grow energy crops in their wastewater systems.

There are also corporations, for instance insurance companies like Swiss Re, and chemical companies like DuPont, that see the handwriting of climate change on the wall. They also want a piece of the action in research and the production of environmentally sound products. Some of them have accepted a goal of 60 to 80 percent reduction in U.S. greenhouse gas emissions.

California is in fact a leader in energy policy today. Governor Schwarzenegger aspires to be a global leader on climate change. In his State of the State address last January he said:

> Not only can we lead California into the future ... we can show the nation and the world how to get there. ...We are the modern equivalent of the ancient city-states of Athens and Sparta. California has the ideas of Athens and the power of Sparta.
>
> ...I propose that California be the first in the world to develop a low carbon fuel standard that leads us away from fossil fuels...Let us blaze the way, for the U.S. and for China and for the rest of the world.
>
> ...California has the muscle to bring about such change. I say use it.[6]

He will go to the United Nations in September and talk about climate change. The Secretary General of the UN has made it a top priority.[7]

There is a parallel to the phase-out of CFCs, which deplete the ozone layer. In the late 1980s and early 1990s, there were so many different local and state regulations on reducing CFC emissions that large corporations began to lobby seriously for national regulations. Something similar needs to happen with setting an ambitious goal for eliminating CO_2 emissions, and there are many signs that it is already happening. Basically, Washington will be forced to act by changes throughout the country. It is important to make it an issue in the next elections at all levels from the local to the presidential.

I did the study to show that it is technically and economically feasible to eliminate fossil fuels from the U.S. economy. That is a pre-condition for pushing to get it done. Of course, it does not guarantee that it will get done. It will take a lot of hard work and several years to build the political muscle for a zero-CO_2 emissions goal to be adopted. But I think it can be done.

The executive summary of Arjun Makhijani's forthcoming book, is available here: http://www.ieer.org/carbonfree/summary.pdf

ENDNOTES

Front Matter

1 Paley Commission 1952, v.IV, page 220
2 Energy Policy Act of 2005. See, for example, Title XIII and Title XVII
3 See, for example, Interior 2006 and Interior 2007. While the Bush administration has not tied the polar bear population decline to anthropogenic climate change, it is cited here because the warming climate has played a central role in it – a fact that is acknowledged in the Department of Interior press release and its Federal Register notice cited here.
4 Interior 2007
5 See NOAA CO_2 Trends.
6 USGCRP 2003
7 See, for example, Walter et al. 2006.
8 See NOAA CO_2 Trends. In addition there are other greenhouse gases. The Stern Review notes that "Greenhouse-gas concentrations in the atmosphere now stand at around 430 ppm CO_2 equivalent." (Stern Review 2007 page 193. For trends on greenhouse gases, see *http://cdiac.ornl.gov/trends/trends.htm* (CDIAC 2003-2006 Trends). In this book, "CO_2 concentration" refers strictly to carbon dioxide, while "CO_2-equivalent concentration" refers to the concentration of a combination of the most important greenhouse gases adjusted to an equivalent CO_2 concentration by a factor called the "global warming potential" which measures their impact in global warming relative to CO_2.
9 Stern Review 2007 pages 93-94
10 IPCC 2007 Table SPM.5, (page 23). See scenario AA.
11 Stern Review 2006 Executive Summary Figure 2 (page v)
12 IPCC 2007 Table SPM.5, (page 23)
13 Smith 2006. See also Makhijani 2004 and Smith and Makhijani 2006. Brice Smith was Senior Scientist at IEER when *Insurmountable Risks* was written. He continues in that role in the summers. He is now Assistant Professor of Physics at the State University of New York College at Cortland.
14 See for instance, the most recent report of the National Research Council, (NAS/NRC 2006)
15 Makhijani and Saleska 1999
16 Bush 2004 and Weisman 2004
17 NPT Article VIII
18 Qusti 2006
19 EIA CABS 2005 US
20 Kissinger 2007 and ISG 2006. See below.
21 Kissinger 2007
22 ISG 2006 page 28
23 ISG 2006 page 30 and EIA Petroleum Persian Gulf 2007
24 Yergin 1991, Chapter 10
25 A truly instructive history of oil, complete with colorful quotes from leaders in the first part of the twentieth century, can be found in Yergin 1991. For instance, Senator Bérenger of France, in 1918, noted, with some drama that oil is "the blood of victory ... Germany had boasted too much of its superiority in iron and coal, but it had not taken sufficient account of our superiority of oil.... As oil had been the blood of war, so it would be the blood of the peace. At this hour, at the beginning of the peace, our civilian populations, our industries, our commerce, our farmers are all calling for more oil, always more oil, for more gasoline, always more gasoline. More oil, ever more oil!" As quoted in Yergin 1991 page 183. Translated from the French in Yergin, with the exception of "More oil, ever more oil".
26 Bush 2006
27 Vedantam 2006
28 I wish to thank Julie Enszer for making the recycling analogy and raising the issue of what social dynamic might cause a similar change in personal energy use habits.
29 President Bush said: "America is on the verge of technological breakthroughs that will enable us to live our lives less dependent on oil. And these technologies will help us be better stewards of

the environment, and they will help us to confront the serious challenge of global climate change." (Bush 2007). His remarks were noted around the world. See, for example, Baker and Mufson 2007.

30 G8 Climate Declaration 2007 page 15

31 For instance, DuPont reports having achieved a 72 percent reduction in greenhouse gas emissions between 1990 and 2003, almost all of which were non-CO_2 greenhouse gases. (DuPont 2006b)

32 Gore 2007

Chapter 1: Setting the Stage

1 G8 Climate Declaration 2007 pages 15-16 (emphasis added)

2 Bush 2000 and Pianin and Goldstein 2001

3 EPA GHG 2006

4 In this study we include use of coal and organic materials in cement manufacture under the rubric of "fossil fuels" for convenience.

5 Buckley 2007

6 The confidence interval that 50 to 85 percent CO_2 reductions will keep the temperature rise to 2 to 2.4 degrees Celsius above pre-industrial levels is 15 to 85 percent. See IPCC 2007 Table SPM.5 (page 23) and footnote d to the Table. This table specifies reductions in CO_2alone, rather than reductions in all greenhouse gases, in terms of CO_2-equivalent emissions.

7 A reference global population of 9.1 billion and a U.S. population of 420 million are used throughout this book in the calculations for the year 2050. World population is from a 2006 United Nations estimate (UN 2006). The U.S. population projection is from the U.S. Census Bureau project (US Census 2004). Global CO_2 emissions in the year 2000 were about 30 billion metric tons; U.S. emissions were 5.8 billion metric tons. U.S. CO_2 emissions data are from the Environmental Protection Agency (EPA GHG 2007 Table 3-2 (page 3-2). Global emissions data for CO_2 from fossil fuels are from the U.S. Energy Information Administration at http://www.eia.doe.gov/environment.html under International Emissions Data (EIA IEA 2006 Table H.1co2). The figure for CO_2 from fossil fuels (24 billion metric tons) has to be increased by about 6 billion metric tons to account for non-fossil-fuel-related global CO_2emissions, for instance, from non-renewable forest burning (Hadley Centre 2005 page 12). Data for non-fossil fuel emissions are for the 1980s. Different sources give somewhat different numbers. Precise estimates are not required for the calculations regarding the target percentage of U.S. emission reductions presented here.

8 In some countries a reduction of land-clearing by burning forests could contribute significant reductions in CO_2 emissions as well, but this does not apply to the United States.

9 Gore 2007

10 As noted above, reductions in greenhouse gas emissions for the United States translate almost directly into reductions in CO_2 emissions from fossil fuels.

11 Gore 2007 (emphasis added)

12 UNFCCC 1992 page 1

13 UNFCCC 1992 Article 3, no.1 (page 4)

14 The author of this book served on the staff of the Energy Policy Project.

15 Many of the recommendations of the final report of the Energy Policy Project, *A Time to Choose* (EPP 1974), were adopted into 1975 legislation, while Dave Freeman was a consultant to the Senate Commerce Committee, and then by the Carter administration. See Freeman 2007, forthcoming book.

16 Nuclear power supplies about 20 percent of the electricity in the United States. (EIA AER 2006 Table 8.4a) The generating efficiency is about one-third — that is, about two-thirds of the heat generated in nuclear power reactors is discharged as waste heat into rivers, oceans, and the atmosphere.

17 EIA AER 2006 Table 5.1

18 EIA AER 2006 Table 2.1d and value of production data derived from the Statistical Abstract of the United States. (Statistical Abstract Online 2007 Table 897 and Table 767)

19 EIA AER 2006 Table 2.1a. All energy data are from the Energy Information Administration, unless otherwise stated.

20 See, for example, EERE 2006b and California Energy Commission 2007.

21 Statistical Abstract Online 2007 Table 1081

22 Rosenfeld and McAuliffe 2006. Emphasis in the original.

23 EIA GHG 2006 Table ES2 (page 2) and EIA AER 2006 Table 1.3

24 In this study, we take a technical approach to the question of what services people want and do not inquire into the reasons for high material demands or alternative ways in which those demands could be fulfilled. For instance, if locally-grown food were a much larger part of the food system, it would likely save energy and probably provide a more secure food system. However, the kinds of policies, practices, and personal preferences that would be needed to make those changes are in themselves quite complex and would require a study of far greater scope than this one to address carefully.

25 Estimated by the author from Rosenfeld 2003 Figure 2.

26 Nadel et al. 2006 Figure 2.1 (page 6). In 1996 dollars. Nadel et al. defines "unit value" as "average manufacturer cost and profit."

27 DOE and EPA 2007

28 USGS 2006

29 Hu and Young 1994 Table 7.16 (page 7-26)

Chapter 2: Broad Energy and Economic Considerations

1 EIA IEA 2006 Table E.1p

2 EIA AEO 2006 Table 1 (page 11)

3 In an interview, Dawn Rittenhouse and John Carberry of DuPont indicated that a one to two percent absolute decline per year was a reasonable energy efficiency goal under a system that capped emission allowances seeking to reduce greenhouse gas emissions greatly from the present-day level. (Rittenhouse and Carberry 2007–See Appendix B)

4 Smith 2006 Tables 2.2 and 2.3 (pages 35 and 36), which were estimated from MIT 2003 and University of Chicago 2004. Costs of power plants are estimated as of 2003 or 2004.

5 Hong and Slatick 1994. A heat rate of 10,000 Btu/kWh is assumed. (EIA Kyoto 1998 Table 17 (page 75)

6 Fritsche and Lim 2006 Figure 4 (page 6)

7 The experience with CO_2 sequestration so far and various cost estimates for sequestration associated with IGCC plants are summarized in Smith 2006 pages 89 to 96.

8 The insurance problem was pointed out to me by Isaac Berzin, Chief Technology Officer of GreenFuel, a company formed to capture power plant exhaust CO_2 in microalgae (see subsequent chapters, including Chapter 3). (Berzin 2007)

9 Schrag 2007

10 MIT 2003 Table 5.1, 25-year- and 40-year levelized costs

11 NCUC 2007 page 213

12 Based on Makhijani 2001 page 30. The estimated added cost of the French program is $800 million for 20 reactors, each using plutonium fuel in 30 percent of the core, over and above the cost of uranium fuel. This amounts to about 2 cents per kWh added cost for the electricity generated using that fuel.

13 The heat rate for a coal-fired power plant assumed = 10,000 Btu/kWh, which represents an efficiency of about 34 percent. This is somewhat higher than the average at present, but lower than new coal-fired power plants. A detailed paper published by the Energy Information Administration indicates CO_2 emission factors between 205 and 227 pounds of CO_2 per million Btu of coal. (EIA 1995 Coal) We have used 215 pounds per million Btu in this calculation, which when rounded yields about $10 per metric ton of CO_2 per cent per kWh at the selected heat rate. The standard emission factor for electric utilities published by the EIA of about 26 million metric tons of carbon per quadrillion Btu for 2002 yields approximately the same result. See EIA factors at EIA GHG 2005 Docs Table 6-1 (page 187).

14 Berzin 2007

15 In this context we will not consider single stage natural gas turbines, since the avoided cost for combined cycle power plants and hence the imputed CO_2 cost is smaller.

16 EIA AER 2006 Table 6.8

17 EIA Electric Power 2006 Table 2.8 (page 23). This is the total of combined cycle and single stage gas turbine capacity.

18 Estimated from total capacity and EIA data for electricity generation. (EIA Electric Power 2006 Table 1.1 (page 13))

19 A heat rate of 7,000 Btu per kWh is assumed for a natural gas combined cycle plant. (EIA Kyoto 1998 Table 17 (page 75)) This corresponds to an efficiency of just under 50 percent.

20 For a discussion of wind-generated electricity costs, see Makhijani et al. 2004.

21 Light 2003. The scenario studied in Light is that of actual electricity generation in fuel cell vehicles. The main cost in that case is that of the fuel. In the example considered here, the batteries in an all-electric vehicle are used for storage and retransmission into the grid. The costs, therefore, are those of the V2G infrastructure plus the electricity losses in charging and discharging.

22 A paper on lithium-ion batteries (Buchmann 2006) and a company that makes lithium-ion batteries for solar racing cars (Solion 2003) claim 99 percent efficiency. However, Tesla Motors provides a figure of 86 percent. See Eberhard and Tarpenning 2005. For further discussion see Chapter 3.

23 For the purposes of this discussion, we ignore the potential for negative CO_2 costs. In effect, we are assuming that policies that will be in place, including CO_2 caps, will cause the adoption of technologies that are profitable even without CO_2 caps (see Chapter 6).

24 See, for instance, Paul 2002 and Escobar 2001.

25 EIA CABS 2006 Oil Prices and EIA STEO 2006

26 COS-Trust 2007, which gives a detailed financial evaluation, estimates the cost at $36.83 (Canadian dollars) per barrel or about $32 (U.S. dollars) per barrel. We will use a range of $30 to $35 (U.S. dollars) per barrel in this report.

27 ISG 2006 page 30, EIA Petroleum Persian Gulf 2007, and EIA Petroleum 2007

28 See, for example, EIA GHG 2006 page 20.

29 EIA Spot Prices at http://tonto.eia.doe.gov/dnav/pet/pet_pri_spt_s1_d.htm, viewed on July 3, 2007

30 EIA Gas Primer 2006

31 Google 2007, viewed early July 2007. The mileage varies somewhat from time to time depending on the specifics of the use of the cars.

32 DuPont 2006

33 I would like to especially thank Hisham Zerriffi, one of the project's Advisory Board members, for pointing to the necessity of developing technologies that would allow large-scale removal of CO_2 from the atmosphere to be a realistic option. Some approaches and policies are discussed in subsequent chapters of this report.

Chapter 3: Technologies—Supply, Storage, and Conversion

1 AWEA 2006

2 The idea of how to illustrate this problem comes from Walt Musial (Musial 2005 Slide 2).

3 GWEC 2007

4 Parsons et al. 2006 page 3

5 Parsons et al. 2006 page 7

6 EnerNex 2006

7 Musial 2005 Slide 10. This estimate excludes Alaska.

8 EIA AER 2006 Table 8.2a. A 35 percent capacity factor is assumed for offshore wind.

9 Keith et al. 2004

10 Makhijani et al. 2004. For an actual example of a wind farm see Kimball 2004 which has a capital cost of $1,330 per kW. A survey of costs in 2003 is available at Public Renewables.

11 Solar energy land-area data are generally provided in metric units and we retain that convention here. One square meter equals about 1.2 square yards or about 11 square feet.

12 DOE 2006

13 DOE 2006

14 Kemp 2006

15 NREL 2004. NREL's research achieved a record 16.5 percent thin film solar PV efficiency in 2001. See Wu et al. 2001.

16 Data about Nanosolar are from its web site, www.nanosolar.com. The timeline with links to more details is at http://www.nanosolar.com/history.htm. For the interview see earth2tech 2007.

17 First Solar 2007 and Fairley 2007

18 See Smith 2006 pages 83-85 for a summary of some recent developments. See also Eskom 2005.

19 Feldt 2006

20 Evergreen Solar 2006, Evergreen Solar 2006b and Evergreen Solar 2006c

21 DOE 2007a

22 Gas turbine cost of $250/kW, operating 300 hours per year. Assumptions: heat rate 13,000 Btu/kWh, gas cost = $8/million Btu

23 Keshner and Arya 2004

24 PowerLight 2002

25 Google Blog 2006

26 Earth Policy 2001. The estimate assumes three parking spots per vehicle and 30 square meters per parking spot. The area per parking spot appears to include both the area of the spot itself as well as associated paved surface needed for movement of vehicles in parking lots.

27 Google has set up a special web site for its plug-in hybrid program, which includes the V2G test. Google 2007

28 EIA 1995 Renewables pages 101-102, 109

29 Herrmann, Geyer, and Kearney 2002 slide 21

30 Fthenakis and Kim 2006

31 Fritsche and Lim 2006 Figure 4 (page 6)

32 Fthenakis and Kim 2006 Table 1 (page 3)

33 Smith 2006 has raised these points in his discussion of solar PV. See pages 84-85.

34 Makhijani and Poole 1975 and Makhijani 1990. Biomass used as food for draft animals is one of the largest energy inputs in parts of rural South Asia, for instance. Yet it is not included in compilations of energy data. It will be important to do so in assessing issues of energy, food, land use, and social and economic justice as the climate debate becomes more intense in regard to Asian developing countries.

35 Sandalow 2006 page 67

36 Bush 2006 and Bush 2007

37 Ethanol Market 2007. Note that ethanol has smaller energy content than gasoline. A gallon of ethanol is equal in fuel value to about 0.61 gallons of gasoline.

38 Bush 2007

39 EERE Solar 2007

40 See NREL map above, Figure 3-6.

41 Typical yields for corn are used. See Farrell et al. 2006b Figures S1 and S2 (pages 14-15). A switchgrass yield of 13,000 kilograms per hectare is assumed. See Farrell et al. 2006 and Farrell et al. 2006b. A value of 5 kWh per square meter day is used for typical incident solar energy. See Figure 3-6.

42 This assumes an energy value of corn of 18 million Btu per metric ton, incident solar energy of 5 kWh per square meter per day, and one crop per year.

43 Farrell et al. 2006b page 4 and Table S3 (page 21)

44 Many studies yielding different results have been done. Farrell et al. 2006 does a careful analysis of six studies and compares the methods and results. Farrell et al. 2006 and the supporting material in Farrell et al. 2006b are used here to provide the basis for the results shown. All figures are rounded and approximate, since that suffices for the purpose of illuminating broad policy directions and concepts for a zero-CO_2 economy and its implications for present policy direction. Gasoline emissions, like ethanol emissions, were computed on a lifecycle basis in Farrell et al. 2006. Overall, a small reduction in greenhouse gas emissions appears to result from corn-derived ethanol, when the energy and emissions credits for the co-products are taken into account.

45 Malkin 2007

46 Runge and Senauer 2007

47 Runge and Senauer 2007

48 Buckland 2005 and Rosenthal 2007

49 Delft Hydraulics 2006 page 30

50 We do not address issues related to the Brazilian ethanol from sugarcane here. It has generally been considered that this has a positive effect on greenhouse gas emissions. However, this does not take into account the overall changes in land use patterns of which ethanol production is a part. The total, direct and indirect, effect of food crops for export, ethanol for fuel, and providing for a growing population with higher incomes creates pressures on the land whose net effect, for instance, on deforestation in the Amazon region is difficult to determine even though sugarcane is not cultivated on cleared Amazon forest land. Further, fuel crops could be grown on cleared forest land. As Farrell et al. have pointed out in the context of potential imports of ethanol into the United States: "The possibility of importing ethanol suggests that land use changes as a result

of U.S. ethanol use could occur outside of the country, raising concerns about, for instance, the conversion of rainforest into plantations for fuel production. Estimating the magnitude of such effects would be very difficult, requiring analysis of land productivity and availability, commodity markets, and other factors...." (Farrell et al. 2006b page 12). Importing large amounts of ethanol or other fuels made from food crops or importing foodstuffs into the West from developing countries for the purpose of producing fuel is likely to have a deleterious effect on poor peasants and landless laborers and other people living in poverty or close to poverty in developing countries. See Runge and Senauer 2007.

51 The total energy content of all crop residues in the United States is about three quadrillion Btu, or less than 5 percent of the natural gas and petroleum use. (Milbrandt 2005 Figure 28 (page 47)). Only a fraction of this would be available for fuel production if appropriate attention is paid to soil conservation issues.

52 Berzin 2007 estimates a productivity of 100 grams per square meter per day for very sunny areas like Arizona. This translates into 250 metric tons per year on the basis of 250 sunny days per year. The productivity depends of the type of microalgae and the circumstances in which they are cultured. See NREL 1998.

53 MIT News 2004 and MIT Cogen 2007

54 Berzin 2007

55 CK Environmental 2004

56 Berzin 2007 and Bane 2007

57 Berzin 2007

58 Berzin 2007

59 Berzin 2007

60 We will use a value of 18 million Btu per metric ton of dry biomass, also called "Bone Dry" biomass, throughout this report. While the figures vary somewhat from one form of biomass to another, the use of a single value is justified given the approximate nature of the calculations. Inferred from values for switchgrass (NREL 2005 Figure 28 and Table 5).

61 Berzin 2007

62 Greene et al. 2004. See page 63 for a discussion of output.

63 Greene et al. 2004 page vi

64 Greene et al. 2004 Table 5 (page 26) and discussion on pages 25 and 26

65 Farrell et al. 2006 and Farrell et al. 2006b

66 Farrell et al. 2006b Table S3 (page 21). One megajoule is about 950 Btu. One gallon of gasoline is about 125,000 Btu.

67 Tilman, Hill, and Lehman 2006

68 Wolverton and McDonald 1977

69 Wolverton and McDonald 1979 page [2]

70 EPA 1988 page 48

71 The rest of this account of the NASA project in Bay St. Louis is based on Wolverton and McDonald 1977.

72 Wolverton and McDonald 1977 page 207

73 EPA 1988. The rest of the discussion is based on this EPA overview and design document, unless otherwise specified.

74 See, for instance, Wolverton and McDonald 1979.

75 See, for instance, Moreland and Collins 1990.

76 DOE 2007

77 DOE 2007 Table 3.1.10

78 DOE 2007 Table 3.1.9

79 EPRI 2005

80 This section is based on MIT 2006.

81 First called the Solar Energy Research Institute.

82 MIT 2006 page 1-6

83 EIA 1995 Renewables page 109

84 In this study, we are not considering new pumped hydropower storage, which uses off-peak power from a source other than hydroelectric power plants to pump water downstream of a dam back into the reservoir. The water is then used to generate electricity at times of peak demand. The capacity for new storage would likely be limited in the context of very large-scale

implementation of solar and wind energy.

85 This would apply to fleet vehicles with charging equipment that can carry large currents. Phoenix Motorcars, Inc. is manufacturing SUV pickup trucks for such applications with a 10-minute charging time. See http://www.phoenixmotorcars.com/.

86 Based on a source in industry and Miller 2007. Lithium-ion battery costs vary and are more than $500 per kWh. Installed costs of battery systems in cars can be well above $2,000 per kWh due to very small-scale (one to a few cars) custom installation.

87 Kempton and Letendre 1997

88 University of Delaware V2G

89 We have focused here on batteries since plug-in hybrids and lithium-ion all-electric vehicles are much closer to commercialization than fuel cell vehicles.

90 See "Recharge a Car, Recharge the Grid, Recharge the Planet" at Google 2007. For the lithium-ion battery type being used by Google, see Hybridcars.com 2007.

91 Light 2003

92 Eberhard and Tarpenning 2006 page 2 and Solion 2003

93 A fact sheet on the battery is available on the company's web site at www.altairnano.com/documents/NanoSafeBackgrounder060920.pdf. (Altairnano 2006). See O'Shea 2006 for a trade journal news report on the final performance test.

94 Not all hybrid cars have the capacity to run on electricity only. The most common one, the Toyota Prius, does.

95 See http://www.calcars.org/carmakers.html#vvquotes at the web site of Calcars, a non-profit that promotes plug-in hybrids.

96 Miller 2007

97 Miller 2007. AFS Trinity Power aims for a liquid fuel efficiency of 150 to 250 miles per gallon (plus electricity enough to drive 40 miles on the battery alone) (AFS Trinity 2006)

98 Experimental work on these capacitors is currently being carried out at MIT, among other places. See Schindall 2007 and MITLEES 2006

99 Shepard and van der Linden 2001 and CAES McIntosh. These are the sources for the following paragraphs.

100 McIntosh Project web site at http://www.caes.net/mcintosh.html. (CAES McIntosh) A heat rate of 10,000 Btu/kWh for coal-fired power plants is assumed.

101 See Energy Services 2003.

102 The energy sector emitted about 6 billion metric tons of CO_2 per year in 2005; the other greenhouse gases account for about 1 billion metric tons per year CO_2 equivalent.

103 Wilson, Johnson, and Keith 2003 page 3476

104 Utah Geological Survey

105 Utah Geological Survey

106 Berzin 2007

Chapter 4: Technologies—Demand-Side Sectors

1 Data for these and other efficient buildings are at http://www.eere.energy.gov/buildings/database/index.cfm. (EERE 2004). This web site provides links to a wealth of material describing energy efficient equipment and design concepts and a glossary at http://www.eere.energy.gov/consumer/information_resources/index.cfm/mytopic=60001.

2 Quote from EERE Hanover 2002. Many design features are described on the Web at http://www.eere.energy.gov/buildings/database/energy.cfm?ProjectID=49.

3 The 58,000 Btu per square foot is calculated from EERE 2006 Table 1.2.3 and EIA AEO Assumptions 2006 page 23 and EERE 2006 Table 2.1.1

4 Winkler, 2007

5 Quote from EERE Takoma 2003 Energy. Many design features are described on the Web at http://www.eere.energy.gov/buildings/database/overview.cfm?projectid=70.

6 Quote from EERE Durant 2007. Many design features are described on the Web at http://www.eere.energy.gov/buildings/database/energy.cfm?ProjectID=46.

7 EERE Cambria 2002

8 Sachs et al. 2004 page 40. "Standby power is the electricity consumed by end-use electrical equipment that is switched off or not performing its main function." (Sachs et al. 2004 page 40)

9 The details of this project are from Parker, Sherwin, and Floyd 1998, unless otherwise mentioned.

[10] Sunlight Direct 2005
[11] See the web site of the Oak Ridge Solar Technologies Program at http://www.ornl.gov/sci/solar/. (ORNL Solar 2007)
[12] Narendran et al. 2005
[13] Tesla Motors 2007 and Phoenix Motorcars. Tesla motors uses commercial lithium-ion batteries in a large battery back specially developed for automobiles. Phoenix Motorcars uses new nanotechnology lithium-ion batteries.
[14] A European Union survey of hydrogen fuel for aircraft can be found in links to documents at European Commission 2000.
[15] DARPA 2006
[16] Tupolev 2006
[17] It should be noted that most people in the infamous Hindenburg disaster survived. There is still a considerable controversy over the causes of the accident and fire, with an excellent survey found at Wikipedia Hindenburg 2007.
[18] European Commission 2000. In an interesting research project, Georgia Tech has done test flights of an unmanned 500 watt hydrogen fuel cell powered plane for one minute at a time. (Georgia Tech 2006)
[19] Airbus Deutschland 2003 page 5
[20] Airbus Deutschland 2003 page 12
[21] Airbus Deutschland 2003 pages 29-30
[22] Airbus Deutschland 2003 page 65
[23] Airbus Deutschland 2003 page 47
[24] The fraction is difficult to read from the bar chart, but appears to be about 5 percent.
[25] Airbus 2001 Slide 11
[26] O'Neill 2006
[27] Bloomberg 2007 Figure i
[28] Environmental Defense 1999 shows a timeline of environmental justice struggles in Los Angeles, *which includes the public transit bus story.*
[29] Rundle et al. 2007
[30] See Appendix B (Rittenhouse and Carberry 2007).

Chapter 5: A Reference Zero-CO_2 Scenario

[1] EERE 2006 Table 2.1.1 (page 2-1) for 2004. The number for 2050 is calculated.
[2] The main efficiency and technology assumptions for the year 2050 for the residential sector are: 1. Overall building envelope heating requirement reduction relative to business-as-usual: 40%. 2. Heating technologies: conventional, similar to natural gas forced air or circulating hot water and geothermal heat pumps, one-third each; solar thermal assisted fuel or electricity, solar portion of the load 13%; CHP (combined heat and power, mainly apartment buildings), 20%. 3. Cooling system efficiency: among the higher efficiency systems available today (coefficient of performance = 6, or SEER = about 20). 4. Hot water: solar thermal portion of the load = 40%. The same end result can be achieved with different combinations of HVAC and water heating technologies. Other appliance efficiency, factor of 2 improvement over that projected in the business-as-usual scenario. Note that the effect of standards for refrigerators, for instance, in thirty years has been an improvement by a factor of 3 to 4. These assumptions are based on a survey of the literature of efficient buildings and residential sector technologies.
[3] The main efficiency and technology assumptions for the year 2050 for the commercial sector are: 1. Overall building envelope heating requirement reduction relative to business-as-usual: 30%. 2. Heating technologies: geothermal heat pumps: one-third each; solar thermal assisted fuel or electricity, solar portion of the load 15%; CHP (combined heat and power), 25%. 3. Cooling system efficiency: coefficient of performance ≈ 6, or SEER = about 20, plus use of absorption air-conditioning for 25 percent of the load. Building envelope and lighting improvements reduce cooling load by 30% relative to business-as-usual. 4. Hot water: solar thermal portion of the load = 40%. Balance electricity and fuel, including that associated with CHP systems. 5. Lighting and other appliance electricity use a factor of 3 lower than business-as-usual – largely due to efficiency improvements in lighting. These assumptions are based on a survey of the literature of efficient buildings and commercial sector technologies, such as LED lights of new designs and solar-hybrid lighting.

4 Based on performance data on the web sites of Tesla Motors (www.teslamotors.com) and of Phoenix Motorcars (http://www.phoenixmotorcars.com), and an industry interview (anonymous).

5 NJC 2007

6 See http://www.teslamotors.com/media/press_room.php?id=29 and http://www.teslamotors.com/media/press_room.php?id=573, viewed on August 1, 2007.

7 Gates 2007

8 1. Light duty vehicle (less than 8,500 pounds) efficiency for new liquid fuelled vehicles: 75 miles per gallon; for new electric vehicles, 11 miles per kWh. 2. Commercial light truck efficiency is assumed to improve relative to 2004 proportionally the same as for the light duty vehicles. 3. Freight trucks, liquid fuelled: 10.7 miles per gallon; electrical (including as part of plug-in system): 1.7 miles per kWh. 4. Aircraft efficiency = 150 seat miles per gallon.

9 See, for instance, Greene et al. 2004.

10 http://www.us-cap.org/

11 The most important index of reliability of an electricity system is its "loss of load probability" or LOLP. Optimization refers in part to minimizing costs for a given level of reliability.

12 We assume only 10 kW per vehicle, even though the total available power would be considerably larger. This is because a moderate power supply level would allow the vehicle to supply energy for a longer time.

13 See the webpage of Ice Energy at http://ice-energy.com/. Example installations are cited at this web site

14 Zwetzig 2007

15 Winkler 2006

16 Zagórze, no date

17 Based on NYSERDA 2005

18 Statistical Abstract Online 2007 Table 828

Chapter 6: Options for the Roadmap to Zero-CO_2 Emissions

1 A kilogram of hydrogen is approximately equivalent in energy terms to a gallon of gasoline.

2 This section is based on DOE 2007 unless otherwise mentioned. See especially Tables 3.1.4 and 3.1.4A and the notes to these tables.

3 "This figure was created and prepared by an employee of the Midwest Research Institute (MRI) as work sponsored by an agency of the United States Government. Neither MRI or the United States Government nor any of their employees make any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or presents that its use would not infringe upon privately owned rights. The reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation or favoring by the United States Government or MRI." –Source: National Renewable Energy Laboratory

4 Hydrogen Cars Now 2006 Gain 2006

5 See footnote L to Table 3.1.4A in DOE 2007.

6 Ford 2004

7 The land-area requirements of wind energy are very small compared to biomass cultivation for liquid biofuels. See Chapter 5.

8 Solar cooling uses an absorption air conditioning system. This is similar to systems that use waste heat for producing a cooling effect, except that the source of heat in this case is a solar energy. Pumps are used for circulation of cool water.

9 ClimateMaster Model Tranquility 27.

10 It may also be possible to use other approaches, notably flywheels. At present the use of flywheels is indicated for short-term storage needs rather than the application under consideration here – which is storage of several hours' worth of electricity supply.

11 We assume 5 kWh per day of generation per peak kW, $200 per kWh storage cost and $200 ancillary equipment capital costs. This would be typical of sunny areas. The same storage capacity would suffice for more than one day's generation in less favorable areas.

12 Siemers 2007 described the plant proposed to be built in New Mexico and also cites a skeptic. The technology has not been used on a commercial scale as yet to produce raw material for new tires.

13 Ironically, France imports all of its uranium. Its energy 'independence" in terms of proportion

of energy supply imported has actually declined – only 15 percent of the energy supply was domestically produced in 2000 compared to 22 percent in 1973. However, France's energy security in the sense of diversity and security of energy supplies has increased. But nuclear power has brought its own vulnerabilities. (Makhijani and Makhijani 2006 pages 34-37)

14 Stern Review 2006 Executive Summary page i

15 Throughout this analysis, we assume that policies in the direction of greater efficiency will be in place. See Chapter 7.

16 Personal vehicles accounted for about 19 percent of total CO_2 emissions in the year 2000 and electric utilities were responsible for another 37 percent (EPRI 2005b). Residential and commercial electricity accounts for just over 70 percent of total electricity consumption. Based on these data, about 45 percent of total CO_2 emissions come from residential and commercial electricity use and personal automobiles (including SUVs and light trucks).

17 Winkler, 2006

18 This section is based on Makhijani and Gurney 1995, unless otherwise noted.

19 The text of the Vienna Convention can be found at http://ozone.unep.org/ pdfs/viennaconvention2002.pdf; viewed on 3 August 2007.

20 Makhijani, Makhijani, and Bickel 1988

21 See Makhijani and Gurney 1995, especially Chapters 12 and 13.

22 Landfill gas (methane is one of the gases created by decay of the organic materials dumped in landfills) and other waste materials could also be used as energy sources. However, waste, including household and commercial municipal waste, can only meet a small fraction of energy requirements and therefore is not dealt with in the context of this report. Yet, the recovery and use of landfill gas is particularly important for global warming since it captures a greenhouse gas and provides a substitute for a fossil fuel.

Chapter 7: Policy Considerations

1 See EPA Fact Sheet at SO_2.

2 A comparative description along with the results can be found in Oliver 2006.

3 Anderson 1999 and the Acid Rain Program SO_2 Allowances Fact Sheet on the web at http://epa.gov/airmarkets/trading/factsheet.html#what (EPA Fact Sheet SO_2).

4 CCAP 1999 page 21

5 Öko-Institut 2005 page 12

6 CCAP 1999 page 21

7 EPRI 2005b

8 USCAP 2007 page 5

9 See, for instance, Rittenhouse and Carberry 2007.

10 Stavins 2005

11 This corresponds to an increase in the cost of coal-generated electricity of about one cent per kWh and about half that for natural gas.

12 See WGA 2006 pages 1, 36, 40, and 44

13 WGA 2006. See also DSIRE 2007 for state by state listings of current incentives.

14 WGA 2006 pages 40 and 44

15 See Karppi 2002, for an example of rebates for earth-source heat pumps provided by a utility to a builder of a hotel in Long Island. Also see LIPA 2006.

16 We have not dealt with the broader problem of CO_2 emissions associated with imported goods in this book. It is highly unlikely that the United States or any other country would go all the way to a zero-CO_2 emissions economy without a more general agreement to reduce global CO_2 emissions by 50 to 85 percent. In that context, the problem of the CO_2 footprint of imported goods may not be a significant issue.

17 Andrews and Wald 2007

18 As quoted in the Atlanta Journal-Constitution editorial published on August 2, 2007

19 See for instance IEER 1999. This article contains a series of graphs prepared by the Department of Energy for the Nuclear Waste Technical Review Board. They show that the geology of the Yucca Mountain site is practically worthless in containing radionuclides, should they leak out of the containers.

20 Safety reasons may cause earlier closures of some plants, but we have not taken that into account in this analysis.

21 USCAP 2007 page 7
22 Mufson and Cho 2007

Chapter 8: Roadmap for a Zero-CO_2 Economy

1 Lithium-ion batteries can be and are recycled. See Buchmann 2003..
2 Winkler 2006
3 Renewable Energy Access 2007
4 Calculated from EIA IEO 2006 Table A3
5 The Energy Information Administration projects crude oil prices to be in the range of about $36 to $100 per barrel in the year 2030. See EIA IEO 2007 Figure 17.
6 Miller 2007
7 Winkler 2006
8 The electricity costs are from http://www.eia.doe.gov/cneaf/electricity/epm/table5_6_a.html (EIA EPM 2007-08). Delivered fuel costs are based on a wellhead price of $7 to 8 per million Btu.
9 Northbridge 2003

Chapter 9: Summary

1 Based on a global population of 9.1 billion and a U.S. population of 420 million in 2050.
2 Offsets allow a purchaser to continue emitting CO_2 while paying for reductions in CO_2 by the party from whom the offsets are purchased. These may or may not result in actual CO_2 reductions. Even when they do, the emissions may be immediate while reductions may be long-term. Verification is difficult and expensive.
3 Qusti 2006

Appendix A: Nuclear Power

1 *Section A is based mainly on the Foreword that the author wrote for Smith 2006. Section C* is mainly based on a portion of Makhijani and Barczak 2007. For more details on the history of nuclear power see Makhijani and Saleska 1999.
2 Murray 1953
3 Cole 1953
4 AEC 1948 page 46
5 Bacher 1949 p. 6 and LANL Biography
6 Suits 1951
7 Makhijani and Saleska 1999 pages 67-68
8 See Makhijani 2001 for details relating to costs associated with efforts to commercialize plutonium fuel use. The uranium and plutonium can be separated with relative ease, yielding plutonium that could be used to make nuclear weapons.
9 J. Robert Oppenheimer, "International Control of Atomic Energy," in Morton Grodzins and Eugene Rabinowitch, eds., *The Atomic Age: Scientists in National and World Affairs*, (New York: Basic Books, 1963), p. 55, as quoted in Makhijani 1997.
10 The EPA standard is at 40 CFR 191. For the Science Advisory Board Report on carbon-14 see EPA 1993.
11 The DOE graphs are reprinted in IEER 1999. See also the quotes from DOE's peer review panel regarding corrosion in this article. For additional analysis of the corrosion issue, see Craig 2004. For the NRC's total system performance assessment standards, see 10 CFR 63.
12 Makhijani, Gunter, and Makhijani 2002
13 More complex methods of "recycling" have been proposed. For a critique of these, see Zerriffi and Annie Makhijani 2000.
14 Warrick 1999
15 PACE-University of Utah 2000
16 The Paducah plant did not make highly enriched uranium for the U.S. military program. However, some of the low enriched uranium that it made was subsequently enriched to weapon-grade levels at the DOE enrichment plant in Portsmouth, Ohio.
17 See Makhijani and Smith 2004.

[18] The official description may be found at http://www.gnep.energy.gov/.

[19] Article VI of the NPT requires negotiations in "good faith towards complete nuclear disarmament." A 1996 World Court advisory opinion stated that the NPT requires the actual achievement of complete elimination of nuclear weapons. See Deller, Makhijani, and Burroughs 2003.

[20] This is my personal assessment. Herbert York, the first Director of Lawrence Livermore National Laboratory concurred with it in an interview he did with me in 2001. York 2001

[21] Smith 2006, pages 38-42

[22] EIA 1986 p. xv (emphasis added)

[23] EIA 1986 page xvi

[24] Georgia IRP 2007 pages 1-15

[25] For a discussion of claims about the safety of new reactor designs and modified existing reactor designs see Makhijani and Saleska 1999.

[26] Kennedy et al. 2006

[27] NCUC 2007 page 213

[28] Andrews and Wald 2007

[29] As quoted in Andrews and Wald 2007

[30] Smith 2006

[31] Smith 2006, Section 4.4

[32] Nature editorial 2007

[33] Associated Press 2007

[34] Godoy 2006

[35] France 2003

Appendix C: Japan Focus Interview on Carbon-Free and Nuclear-Free

[1] Karbuz 2007

[2] Gore 2007

[3] G8 Climate Declaration 2007. The declaration states that the United States will "consider seriously the decisions made by the European Union, Canada and Japan which include at least a halving of global emissions by 2050." (paragraph 49) In fact the EU goal is to limit the temperature rise to 2 to 2.4 degrees Celsius. This implies a 50 to 85 percent reduction in CO_2 emissions. See IPCC 2007 and European Parliament 2007, p. 1.

[4] See New York City Department of City Planning at http://www.nyc.gov/html/dcp/html/transportation/td_projectbicycle.shtml (NYC 2007).

[5] Changing modes of transport are not included in the reference scenario. However, certain changes help in reducing energy use and pollution. See Chapters 4 and 6.

[6] Schwarzenegger 2007

[7] Chea 2007

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40 CFR 191	*Code of Federal Regulations. Title 40--Protection of Environment. Chapter I--Environmental Protection Agency. Part 191—Environmental Radiation Protection Standards For Management And Disposal Of Spent Nuclear Fuel, High-Level And Transuranic Radioactive Wastes* 1-06 Edition. Washington, DC: Office of the Federal Register, National Archives and Records Administration; United States Government Printing Office, 2006. On the Web at http://www.access.gpo.gov/nara/cfr/waisidx_06/40cfr191_06.html.
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Airhart 2006	Marc Airhart. *Scientists Deepen Confidence in Technique to Reduce Greenhouse Gas Emissions.* News Releases and Features. Austin: Jackson School of Geosciences, University of Texas at Austin, Nov. 15, 2006. On the Web at http://www.jsg.utexas.edu/news/feats/2006/frio.html.
Altairnano 2006	Altairnano. *NanoSafe™ Battery Technology.* Reno, NV: Altairnano, [September 20, 2006]. On the Web at www.altairnano.com/documents/NanoSafeBackgrounder060920.pdf.
Anderson 1999	Robert C. Anderson, with the assistance of Alan Carlin. *Economic Savings From Using Economic Incentives for Environmental Pollution Control.* [Washington, DC: Environmental Law Institute], June 1999. Section 3.2.3. Acid Rain Allowance Trading. On the Web at http://yosemite.epa.gov/ee/epa/incsave.nsf/437c451fb25915d5852564db00579f01/e8448f37d3eeb89b85256636004f926e!OpenDocument. Viewed August 23, 2007.
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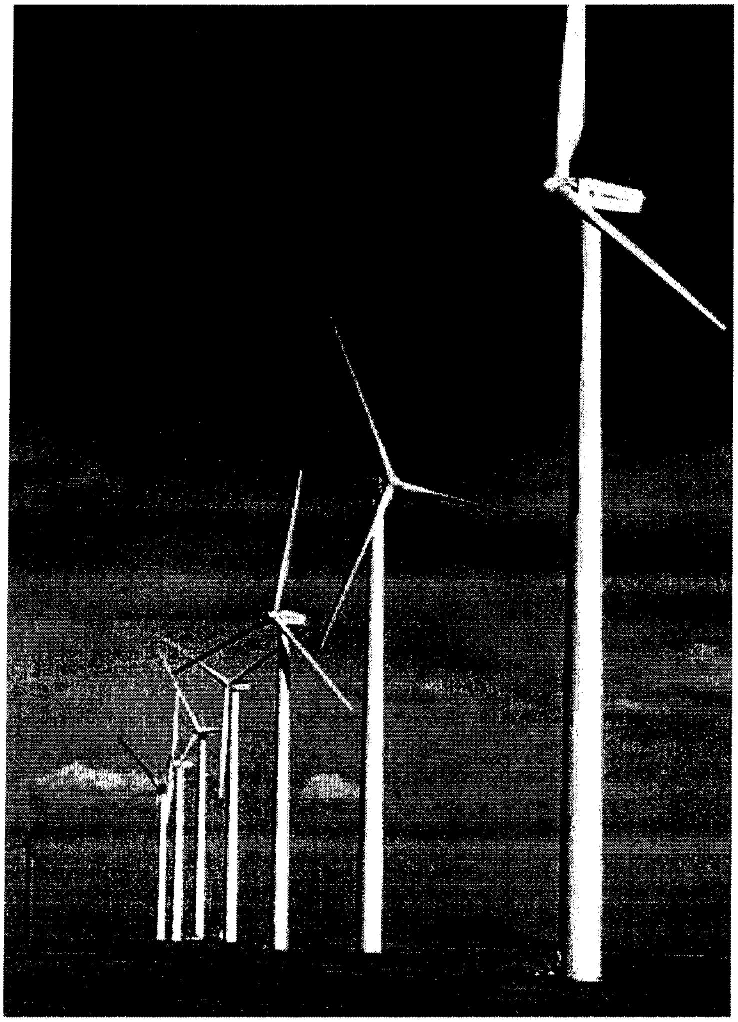
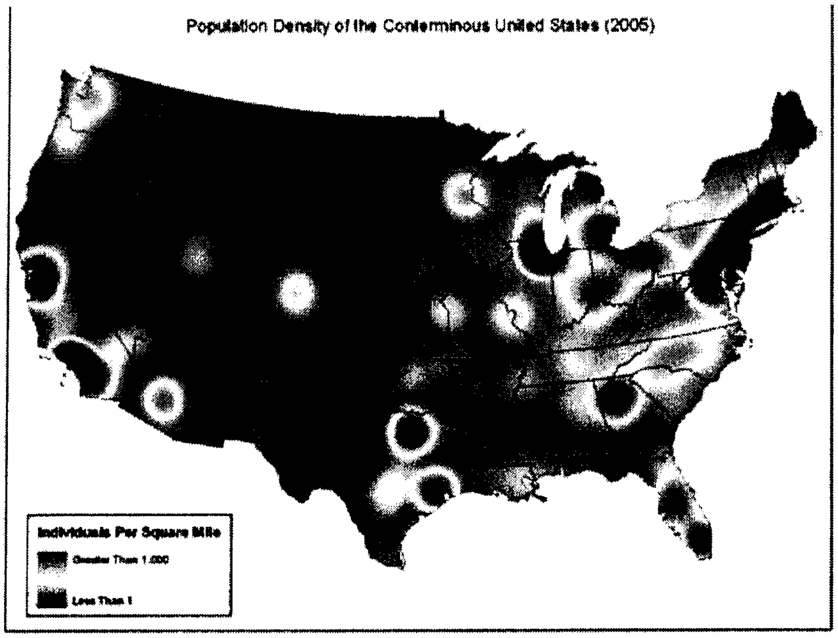
Chapter 3

Figure 3-1: Colorado Green Wind Farm



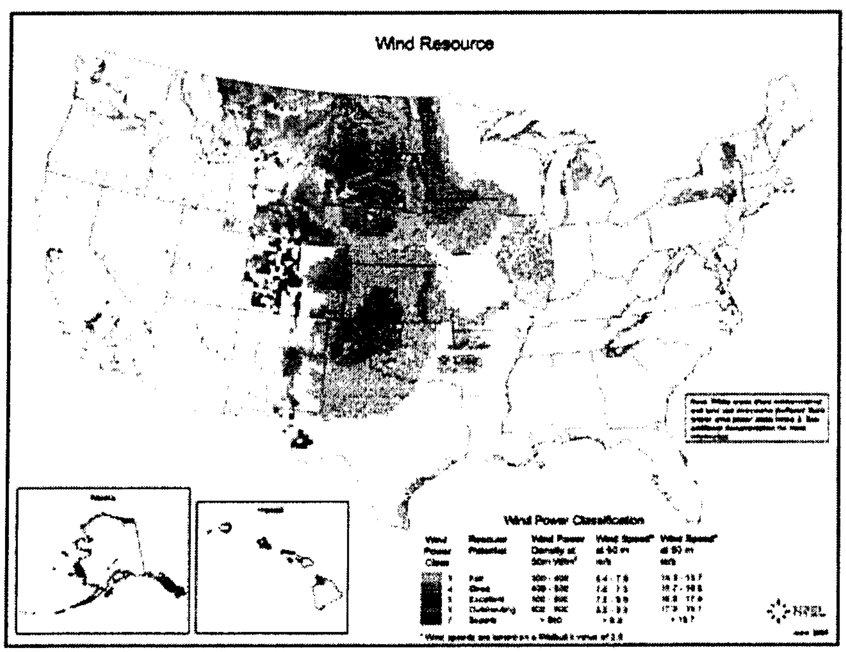
Courtesy of DOE/NREL, Credit: Sandia National Laboratories

Figure 3-2a: Population Density



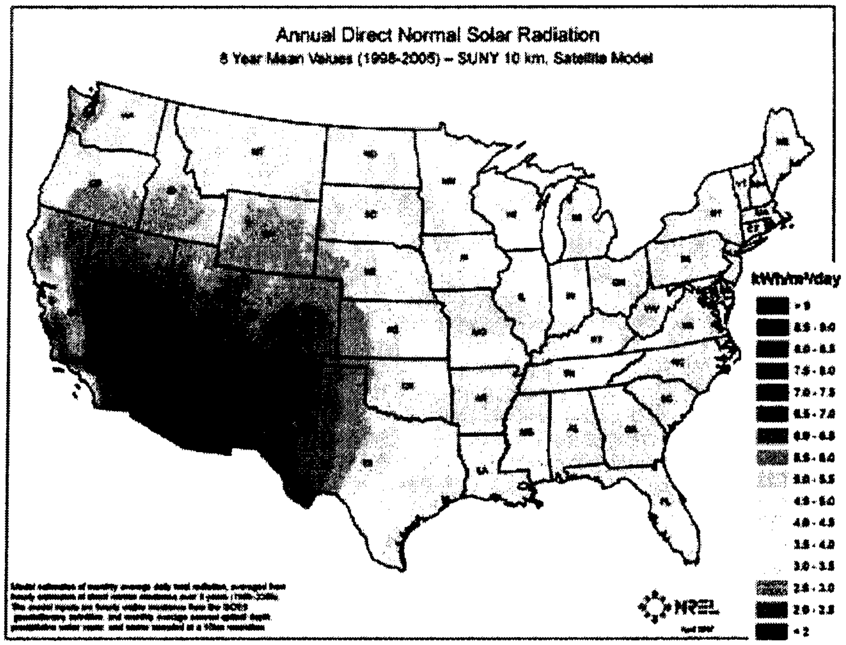
Provided by AWS Truewind, LLC

Figure 3-2b:Wind Resource Density



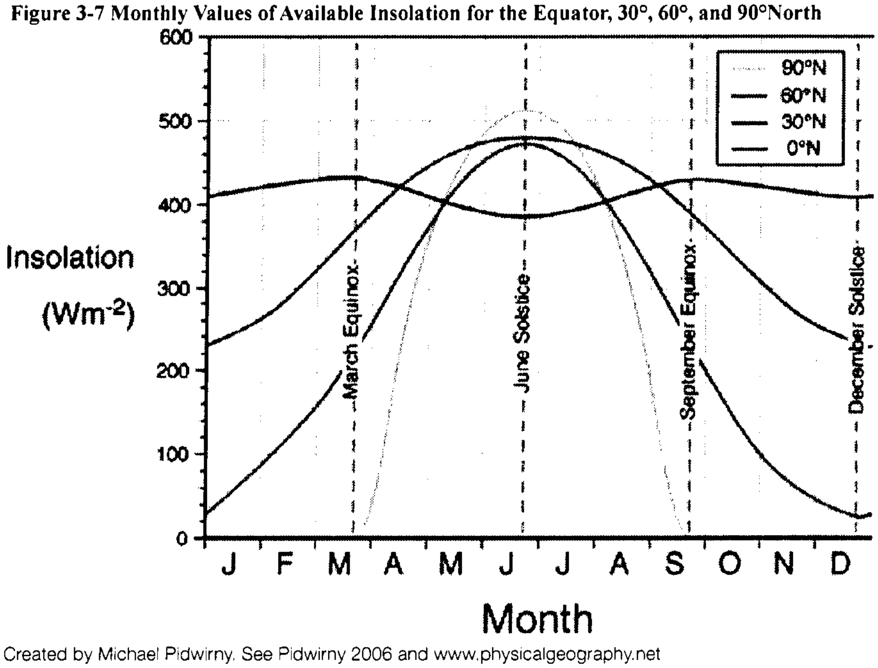
Provided by National Renewable Energy Laboratory.

Figure 3-6: Solar Insolation, in kWh Incident per Day (Annual Average Values)



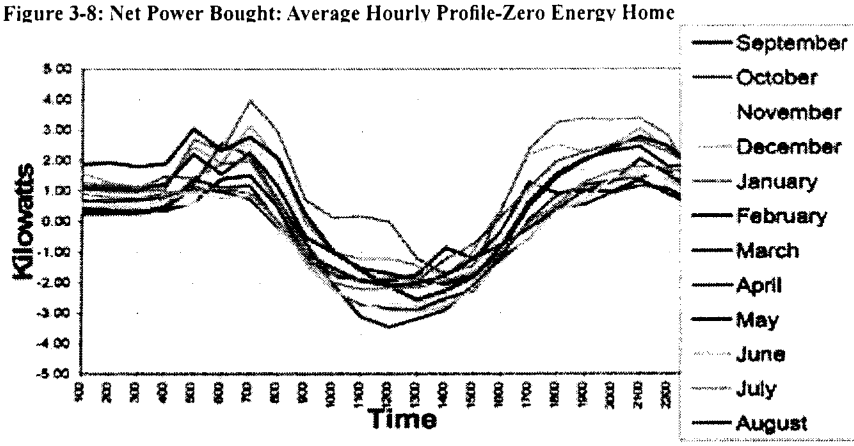
Provided by National Renewable Energy Laboratory.

Figure 3-7 Monthly Values of Available Insolation for the Equator, 30°, 60°, and 90°North



Created by Michael Pidwirny. See Pidwirny 2006 and www.physicalgeography.net

Figure 3-8: Net Power Bought: Average Hourly Profile-Zero Energy Home

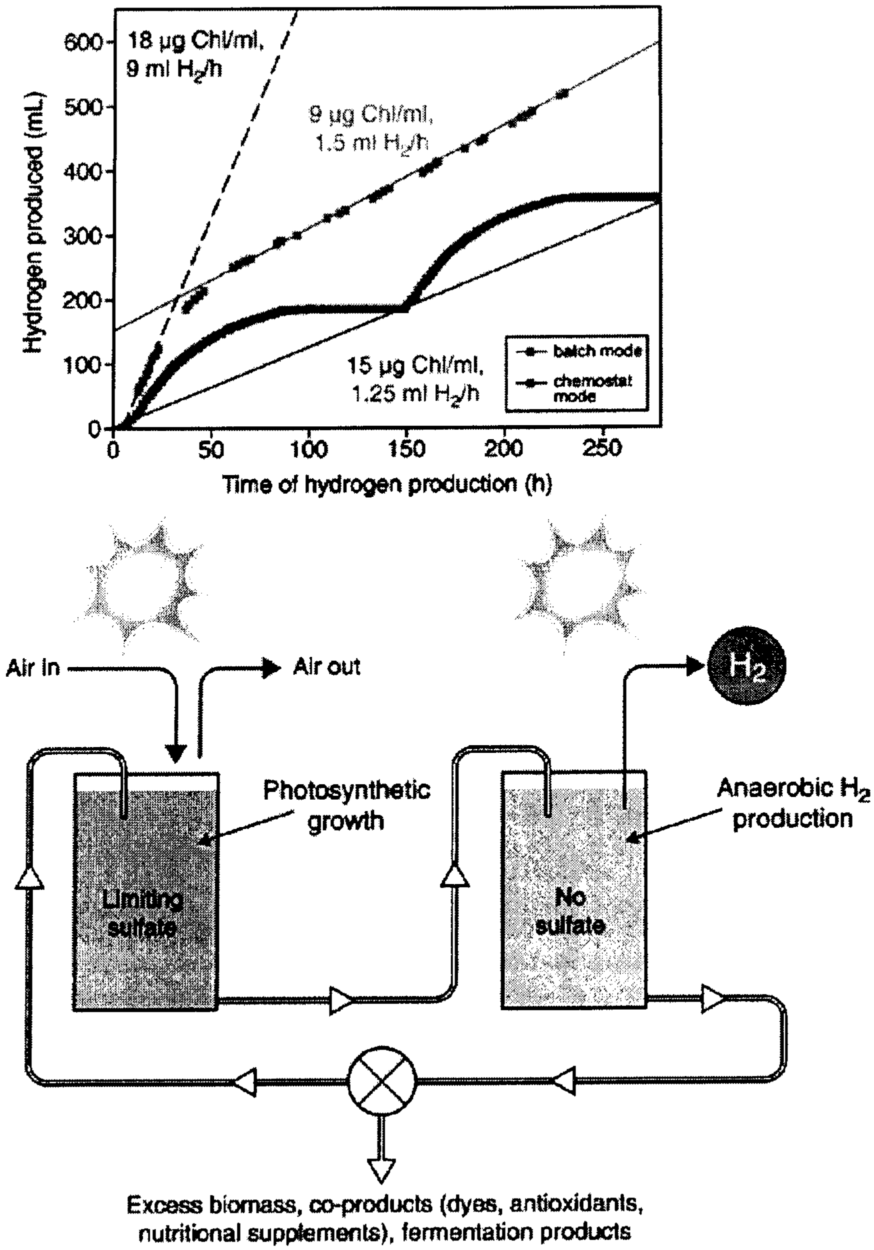


Courtesy of Environmental Resources Trust, Inc.

Figure 3-12: Water Hyacinths Can Yield up to 250 Metric Tons per Hectare in Warm Climates

Courtesy of Center for Aquatic and Invasive Plants, Institute of Food and Agriculture Sciences School, University of Florida

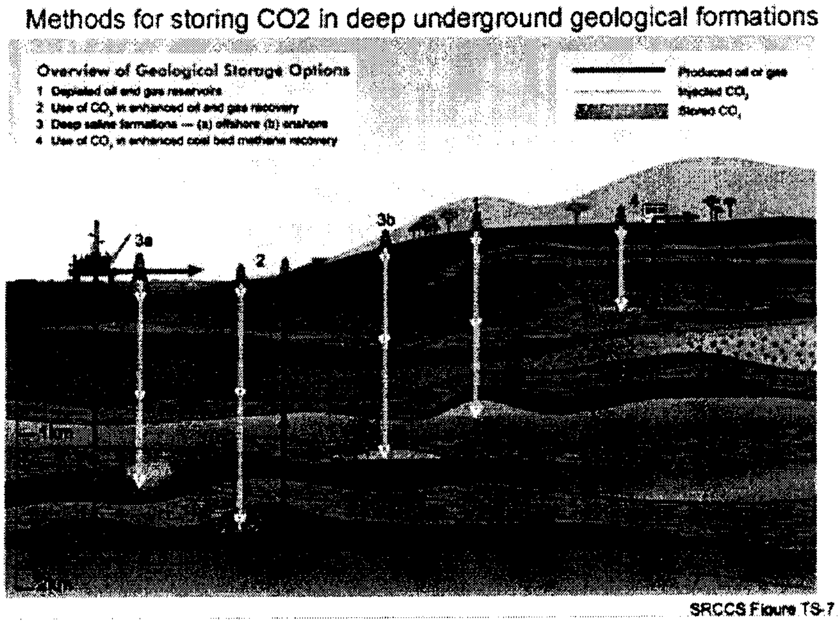
Figure 3-15: Direct Solar Production of Hydrogen Using Algae



This diagram/graph was developed by the National Renewable Energy Laboratory for the U.S. Department of Energy. See Ghirardi and Seibert 2003.

Note: In the *"batch mode"* the production is stopped periodically to replenish the nutrients. In the *"chemostat mode"* nutrients are supplied continuously to maintain production. "Chl" stands for chlorophyll.

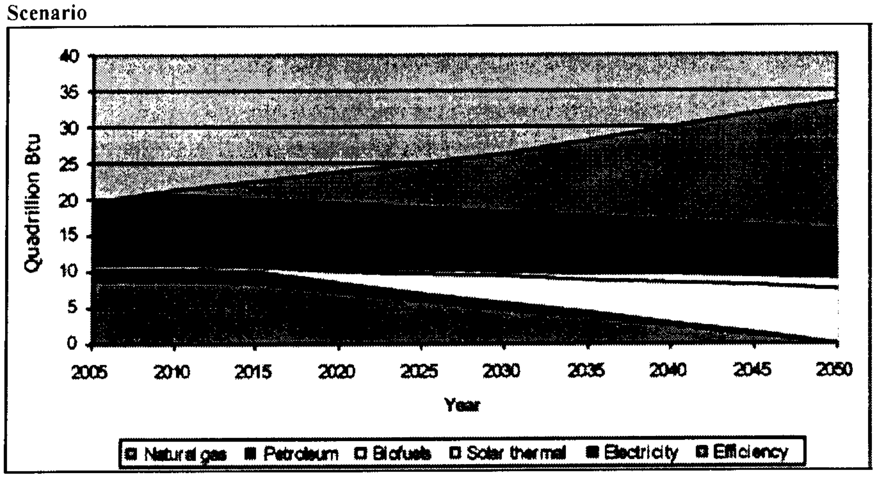
Figure 3-17: Schematic Showing Different Methods of CO_2 Sequestration



Source: IPCC 2005 Figure TS.7 (page 32). Used with permission.
Note: Airhart 2006 provides a good summary of sequestration.

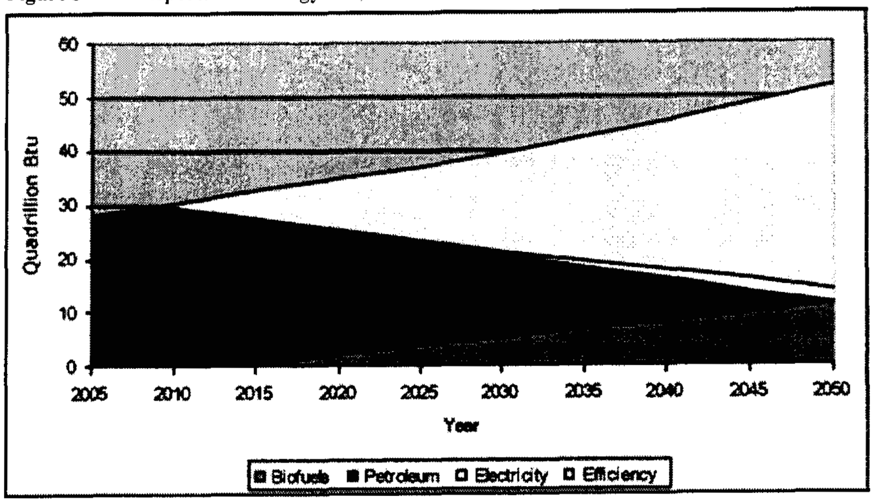
Chapter 5

Figure 5-2: Residential and Commercial Energy, Delivered Energy Basis, IEER Reference Scenario



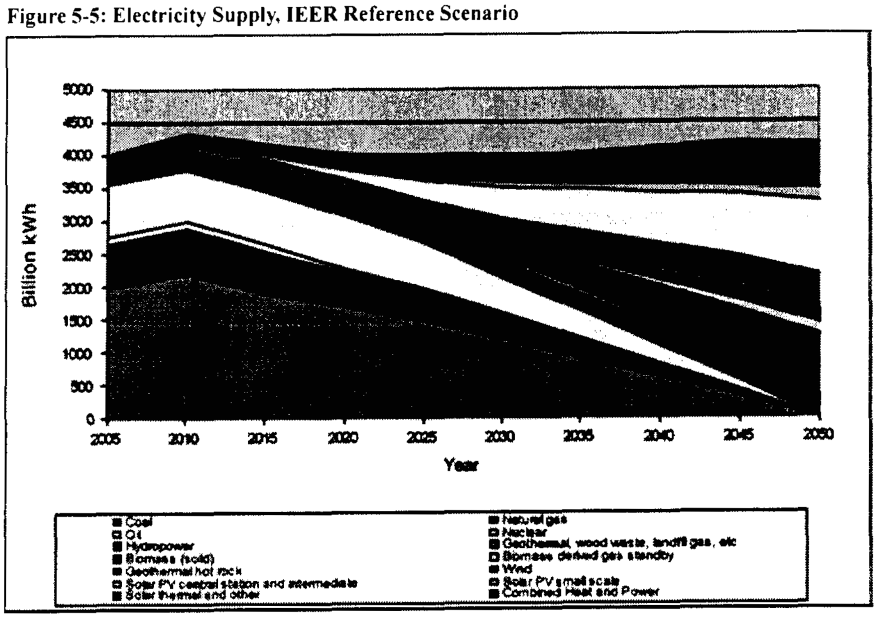
Source: IEER

Figure 5-4: Transportation Energy Use, IEER Reference Scenario



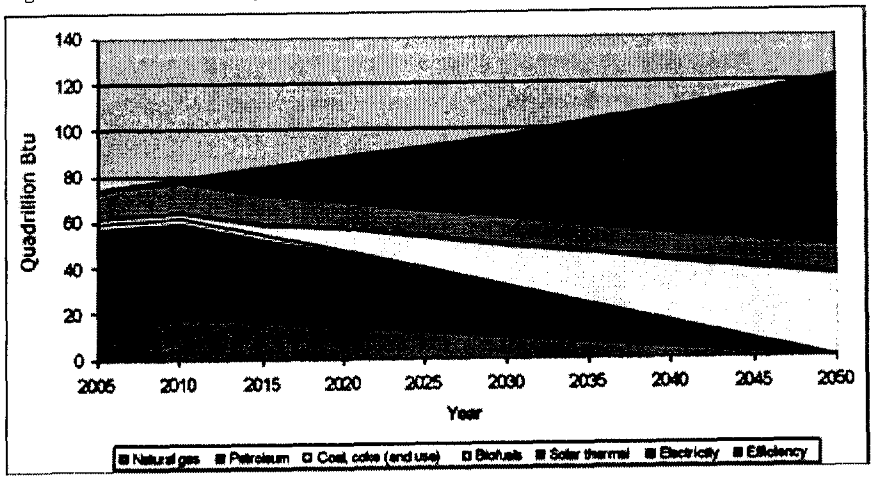
Source: IEER

Figure 5-5: Electricity Supply, IEER Reference Scenario



Source: IEER

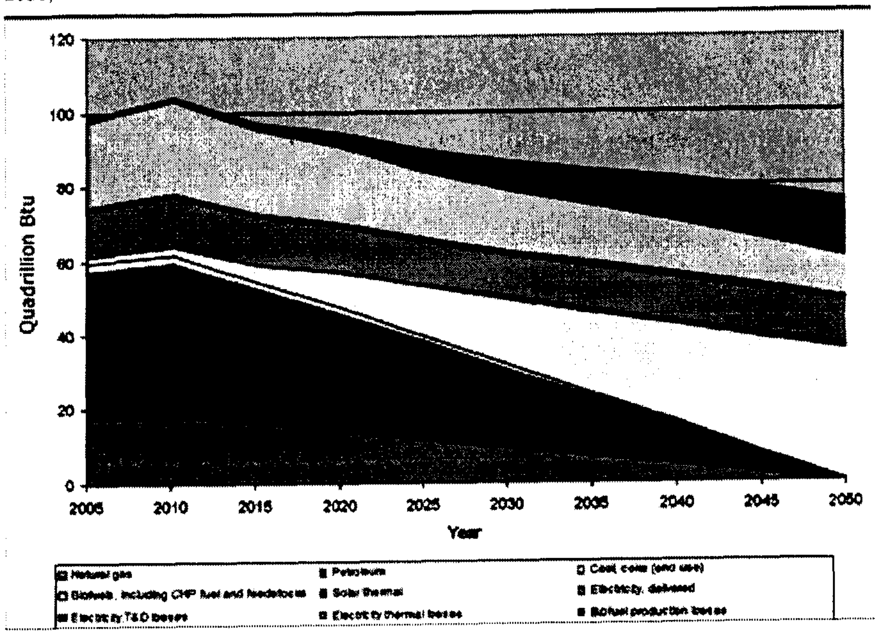
Figure 5-7: Delivered Energy, IEER Reference Scenario



Source: IEER

Note: Fuels used for electricity generation are not shown here. See Figure 5-5.

Figure 5-8: Total Energy Inputs in the Transition to a Zero-CO_2, Non-nuclear Economy by 2050, IEER Referene Scenario



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'An artefact of prior decisions otherwise concealed'

Walt Patterson argues that electricity cost comparisons are political, not economic

Posted by David Roberts at 10:14 AM on 09 Oct 2007

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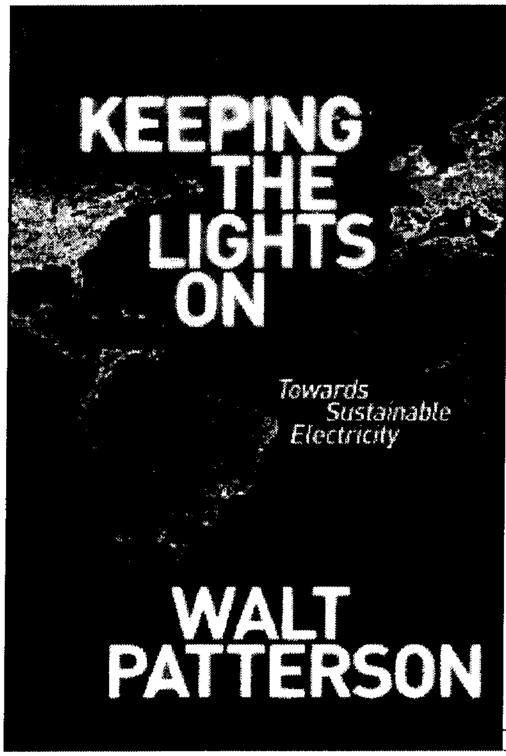
Comparisons of electricity generation costs from various sources are a ubiquitous feature of energy discussions. Virtually everyone accepts as fact that coal is the cheapest source of electricity, that natural gas is the next cheapest, that solar PV is the most expensive, that wind is competitive in some states and not others, etc. Sometimes the specific numbers that support these comparisons are contested; cents-per-kilowatt-hour are adjusted up or down by a few cents here and there. **What is rarely if ever questioned is the underlying assumption that objective cost comparisons are possible** when it comes to varieties of electricity generation.

These comparisons have always rubbed me the wrong way. Intuitively, their purported objectivity has always struck me as a veneer covering dozens of contestable and sometimes arbitrary assumptions. Worse, they're often used as rhetorical bludgeons to shut down discussion, substituting economics for what are essentially political, even moral, decisions.



However, I'm not smart enough, and don't know the electrical industry well enough, to mount a decent argument to that effect. Imagine my delight, then, when I stumbled across someone who *is* smart enough, and who knows the industry like the back of his hand, making the case for me. He is energy guru Walt Patterson, and the argument is made in his latest book *Keeping the Lights On: Towards Sustainable Electricity*. (It's fairly dry, and some parts make by brain hurt, but it will change the way you think about electricity in particular and energy in general.)

In a nutshell, his argument is this: "**As far as comparative costs are concerned, the choice of generation is political, not economic.**" He supports that thesis with the following points:

- The cost of a given generator's electricity depends on the entire electricity system -- other generators, the grid, and loads. Under such conditions of "continually shifting non-linearity," the unit-cost of electricity from the generator is constantly shifting. Further, it shifts in different ways and at different speeds and scales for different types of generators. This makes comparison across generation types "egregiously tendentious."
- Traditional electricity cost estimates are based on "engineering economics rather than financial economics" -- that is to say, they take no account of risk over the life of the generator, including shifting fuel prices and fuel taxes (and, I would add, regulations). Different generators have different risk profiles that can dramatically affect costs over time.
- The costs of so-called "externalities" -- social and environmental costs not borne by generators themselves -- are to a large degree arbitrary and unquantifiable. Decisions on how to account for externalities are driven by politics, not science.

Under the fold is a longish passage wherein Patterson makes the case in more detail. It's from Chapter Six: "Generating Change" (a working version of the chapter is available as a PDF; I've added some links and emphases). I hope everyone will read it.

In an interconnected electricity system, not only the revenues but also the costs of a particular generator depend to a significant extent on the rest of the system and how it operates. To give but one obvious example: if the system load and other generation make a given steam-cycle unit operate at below maximum capacity -- as is often the case -- the unit's fuel-efficiency falls, and its output therefore costs more per unit. **Against this background of continually shifting non-linearity, the common practice of stating the 'cost' of a unit of electricity as '2.7 cents per kWh' or some similar figure is frankly indefensible.** It becomes yet more so when such numbers, stated even to three significant figures, are used to advocate or justify choosing to invest in a particular generator technology or design as against others claimed to produce 'more expensive' electricity. The practice was disreputable even when the choice lay between otherwise similar technologies, as for example between types of coal-fired or nuclear generation. When the choice is between technologies so fundamentally different, say, as gas-fired combined cycles and photovoltaics, the use of such purported cost comparisons becomes egregiously tendentious.

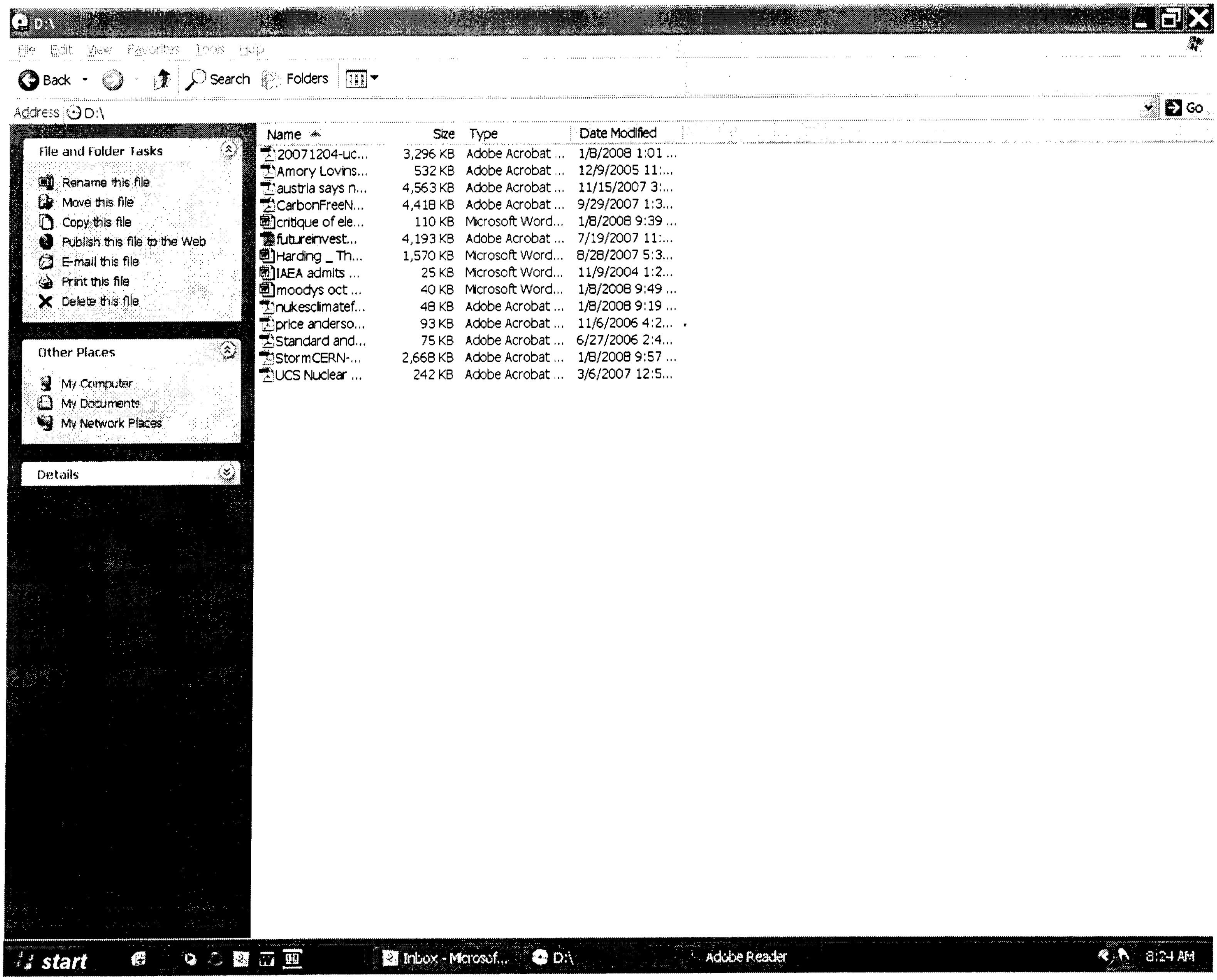
In any case, moreover, recent studies suggest that traditional techniques of estimating the anticipated cost of electricity from a proposed generator may be inherently and seriously flawed. In 2002 Shimon Awerbuch, at the time a senior advisor in the Renewable Energy Unit of the International Energy Agency, produced a draft report called *Estimating Electricity Costs and Prices: The Effects of Market Risk and Taxes*. The report demonstrated just how untrustworthy such estimates can be. The thesis was straightforward, if complex to demonstrate. It declared that **the traditional approach to estimating the cost of electricity from a particular generator is based on engineering economics rather than financial economics**. Engineering economics fails to apply a premium to account for the risk that over the life of the generator fuel prices and fuel taxes may vary from those used to estimate the cost of electricity. So long as alternative generating options have broadly similar risks, and those risks move in the same direction with contingencies, the effect on choice of generating technology may be modest to trivial. However, **between technologies with dramatically different risk profiles, failure to account for risk may drastically skew the comparison of costs**.

Consider, for instance, comparing fuel-based generation with non-biomass renewable generation -- say, a gas-fired combined cycle station with a wind farm. An investor trying to choose between putting money into one or the other will be aware that the price of natural gas may rise unpredictably during the operating life of the combined-cycle station. The investor will therefore require a higher return, to compensate for the risk that the station output may not be as profitable as anticipated. That in turn will increase the cost of generating a unit of electricity. For the wind farm, however, no such fuel-price risk arises. Apart from small and predictable running costs for maintenance, the entire cost of the wind farm is the initial capital investment, known at the outset and unvarying over the operating life of the wind farm. Using well-established techniques of financial analysis demonstrates that adding renewable generation free of fuel-price risk to a generating portfolio otherwise based on fossil fuels reduces the risk for an equivalent return, or alternatively increases the return for the same risk.

Again, an increase in fossil fuel prices appears to be strongly correlated with a downturn in overall economic activity, reducing demand for electricity and aggravating the problem of higher electricity cost. Renewables, however, whose costs are mainly servicing capital charges, may actually benefit from the economic downturn, if interest rates fall. Adding renewables thus diversifies the portfolio and reinforces its robustness against unwelcome surprises. The prevailing assumption is that official support for renewables, especially in Europe, is making electricity more expensive. The financial reality, however, may well be that adding renewables free of fuel-price risk should reduce the overall investment cost of generation on systems. Developing and extending this ground-breaking comparative analysis of generating options, refining and sharpening estimates of comparative cost in this way could have striking consequences for the technology choices that drive the evolution of electricity systems.

Other aspects of comparative generating cost are likewise controversial. For instance, environmental impacts associated with different forms of generation have been called 'externalities' because their putative costs are borne not by the generator but by the environment within which it operates -- the air, the land, the water, and by extension the other people who use the same environment. The decision as to whether and how to account for such externalities has a dramatic effect on the cost, operability and profitability of individual generating plant. Over the years analysts, planners, legislators and regulators have tried to quantify these externalities, and incorporate some suitable numerical and financial measure into the costs attributed to generators. The judgements are necessarily arbitrary; some consider them invidious. **Comparative quantification, perhaps in cents or pence per unit, of the different environmental impacts of, say, coal-fired, nuclear or wind-powered generation is ultimately political, not scientific.**
...

All in all, what with assorted, perverse and often enormous subsidies to fossil fuels and nuclear power, and more modest but more visible subsidies for renewables; with inadequate accounting for risks; and with arbitrary and distorted provisions for externalities, only one conclusion can be drawn. **As far as comparative costs are concerned, the choice of generation is political, not economic. Electricity costs stated as so many cents or pence per kilowatt-hour are just window-dressing after the fact, an artefact of prior decisions otherwise concealed.** The same applies to the other original nineteenth-century criteria for choice of generation. Size and location are profoundly affected by politics, especially planning constraints on siting and operation. So is connection to networks ... **Once we acknowledge that the choice of generating technology, including its type, size, location and network connection, is fundamentally political, electricity policy takes on a significantly different flavour.**



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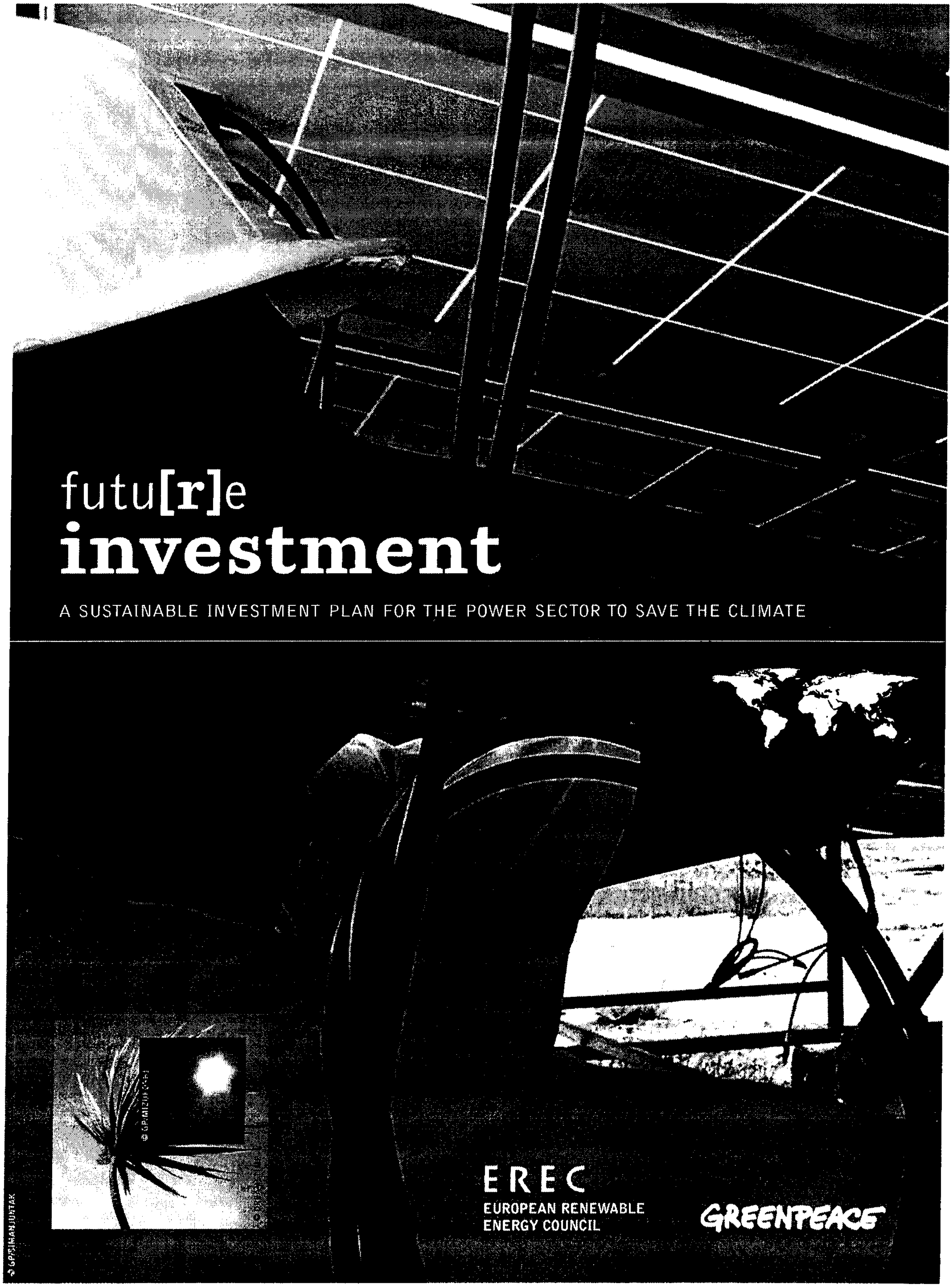

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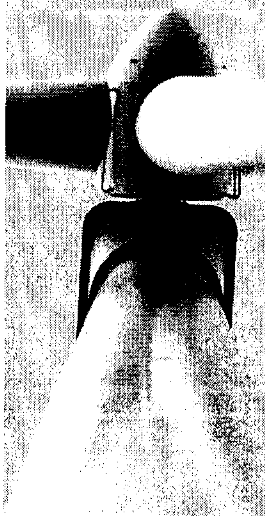

Greenpeace International, European Renewable Energy Council (EREC)

date July 2007

"Futu[r]e Investment" is based on the Global Energy Scenario report "Energy [R]evolution", published in January 2007. "Futu[r]e Investment" takes a step further by looking at the changes needed in investment by the power sector into renewable energy to fully realise the outcomes of the "Energy [R]evolution". For further information about the "Energy [R]evolution" please see the full report at www.energyblueprint.info.

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cover image SOLAR AND WIND ENERGY GENERATION.
image WIND TURBINE.

foreword

2007 has seen unprecedented momentum on the issue of climate change, from an unequivocal conclusion by scientists that it is underway to the sobering impacts and the cautiously optimistic economics of what it might cost to curb climbing temperatures. A big part of the economics—of the transition to a low carbon global GDP—will be technology including energy generation systems allied to the enormous energy efficiency gains possible in homes, workplaces, power plants and in the transportation sector.

Renewable energies, from wind and solar to biomass and geothermal will have an important role to play in switching the globe's economies onto a more climate-friendly trajectory if intelligent market instruments continue to be deployed and expanded. Meanwhile increased investment in research and development could see other kinds of renewables such as ocean thermal energy conversion, tidal and wave power becoming commercial and widespread over the decades to come.

The scale and pace of investments in commercial forms of renewables has been rising in recent years at an exceptional speed. Wind, solar and biomass are now in some areas, independent of oil prices. Around 18 per cent of global investment, or about $100 billion in power generation in 2006, was in renewables by some estimates. Much of this is in OECD countries, but there is also emerging interest in developing countries, in particular in China and India, where new renewable corporations are emerging as global players.

The growth is also spawning a new generation in high-tech industries and jobs with some experts estimating that by 2020 more people in Germany, for example, will be employed in environmental industries like renewables than in the automotive industry.

There are many factors driving this surging interest including energy security concerns. But above all it is the issue of climate change and the need to address greenhouse gas emissions which is at the heart of the renewable investment rush. The United Nations, via the Kyoto Protocol emission reductions treaty and its flexible mechanisms, can take some credit for establishing innovative markets that are accelerating deployment of renewables in developed and developing countries. Indeed the Clean Development Mechanism is set to deliver financial flows in part to renewable energy schemes of some $100 billion, perhaps more over the coming years.

The attraction of renewables goes beyond their simplicity and their greenhouse gas emission reduction potential. In many rural areas of developing countries they offer a rapid chance for poorer communities to gain access to electricity without waiting for a grid.

A United Nations Environment Programme report on the world's deserts noted that there is enough solar power in an 800 by 800 km area of a desert, such as the Sahara to generate all the world's electricity needs and more. Part of this could be used to generate electricity directly or to produce hydrogen—a promising alterative fuel. Over the coming few months we will gain an insight into whether the political world is ready to back the deep emission reductions urgently needed post 2012 which will stimulate renewable energy investments even further.

The European Union has set a 20 per cent emission reduction for 2020 and positive signals are emerging from other quarters including Japan and the United States. Some countries, from Costa Rica and New Zealand to Norway have pledged to go carbon neutral by mid century. The speed at which the transition to a low, perhaps even de-carbonised economy will occur, will depend on serious and sustained political will if we are to achieve the ultimate goal of an up to 80 per cent cut in greenhouse gases. It will also depend on creative thinking and a dispassionate assessment of all the options available.

This new report is just the kind of publication that will strike a thoughtful chord with the expert and the novice in the field of renewable energy. I am sure it will spark even greater interest and action towards a more sustainable, climate friendly, energy mix and allow renewables to achieve their full and very exciting potential.

Achim Steiner
UNEP
JULY 2007

introduction

THIS REPORT SHOWS THAT INVESTMENT IN RENEWABLES PAYS OFF QUITE QUICKLY DUE TO MASSIVE SAVINGS IN FUEL COSTS. IN FACT, A 'BUSINESS AS USUAL' MIX IN THE WORLD GLOBAL POWER GENERATION SECTOR WOULD RESULT IN 10 TIMES HIGHER FUEL COSTS, WHEN COMPARED TO THE ADDITIONAL INVESTMENT NEEDED TO IMPLEMENT THE ENERGY [R]EVOLUTION PATHWAY.

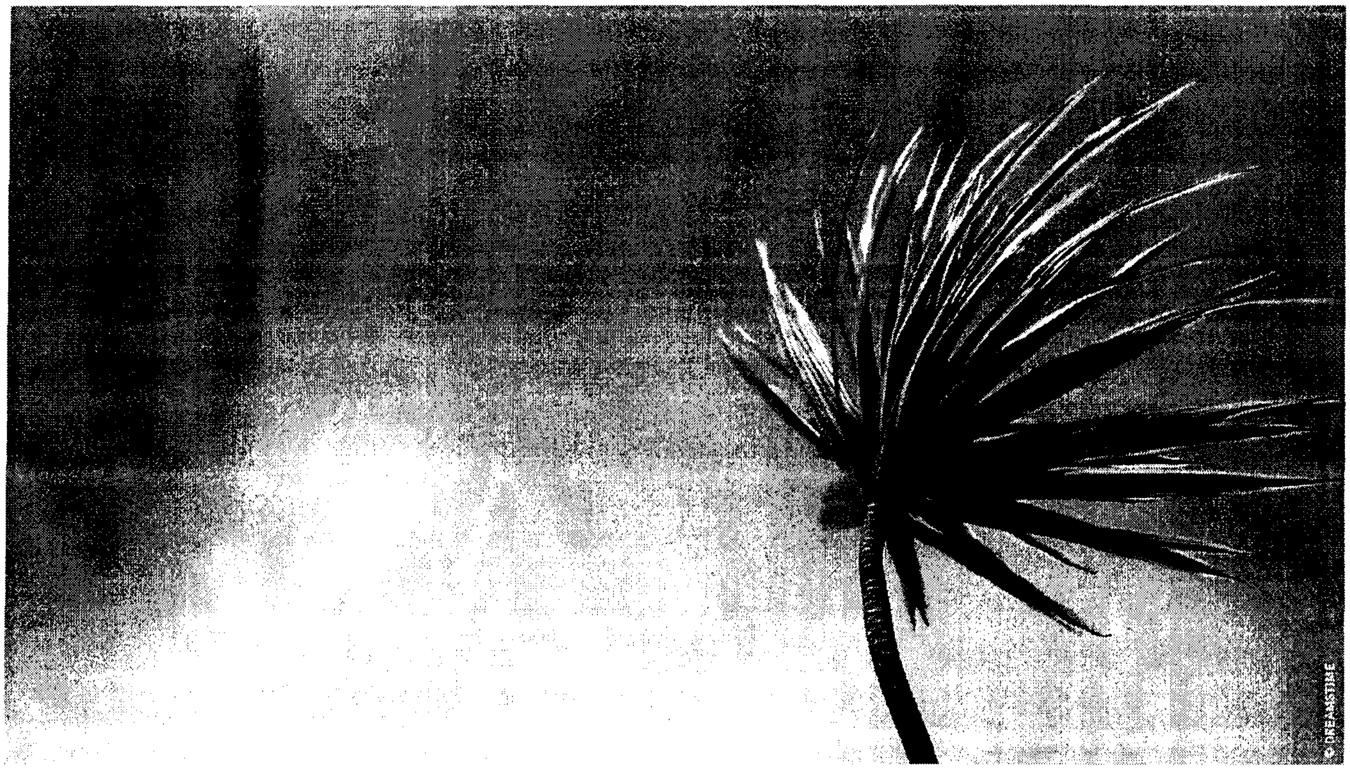


image HARNESSING NATURE'S SUSTAINABLE ELEMENTS.

Since "*Energy [R]evolution*" was first published at the end of January 2007, Greenpeace and EREC have received an overwhelming wave of support. The *Energy [R]evolution Scenario* is a real alternative to the IEA's world energy outlook – and the only practical blueprint for how to cut global energy related CO_2 emission by 50% by 2050 to avoid dangerous climate change, while maintaining global economic growth.

The *Energy [R]evolution* report shows that renewable energy is not a dream for the future – it is real, mature and can be deployed on a large scale. Decades of technological progress have seen renewable energy technologies such as wind turbines, solar photovoltaic panels, biomass power plants, geothermal power and solar thermal collectors move steadily into the mainstream. The global market for renewable energy is growing dramatically; in 2005 its turnover was US$38 billion, 26% more than the previous year.

The time window for making the shift from fossil fuels to renewable energy is very short. Within the next decade many of the existing power plants in the OECD countries will come to the end of their technical lifetime and will need to be replaced. But a decision taken to construct a coal power plant today will result in the production of CO_2 emissions until 2050.

Energy policy options and future pathways are naturally influenced to a huge extent by political decision makers. Decisions need to be made now. Plans made by power utilities over the next few years will define the energy supply of the next generation. We strongly believe that this should be the "solar generation". The current energy supply structure can clearly not be maintained in a sustainable way. The economic, social and environmental costs would be unacceptable to humanity.

Over the coming two decades we will witness the largest turnover in electricity generating technology the world has ever seen. Existing plants will need to be retired, in addition new plants will have to be built to satisfy the increasing global demand for power - not least from India and China. We must use this opportunity to change our energy supply structure to include a much larger share of indigenous, renewable resources, so we can develop our economies on the basis of known and predictable costs of electricity.

During the last few months, as we have presented the *Energy [R]evolution Scenario* at press conferences, energy conferences and one-to-one interviews with politicians, financial experts and utilities, it has become clear that detailed investment figures for our scenario are of great interest. Therefore, this report takes a close look at the investment pathways of the power sector. We concentrate on the power sector, because comparative figures were more easily available.

image UTTARADIT, THAILAND, 26 MAY 2006. DESTRUCTION ENGULFS THE DISTRICT OF LABLAE IN UTTAPADIT PROVINCE AFTER A MUDSLIDE SWEPT THROUGH THE DISTRICT AND DESTROYED EVERYTHING ON ITS PATH. MORE THAN A HUNDRED ARE FEARED DEAD AND MISSING AS THE PROVINCE OF UTTARADIT AND OTHER NORTHERN THAI PROVINCES WERE SUBMERGED IN THE AREA'S WORST FLOODS IN RECENT HISTORY. SCIENTISTS WARN THAT EXTREME WEATHER EVENTS DUE TO CLIMATE CHANGE WILL HIT HARD AND MORE OFTEN IN THE COUNTRY, ALONG WITH OTHER PARTS OF ASIA.

First positive developments

Wind provides an example of what is possible if technological development accompanies favourable political development. Wind energy had a record year in 2006. Global demand for wind power capacity grew by 32%, following an increase in the market of more than 40% in 2005. The value of wind turbines sold last year was €18 billion. In Europe, for the seventh consecutive year, wind power was second only to gas in terms of new capacity. New wind power installations in 2006 amounted to 7588 MW, seriously challenging gas (approximately 8500 MW in 2006) as the preferred European choice in electricity generating capacity. A similar pattern is emerging in the US, where wind was second only to gas in terms of new installations in 2005, according to the US Energy Information Administration. The same is expected for 2006. A similar success story could be told for other technologies such as solar PV which has shown average growth rates above 30% during the last few years. Between 2001 and 2005, 35% of all new capacity installed in the EU was based on renewables.

For the majority of countries experiencing high and increasing energy imports, the coming years will be a balancing act between reducing import dependence and exposure to fluctuating and unpredictable fuel import prices on the one hand, while simultaneously working to curb emissions of greenhouse gases and other pollutants from electricity generation on the other. We have a 10-year window to avoid irreversible damage to the world as a result of man-made climate change. Deploying indigenous wind energy and building new gas plants, while securing gas supplies, is certainly not the worst response importing countries can make when trying to navigate through the increasingly challenging climate and energy situation.

As mentioned, the global market for wind turbines was worth some €18 billion in 2006. The amount comes very close to the increase in the EU's gas bill every time the price of oil increases by US$20. The European Commission has calculated that for every US$20 increase in the price of oil, the price of Europe's gas imports rises by €15 billion annually, given the unfortunate link between gas and oil prices. For comparison, the cost of wind turbines installed in Europe in 2007 was approximately €9 billion. A tripling of oil prices from US$20 to US$60, as we have experienced in the past few years, thus adds €30 billion annually to Europe's gas import bill, and constitutes a transfer of wealth from Europe to gas-exporting countries. Europe is not an isolated case. Very few countries are net exporters of fuel, and even fewer will be in the future. Due to the concentration of the remaining reserves, most countries will be transferring an ever-increasing share of their wealth abroad if imports continue to grow and prices continue to rise. And there is only one long-term direction for oil and gas prices: up!

The dependence on few fossil fuel sources is of particular concern in many developing countries. Some developing countries spend nearly all their development aid on coping with increasing - and volatile - oil prices. Europe, as well as North America, Japan, India, China and many other importing countries will have to accept a transfer of wealth to fuel exporters in the medium term. But the impact on their economies and the global environment can be limited, in the short, medium and long term, through much-needed energy efficiency measures and the deployment of renewables.

The battle for energy in this century will not be won by following the strategy that proved to be the winning one in the 20th century, i.e. of either producing fuel or of controlling fuel supplies. It will be won by those regions of the world that have the foresight to act now to protect their economies and the global climate. It will be won by the regions that excel in developing, deploying and exporting renewable energy technologies to a world that cannot afford to do without them. A well-known consultancy has just produced a report saying that by 2020 in Germany, environmental technologies will be the major industry, ahead of the automobile and steel industries for which Germany is famous.

Long term energy policy will attract investors

In order to build up a large scale renewable industry – big enough to satisfy the growing demand for power supply globally – long term energy policies are needed. Short term thinking – aimed at 'the next election' - will have dire consequences for future generations. Those countries with long term policies for renewable power generation such as Germany, Spain and Denmark have been able to build up strong renewable industries. The weaker the policy, the smaller the renewable industry and the higher the prices for power generation equipment.

We have shown two best practice examples for renewable power policy: The German Feed-in law and the Texas Renewable Portfolio Standard – just two out of numerous good examples around the world. The money is available, so it's just a matter of lowering the risk for RE investors and making RE investments commercially viable through a defined and stable return that can only be provided by appropriate government policies. The bottleneck therefore is not because there is no money for renewables but because there is either a total absence of policy to encourage major investment in renewable energy, or weak policies that result in smaller scale investments, hence the impression that renewables can only work on a much smaller scale.

This report shows that investment in renewables pays off quite quickly due to massive savings in fuel costs. In fact, a 'business as usual' mix in the world global power generation sector would result in 10 times higher fuel costs, when compared to the additional investment needed to implement the *Energy [R]evolution* pathway.

Today's politicians can change the energy supply for the next generation – a good argument for the next election! As more and more people will say:

"I love renewable energy – and I vote!!"

Oliver Schäfer   Sven Teske

Oliver Schäfer
EUROPEAN RENEWABLE
ENERGY COUNCIL (EREC)
JULY 2007

Sven Teske
CLIMATE & ENERGY UNIT
GREENPEACE INTERNATIONAL

executive summary

THE AVERAGE ANNUAL FUEL COST SAVINGS OF THE ENERGY [R]EVOLUTION SCENARIO IS 10 TIMES HIGHER THAN THE ADDITIONAL INVESTMENT COST OF THIS SCENARIO.

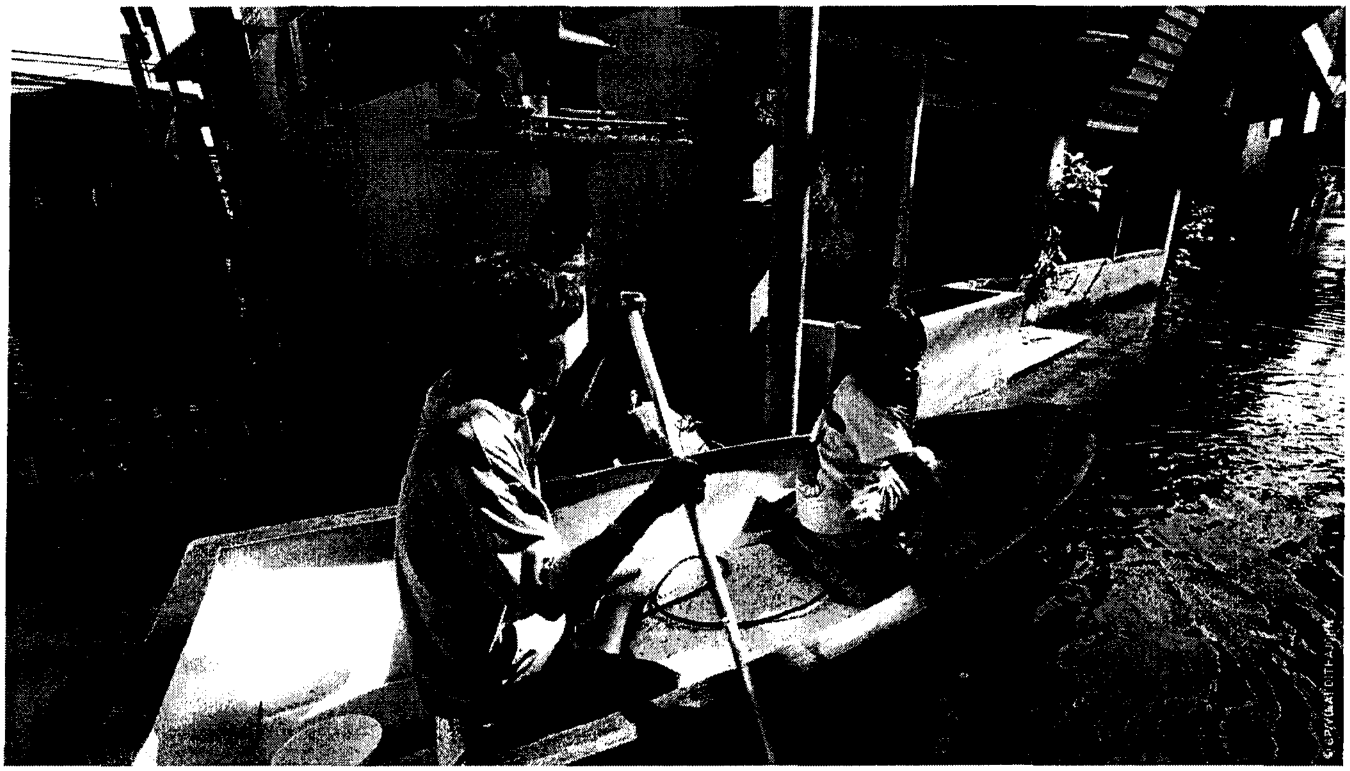


image 30TH OCTOBER 2006 NONTHABURI, THAILAND - VILLAGERS PADDLE A BOAT AT A VILLAGE IN KOH KRED ISLAND WHICH WAS ENGULFED BY RECENT FLOODING. KOH KRED IS A TINY ISLAND IN THE CHAO PHRAYA RIVER, LOCATED IN NONTHABURI PROVINCE OUTSKIRT OF BANGKOK. EARLIER IN THE YEAR, SCIENTISTS WARNED THAT THAILAND WOULD EXPERIENCE MORE FREQUENT EXTREME WEATHER EVENTS DUE TO THE IMPACTS OF CLIMATE CHANGE.

climate threats and solutions

Global climate change, caused by the relentless build-up of greenhouse gases in the Earth's atmosphere, is already disrupting ecosystems and causing about 150,000 additional deaths per year. An average global warming of 2°C threatens millions of people with an increased risk of hunger, malaria, flooding and water shortages.

If rising temperatures are to be kept within tolerable limits then we need to significantly reduce our greenhouse gas emissions. This makes both environmental and economic sense. The main greenhouse gas is carbon dioxide (CO_2) produced by using fossil fuels for energy and transport.

Recent large increases in the price of oil and gas; the 'weaponisation' of energy supplies for political purposes (i.e., Russia/Ukraine, Russia/EU, Venezuela/US, Argentina/Chile, etc.); and the dependence of many economies on sources of supply in some of the most unstable regions of the world, have brought the issue of security of supply to the top of the energy policy agenda.

One reason for the price increases is that supplies of all fossil fuels - especially oil and gas - are becoming scarcer and more expensive to produce. The days of "cheap oil and gas" are coming to an end. This opens the door for the use of unconventional sources like oil shale or tar sands with huge environmental impacts. Coal also faces rising prices. China, a former coal exporting country will soon import increasing amounts of coal to satisfy its booming economy. In addition, the outlook for capturing and storing CO_2 after 2020 (irrespective of whether this is realistic or just wishful thinking) is encouraging industrialised countries to built new coal power plants in the coming years.

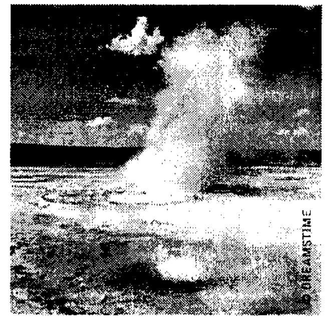
Uranium, the fuel for nuclear power, is also a finite resource.

By contrast, the reserves of renewable energy that are technically accessible globally are large enough to provide about six times more energy than the world currently consumes - forever.[1]

Renewable energy technologies vary widely in their technical and economic maturity, but there are a range of sources which offer increasingly attractive options. These sources include wind, biomass, photovoltaic, solar thermal, geothermal, ocean and hydroelectric power. Their common feature is that they produce little or no greenhouse

references
1 ISES / DR. STRADMANN / DR. NITSCH

image GEOTHERMAL ACTIVITY.



gases, and rely on virtually inexhaustible natural sources for their "fuel". Some of these technologies are already competitive. Their economics will further improve as they develop technically, as the price of fossil fuels continues to rise and as their saving of carbon dioxide emissions is given a monetary value globally.

At the same time there is enormous potential for reducing our consumption of energy, while providing the same level of energy 'services'.

Nuclear power plants pose multiple threats to people and the environment from their operation. These include the risks and environmental damage from uranium mining, processing and transport; the risk of nuclear weapons proliferation; the unsolved problem of nuclear waste; and the potential hazard of a serious accident. Therefore nuclear is not considered in this analysis. The solution to our future energy needs lies instead in greater use of renewable energy sources for both heat and power.

Carbon dioxide capture and storage (CCS) is a technology still under development. Although the number of pilot projects under development is increasing, no project including a coal power plant with CO_2 storage has so far been realised. The earliest CCS will begin is 2020, it will probably not become commercially viable until 2030. CCS is expensive and increases the costs of power generation between 40% and 80% compared with conventional power plants, depending on the location of the plant, the storage site, and the transport and capture technology used. CCS also further reduces the efficiency of power plants and thus requires more resources. In addition, all CCS technologies require that between 11% and 40% more fossil fuel resources are used to generate the same amount of electricity[2], also incurring proportional additional environmental damage from air and water pollution associated with extraction of that extra fuel. CCS produces additional long-term costs. Monitoring and verification over the years is necessary to guarantee the retention of the stored carbon dioxide. Even then, opportunities to intervene in order to prevent or control unexpected leakage are likely to be limited. Therefore CCS is not considered in this analysis.

the energy [r]evolution of the power sector

Two scenarios up to the year 2050 are outlined in this report. The *Reference Scenario* is based on the Reference Scenario published by the International Energy Agency in World Energy Outlook 2004, extrapolated forward from 2030. Compared to the 2004 IEA projections, the new World Energy Outlook 2006 assumes a slightly higher average annual growth rate of world GDP of 3.4%, instead of 3.2%, for the 2004-2030 time horizon. At the same time, WEO 2006 expects final energy consumption in 2030 to be 4% higher than in WEO 2004. A sensitivity analysis on the impact of economic growth on energy demand under the *Energy [R]evolution Scenario* shows that an increase of average world GDP of 0.1% (over the time period 2003-2050) leads to an increase in final energy demand of about 0.2%.

The *Energy [R]evolution Scenario* sets a target for the reduction of worldwide emissions by the power sector of 60% below current levels by 2050. A second objective is the global phasing out of nuclear energy. To achieve these targets, the scenario is characterised by significant efforts to fully exploit the large potential for energy efficiency. At the same time, all cost-effective renewable energy sources are accessed for electricity generation, and cogeneration from both fossil fuels and renewable energy sources (such as geothermal and bio energy) is expanded.

Today, renewable energy sources account for 18% of the world's electricity demand. Large hydro power plants are currently the largest renewable source, but wind energy is rapidly picking up. The share of new renewable energy (e.g. solar energy, biomass, and geothermal) in electricity generation is currently well under 1%, but with double digit growth rates in the past decade. The *Energy [R]evolution Scenario* describes a development pathway which transforms the present situation into a sustainable energy supply:

- Exploitation of the large energy efficiency potential will slow down the rapidly growing electricity demand from the current 13,675 TWh/a (billion kWh per year) to 26,000 TWh/a by 2050. Under the *Reference Scenario* there would be an increase to 39,000 TWh/a. Commitment to a successful efficiency strategy within the power sector is a crucial prerequisite for achieving a significant share of renewable energy sources, compensating for the phasing out of nuclear energy and reducing the consumption of fossil fuels.
- The increased used of combined heat and power generation (CHP) also improves the supply system's energy conversion efficiency, increasingly using natural gas and biomass. In the long term, decreasing demand for heat and the large potential for producing heat directly from renewable energy sources limits the further expansion of CHP.
- The electricity sector will be the pioneer of renewable energy utilisation. By 2050, around 70% of electricity will be produced from renewable energy sources, including large hydro. An installed capacity of 7,100 GW will produce 21,400 Terawatt hours per year (TWh/a) of electricity in 2050.
- By 2050, 16% of electricity generation will be covered by combined heat and power plants - roughly half of those plants will run on biomass, and more than 40% will use gas as a fuel.

To achieve an economically attractive growth of renewable energy sources, a balanced and timely mobilisation of all renewable technologies is of great importance. This depends on technical potentials, actual costs, cost reduction potentials and technological maturity.

references
2 IPCC SR ON CCS TECHNICAL SUMMARY TABLE TS.3

development of CO_2 emissions by the power sector

Worldwide CO_2 emissions by the power sector will almost double under the *Reference Scenario* by 2050 - far removed from a sustainable development path. But under the *Energy [R]evolution Scenario*, power sector emissions will decrease from 10,200 million tonnes in 2003 to 4,200 m/t in 2050. In spite of the phase-out of nuclear energy, and increasing electricity demand, CO_2 emissions in the electricity sector will decrease enormously due to the use of renewable energy and energy efficiency. With a share of 36% of total CO_2 emissions in 2050, the power sector will fall behind the transport sector as the largest source of emissions.

generation costs

Due to the growing demand for power, we are facing a significant increase in society's expenditure on electricity supply. Under the *Reference Scenario*, the undiminished growth in demand, the increase in fossil fuel prices and the costs of CO_2 emissions all result in electricity supply costs rising from today's US$1,130 billion per year to more than US$4,300 billion per year in 2050.

The *Energy [R]evolution Scenario* not only complies with global CO_2 reduction targets, but also helps to stabilise energy costs and thus relieves the economic pressure on society. Increasing energy efficiency and shifting energy supply to renewable energy resources leads to long term costs for electricity supply that are one third lower than in the *Reference Scenario*. Following stringent environmental targets in the energy sector pays off in economic terms.

investment in power plants

The global market for new power generation equipment is - after years of stagnation - booming. While most existing power plants are ageing and need to be replaced (= "repowering"), developing countries such as China and India are building up new infrastructures for rapidly increasing electricity demand.

There is huge opportunity in the next 5 to 15 years to invest in new sustainable and climate-friendly power generation. Every decision taken about new power plants today, will influence the energy mix of the next 30 to 40 years.

Renewable energy sources - with the exception of bioenergy power plants - do not need any fuel, which makes operation costs independent of fluctuating world market fossil fuel prices, and generation costs predictable over a period of 20 years and longer.

In the *Reference Scenario* there will be almost 10,000 new fossil fuel power plants[3] by 2030. Roughly half of those power plants will be run on gas, the other half on coal. Lignite power plants remain a niche market. New renewable energy capacity may be in the same range as new coal. However 70% of the new installed power plants in the *Reference Scenario* would be based on fossil fuel, 25% renewable and 5% nuclear. As new nuclear capacity would replace mainly old existing power plants, nuclear will remain marginal on the global scale.

figure 1: development of global electricity generation under the energy [r]evolution scenario

'EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO

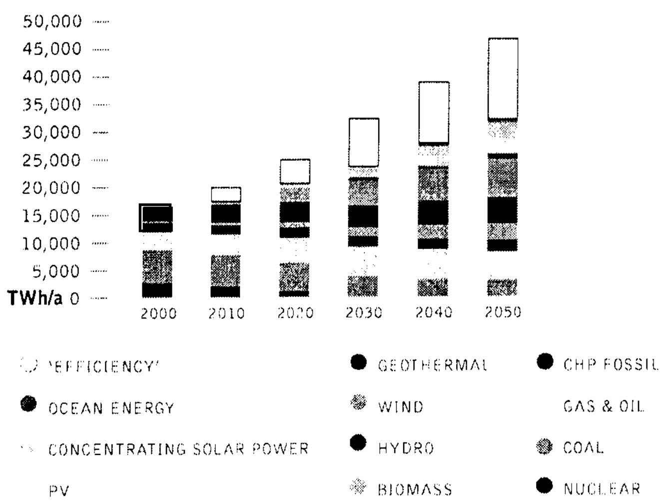
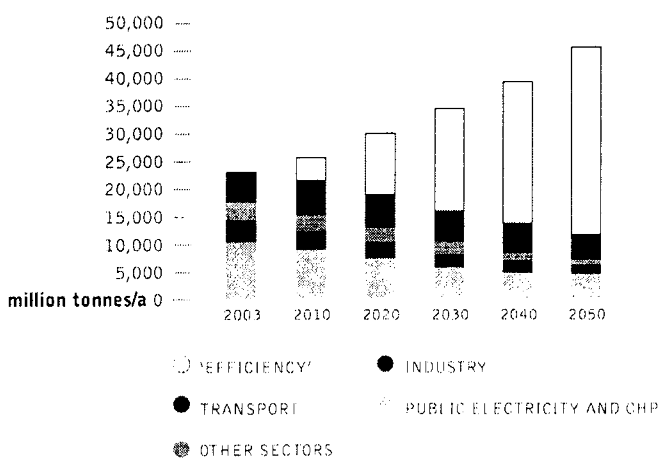


figure 2: development of global CO_2 emissions by sector under the energy [r]evolution scenario

'EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO



references

3 ASSUMING THAT THE AVERAGE SIZE IS 500 MW PER POWER PLANT

image SOLAR AND WIND FACILITY NEAR ROSTOCK.

In the *Energy [R]evolution Scenario*, however, there will be just 4,000 new fossil fuel power plants by 2030. A large percentage of those power plants are currently under construction or have gone online between 2004 and January 2007. Gas power plants - especially cogeneration - play an important role. More than half of the new power plants run on gas, the remainder on coal. Lignite power plants will not be built under the *Energy [R]evolution Scenario*. However, two thirds of new installed power capacity in the *Energy [R]evolution Scenario* would be based on renewable energy sources, leaving one third to fossil fuels - around half of these power plants will be efficient combined heat and power plants (CHP). Nuclear capacity would cease by 2030 when old existing power plants will be replaced by renewable power plants.

future energy prices and power plant investment costs

The recent dramatic increase in global oil and gas prices has resulted in much higher forward price projections. Under the 2004 'high oil and gas price' scenario by the European Commission (2004), for example, an oil price of just US$34/bbl in 2030 was assumed, and under a 'soaring oil and gas prices' scenario the oil price reached US$50/bbl in 2030. Only two years later, the IEA-WEO expects the oil price to be at US$52/bbl in 2030 (IEA 2006a), and in the 'high' projections of the US Department of Energy's Annual Energy Outlook the oil price reaches US$90/bbl in 2030 ($54 in the reference case) (US DoE 2006). Considering the IEA's continuous underestimation of oil prices in the past and the growing global oil and gas demand, which goes along with the expected passing of the global oil mid depletion point, we assume a price development path in which the price of oil reaches US$85/bbl by 2030 and US$100/bbl in 2050 (Table 1). Gas prices are assumed to increase to US$9-10/GJ by 2050.

Compared to fossil fuels, biomass prices are highly variable, ranging from no or low costs for residues or traditional biomass in Africa or Asia to comparatively high costs for biofuels from energy crops. Despite this variability, this paper assumes an aggregated price for biomass in Europe. The increasing biomass prices reflect the link between biofuel and fossil fuel prices and a rising share of energy crops. For other regions prices are assumed to be lower, considering the large amount of traditional biomass use in developing countries and the high potential of as yet unused residues in North America and the Transition Economies.

Projections of CO_2 emission costs are even more uncertain than energy prices. IEA (2006b) assumes a CO_2 reduction incentive of 25 US$/t$CO_2$ in 2050. A study commissioned by the German Advisory Council on Global Change (WBGU 2003) suggest that under a 450 ppm CO_2 stabilisation scenario the price for global CO_2 emission allowances will rise to around 50 US$/t$CO_2$ in 2030, and - depending on the scenario - to more than 100 US$/t$CO_2$ in 2050. We assume that CO_2 costs rise linearly from 10 US$/t$CO_2$ in 2010 to 50 US$/t$CO_2$ in 2050, which is twice as high as the IEA's projection, but still conservative compared with other studies. We assume that CO_2 emission costs will be accounted for in Non-Annex B countries only after 2020.

Besides the conventional fossil based technologies, which still show a significant potential for cost reduction and improvement of efficiencies, there is a broad range of renewable energy technologies available today, which differ in terms of their technical maturity, costs, and development potentials. Most of the renewable technologies employed today are at an early stage of market development. Accordingly, their costs are generally higher than for competing conventional systems - particularly also because it is still virtually free to destroy the environment by emitting greenhouse gases (GHG). If a polluter-pays principle were to be in operation, and CO_2 already had a price according to the damages it causes, the competitiveness of renewables would be greatly strengthened.

Stimulating market introduction would drive these technologies through their learning curves, thus exploiting the large potential for cost reduction. Table 2 shows the expected development of specific investment costs for key electricity generation technologies. The prerequisite for this cost development is the further dynamic market uptake of renewable energy technologies to facilitate technical learning.

fuel costs versus investment costs

The total costs for fossil fuels in the *Reference Scenario* between 2004 and 2030 add up to a total of US$18,6 trillion - compared to US$13,1 trillion in the *Energy [R]evolution Scenario*. This means fuel costs in the *Energy [R]evolution Scenario* are already 30% lower in the year 2030 (in 2050, the fuel costs are more than 70% lower). The "gas bill" remains roughly at the same level - in the *Energy [R]evolution Scenario* it is 10% below the *Reference Scenario*. Equally importantly, the money spent on the alternative scenario for oil and coal to generate electricity is also 50% below the *Reference Scenario*.

The total fuel cost savings in the *Energy [R]evolution Scenario* are as high as US$5.4 trillion or US$202 billion dollar per year.

table 1: **total global fuel cost savings in the energy [r]evolution scenario compared to the reference scenario**

	CUMULATIVE COST IN BILLION $2000				AVERAGE ANNUAL SAVINGS FOR FUEL IN BILLION $2000
FOSSIL FUELS	2004 - 2010	2011 - 2020	2021 - 2030	**2004 - 2030**	**2004 - 2030**
Hard coal Mill t	134	780	1,753	**2,667**	**99**
Natural gas in E+9m3	19	148	663	**831**	**31**
Crude oil in Mill barrel	127	700	1,135	**1,962**	**73**
Total	281	1,628	3,551	**5,459**	**202**

table 2: **Investment Costs Energy [R]evolution versus Reference**

ENERGY [R]EVOLUTION VERSUS REFERENCE			BILLION $		AVERAGE PER YEAR BILLION $
INVESTMENT	2004 - 2010	2011 - 2020	2021 - 2030	**2004 - 2030**	**2004 - 2030**
Nuclear power plant	-222	-190	-168	**-581**	**-22**
Fossil fuels	-325	-628	-762	**-1,714**	**-63**
Renewables	113	1,105	1,672	**2,890**	**107**
Total	-434	287	742	**595**	**22**

The comparison between the extra fuel costs in the *Reference Scenario* and the extra investment costs of the *Energy [R]evolution Scenario* shows that the average annual additional fuel costs of the *Reference Scenario* are about 10 times higher than the additional investment requirement of the *Energy [R]evolution Scenario.*

In fact the additional costs for coal from today till the year 2030 are as high as US$100 billion per year, which would cover 92.5% of the total annual investments needed in renewable power generation required to implement the *Energy [R]evolution Scenario.*

But these renewable energy sources will produce electricity without any further fuel costs beyond 2030, while the fuel costs for coal and gas will continue to be a burden on national economies.

reform of global finance institutions

Demand for energy, particularly electricity, is increasing worldwide. This is especially the case in developing countries, which rely heavily on export credit agencies (ECAs) and multi-lateral development banks to provide financing for energy and other industrial projects.

To be consistent with the emerging international regime for limiting greenhouse gas emissions, ECAs and other international financial institutions which support or underwrite projects around the world must have policies consistent with the need for limiting greenhouse gas emissions and climate protection. At the same time there needs to be a transition plan and flexible timeframes to avoid imposing undue adversity on developing countries' economies that are overly reliant on conventional energy sources and exports. There also needs to be recognition that meeting the development goals of the world's poorest will require significant support for the foreseeable future.

Policies to address these issues must include:

- A defined and increasing percentage of overall energy sector lending directed towards renewable energy and energy efficiency projects.
- A rapid phase out of explicit and implicit subsidies for conventional, polluting energy projects.

to implement the Energy [R]evolution in the power sector and to avoid dangerous climate change, Greenpeace and EREC demand the following from the power sector:

- Phase out of all subsidies for fossil fuels and nuclear energy and the internalisation of external costs
- Set legally binding targets for renewable energy
- Provide defined and stable returns for investors
- Guaranteed priority access to the grid for renewable generators - and clear and simple administrative procedures
- Strict efficiency standards for all electricity consuming appliances

installed capacity by technology

THERE IS HUGE OPPORTUNITY IN THE NEXT 5 TO 15 YEARS TO INVEST IN NEW SUSTAINABLE AND CLIMATE-FRIENDLY POWER GENERATION

image MAN USING METAL GRINDER ON PART OF A WIND TURBINE MAST IN THE VESTAS FACTORY, CAMPBELLTOWN, SCOTLAND, GREAT BRITAIN. WIND TURBINES ARE NOT ONLY A SOURCE OF RENEWABLE ENERGY, BUT ALSO OF EMPLOYMENT.

The global market for new power generation equipment is - after years of stagnation - booming. While most existing power plants are ageing and need to be replaced (= "repowering"), developing countries such as China and India are building new infrastructure for rapidly increasing electricity demand.

There is huge opportunity in the next 5 to 15 years to invest in new sustainable and climate-friendly power generation. Every decision about new power plants taken today, will influence the energy mix of the next 30 to 40 years.

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new installed capacity (global)

reference scenario

In the *Reference Scenario* there will be almost 10,000 new fossil fuel power plants[4] by 2030. Roughly half of those power plants will be run on gas, the other half on coal. Lignite power plants remain a niche market. New renewable energy capacity may be in the same range as new coal. However 70% of the new installed power plants in the *Reference Scenario* would be based on fossil fuel, 25% renewable and 5% nuclear. As new nuclear capacity would mainly replace old existing power plants, nuclear will remain marginal on the global scale.

energy [r]evolution

In the *Energy [R]evolution Scenario*, however, there will be just 4,000 new fossil fuel power plants by 2030. A large percentage of those power plants are currently under construction or have gone online between 2004 and January 2007. Gas power plants - especially cogeneration - play an important role. More than half of the new power plants run on gas, the remainder on coal. Lignite power plants will not be built under the *Energy [R]evolution Scenario*. However, two thirds of new installed power capacity in the *Energy [R]evolution Scenario* would be based on renewable energy sources, leaving one third to fossil fuels - around half of these power plants will be efficient combined heat and power plants (CHP). Nuclear capacity would cease by 2030 when old existing power plants will be replaced by renewable power plants.

references

4 ASSUMING THAT THE AVERAGE SIZE IS 500 MW PER POWER PLANT

figure 3: **new capacity in GW - REF Scenario**

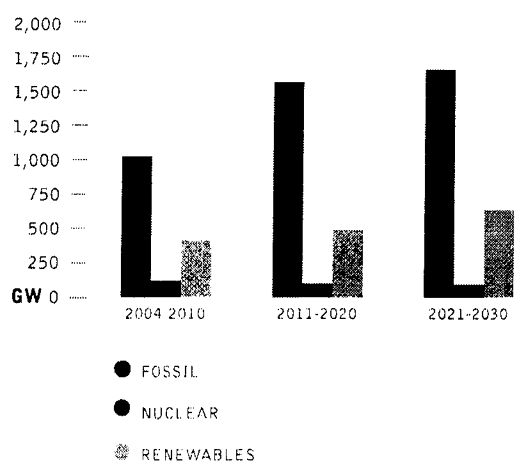


figure 4: **new capacity in GW - energy [r]evolution scenario**

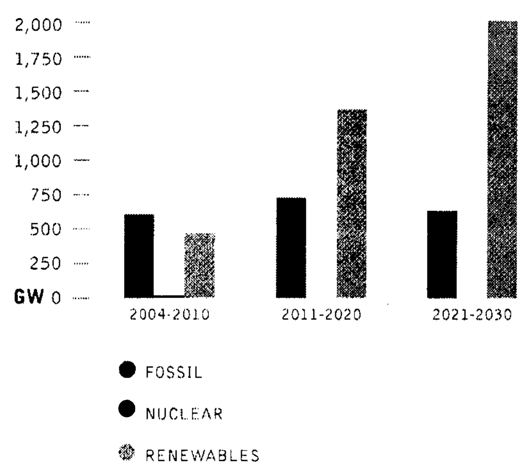


table 3: **total new installed capacity till 2030 by technology - REF**

TECHNOLOGY	GW	2004 - 2010	2011 - 2020	2021 - 2030	**2004 - 2030**
Fossil	GW	1,027	1,568	1,669	**4,264**
- Lignite	GW	24	27	29	**80**
- Coal	GW	399	619	679	**1,697**
- Oil	GW	172	202	195	**568**
- Gas	GW	432	720	766	**1,918**
Nuclear	GW	126	107	94	**327**
Renewables	GW	415	489	633	**1,536**
- PV power	GW	6	16	38	**61**
- Solar thermal	GW	1	1	3	**5**
- Wind power	GW	89	126	249	**464**
- Biomass and waste	GW	16	18	28	**61**
- Geothermal	GW	11	8	17	**36**
- Hydro power	GW	291	319	296	**906**
- Ocean energy	GW	0	1	1	**3**
Total	GW	1,568	2,163	2,396	**6,127**

table 4: **total new installed capacity till 2030 by technology - E[R]**

TECHNOLOGY	GW	2004 - 2010	2010 - 2020	2021 - 2030	**2004 - 2030**
Fossil	GW	608	720	623	**1,950**
- Lignite	GW	0	0	1	**7**
- Coal	GW	196	163	62	**420**
- Oil	GW	39	41	50	**130**
- Gas	GW	367	516	511	**1.394**
Nuclear	GW	17	0	0	**17**
Renewables	GW	477	1,371	2,023	**3,872**
PV power	GW	22	176	551	**750**
- Solar thermal	GW	2	27	109	**138**
- Wind power	GW	138	809	1,026	**1,972**
- Biomass and waste	GW	12	21	27	**60**
- Geothermal	GW	10	11	20	**41**
- Hydro power	GW	289	316	274	**879**
- Ocean energy	GW	2	11	16	**30**
Total	GW	1,101	2,101	2,647	**5,849**

development of power plants: investment costs

WITH RENEWABLE ENERGY TECHNOLOGIES LARGE COST REDUCTIONS CAN BE ACHIEVED DUE TO TECHNICAL LEARNING, MANUFACTURING IMPROVEMENTS AND LARGE-SCALE PRODUCTION, UNLIKE CONVENTIONAL TECHNOLOGIES.

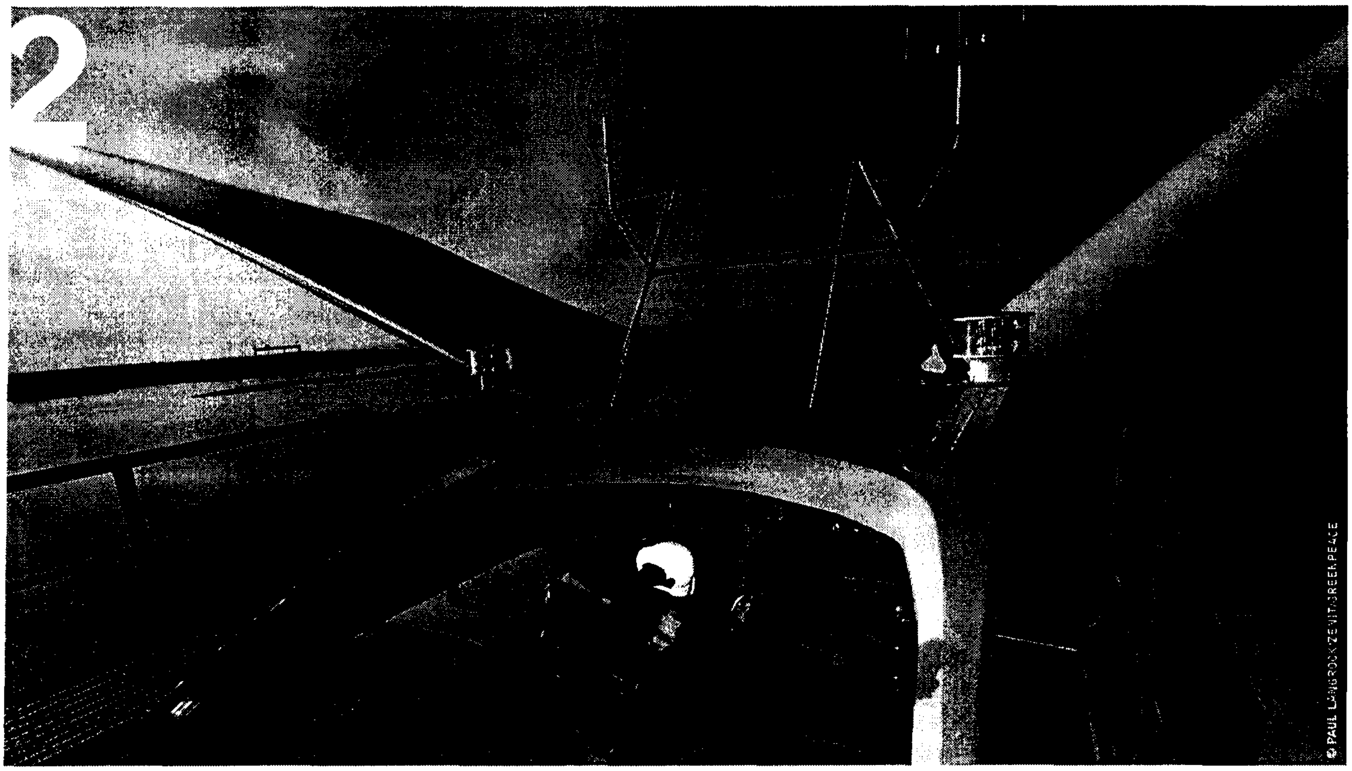


image TWO TECHNICIANS WORKING INSIDE THE TURBINE OF TEST WINDMILL N90 2500, BUILT BY THE GERMAN COMPANY NORDEX, IN THE HARBOUR OF ROSTOCK. THIS WINDMILL PRODUCES 2,5 MEGA WATT AND IS TESTED UNDER OFFSHORE CONDITIONS. AT LEAST 10 FACILITIES OF THIS TYPE WILL BE ERECTED 20 KM OFF THE ISLAND DARSS IN THE BALTIC SEA BY 2007. TWO TECHNICIANS WORKING INSIDE THE TURBINE.

fossil fuel technologies and carbon capture and storage (CCS)

While the fossil fuel power technologies employed today for the utilisation of coal, gas, lignite and oil are established and at a very late stage of market development, further cost reduction potentials are assumed. However the overall potential for cost reductions is rather limited and will be achieved mainly via an increase in efficiency, which will bring down specific investment costs.[5]

There is much speculation about the potential of carbon capture and storage (CCS) technology as a solution to mitigate climate change even though the technology is still under development.

CCS is a means of trapping CO_2 from fossil fuels, either before or after they are burned, and "storing" (effectively disposing of) it in the sea or beneath the surface of the earth. There are currently three different methods of capturing CO_2: 'pre-combustion', 'post-combustion', and 'oxyfuel combustion'. However, the earliest CCS could be implemented is 2020, and it will probably not become commercially viable until 2030.

The power company, Siemens, estimates that CO_2 capture costs for oxyfuel coal combustion is US$20-50 per tonne of CO_2. The IEA estimates capture costs between US$30-60 per tonne of CO_2 not emitted into the atmosphere. The costs include CO_2 compression but do not include the costs of CO_2 transport and storage. If CO_2 is transported 300 km from a single power plant, and is stored in an onshore reservoir that does not produce economic revenue, the additional cost may be around US$8 per tonne of stored CO_2. If CO_2 is transported a greater distance or stored in a distant offshore reservoir, the additional costs may be higher, up to US$20 per tonne of stored CO_2. As long as the price per tonne of CO_2 is below US$25-30, CCS might never take off - except with heavy subsidies and incentives, distorting competition for the best available technology including renewables: increase of end-use efficiency, gas-fired electricity generation and wind are already commercially available and have lower costs than future coal-fired electricity generation with CCS. In plants with CCS, about 10-15% of the CO_2 would still be emitted into the atmosphere. In addition, all of the power generation technologies emit some CO_2 and other pollutants indirectly, during fuel production and transportation and power plant production. Life-Cycle Assessments (LCA) covers such indirect emissions.

For the above reasons, CCS power plants are not included in our financial analysis.

reference

5 GREENPEACE INTERNATIONAL BRIEFING: CARBON CAPTURE AND STORAGE, DR. GOERNE, 2007

table 5: development of efficiency and investment costs for selected power plant technologies

		2010	2030	2050
Coal-fired condensing power plant	Efficiency (%)	41	45	**48**
	Investment costs ($/kW)	980	930	**880**
	Electricity generation costs including CO_2 emission costs ($ cents/kWh)	6.0	7.5	**8.7**
	CO_2 emissions [a] (g/kWh)	837	728	**697**
Oil fired condensing power plant	Efficiency (%)	39	41	**41**
	Investment costs ($/kW)	670	620	**570**
	Electricity generation costs including CO_2 emission costs ($ cents/kWh)	22.5	31.0	**46.1**
	CO_2 emissions [a] (g/kWh)	1,024	929	**888**
Natural gas combined cycle	Efficiency (%)	55	60	**62**
	Investment costs ($/kW)	530	490	**440**
	Electricity generation costs including CO_2 emission costs ($ cents/kWh)	6.7	8.6	**10.6**
	CO_2 emissions [a] (g/kWh)	348	336	**325**

source DLR, 2006 a) REFERS TO DIRECT EMISSIONS ONLY, LIFE-CYCLE EMISSIONS ARE NOT CONSIDERED HERE.

investment cost projections for renewable energy technologies

Many of the technologies employed today for the utilisation of renewable energy sources are at a relatively early stage of market development. Accordingly, the costs of electricity, heat and fuel production are as a rule higher today than the costs of competing conventional systems - a reminder that external costs of conventional power production are not calculated within the prices. It is expected, however, that compared with conventional technologies large cost reductions can be achieved due to technical learning, manufacturing improvements and large-scale production. Especially when developing long-term scenarios spanning periods of several decades, the dynamic trend of cost developments over time plays a crucial role in identifying economically sensible expansion strategies.

The correlation between specific investment costs and cumulative production volume of a technology that is empirically observed for many products can be represented in the form of so-called learning curves. The cost reduction that can be achieved by doubling cumulative production is known as the progress ratio (or learning factor; a progress ratio f = 0.9 means that costs fall by 10% if cumulative production doubles; this corresponds to a learning rate of 0.1). Technology-specific progress ratios are derived from a literature review.

No learning curves for technologies for the use of renewables have been as closely investigated as those for the photovoltaic (PV) sector, and there is scarcely any other technology for which one can find such agreement in the literature on the findings: the learning factor for PV modules, taken as the mean of the figures for various module types, is fairly constant over a period of 30 years at around 0.80, which is relatively high. This optimistic estimate is supported by the fact that it is still possible to achieve ongoing increases in the efficiency of PV modules both in the laboratory and under real conditions. In the long run, however, it must be assumed that the photovoltaic sector too will see a decline in the opportunities for cost reductions through technical learning, and that the learning rate will fall.

In the last 20 years the development of wind energy markets has taken very different courses in different regions. Accordingly, various studies have observed relatively large regional differences in the individual learning factors. In England, for example, a country where expansion of wind energy has been very hesitant to date, the learning factor is still around 0.75, which points to a sharp downward trend in costs. In Germany, by contrast, a learning factor of 0.94 was determined for wind energy systems built between 1990 and 2000. The low learning rate of 0.06 can be explained by the high level of advance investment by the manufacturers, who kept on putting new performance classes on the market at very short intervals. Although expectations are that the existing cost reduction potential is not yet exhausted, the low learning rate found for onshore systems in Germany is adopted here and taken as constant for the period under consideration. Owing to the relative lack of experience in the offshore sector, however, a greater cost reduction potential is expected here and it is assumed that the learning rate will be correspondingly higher.

Owing to the small number of concentrated solar power plants built to date, it is particularly difficult to arrive at reliable learning factors for this sector. Here it is assumed that the learning factor of 0.88 derived from the data for parabolic trough reflectors built in California will change to 0.95 in the course of market introduction up to 2050.

For geothermal power generation systems there are no learning curves in the literature despite a worldwide installed capacity of around 10,000 MWel. Since a large proportion of the costs in the geothermal field is due to deep drilling, the figures for the oil production sector can be used for drawing analogies here. Scenarios drawn up by the IPCC work on the basis that geothermal power generation costs will fall by nearly 50 percent by 2050.

A learning factor of 0.986 was determined for hydropower plants built in the OECD countries between 1975 and 1993. Recent experience however shows that as a result of compensating measures for nature conservation, which can amount to as much as 30 % of the investment volume, the specific costs for hydropower plants will tend to rise. We thus assume a progress ratio of 1.1, leading to an increase of specific investment costs.

table 6: **investment cost projections for renewable energy technologies**

		2003	2010	2020	2030	2040	2050
Photovoltaic							
capacity	GW	0.56	22.9	202	511	735	894
cumulated capacity	GW	2.88	25.4	214	604	1,032	1,485
progress ratio			0.8	0.8	0.85	0.9	0,92
investment costs	€/kWp	5,750	2,853	1,436	1,126	1,038	994
Generation costs (min/max)	ct/kWh	0.37-0.76	0.21-0.45	0.11-0.22	0.07-0.14	0.06-0.11	0.05-0.1
Concentrating solar thermal							
capacity	GW	0.354	4.6	72	273	459	628
cumulated capacity	GW	0.354	4.7	74	311	634	1,032
progress ratio			0.88	0.88	0.93	0.95	0.95
investment costs	€/kWp	2,300	1,426	858	738	701	676
Generation costs (min/max)	ct/kWh	0.18-0,20	0.08-0.12	0.06-0.09	0.06-0.09	0.06-0.09	0.05-0.09
Wind							
capacity	GW	41	256	1,024	1,509	1,884	2225
cumulated capacity	GW	41	270	1,166	2,163	3,293	4,576
progress ratio			0.94	0.94	0.94	0.94	0.94
investment costs	€/kWp	1,350	1,141	1,001	948	913	886
Generation costs (min/max)	ct/kWh	0.08-0.1	0.07-0.08	0.06-0.07	0.05-0.06	0.05-0.06	0.05-0.06
Biomass (no CHP applications)							
capacity	GW	28	85	177	261	352	433
cumulated capacity	GW	28	95	229	402	623	880
progress ratio			0.85	0.86	0.87	0.9	0.92
investment costs	€/kWp	3,850	2,893	2,387	2,132	1,995	1,914
Generation costs (min/max)	ct/kWh	0.06-0.10	0.06-0.11	0.06-0.11	0.06-0.12	0.07-0.12	0.07-0.12
Geothermal							
capacity	GW	10	17	26	39	54	69
cumulated capacity	GW	10	21	38	64	99	141
progress ratio			0.8	0.8	0.85	0.9	0.9
investment costs	€/kWp	8,000	6,349	5,205	4,606	4,314	4,087
Generation costs (min/max)	ct/kWh	0.12-0.23	0.11-0.19	0.10-0.15	0.08-0.12	0.07-0.10	0.07-0.10
Hydro							
capacity	GW	800	938	1,089	1,193	1,285	1,358
cumulated capacity	GW	800	1,218	1,838	2,487	3,175	3,891
progress ratio			1.1	1.1	1.1	1.1	1.1
investment costs	€/kWp	2,200	2,331	2,467	2,571	2,659	2,734
Generation costs (min/max)	ct/kWh	0.03-0.07	0.04-0.09	0.05-0.10	0.05-0.10	0.06-0.10	0.06-0.11
Ocean energy							
capacity	GW	0.24	3.4	13	36	70	104
cumulated capacity	GW	0.24	3.5	15	44	96	165
progress ratio			0.85	0.85	0.87	0.9	0.92
investment costs	€/kWp	6,000	3,204	2,276	1,830	1,626	1,524
Generation costs (min/max)	ct/kWh	0.49-0.55	0.11-0.36	0.07-0.19	0.06-0.17	0.05-0.13	0.04-0.10

figure 5: **maximum and minimum electricity generating costs of renewable and non renewable energy sources. PV vs Oil/Diesel including peak power and residential power prices**

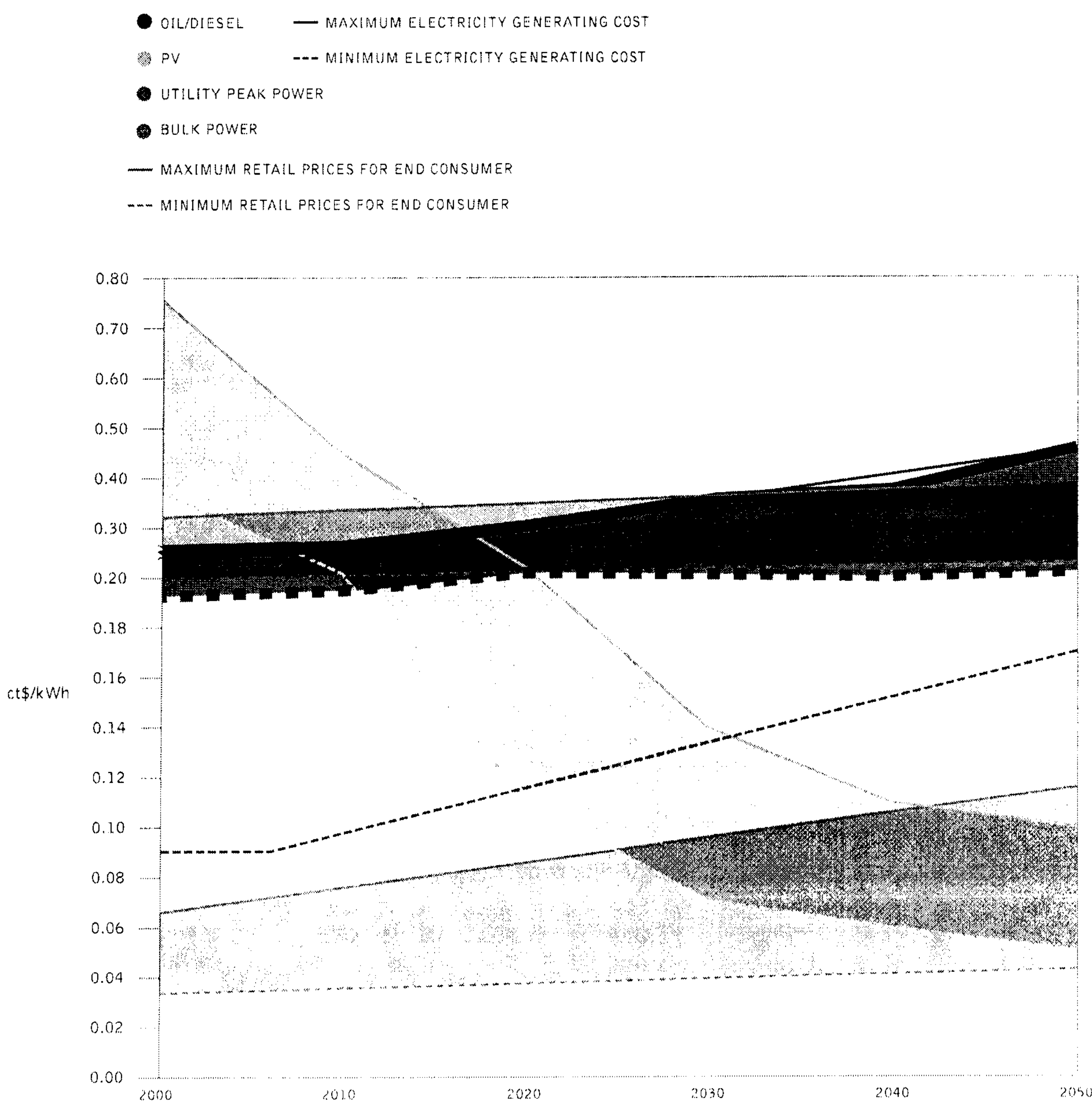


figure 6 & 7: **maximum and minimum electricity generating costs of renewable and non renewable energy sources**

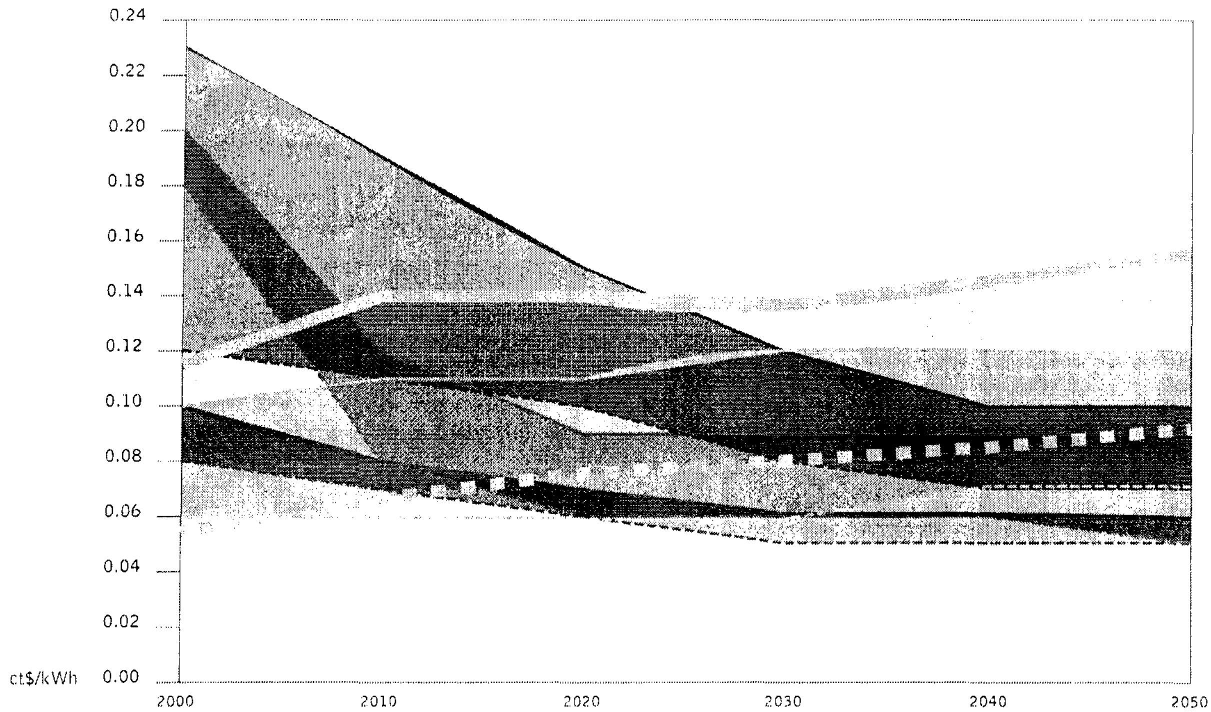
— MAXIMUM ELECTRICITY GENERATING COST

--- MINIMUM ELECTRICITY GENERATING COST

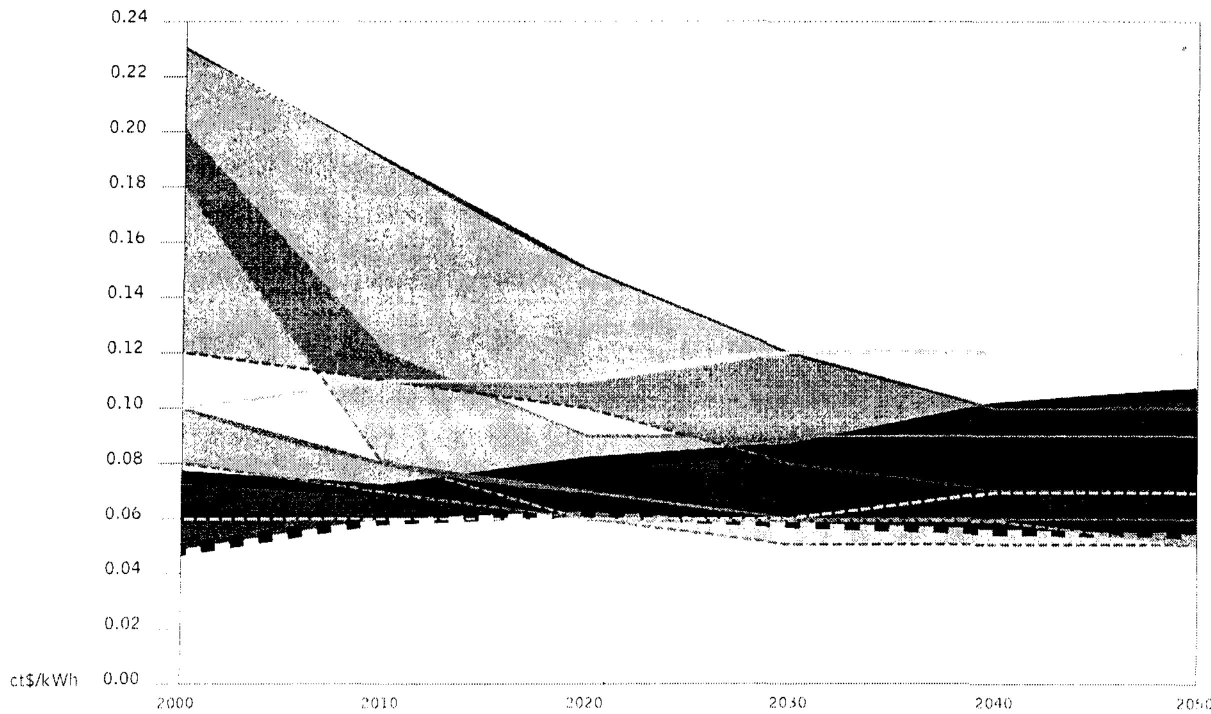
NATURAL GAS CC | WIND | BIOMASS (NO CHP APPLICATIONS)

COAL | GEOTHERMAL CHP | CONCENTRATING SOLAR THERMAL

gas vs concentrating solar thermal, wind, biomass and geothermal



coal vs concentrating solar thermal, wind, biomass and geothermal



fuel costs

THE RECENT DRAMATIC INCREASE IN GLOBAL OIL PRICES HAS RESULTED IN MUCH HIGHER FORWARD PRICE PROJECTIONS.

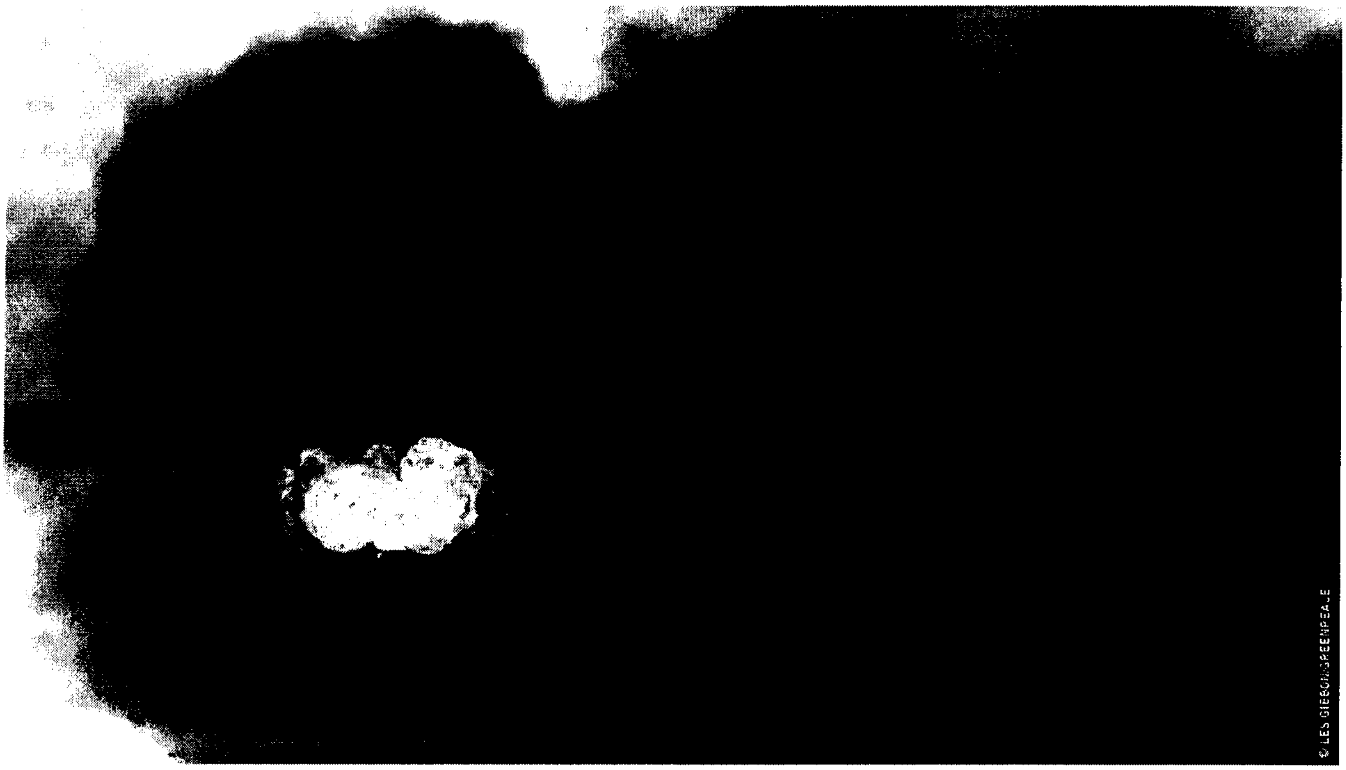


image FLARE STACK AT AN OIL REFINERY IN IMMINGHAM, UK.

fossil fuel price projections

The recent dramatic increase in global oil prices has resulted in much higher forward price projections. Under the 2004 'high oil and gas price' scenario by the European Commission, for example, an oil price of just US$34/bbl was assumed in 2030. Ongoing modelling funded by the Commission (CASCADE-MINTS 2006), on the other hand, assumes an oil price of US$94/bbl in 2050, a gas price of US$15/GJ and an international coal price of US$95/t.

Current projections of oil prices in 2030 range from the IEA's US$52/bbl up to over US$100. As the supply of natural gas is limited by the availability of pipeline infrastructure, there is no world market price for natural gas. In most regions of the world the gas price is directly tied to the price of oil. Current projections of gas prices in 2030 range from the US Department of Energy's US$4.5/GJ up to the highest figure of US$6.9/GJ. Taking into account the recent development of energy prices, these projections might be considered too conservative. Considering the growing global demand for oil and gas we have assumed a price development path for fossil fuels in which the price of oil reaches US$85/bbl by 2030 and US$100/bbl in 2050. Gas prices are assumed to increase to US$9-$10/GJ by 2050.

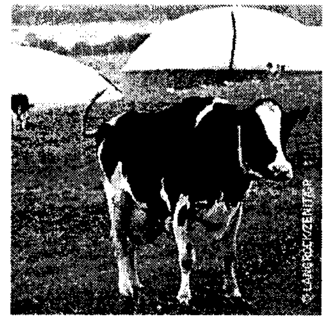


image A COW IN FRONT OF A BIOREACTOR IN THE BIOENERGY VILLAGE OF JUEHNDE. IT IS THE FIRST COMMUNITY IN GERMANY THAT PRODUCES ALL OF ITS ENERGY NEEDED FOR HEATING AND ELECTRICITY, WITH CO_2 NEUTRAL BIOMASS.

table 7: assumptions on fossil fuel price development

FOSSIL FUELS	2004	2010	2020	2030	2040	**2050**
Crude oil in $2000/bbl	28.0	62.0	75.0	85.0	93.0	**100.0**
Natural gas in $2000/GJ						
- America	3.1	4.4	5.6	6.7	8.0	**9.2**
- Europe	3.5	4.9	6.2	7.5	8.8	**10.1**
- Asia	5.3	7.4	7.8	8.0	9.2	**10.5**
Hard coal $2000/t	42.3	59.4	66.2	72.9	79.7	**86.4**

table 8: assumptions on biomass price development

$2000/GJ

BIOMASS	2004	2010	2020	2030	2040	**2050**
Biomass in $2000/GJ						
- Europe	4.8	5.8	6.4	7.0	7.3	**7.6**
- other Regions	1.4	1.8	2.3	2.7	3.0	**3.2**

table 9: assumptions on CO_2 price development

($/$TCO_2$)

COUNTRIES	2010	2020	2030	2040	**2050**
Kyoto Annex B countries	10	20	30	40	**50**
Non-Annex B countries		20	30	40	**50**

biomass price projections

Compared to fossil fuels, biomass prices are highly variable, ranging from no or low costs for residues or traditional biomass in Africa or Asia to comparatively high costs for biofuels from energy crops. Despite this variability, this paper assumes an aggregated price for biomass in Europe. The increasing biomass prices reflect the link between biofuel and fossil fuel prices and a rising share of energy crops. For other regions prices are assumed to be lower, considering the large amount of traditional biomass use in developing countries and the high potential of as yet unused residues in North America and the Transition Economies.

cost of CO_2 emissions

Projections of CO_2 emission costs are even more uncertain than energy prices. IEA (2006b) assumes a CO_2 reduction incentive of 25 US$/t$CO_2$ in 2050. A study commissioned by the German Advisory Council on Global Change (WBGU 2003) suggests that under a 450 ppm CO_2 stabilisation scenario the price for global CO_2 emission allowances will rise to around 50 US$/t$CO_2$ in 2030, and - depending on the scenario - to more than 100 US$/t$CO_2$ in 2050. We assume that CO_2 costs rise linearly from 10 US$/t$CO_2$ in 2010 to 50 US$/t$CO_2$ in 2050, which is twice as high as the IEA's projection, but still conservative compared with other studies. We assume that CO_2 emission costs will be accounted for in Non-Annex B countries only after 2020.

Assigning a price to CO_2 emissions we implicitly assume the introduction of a global CO_2 tax, which further increases the economic competitiveness of renewable energies compared to fossil fuels.

renewable energy investments - status quo

RENEWABLE ENERGY MARKETS GREW ROBUSTLY IN 2005.
source ERIC MARTINOT / REN21

4

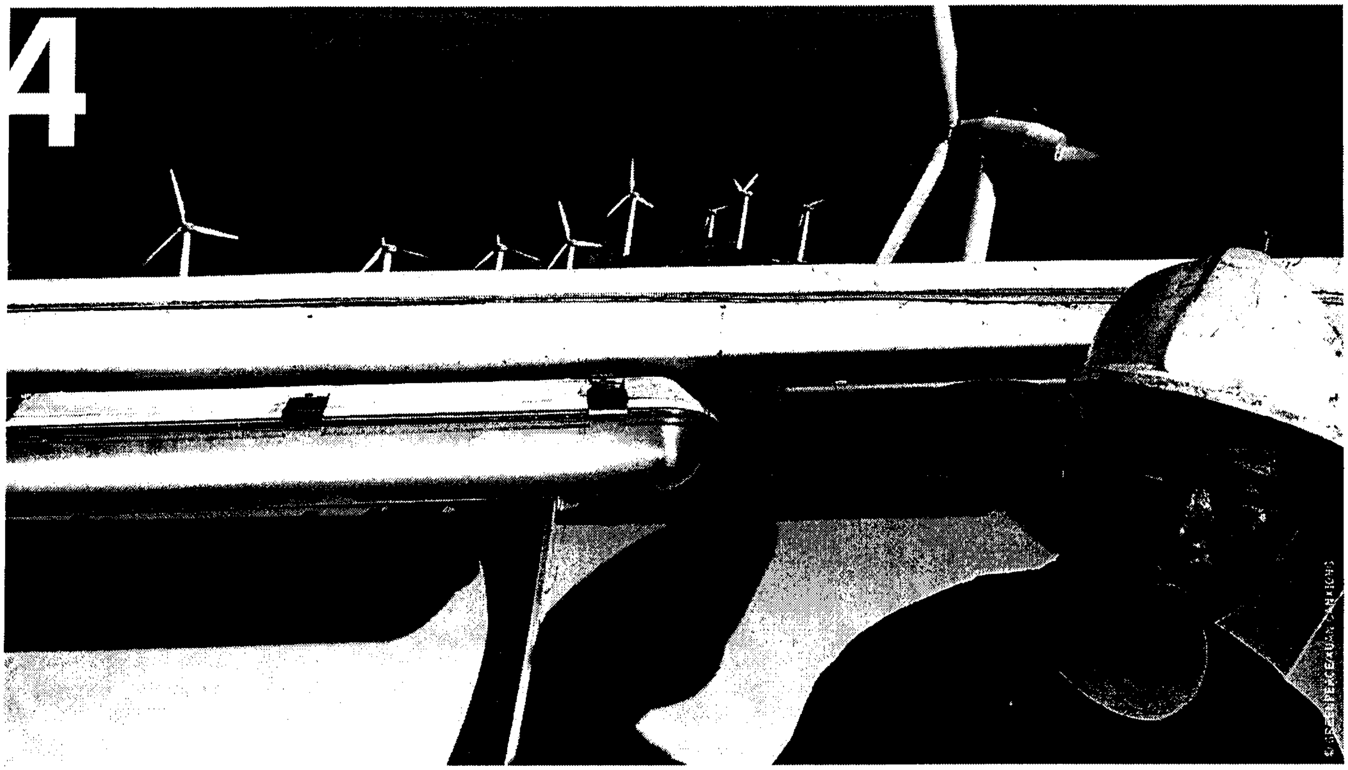


image A MAINTENANCE ENGINEER INSPECTS A WIND TURBINE AT THE DAN NAN WIND FARM IN NAN'AO, GUANGDONG PROVINCE WHICH HAS ONE OF THE BEST WIND RESOURCES IN CHINA AND IS ALREADY HOME TO SEVERAL INDUSTRIAL SCALE WIND FARMS. CHINA HAS INVESTED IN WIND POWER TO HELP OVERCOME ITS RELIANCE ON CLIMATE DESTROYING FOSSIL FUEL POWER AND SOLVE ITS ENERGY SUPPLY PROBLEM.

a global market overview

Renewable energy markets grew robustly in 2005. Large hydropower increased by an estimated 12-14 Gigawatts (GW) in 2005, led by China (7 GW added), Brazil (2.4 GW added), and India (over 1.3 GW added). Small hydro increased by 5 GW to total 66 GW worldwide, with 38.5 GW existing in China alone as the boom in small hydro investment there continued.

Wind power was second in power capacity added, with 11.5 GW added and existing capacity growing by 24 percent to reach 59 GW. More than half of global wind power additions were in three countries: the United States (2.4 GW), Germany (1.8 GW), and Spain (1.8 GW). India jumped ahead of Denmark into fourth place in terms of total installed capacity, adding 1.4 GW in 2005. Strong growth took place in China, with 0.5 GW added to the previous existing 0.8 GW. Offshore wind installations grew by at least 180 mega-watts (MW).

Biomass power generation and heat supply continued to increase at both large and small scales, with an estimated 2-3 GW power capacity added in 2005, bringing existing biomass power capacity to about 44 GW. Annual increases of 50-100 % or more in biomass power production were registered for 2004 (most recent data) in several OECD countries, including Germany, Hungary, the Netherlands, Poland, and Spain. Other increases of 10-30 % were registered in Australia, Austria, Belgium, Denmark, Italy, South Korea, New Zealand, and Sweden. There is an increasing proliferation of small projects in developing countries, such as Thailand's "small power producers" program, which resulted by 2005 in 50 biomass power projects totalling 1 GW and several small-scale biogas power projects. Bagasse power plants are under development by the sugar industry in several countries, such as the Philippines and Brazil. Geothermal power saw continued growth as well, with contracts for an additional 0.5 GW in the United States and plants under construction in 11 countries.

Grid-connected solar photovoltaic (PV) continued to be the fastest growing power generation technology, with a 55 % increase in cumulative installed capacity to 3.1 GW, up from 2.0 GW in 2004. More than half of the annual global increase occurred in Germany, which saw over 600 MW of PV installed in one year. Grid-connected solar PV increased by about 300 MW in Japan and 70 MW in the United States. Several milestones occurred in 2005, such as the commissioning of the world's largest solar PV power plant, 10 MW

image CONCENTRATING SOLAR POWER (CSP) AT A SOLAR FARM IN DAGGETT, CALIFORNIA, USA.

total, in Germany, and many large commercial installations of tens and hundreds of kilowatts (kW) each. German cumulative PV capacity exceeded Japan's for the first time. Including off-grid applications, total PV existing worldwide increased to 5.4 GW, up from 4.0 GW in 2004.3

Overall, renewable power capacity expanded to 182 GW, up from 160 GW in 2004, excluding large hydropower. The top six countries were China (42 GW), Germany (23 GW), the United States (23 GW), Spain (12 GW), India (7 GW), and Japan (6 GW). India's renewable power capacity exceeded Japan's for the first time. The capacity in developing countries grew from 70 GW to 80 GW, with China (small hydro) and India (wind) leading the increase. The developing-country share thus remained constant compared to 2004, at 44 percent. Including large hydropower, renewable power capacity reached 930 GW in 2005.

investment flows

An estimated US$38 billion was invested in new renewable energy capacity worldwide in 2005, up from US$30 billion in 2004. Almost all the increase was due to increased investment in solar PV and wind power. Technology shares of the US$38 billion annual investment were wind power (37 percent), solar PV (26 percent), solar hot water (11 percent), small hydropower (11 percent), biomass power and heat (7 percent), and geothermal power and heat (7 percent). So the overall investment in renewables within the power sector in 2006 was approximately US$33 billion. An additional US$15-20 billion was invested in large hydropower.

The largest country shares of annual investment were by Germany, China, the United States, Spain, Japan, and India. Investment in Germany and China increased from US$6 billion each in 2004 to US$7 billion each in 2005, mostly for wind and solar PV in Germany and for small hydro and solar hot water in China. The United States was number three, with about US$3.5 billion, followed by Spain and Japan, with more than US$2 billion each, and then India. (These figures do not include large hydropower; investment in large hydropower in China was an additional US$10 billion in 2005, with 7 GW of new capacity installed. Thus, counting large hydropower, China's investment was about US$17 billion.)

In addition to renewable energy capacity investment, the solar PV industries made substantial capital investments in new manufacturing plants and equipment in 2005. Investment by the solar PV industry in 2005 was an estimated US$6 billion and was expected to reach US$8-9 billion in 2006. Development assistance for renewables investments in developing countries continued at a slightly faster pace in 2005, as increased commitments and special funds came into play. KfW committed 137 million (US$170 million) to renewables in developing countries in 2005. The World Bank Group committed US$150 million to renewables (excluding GEF funds and carbon finance) plus US$420 million for large hydropower, both increases from 2004. The Global Environment Facility continued as in 2004, with US$100 million committed, about half of that for World Bank projects and the rest for other agencies. In addition, the "Special Facility for Renewable Energies and Energy Efficiency" announced at the "Renewables 2004" conference by the German government was launched in 2005 with funding of € 500 million (US$625 million). Established by KfW, this facility will provide concessional loans to public agencies through 2009 for investments in countries that form part of Germany's program of development cooperation. In 2005, the German government made financing commitments of 170 million (US$210 million) under this facility.

table 10: selected indicators

	2004	2005
Investment in new renewable capacity (annual)	$30	$38 billion
Renewables power capacity (existing, excl. large hydro)	160	182 GW
Renewables power capacity (existing, incl. large hydro)	895	930 GW
Wind power capacity (existing)	48	59 GW
Grid-connected solar PV capacity (existing)	2.0	3.1 GW
Solar PV production (annual)	1,150	1,700 MW
Solar hot water capacity (existing)	77	88 GWth
Ethanol production (annual)	30.5	33 bill. litrs
Biodiesel production (annual)	2.1	3.9 bill. litrs
Countries with policy targets	45	49
States/provinces/countries with feed-in policies	37	41
States/provinces/countries with RPS policies	38	38
States/provinces/countries with biofuels mandates	22	38

map 1: **investment in energy sources under the reference and the energy [r]evolution scenarios**

WORLDWIDE SCENARIO

SCENARIO

LEGEND

REFERENCE SCENARIO

ALTERNATIVE SCENARIO

DIFFERENCE BETWEEN SCENARIOS

% INCREASE OR DECREASE IN INVESTMENT NEEDED UNDER THE E[R] SCENARIO WHEN COMPARED TO REFERENCE SCENARIO 2004-2030. GLOBAL CHANGE IN INVESTMENT IS 9.4%

0 1000 KM

INVESTMENT IN NUCLEAR POWER PLANTS BILLION $

INVESTMENT IN FOSSIL FUEL POWER PLANTS BILLION $

INVESTMENT IN RENEWABLE POWER PLANTS BILLION $

OECD NORTH AMERICA

		REF	ALT	DIF
	2004-2010	61.0	0.0	-61
	2011-2020	61.2	0.0	-61
	2021-2030	41.9	0.0	-42
	2004-2030	164.1	0.0	-164
	2004-2010	199.3	53.0	-146
	2011-2020	218.0	44.2	-174
	2021-2030	202.8	38.8	-164
	2004-2030	620.1	136	-484
	2004-2010	164.6	214.1	50
	2011-2020	160.9	430.6	270
	2021-2030	220.9	506.8	286
	2004-2030	546.4	1151.4	606
	2004-2010	424.9	267.1	-158
TOTAL	2011-2020	440.0	474.8	35
	2021-2030	465.6	545.6	80
	2004-2030	1330.5	1287.4	-43

LATIN AMERICA

		REF	ALT	DIF
	2004-2010	1.6	0.0	-2
	2011-2020	3.3	0.0	-3
	2021-2030	1.5	0.0	-2
	2004-2030	6.4	0.0	-6
	2004-2010	37.6	22.2	-15
	2011-2020	57.7	2.2	-55
	2021-2030	84.7	6.0	-79
	2004-2030	180	30.4	-150
	2004-2010	133.7	92.4	-41
	2011-2020	155.0	189.2	34
	2021-2030	163.6	219.4	56
	2004-2030	452.3	501.1	49
	2004-2010	172.9	114.6	-58
TOTAL	2011-2020	215.9	191.4	-25
	2021-2030	249.8	225.4	-24
	2004-2030	630.7	531.5	-107

OECD EUROPE

		REF		DIF
	2004-2010	52.9	0.0	-53
	2011-2020	18.6	0.0	-19
	2021-2030	33.1	0.0	-33
	2004-2030	104.6	0.0	-105
	2004-2010	74.7	42.9	-32
	2011-2020	103.3	43.8	-59
	2021-2030	85.9	38.8	-47
	2004-2030	263.8	125.5	-138
	2004-2010	154.4	206.2	52
	2011-2020	190.0	343.6	154
	2021-2030	220.0	365.7	146
	2004-2030	564.4	915.5	351
	2004-2010	282.0	249.1	-33
TOTAL	2011-2020	311.9	387.4	76
	2021-2030	339.0	404.5	65
	2004-2030	932.9	1,041.0	108

MIDDLE EAST

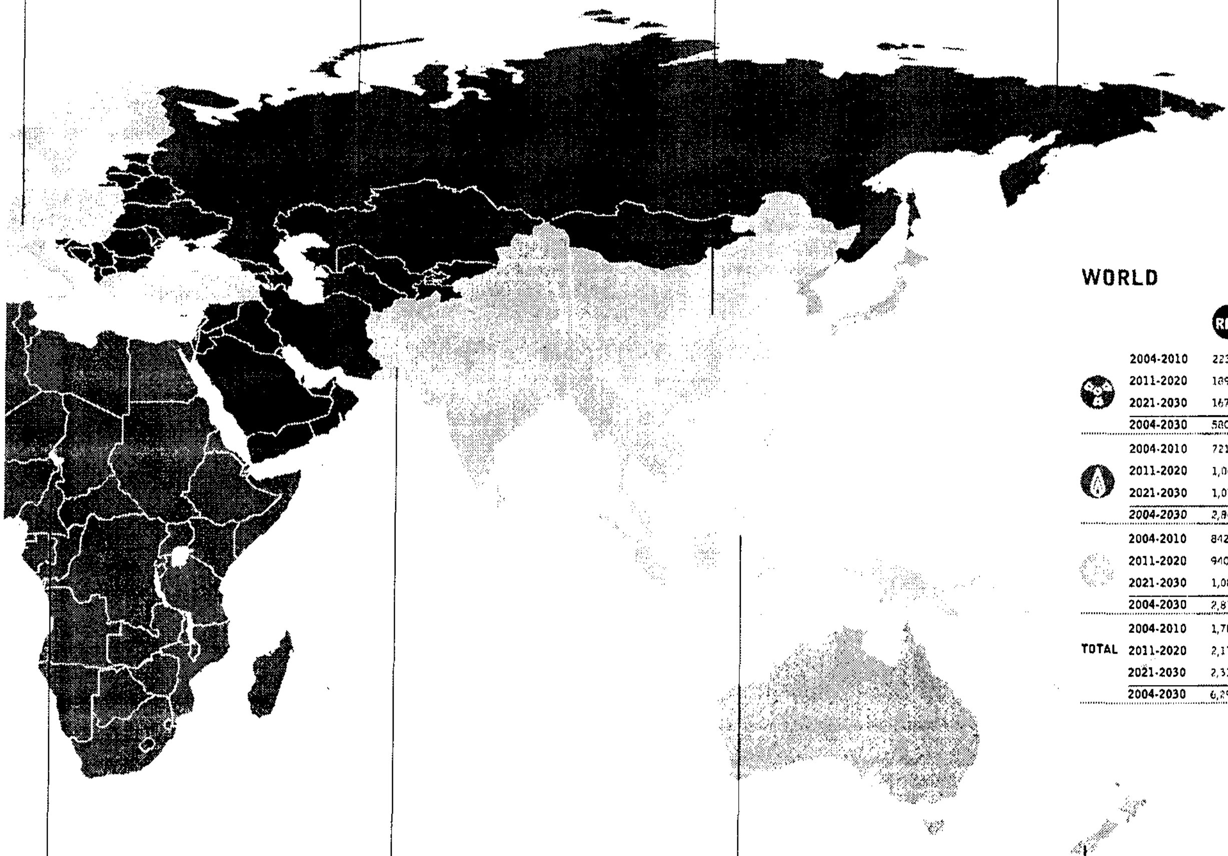
		REF		DIF
	2004-2010	1.5	0.0	-1
	2011-2020	0.0	0.0	0
	2021-2030	0.0	0.0	0
	2004-2030	1.5	0.0	-1
	2004-2010	37.1	21.6	-15
	2011-2020	61.8	31.2	-31
	2021-2030	63.2	13.6	-50
	2004-2030	162.0	66.4	-96
	2004-2010	17.6	25.4	8
	2011-2020	10.1	64.7	55
	2021-2030	13.3	178.3	165
	2004-2030	40.9	268.3	227
	2004-2010	56.1	47.0	-9
TOTAL	2011-2020	71.9	95.8	24
	2021-2030	76.4	191.9	115
	2004-2030	204.4	334.8	130

CHINA

		REF		DIF
	2004-2010	10.7	1.5	-9
	2011-2020	24.6	0.0	-25
	2021-2030	26.2	0.0	-26
	2004-2030	61.5	1.5	-62
	2004-2010	141.6	119.2	-22
	2011-2020	234.9	146.6	-88
	2021-2030	239.1	96.1	-143
	2004-2030	615.6	361.9	-254
	2004-2010	102.7	130.6	28
	2011-2020	178.6	353.7	175
	2021-2030	170.6	546.1	376
	2004-2030	451.9	1,030.4	579
	2004-2010	255.0	251.4	-4
TOTAL	2011-2020	438.1	500.3	62
	2021-2030	435.9	642.2	206
	2004-2030	1,129.0	1,392.4	263

TRANSITION ECONOMIES

		REF		DIF
	2004-2010	17.0	0.0	-17
	2011-2020	26.9	0.0	-27
	2021-2030	15.3	0.0	-15
	2004-2030	59.2	0.0	-59
	2004-2010	19.9	9.9	-10
	2011-2020	33.8	14.6	-19
	2021-2030	37.4	3.9	-33
	2004-2030	91.0	28.2	-63
	2004-2010	79.2	50.6	-29
	2011-2020	66.1	84.7	19
	2021-2030	73.6	201.6	128
	2004-2030	218.8	336.9	118
	2004-2010	116.1	60.2	-56
TOTAL	2011-2020	126.7	99.3	-27
	2021-2030	126.2	205.5	79
	2004-2030	369.1	365.1	-4



WORLD

		REF		DIF
	2004-2010	223.7	1.5	-222
	2011-2020	189.6	0.0	-190
	2021-2030	167.6	0.0	-168
	2004-2030	580.9	1.5	-580
	2004-2010	721.7	397.2	-325
	2011-2020	1,044.0	416.4	-628
	2021-2030	1,078.3	316.0	-762
	2004-2030	2,844.1	1,129.6	-1,715
	2004-2010	842.4	955.0	113
	2011-2020	940.2	2,044.9	1,105
	2021-2030	1,089.3	2,761.5	1,672
	2004-2030	2,871.1	5761.3	2,890
	2004-2010	1,787.8	1,353.7	-434
TOTAL	2011-2020	2,173.0	2,461.3	287
	2021-2030	2,335.2	3,077.6	742
	2004-2030	6,296.1	6891.0	595

AFRICA

		REF		DIF
	2004-2010	0.9	0.0	-1
	2011-2020	0.9	0.0	-1
	2021-2030	0.9	0.0	-1
	2004-2030	2.7	0.0	-3
	2004-2010	39.4	20.4	-19
	2011-2020	59.9	21.6	-38
	2021-2030	75.6	12.8	-63
	2004-2030	174.9	54.7	-120
	2004-2010	13.6	22.0	8
	2011-2020	14.5	85.6	71
	2021-2030	41.8	199.2	157
	2004-2030	69.1	306.7	238
	2004-2010	54.0	42.3	-12
TOTAL	2011-2020	75.3	107.2	32
	2021-2030	118.3	212.0	94
	2004-2030	246.7	361.4	115

SOUTH ASIA

		REF		DIF
	2004-2010	10.1	0.0	-10
	2011-2020	8.1	0.0	-8
	2021-2030	12.5	0.0	-12
	2004-2030	30.7	0.0	-31
	2004-2010	45.2	18.3	-27
	2011-2020	84.6	31.8	-53
	2021-2030	107.4	29.9	-77
	2004-2030	237.1	80.0	-157
	2004-2010	57.1	77.3	20
	2011-2020	57.1	143.3	86
	2021-2030	53.5	195.1	142
	2004-2030	167.7	415.7	248
	2004-2010	112.3	95.6	-17
TOTAL	2011-2020	149.8	175.1	25
	2021-2030	173.3	225.0	52
	2004-2030	435.4	495.7	60

EAST ASIA

		REF		DIF
	2004-2010	6.5	0.0	-6
	2011-2020	4.6	0.0	-5
	2021-2030	4.6	0.0	-5
	2004-2030	15.7	0.0	-16
	2004-2010	54.3	28.6	-26
	2011-2020	96.4	31.6	-65
	2021-2030	100.1	20.2	-80
	2004-2030	250.9	80.4	-170
	2004-2010	73.5	81.1	8
	2011-2020	49.8	158.5	109
	2021-2030	60.9	191.8	131
	2004-2030	184.2	431.4	247
	2004-2010	134.3	109.7	-25
TOTAL	2011-2020	150.9	190.1	39
	2021-2030	165.6	212.0	46
	2004-2030	450.8	511.8	61

OECD PACIFIC

		REF		DIF
	2004-2010	61.5	0.0	-61
	2011-2020	41.4	0.0	-41
	2021-2030	31.6	0.0	-32
	2004-2030	134.4	0.0	-134
	2004-2010	72.8	61.3	-11
	2011-2020	93.6	48.8	-45
	2021-2030	82.1	55.9	-26
	2004-2030	248.5	166	-82
	2004-2010	46.1	55.3	9
	2011-2020	58.2	191.0	133
	2021-2030	71.3	157.5	86
	2004-2030	175.6	403.8	228
	2004-2010	180.3	116.6	-64
TOTAL	2011-2020	193.2	239.8	47
	2021-2030	185.1	213.5	28
	2004-2030	558.6	569.8	11

map 1: **fuel costs in the reference and the energy [r]evolution scenario**

WORLDWIDE SCENARIO

SCENARIO

COST

LEGEND

>0 >5 >10

>40

>45 >50 % FUEL COST SAVING IN THE ALTERNATIVE SCENARIO COMPARED TO THE REFERENCE SCENARIO 2004-20030 GLOBAL FUEL SAVING IS 29.38%.

COST OF COAL BILLION $

COST OF GAS BILLION $

COST OF OIL BILLION $

REF REFERENCE SCENARIO

ALTERNATIVE SCENARIO

DIF DIFFERENCE BETWEEN SCENARIOS

0 1000 KM

OECD NORTH AMERICA

		REF		DIF
	2004-2010	409	351	58
	2011-2020	639	353	286
	2021-2030	723	197	525
	2004-2030	1,771	901	870
	2004-2010	327	304	23
	2011-2020	578	464	114
	2021-2030	776	552	224
	2004-2030	1,680	1,320	361
	2004-2010	128	103	26
	2011-2020	235	98	137
	2021-2030	240	53	187
	2004-2030	604	254	350
TOTAL ALL FUELS	2004-2010	865	758	107
	2011-2020	1,452	915	537
	2021-2030	1,738	802	936
	2004-2030	4,055	2,475	1,580

OECD LATIN AMERICA

		REF		DIF
	2004-2010	6	4	2
	2011-2020	13	4	9
	2021-2030	20	4	16
	2004-2030	39	11	28
	2004-2010	52	50	1
	2011-2020	163	105	58
	2021-2030	336	106	230
	2004-2030	551	261	289
	2004-2010	53	40	13
	2011-2020	93	35	58
	2021-2030	84	16	69
	2004-2030	231	91	140
TOTAL ALL FUELS	2004-2010	111	94	17
	2011-2020	268	143	125
	2021-2030	441	126	315
	2004-2030	820	363	457

OECD EUROPE

		REF		DIF
	2004-2010	132	114	18
	2011-2020	237	143	94
	2021-2030	308	115	193
	2004-2030	677	372	305
	2004-2010	192	204	-12
	2011-2020	363	399	-36
	2021-2030	528	581	-53
	2004-2030	1,083	1,183	-100
	2004-2010	92	87	5
	2011-2020	117	87	30
	2021-2030	86	40	47
	2004-2030	295	214	81
TOTAL ALL FUELS	2004-2010	416	405	11
	2011-2020	718	629	89
	2021-2030	922	735	187
	2004-2030	2,056	1,769	287

MIDDLE EAST

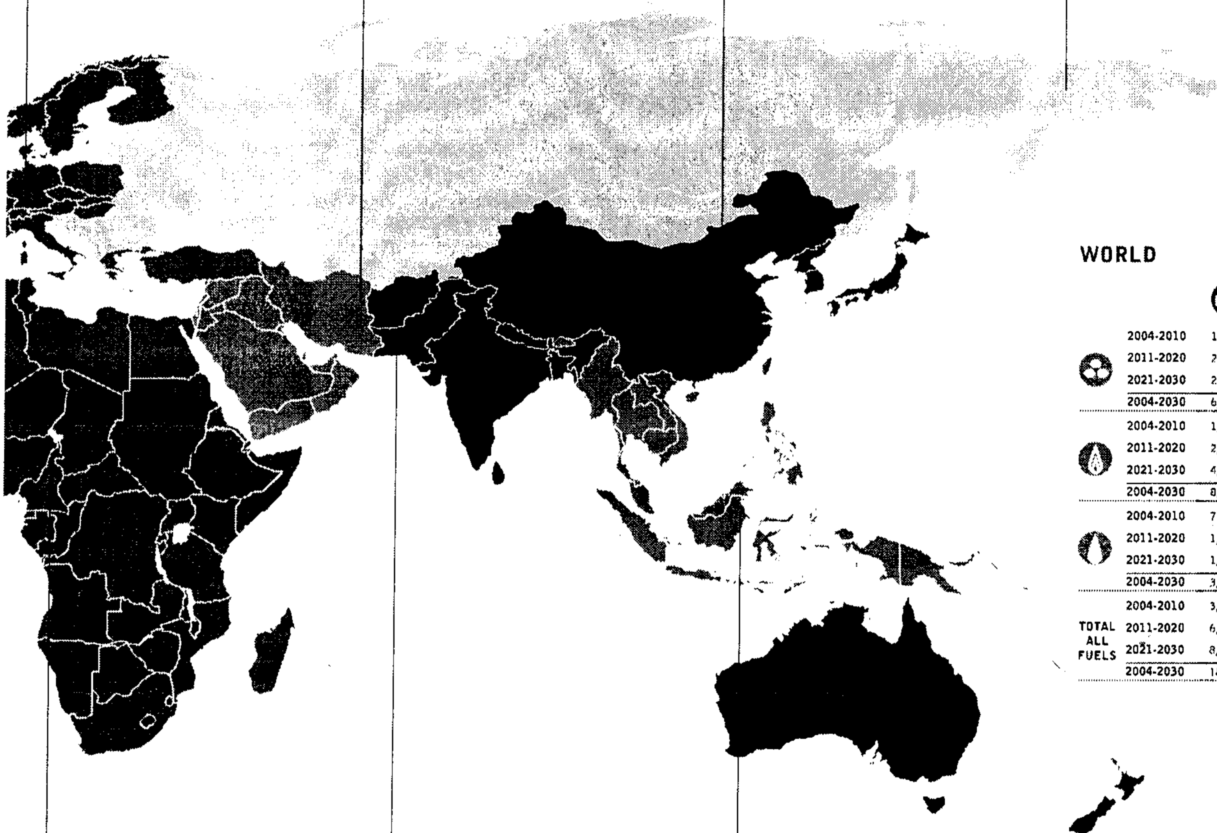
		REF		DIF
	2004-2010	6	5	1
	2011-2020	12	7	4
	2021-2030	16	8	7
	2004-2030	33	21	12
	2004-2010	124	120	4
	2011-2020	260	232	28
	2021-2030	397	287	110
	2004-2030	780	638	141
	2004-2010	128	108	20
	2011-2020	275	132	143
	2021-2030	383	73	310
	2004-2030	786	313	473
TOTAL ALL FUELS	2004-2010	258	233	25
	2011-2020	546	371	175
	2021-2030	796	368	427
	2004-2030	1,599	972	627

CHINA

		REF		DIF
	2004-2010	322	304	18
	2011-2020	639	494	145
	2021-2030	937	516	421
	2004-2030	1,898	1,315	584
	2004-2010	19	43	-24
	2011-2020	84	219	-135
	2021-2030	166	460	-295
	2004-2030	269	722	-453
	2004-2010	36	33	3
	2011-2020	69	53	17
	2021-2030	71	43	28
	2004-2030	177	129	48
TOTAL ALL FUELS	2004-2010	377	379	-3
	2011-2020	795	767	26
	2021-2030	1,174	1,020	154
	2004-2030	2,344	2,166	178

TRANSITION ECONOMIES

		REF		DIF
	2004-2010	99	86	13
	2011-2020	137	94	44
	2021-2030	126	72	54
	2004-2030	362	251	110
	2004-2010	378	376	2
	2011-2020	532	466	66
	2021-2030	646	402	244
	2004-2030	1,556	1,245	311
	2004-2010	48	37	11
	2011-2020	81	33	48
	2021-2030	79	14	65
	2004-2030	208	84	124
TOTAL ALL FUELS	2004-2010	525	499	26
	2011-2020	751	593	158
	2021-2030	851	488	362
	2004-2030	2,126	1,580	546



WORLD

		REF		DIF
	2004-2010	1,248	1,114	134
	2011-2020	2,213	1,433	780
	2021-2030	2,929	1,176	1,753
	2004-2030	6,389	3,723	2,667
	2004-2010	1,538	1,519	19
	2011-2020	2,883	2,735	148
	2021-2030	4,154	3,491	663
	2004-2030	8,576	7,745	831
	2004-2010	718	590	127
	2011-2020	1,373	673	700
	2021-2030	1,525	390	1,135
	2004-2030	3,616	1,654	1,962
TOTAL ALL FUELS	2004-2010	3,504	3,223	281
	2011-2020	6,469	4,842	1,628
	2021-2030	8,608	5,057	3,551
	2004-2030	18,581	13,122	5,459

AFRICA

		REF		DIF
	2004-2010	44	43	1
	2011-2020	83	65	18
	2021-2030	114	59	56
	2004-2030	242	167	75
	2004-2010	54	47	7
	2011-2020	157	107	50
	2021-2030	331	169	161
	2004-2030	542	323	218
	2004-2010	43	28	15
	2011-2020	114	31	83
	2021-2030	167	14	152
	2004-2030	324	73	251
TOTAL ALL FUELS	2004-2010	141	118	24
	2011-2020	355	203	151
	2021-2030	612	242	369
	2004-2030	1,108	564	544

SOUTH ASIA

		REF		DIF
	2004-2010	99	86	14
	2011-2020	192	107	85
	2021-2030	297	81	216
	2004-2030	588	273	315
	2004-2010	65	38	26
	2011-2020	159	156	2
	2021-2030	256	262	-6
	2004-2030	480	457	23
	2004-2010	36	23	13
	2011-2020	94	22	72
	2021-2030	129	8	121
	2004-2030	259	53	205
TOTAL ALL FUELS	2004-2010	199	147	53
	2011-2020	445	285	159
	2021-2030	682	351	331
	2004-2030	1,326	783	543

EAST ASIA

		REF		DIF
	2004-2010	39	38	0
	2011-2020	92	56	36
	2021-2030	185	48	137
	2004-2030	316	142	174
	2004-2010	137	132	4
	2011-2020	262	228	34
	2021-2030	329	259	69
	2004-2030	727	619	108
	2004-2010	67	47	20
	2011-2020	165	68	97
	2021-2030	185	51	134
	2004-2030	418	166	251
TOTAL ALL FUELS	2004-2010	243	218	25
	2011-2020	518	351	167
	2021-2030	699	359	341
	2004-2030	1,460	928	532

OECD PACIFIC

		REF		DIF
	2004-2010	92	83	9
	2011-2020	169	110	59
	2021-2030	202	75	127
	2004-2030	464	269	195
	2004-2010	191	204	-13
	2011-2020	326	359	-33
	2021-2030	391	412	-21
	2004-2030	908	975	-67
	2004-2010	86	85	1
	2011-2020	129	115	14
	2021-2030	100	78	23
	2004-2030	315	278	38
TOTAL ALL FUELS	2004-2010	370	373	-3
	2011-2020	624	584	40
	2021-2030	693	565	128
	2004-2030	1,687	1,522	165

table 11: top five contries with regards to renewable energy capacity[6]

TOP FIVE COUNTRIES	#1	#2	#3	#4	#5
Annual amounts or capacity addition in 2005					
Annual investment	Germany/China (equal)		United States	Japan	Spain
Wind power	United States	Germany	Spain	India	China
Solar PV (grid connected)	Germany	Japan	United States	Spain	France
Solar hot water	China	Turkey	Germany	India	Austria/Greece/ Japan/Australia
Ethanol production	Brazil/United States (equal)		China	Spain/India (equal)	
Biodiesel produciton	Germany	France	Italy	United States	Czech Republic
Existing capacity as of 2005					
Renewables power capacity (excl. large hydro)	China	Germany	United States	Spain	India
Large hydro	United States	China	Brazil	Canada	Japan/Russia
Small hydro	China	Japan	United States	Italy	Brazil
Wind power	Germany	Spain	United States	India	Denmark
Biomass power	United States	Brazil	Philippines	Germany/Sweden/Finland (equal)	
Geothermal power	United States	Philippines	Mexico	Indonesia/Italy (equal)	
Solar PV (grid connected)	Germany	Japan	United States	Spain	Netherlands
Solar hot water	China	Turkey	Japan	Germany	Israel

source ERIC MARTINOT, REN21

figure 8: renewable power capacities for developing countries, EU, and top 6 individual countries, 2005.[7]

EXCLUDES LARGE HYDROPOWER

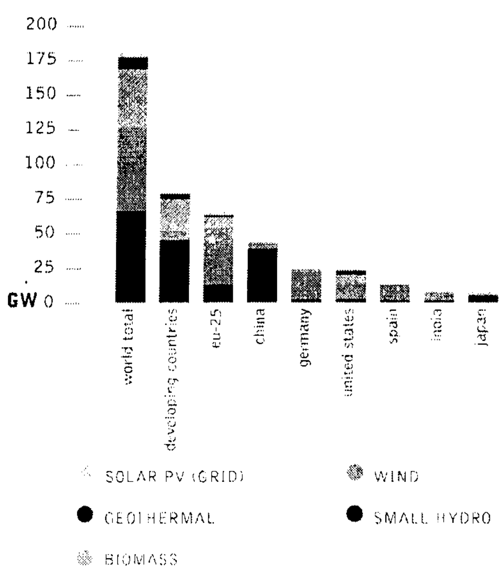
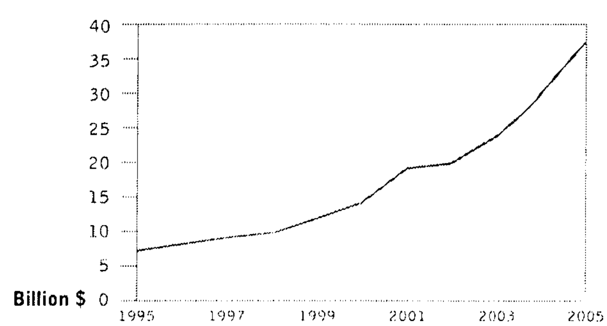


figure 9: annual investment in renewable energy 1995-2005.[8]



references

6 ERIC MARTINOT, REN21
7 ERIC MARTINOT, REN21
8 ERIC MARTINOT, REN21

investment in new power plants

THE AVERAGE ANNUAL INVESTMENT IN THE POWER SECTOR IN THE ENERGY [R]EVOLUTION SCENARIO BETWEEN 2004 AND 2030 IS APPROX. €280 BILLION (= US$300-350 BILLION) - WHICH IS EQUAL TO THE CURRENT AMOUNT OF SUBSIDIES FOR FOSSIL FUELS GLOBALLY.

image BIOMASS ENERGY PLANT NEAR VARNAMO, SWEDEN.

The overall global market volume for new power plants until 2030 will be in the region of US$7 trillion.

The main driver for investment in new power generation in OECD countries will be the ageing power plant fleet.

Utilities will make their technology choices within the next 5 to 10 years based on national energy policies - especially liberalisation, renewable energy and CO_2 reduction targets.

Within Europe, the emission trading scheme may have a large impact on whether the majority of investment will go towards conventional fossil fuel power plants or co-generation.

International finance institutes will not play a role in the investment decisions of OECD based utilities, as they will finance the new projects themselves. However, in developing countries, international financial institutes will play a major role in future technology choices.

The investment volume in the *Energy [R]evolution Scenario* is US$7.5 trillion, approx 9% higher than in the *Reference Scenario*, which will require US$6.9 trillion.

While the overall investment in renewable energy and fossil fuels is almost equal in the *Reference Scenario*, with approx. US$3.1 trillion each until 2030, the *Energy [R]evolution Scenario* shifts more than 80% of the investment towards renewable energy. The fossil fuels share within the power sector focuses mainly on combined heat and power and efficient gas power plants.

The average annual investments in the power sector in the *Energy [R]evolution Scenario* between 2004 and 2030 is approx. €280 billion (= US$300-350 billion) - which is equal to the current amount of subsidies for fossil fuels globally.

figure 10: **global investment in new power plants**

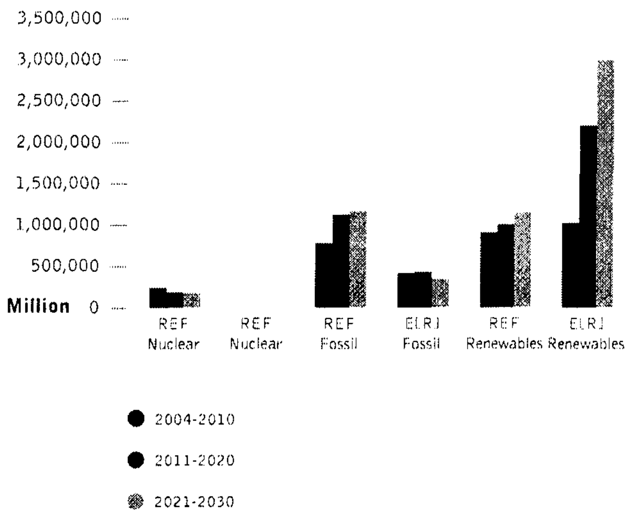


figure 11: **change in cumulative power plant investment in the energy [r]evolution scenario**

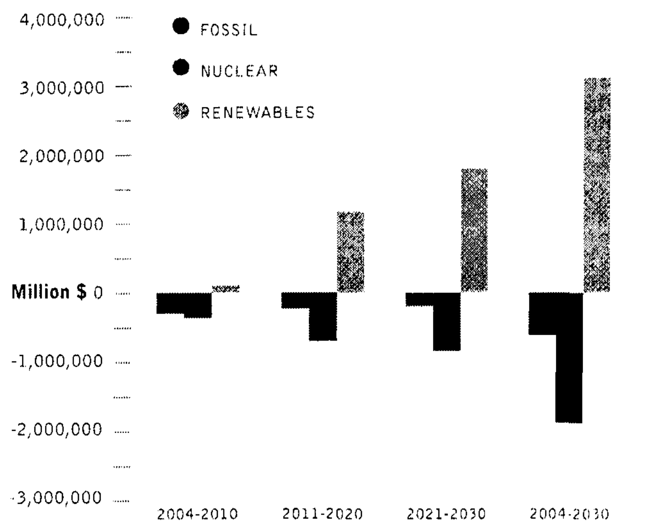


table 12: **global investment in new power plants - REF**

ENERGY INVESMENT	2004 - 2010 billion $2000	2011 - 2020 billion $2001	2021 - 2030 billion $2002	**2004 - 2030** billion $2004	**2004 - 2030** billion $200?
- Nuclear power plant	224	190	168	**581**	**22**
- Fossil fuels	722	1,044	1,078	**2,844**	**105**
- Renewables	842	940	1,089	**2,871**	**106**
Total	1,788	2,174	2,335	**6,296**	**233**

table 13: **global investment in new power plants - E[R]**

ENERGY INVESMENT	2004 - 2010 billion $2000	2011 - 2020 billion $2001	2021 - 2030 billion $2002	**2004 - 2030** billion $2004	**2004 - 2030** billion $200?
- Nuclear power plant	2	0	0	**0**	**0**
- Fossil fuels	397	415	316	**1,130**	**42**
- Renewables	955	2,045	2,762	**5,761**	**213**
Total	1,354	2,461	3,078	**6,891**	**255**

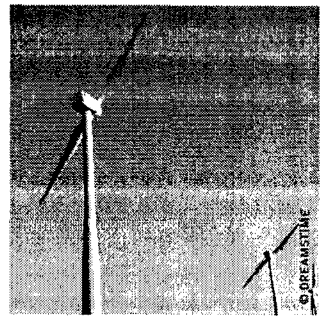


figure 12: **investment shares - REF versus E[R]**

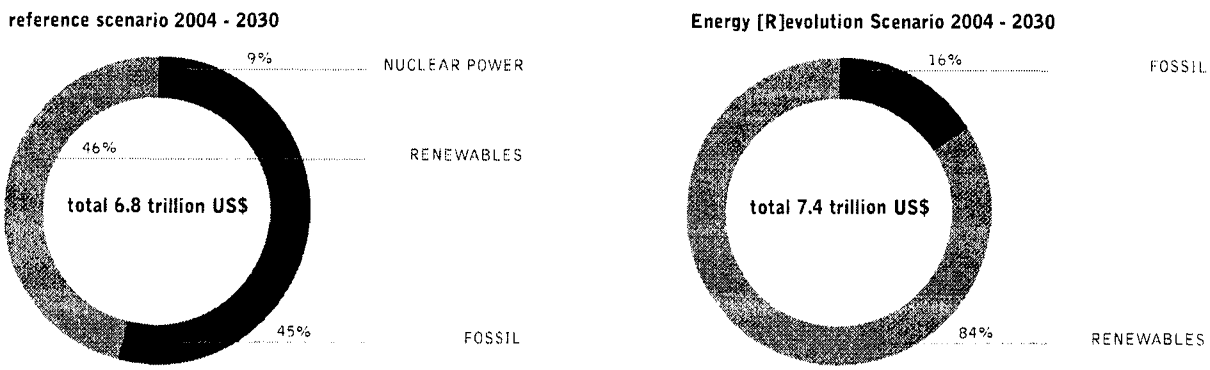
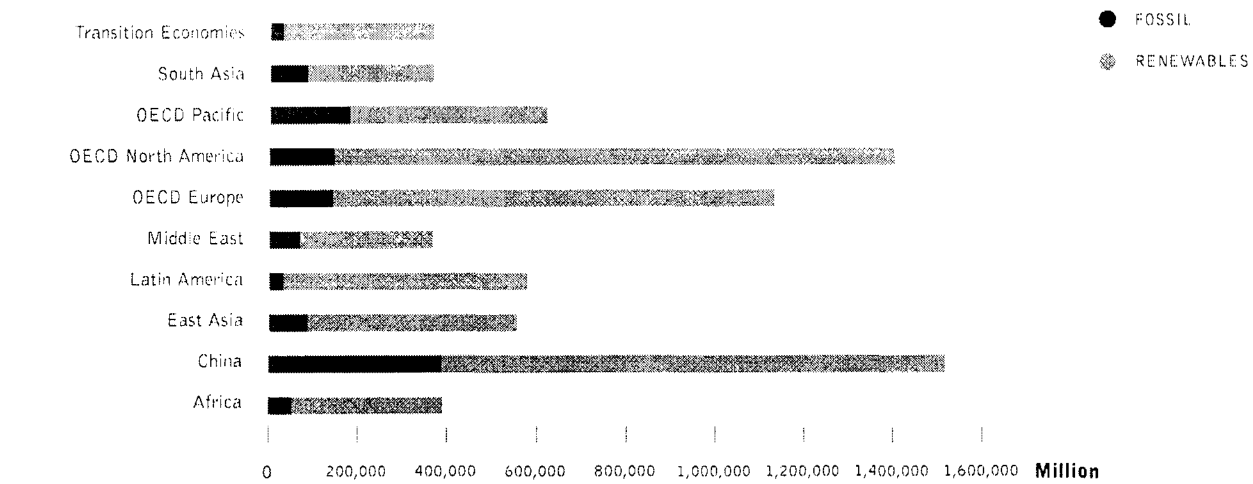


table 14: **investment shares - REF versus E[R]**

ENERGY [R]EVOLUTION VERSUS REFERENCE			BILLION $		AVERAGE PER YEAR BILLION $
INVESTMENT	2004 - 2010	2011 - 2020	2021 - 2030	**2004 - 2030**	**2004 - 2030**
- Nuclear power plant	-222	-190	-168	**-581**	**-22**
- Fossil fuels	-325	-628	-762	**-1,714**	**-63**
- Renewables	113	1,105	1,672	**2,890**	**107**
Total	-434	287	742	**595**	**22**

figure 13: **cumulative power plant investments by region 2004-2030**



The main investments in new power generation will take place in China, followed by North America and Europe. South Asia - namely India - and countries of the East Asia region - such as Indonesia, Thailand and the Philippines are "hot spots" of new power generation investments.

investment by technology

renewable power generation investment

In the *Reference Scenario* the investment volume for renewable electricity generation is in a range of US$2.8 trillion - compared to US$5.7 trillion in the *Energy [R]evolution Scenario* - however the regional distribution in the *Reference Scenario* and the *Energy [R]evolution Scenario* is almost equal.

table 15: **total new investment till 2030 by technology - REF**

NEW INVESTMENT	2004 - 2010 billion $2000	2011 - 2020 billion $2001	2021 - 2030 billion $2002	**2004 - 2030** billion $2004
Renewables	842	940	1,091	**2,874**
- PV power plant	23	31	45	**98**
- Solar thermal power plant	2	4	10	**16**
- Wind power	102	123	222	**447**
- Biomass power plant	30	32	49	**111**
- Geothermal power plant	77	42	75	**194**
- Hydro power	607	705	688	**2,001**
- Ocean energy power plant	1	4	2	**8**

table 16: **total new investment till 2030 by technology - E[R]**

NEW INVESTMENT	2004 - 2010 billion $2000	2011 - 2020 billion $2001	2021 - 2030 billion $2002	**2004 - 2030** billion $2004
Renewables	945	2,016	2,732	**5,693**
- PV power plant	84	337	641	**1,062**
- Solar thermal power plant	6	93	403	**502**
- Wind power	157	792	916	**1,865**
- Biomass power plant	24	38	47	**109**
- Geothermal power plant	71	57	89	**217**
- Hydro power	603	700	636	**1,939**
- Ocean energy power plant	10	30	32	**72**

The investment volume within the different renewable power generation technologies depends on the status of technical development. Technologies like wind power - which is in some regions with good wind resources already cost competitive - will have a larger investment volume and a bigger market share within the overall renewable investments. However the market volume by technology and region also depends on the local resources and the policy framework. Figure 15, 17a and table 22 provide an overview about the investments by technology and region.

For solar photovoltaic, the main market will for some years remain Europe and the US, but it will expand across China and India. Solar PV is a highly modular and decentralised technology, which can be used almost anywhere. Therefore it can be marketed across the globe.

Concentrated solar power systems (CSP) can only be operated within the sunbelt of the world. Therefore, the main investments in this technology will take place in North Africa, the Middle East, parts of the USA and Mexico, as well as south-west China, India and Australia. Due to the lack of direct sunlight, the market in Europe will be limited.

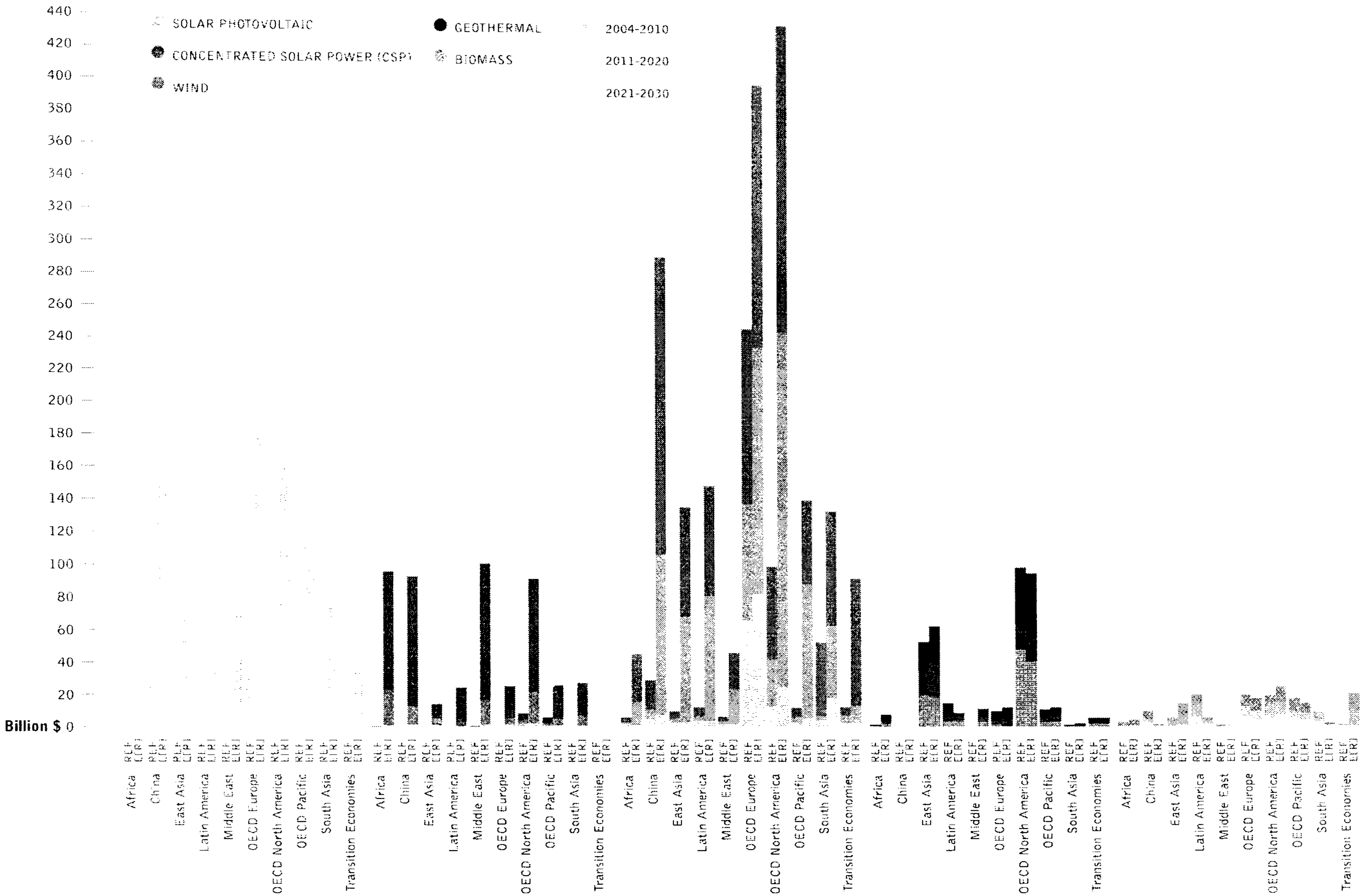
The main development of the wind industry will take place in Europe, North America and China. Offshore wind technology will have a larger share from approx 2015 onwards. The main offshore wind development will take place in North Europe and North America.

The market for geothermal power plants is mainly North America and East Asia. The USA, Indonesia and the Philippines and some countries of central and southern Africa have the highest potential for the next 20 years. After 2030, geothermal power generation will expand to other parts of the world like Europe and India.

Bioenergy power plants are distributed over the whole world as there is potential almost everywhere for biomass and/or biogas (cogeneration) power plants.

figure 14: **investment in renewable energy sources by region**

"This is only one way how a sustainable pathway could look like. Within the renewable energy sector some technologies could develop even more dynamic as particular industries, such as PV or biomass, expect. Further technological breakthroughs and rapid cost reduction could lead into much higher deployment rates."



fossil fuel power plant investment

Under the *Reference Scenario*, the main market expansion for new fossil fuel power plants is in China, followed by North America - which would have a volume equal to India and Europe together.

In the *Energy [R]evolution Scenario* the overall volume for fossil fuel power stations until 2030, is with 1,200 billion (REF 3,100 billion) significantly lower.

investment in new coal power plants

China is by far the biggest investor in coal power plants in both scenarios. While in the *Reference Scenario* the growth trend of the decade (2000-2010) continues towards 2030, the *Energy [R]evolution Scenario* assumes that in the second and third decade (2011-2030) growth slows down significantly. In the *Reference Scenario* the massive coal expansion is due to China, followed by the USA, India, East Asia and Europe.

figure 15: **investment in coal power plants**

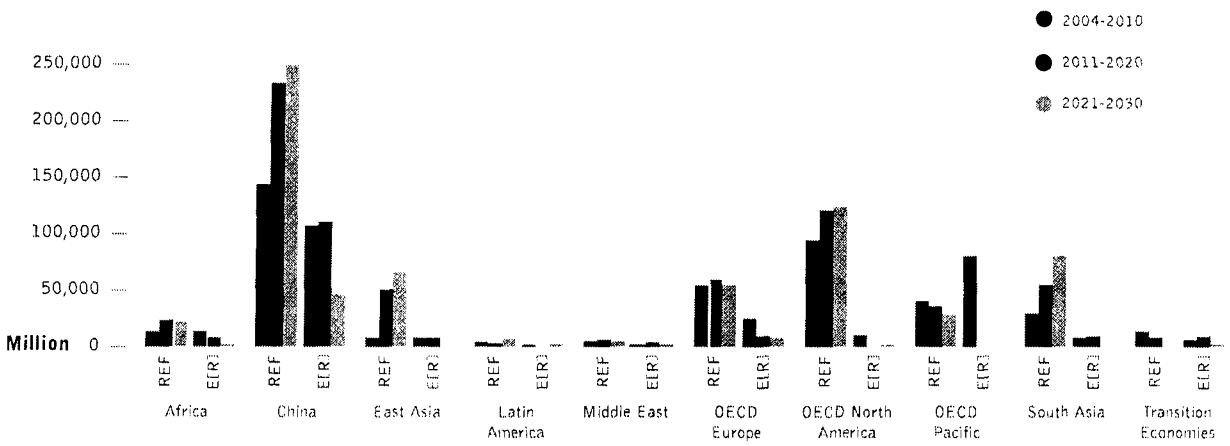


table 17: **investment in coal power plants**

		2004-2010	2011-2020	2021-2030	2004-2030
Africa	Reference	14,495	24,078	23,659	62,232
	Energy [R]evolution	12,720	7,891	759	21,370
China	Reference	143,439	233,350	248,941	625,731
	Energy [R]evolution	107,813	110,109	47,524	265,446
East Asia	Reference	9,106	51,094	66,974	127,174
	Energy [R]evolution	8,443	8,036	0	16,479
Latin America	Reference	4,313	2,206	5,793	12,312
	Energy [R]evolution	488	0	1,563	2,051
Middle East	Reference	1,794	4,172	2,690	8,656
	Energy [R]evolution	147	2,223	178	2,584
OECD Europe	Reference	55,372	58,711	55,720	169,803
	Energy [R]evolution	24,306	9,158	7,090	40,555
OECD North America	Reference	95,422	121,815	124,574	341,812
	Energy [R]evolution	9,658	0	296	9,954
OECD Pacific	Reference	38,708	36,334	28,617	103,659
	Energy [R]evolution	21,980	0	0	21,980
South Asia	Reference	28,970	56,028	79,806	164,803
	Energy [R]evolution	7,109	9,365	0	16,475
Transition Economies	Reference	12,505	8,643	0	21,147
	Energy [R]evolution	6,248	10,049	319	16,616
Global Total	Reference	404,124	596,431	636,774	1,637,328
	Energy [R]evolution	198,913	156,831	57,729	413,473

(more) costs for fossil fuels

THE MONEY SPENT IN THE ENERGY [R]EVOLUTION SCENARIO FOR OIL AND COAL TO GENERATE ELECTRICITY IS 50% BELOW THE REFERENCE SCENARIO.

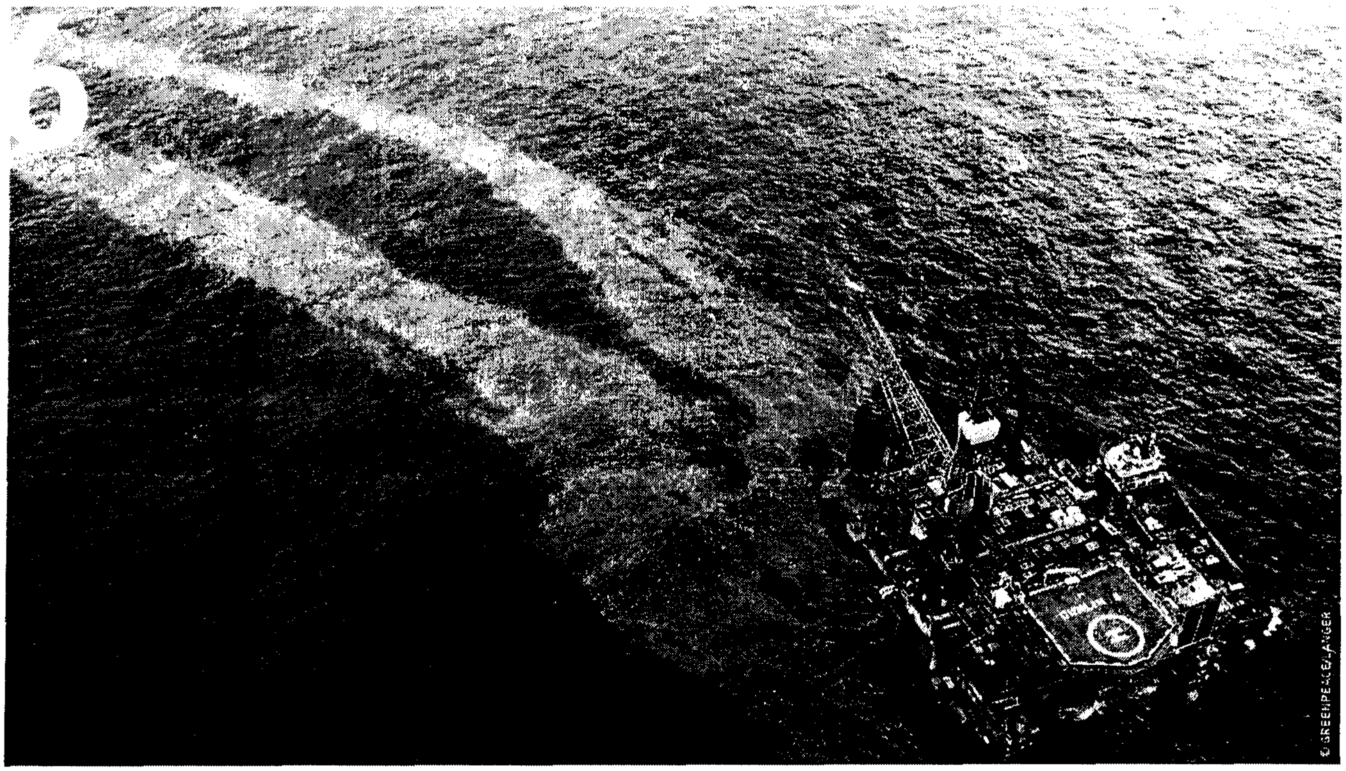


image PLATFORM/OIL RIG DUNLIN A IN THE NORTH SEA SHOWING OIL POLLUTION.

The total costs for fossil fuels in the *Reference Scenario* between 2004 and 2030 add up to a total of US$18,6 trillion - compared to US$13,1 trillion in the *Energy [R]evolution Scenario*. So fuel costs in the *Energy [R]evolution Scenario* are already 30% lower in the year 2030 (in 2050, the fuel costs are more than 70% lower). The "gas bill" remains roughly on the same level - in the *Energy [R]evolution Scenario* it is 10% below the *Reference Scenario*. The money spent in the alternative scenario for oil and coal to generate electricity is 50% below the *Reference Scenario*.

table 18: cumulative fossil fuel costs - global Reference scenario (power generation)

FOSSIL FUEL	2004-2010	2011-2020	2021-2030	2004-2030
			CUMULATIVE COST IN BILLION $2000	
Hard coal in Mill t	1,248	2,213	2,929	**6,389**
Natural gas in E+9m³	1,538	2,883	4,154	**8,576**
Crude oil in Mill barrel	718	1,373	1,525	**3,616**
Total	3,504	6,469	8,608	**18,581**

(DLR: EURO1 = US$2000 0.92)

table 19: cumulative fossil fuel costs - energy [r]evolution scenario (power generation)

FOSSIL FUEL	2004-2010	2011-2020	2021-2030	2004-2030
			CUMULATIVE COST IN BILLION $2000	
Hard coal in Mill t	1,114	1,433	1,176	**3,723**
Natural gas in E+9m³	1,519	2,735	3,491	**7,745**
Crude oil in Mill barrel	590	673	390	**1,654**
Total	3,223	4,842	5,057	**13,122**

(DLR: EURO 1 = US$2000 0.92)

table 20: fuel costs versus renewable energy sources without fuel

THE TOTAL FUEL COST SAVINGS IN THE ENERGY [R]EVOLUTION SCENARIO ARE AS HIGH AS US$5.4 TRILLION OR US$202 BILLION PER YEAR.

FOSSIL FUEL	2004 - 2010	2011 - 2020	2021 - 2030	2004 - 2030	2004 - 2030
			CUMULATIVE COST IN BILLION $2000		AVERAGE ANNUAL SAVINGS FOR FUEL IN BILLION $2000
Hard coal Mill t	134	780	1,753	**2,667**	**99**
Natural gas in E+9m3	19	148	663	**831**	**31**
Crude oil in Mill barrel	127	700	1,135	**1,962**	**73**
Total	281	1,628	3,551	**5,459**	**202**

table 21: Investment Costs Energy [R]evolution versus Reference

ENERGY [R]EVOLUTION VERSUS REFERENCE INVESTMENT	2004 - 2010	2011 - 2020	2021 - 2030	2004 - 2030	2004 - 2030
			BILLION $		AVERAGE PER YEAR BILLION $
Nuclear power plant	-222	-190	-168	**-581**	**-22**
Fossil fuels	-325	-628	-762	**-1,714**	**-63**
Renewables	113	1,105	1,672	**2,890**	**107**
Total	-434	287	742	**595**	**22**

The average annual additional fuel costs of the reference scenario are about 10 times higher than the additional investment requirements of the energy [r]evolution scenario.

The comparison between the extra fuel costs in the *Reference Scenario* and the extra investment costs of the *Energy [R]evolution Scenario* shows that the average annual additional fuel costs of the *Reference Scenario* are about 10 times higher than the additional investment requirements of the *Energy [R]evolution Scenario*.

In fact, the additional costs for coal from today until the year 2030 are as high as US$100 billion per year: this would cover 92.5% of the total annual investments in renewable power generation, required to implement the *Energy [R]evolution Scenario*.

But these renewable energy sources will produce electricity without any further fuel costs beyond 2030, while the fuel costs for coal and gas will continue to be a burden on national economies.

policy recommendations

HOW DO WE PUT A PRICE ON LOST HOMES ON PACIFIC ISLANDS AS A RESULT OF MELTING ICECAPS OR ON DETERIORATING HEALTH AND HUMAN LIVES?

image WALRUS ON AN ICE FLOW IN THE CHUCKCHI SEA, ARCTIC.

internalisation of the social and environmental costs of polluting energy

The real cost of energy production by conventional energy includes expenses absorbed by society, such as health impacts and local and regional environmental degradation - from mercury pollution to acid rain - as well as the global negative impacts from climate change.

Hidden costs include the waiving of nuclear accident insurance that is too expensive to be covered by the nuclear power plant operators, and is hence paid by tax-payers. The Price-Anderson Act, for instance, limits the liability of US nuclear power plants in the case of an accident up to US$98 million per plant, and only US$15 million per year per plant, with the rest being drawn from an industry fund for up to US$10 billion - and after that taxpayer pays.

Environmental damage should, as a priority, be rectified at source. Translated into energy generation this would mean that, ideally, production of energy should not pollute and that it is the energy producers' responsibility to prevent pollution. If they do pollute they should pay an amount equal to the damage the production causes to society as a whole. The environmental impacts of electricity generation can be difficult to quantify, however. How do we put a price on lost homes on Pacific Islands as a result of melting icecaps or on deteriorating health and human lives?

An ambitious project, funded by the European Commission - ExternE - has tried to quantify the true costs, including the environmental costs, of electricity generation. It estimates that the cost of producing electricity from coal or oil would double and that from gas would increase by 30% if external costs, in the form of damage to the environment and health, were taken into account. Other, more recent studies come to even higher numbers of external costs.

If those environmental costs were levied on electricity generation according to their impact, many renewable energy sources would not need any support. If, at the same time, direct and indirect subsidies to fossil fuels and nuclear power were removed, the need to support renewable electricity generation would seriously diminish or cease to exist.

the definition of external costs

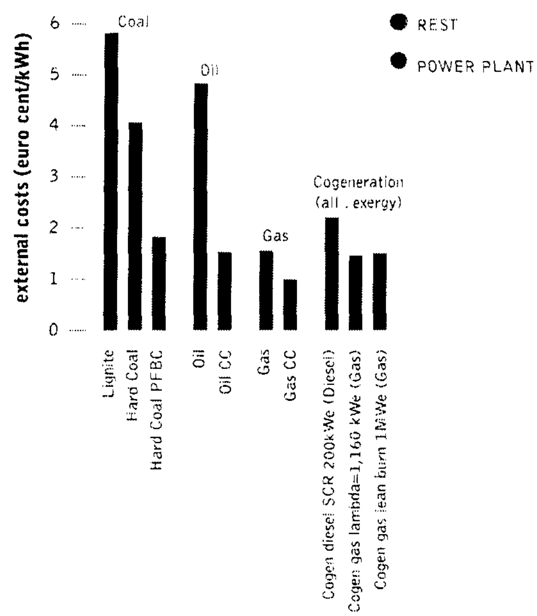
The scope of the ExternE Project is to value the external costs, i.e. the major impacts, of economic activities, referred to both production and consumption. Up to now, valuations of external costs have mainly been applied to energy-related activities such as fuel cycles, and activities related to transport of persons and freight, but the focus is being broadened and the methodology extended to activities such as different industrial processes.

An external cost, also known as an externality, arises when the social or economic activities of one group of persons have an impact on another group and when that impact is not fully accounted, or compensated for, by the first group. Thus, a power station that generates emissions of SO2, causing damage to building materials or human health, imposes an external cost. This is because the impact on the owners of the buildings or on those who suffer damage to their health is not taken into account by the generator of the electricity when deciding on the activities causing the damage. In this example, the environmental costs are "external" because, although they are real costs to these members of society, the owner of the power station is not taking them into account when making decisions. Note that external costs are unintended and result from there being no property rights or markets for these environmental effects. The potential value of the ExternE project therefore lies in valuing external costs in order for those values to be included in the design of policy to make up for the present lack of such property rights and markets.

There are several ways of taking account of the cost to the environment and health, i.e. for 'internalising' external costs. One possibility would be via eco-taxes, i.e. by taxing damaging fuels and technologies according to the external costs caused. For example, if the external cost of producing electricity from coal were to be factored into electricity bills, between 2 and 7 cents per kWh would have to be added to the current price of electricity in the majority of EU Member States. Another solution would be to encourage or subsidise cleaner technologies thus avoiding socio-environmental costs. The Community guidelines on state aid for environmental protection explicitly foresee that EU member states may grant operating aid, calculated on the basis of the external costs avoided, to new plants producing renewable energy. Besides that, in many other widely accepted evaluation methods such as green accounting, life-cycle analysis and technology comparison, the quantitative results of external costs are an important contribution to the overall results.

source EXTERNE (WWW.EXTERNE.INFO)

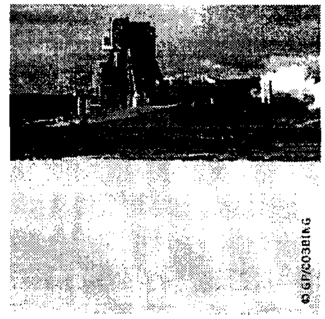
figure 16: **external costs of current and advanced electricity systems, associated with emissions from the operation of power plants and with the rest of the energy chain - fossil fuels**



source FINAL REPORT EXTERNE POL, VERSION 2, AUGUST 2005, PAGE 35

"The ExternE study is used here as an example, because it is one of very few studies which went a long way. Still there are many shortcomings in ExternE in our point of view. It for example does not take into account nuclear liabilities at all and therefore gives a wrong impression of the true costs of nuclear. Also other significant external cost factors for conventional sources were not taken into account. A more detailed study would most likely result in substantially higher external cost calculations for nuclear and fossil fuels."

image GEOTHERMAL ENERGY PLANT NEAR REYKJAVIK, ISLAND.



financing sustainable development

reform of export credit agencies (ECAs), multi-lateral development banks (MDBs) and international finance institutions (IFIs)

Demand for energy, particularly electricity, is increasing worldwide. This is especially the case in developing countries, which rely heavily on export credit agencies and multi-lateral development banks to provide financing for energy and other industrial projects.

ECAs and other IFIs that support or underwrite projects around the world must have policies consistent with the need to limit greenhouse gas emissions. At the same time there needs to be a transition plan and flexible timeframes to avoid undue hardships on developing country economies that are overly reliant upon conventional energy sources and exports. It should also be recognised that meeting development goals for the world's poorest will require subsidies for the foreseeable future.

Policies to address these issues must include:

- A defined and increasing percentage of overall energy sector lending directed to renewable energy projects.
- A rapid phase out of support for conventional, polluting energy projects.

export credit agencies

Export Credit Agencies are the world's largest public financial institutions. They are mainly based in OECD countries and represent by far the single largest source of public financial flows from North to South. They are the least examined, the least transparent, the least accountable, and, perhaps in some ways, the most harmful. They include the US Export Import Bank (USEXIM), the Japan Bank for International Cooperation (JBIC), Germany's Hermesbürgschaft (Hermes Guarantee), France's COFACE, the British Export Credit and Guarantee Department (ECGD), Belgium's Office National du Ducroire, Canada's Export Development Corporation, Italy's SACE and various Scandinavian ECAs. In addition, there are lesser-known ECAs from China, India, Korea, Thailand, Malaysia and Sri Lanka. The World Bank's Multilateral Investment Guarantee Agency (MIGA) acts as the World Bank's ECA70.

It is essential to note that ECAs are *public* financial institutions and use taxpayers' money with national governments determining their policies and the projects that they support.

The purpose of ECAs is to support the sales of goods and services from companies in the home country of the ECA to buyers, mainly in southern countries, and to provide political risk insurance as companies seek security for their projects against nationalisation and expropriation, currency instability, war and civil disturbance. The host country, through the use of military and paramilitary forces, often provides security. ECAs help attract commercial banks, equipment suppliers and contractors.

how ECAs work When a company needs loans from commercial banks for a large project that could have political and/or economic risks, it first attempts to obtain ECA support, in the form of a direct loan, an investment guarantee or political risk insurance.

In many cases, the ECA in turn may require a sovereign guarantee from the host country where the project will be implemented so that if the project were to fail for economic or political reasons that would trigger ECA liability, the host country is liable for the replacement of funds paid out by the ECA. Hence the system converts the corporate risks inherent in dubious and purely private sector transactions into public debt (i.e. the government and people) of a developing country. Even without such host country guarantees, in practice political pressure is applied in order to bail out failed projects.

Sometimes multilateral development banks provide joint financing of projects supported by ECAs. Such partnerships open a country for foreign investment but with 'structural adjustment policies' as part of the criteria; such policies include deregulation, privatisation, and liberalisation of the national economy. For example, JBIC partnered with the World Bank to provide US$530 million for a coal sector rehabilitation package for 24 open cast coalmines in India. The World Bank loan was tied to a structural adjustment agenda aimed at liberalising coal imports, deregulating coal prices and reducing the workforce leading to 20,000 people losing their jobs.

ECAs have supplied funding of over US$20 billion for fossil fuel plants in Bangladesh, Cambodia, China, Hong Kong, India, Indonesia, Laos, Malaysia, New Zealand, Pakistan, Philippines, and Thailand. The power sector - nuclear, big dam hydropower, fossil fuels and attendant infrastructure - represents by far the highest value sector for projects for which total finance data is available. Only a very small portion of current ECA business supports renewable energy projects. For example, between 2000 and 2003, support to renewable energy projects was less than 1% of total support by most ECAs. Of the US$28 billion Ex-Im Bank (US ECA) provided in loans and guarantees for energy-related projects from 1990 to 2001, 93% was used to finance fossil fuel projects and 3% was for renewable energy projects.

Not surprisingly, the most important destinations of ECA export credits and project financing for energy intensive activities include developing countries with some of the largest greenhouse gas emissions (Brazil, China, India, Indonesia and Mexico). The seven leading industrialised economies (Canada, France, Germany, Italy, Japan, the United Kingdom and the United States) provided most of the ECA financing for energy intensive exports.

Apart from providing financial support to polluting energy sources, another key problem of ECAs is their lack of transparency. The denial of public access to information by ECAs makes it difficult to really identify those that are supporting the expansion of coal power throughout Asia. It also leads to a lack of accountability for the environmental consequences of their financing. Over three-quarters of ECA-supported fossil-fuelled energy and power project financing in East and South Asia went to just five countries: China (US$6.2 billion), Indonesia (US$5 billion), Pakistan (US$3.6 billion), the Philippines (US$3.6 billion), and India (US$3.3 billion).

JBIC - the largest public financier of coal power plants in asia The Japan Bank for International Cooperation is the largest public financial institution in the world and provides a good example of the massive support provided for home corporations like the Mitsubishi group companies as well as coal and power companies from other countries.

JBIC was established in 1999 when two Japanese financial institutions - the Japan Export-Import Bank (JEXIM) and the Overseas Economic Cooperation Fund (OECF) - merged into one bank. OECF was mainly responsible for giving loans to governments in developing countries as Official Development Assistance (ODA), the role of which, according to the Japanese government, is to promote the economic development and welfare of developing countries.

JEXIM, on the other hand, gave export or import loans, investment and untied loans to both governments and private companies in support of Japanese companies' exports and investments. Hence JBIC now lends to governments and to both Japanese and foreign companies. According to the JBIC annual report 2003, the bank has US$192.3 billion worth of outstanding loans and lends US$17.7 billion annually to 40 countries; most (80%) are in Asia. By comparison, the World Bank has outstanding loans of US$223.1 billion and an annual lending of US$18.5 billion.

Japanese ODA (part of JBIC) in the energy sector greatly favours fossil fuel projects and, as a result, Japan is one of the world's largest CO_2 emission contributors amongst the developing countries. In 1993, Japanese ODA financing of fossil fuel related projects was about four times that spent on energy conservation-related projects. By 2002, this had grown to seven to one. The sum of the budget allocated for energy ODA between 1992 and 2001 reached US$19.7 billion. It is clear that the focus for Japan's foreign aid and investment through JBIC is on energy sector development in Asian countries, as among the top ten recipients, eight countries are located in Asia with China and India the two largest. Among fossil fuel-based projects, fossil fuel power generation projects are dominant. Between 1993 and 2002, approximately US$7.6 billion was loaned for a total of 53 fossil fuel power generation projects, with most of the loans (32 projects or 63.1%) for coal projects.

Over 70% of the lending to China has been to support coal-fired power plants. The key Japanese industries that have benefited from these projects are companies such as the Mitsubishi group (Mitsubishi Heavy Industries, Ltd. and Mitsubishi Corp) and China Light and Power (CLP) based in Hong Kong.

Loans to India from JBIC were provided for construction of five coal-fired thermal power plants, one natural gas-based power plant, one oil/gas combined cycle plant, five transmission line and distribution system projects, and two power efficiency projects. The total financing for fossil fuel projects for the past decade accounts for up to 77.8% excluding transmission and distribution projects. Between 1993 and 2002, only 6 renewable energy projects have received support and these were in 3 countries - the Philippines (two geothermal and one wind project), Indonesia (two small hydro projects), and Brazil (one wind project). The total expenditures for renewables projects for the years 1993-2002 accounted for 3.3% of the total energy and infrastructure expenditures.

multilateral development banks (MDBs)

Unlike the ECAs, the mandate of the MDBs includes development. In other words, the projects they fund should be targeted at poverty alleviation. MDBs are the largest source of development finance in the world, typically lending between US$30-40 billion to low and middle-income countries in any given year. Their financing comes coupled with policies that govern the direction and type of 'development'.

Despite their mission to reduce poverty and encourage economic development, MDB loans have been responsible for causing widespread environmental and social damage from ill-conceived programmes that have adversely affected millions of people in developing countries.

The MDBs include: the Asian Development Bank; the African Development Bank; the European Bank for Reconstruction and Development; the Inter-American Development Bank and the World Bank Group, which includes the World Bank, the International Bank for Reconstruction and Development, the International Development Association, the International Finance Corporation and the Multilateral Investment Guarantee Agency. In Asia, the two key MDBs are the Asian Development Bank and the World Bank Group.

the asian development bank (ADB) The ADB, established in 1966, is comprised of shareholders from 63 member countries (45 from Asia and Pacific and 18 from other parts of the globe) the largest being Japan and the United States. Each member country has a representative serving on the Board of Governors. The stated mission of the ADB is to reduce poverty in the Asia Pacific region.

Although the ADB claims to operate in the interest of Asia's poorest citizens, civil society groups have long been concerned about the ADB's failure to promote sustainable and equitable growth in the region. ADB-

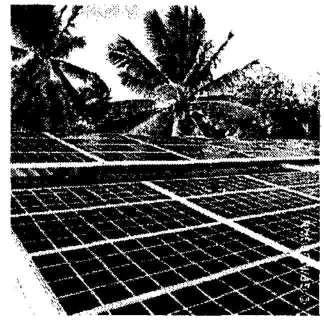


image SOLAR PANELS ON REFRIGERATION PLANT (FOR KEEPING FISH FRESH). LIKIEP ATOLL MARSHALL ISLANDS.

funded operations have been responsible for causing widespread environmental and social damage, adversely affecting some of the region's poorest and most vulnerable communities.

Though publicly financed by taxpayers, ADB activities (and those of other MDBs) are often carried out without informed participation of taxpayers themselves, affected people, non-governmental organisations (NGOs), or, in many cases, elected officials in the borrowing countries.

Between 1970 and 2003, the ADB co-financed projects to the tune of US$40.6 billion, 41% of which was to the energy sector. The stated goal of the ADB's new energy policy (2000) is that they will actively promote the development of renewable energy resources and support the uptake of cost-effective renewable energy technologies and assist countries in formulating renewable energy projects for remote areas. However, only one out of the eight energy sector projects receiving ADB funding of US$756.7 million in 2003 was for a form of clean energy development. In the Philippines, ADB financing for renewable energy amounts to only 0.09 percent of the ADB's entire funding support for the country. Much of the ADB's financing was channelled in support of coal-fired power initiatives.

The ADB has recently announced programs that it says will help combat climate change. These are the Energy Efficiency Initiative (which has been renamed the Clean Energy Initiative [CEI] to include renewable energy), the Carbon Market Initiative (CMI), and the creation of Regional Energy Hubs. The announcements are welcome but also deserve further scrutiny.

the world bank group The mission of the original World Bank, founded together with the International Monetary Fund (IMF) at the 1944 Bretton Woods conference, was largely to provide reconstruction financing for post-World War II Europe.

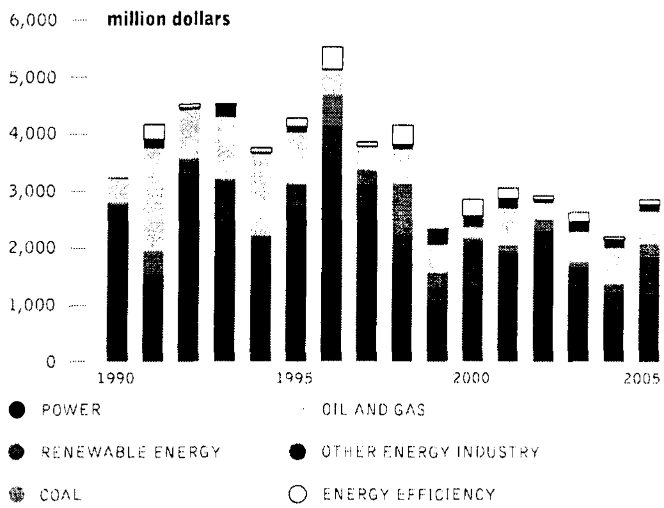
However, after only four reconstruction loans, the Bank shifted its attention to less developed countries. In 1948, Chile became the Bank's first developing country client. Since then, the World Bank has lent over US$500 billion to low and medium income countries.

As the single largest source of development finance in the world, the World Bank has an enormous impact on the lives and livelihoods of millions of people in developing and transition countries. Given its lending resources, policy prescriptions, and political backing, the World Bank plays a pivotal role in shaping the development priorities of countries around the world.

Although the World Bank's stated mission is to "to promote sustainable private sector investment in developing countries, helping to reduce poverty and improve people's lives", this does not happen in practice. For instance, in 2002-2003 the Bank's energy financing for big fossil fuel projects beat renewable and energy efficiency projects by a 17 to 1 ratio.

The MIGA is the political risk insurance arm of the World Bank Group - the World Bank's ECA. It provides non-commercial risk insurance for private enterprises investing in developing countries and provides developing country members with technical assistance on investment promotion. Like the ECAs, MIGA guarantees to protect investors against loss resulting from expropriation, breach of contract, war, and terrorism. In addition to offering insurance to private companies, MIGA mobilises additional guarantees for investors and assists host governments with legal services and strategic advice regarding investment. As of June 2003, MIGA had issued guarantees worth over US$12 billion since its inception.

figure 17: **World Bank investment in energy by recipient, 1990-2005**



source IEA

financing sustainable development: the ADB as an example

An energy revolution is both required and desirable. It is economically and technologically viable, but it can only succeed if ECAs, MDBs and IFIs join and help to lead it.

The responsibility of major development institutions such as the ADB is not to finance fossil fuel development, but to ensure that its member countries are able to fully exploit their efficiency and renewables potential sustainably and equitably, both in on-grid and off-grid applications.

What should a development bank such as the ADB do?

quit coal Programs such as the CEI and CMI will be rendered meaningless unless and until the ADB stops supporting coal projects. The ADB must recognize that every dollar that it spends on perpetuating the illusion of "clean coal" is a dollar diverted away from efficiency and renewables – the real energy solutions. Getting out of coal will also force the ADB to develop the energy efficiency and renewables market to its full promise.

reverse over-reliance on carbon market Based on its emphasis on the CMI, the ADB appears to be relying too much on carbon market instruments.

The carbon market is not a bad thing per se but, the fact is, it will also not drive fundamental realignments in investment in the energy sector, especially in the near-term. It needs to be complemented by other policies. The market that the ADB intends to tap is based on the Clean Development Mechanism (CDM) of the Kyoto Protocol, and right now investment flows in the CDM are overwhelmingly going to non-CO_2 gases such as HFC23 (used in refrigeration) and methane which have no impact on developing countries' energy sectors and their development. These types of projects are cheap and easy, which is what the market wants.

Initiatives such as the CMI can't just leave the development of sustainable energy options to the market. Institutions such as the ADB need to shift resources towards actual renewables and efficiency projects and at the same time put in place policies that can stimulate the development of real energy solutions, such as what feed-in tariffs have done for wind development in India. Other policy measures include getting developing member countries to govern their energy choices through Integrated Resource Planning (IRP). Implementing the IRP ensures that a country's available renewable and efficiency potentials are evaluated first for full utilisation before new capacity is even considered.

increase US$1 billion per year to CEI, keep it coal-free The ADB has committed to provide a minimum of US$1 billion per year to fund the CEI. This is welcome. However, in order for the ADB to play a leading role in developing the renewables and efficiency market in Asia, the ADB must also:

- Set a target period of at least 10 years for the implementation of its clean energy facility.
- Increase the US$1 Billion Clean Energy Pipeline by 10 percent annually. It is a fact that the expected cost reduction in renewables is essentially not a function of time, but of cumulative capacity, which means dynamic market development is required. The yearly 10 percent growth in the facility furthers such development.
- Keep coal out of the US$1 billion pipeline. The ADB must secure the environmental integrity of its clean energy facility and ensure that it is used exclusively for new, renewable energy and energy efficiency projects and programs, preferably based on a combination of new, large on-grid projects and grid adjustments that will facilitate the rapid development of the renewable energy market, using the decentralized energy approach where applicable, for instance in the Pacific and in countries where rural electrification is key such as Laos and Bangladesh.

ensure energy hubs are relevant While such information sharing initiatives are important in terms of capacity building and developing country expertise, it is crucial that the ADB plays a more active role in demonstrating the kind of policy environment that will allow renewables to flourish. For instance, it needs to demonstrate to member countries successful frameworks used in effective renewables legislation across Asia.

policy recommendations

There are five key issues driving the need for a massive expansion of renewable energy technologies:

- Protection of the global climate
- The need for secure energy supplies that do not suffer dramatic and sudden swings in prices which largely create macroeconomic instability
- The need for poverty alleviation
- Protection of local human health, social welfare and the environment
- The need for a large number of distributed sources of generation, which are inherently more stable, and less prone to catastrophic accidents or failure, and much less vulnerable to attack from hostile forces

These demand an urgent change in the way governments plan for and support the development of energy sources.

All governments need to rapidly accelerate the development of renewable energy markets to cut CO_2 emissions and drastically reduce costs making sustainable energy sources accessible to developing countries.

The international finance system must stop actively encouraging the expansion of energy- and carbon intensive production capacities and infrastructure. Governments must establish a coherent policy framework across all financial actors - public, national, international and private - and demonstrate a true willingness to stop climate change and encourage the expansion of renewable energy technologies and energy efficiency programmes.

Only through a fundamental shift in the policies of governments (north and south) and of public and private financial institutions, can political and fiscal barriers be removed so as to provide the necessary spur for the massive global uptake of renewable energy technologies and energy efficiency programmes.

reference

THE US$1 BILLION CLEAN ENERGY FUND INITIATIVE OF THE ADB IS NOT ACTUALLY A NEW IDEA. IT WAS ACTUALLY PROPOSED 11 YEARS AGO BY THE NGO WORKING GROUP ON THE ADB. SEE THE NGO PO CAMPAIGN MANUAL ON THE ADB, ED. ELIZABETH PUA VILLAMOR AND MELINDA MAL BUAN OCAMPO, NGO WORKING GROUP ON THE ASIAN DEVELOPMENT BANK, OCTOBER 1996.

good practice / case studies

GERMANY HAS DEVELOPED THE MOST DYNAMIC RENEWABLE ELECTRICITY MARKET AND RENEWABLE INDUSTRY WORLD WIDE.

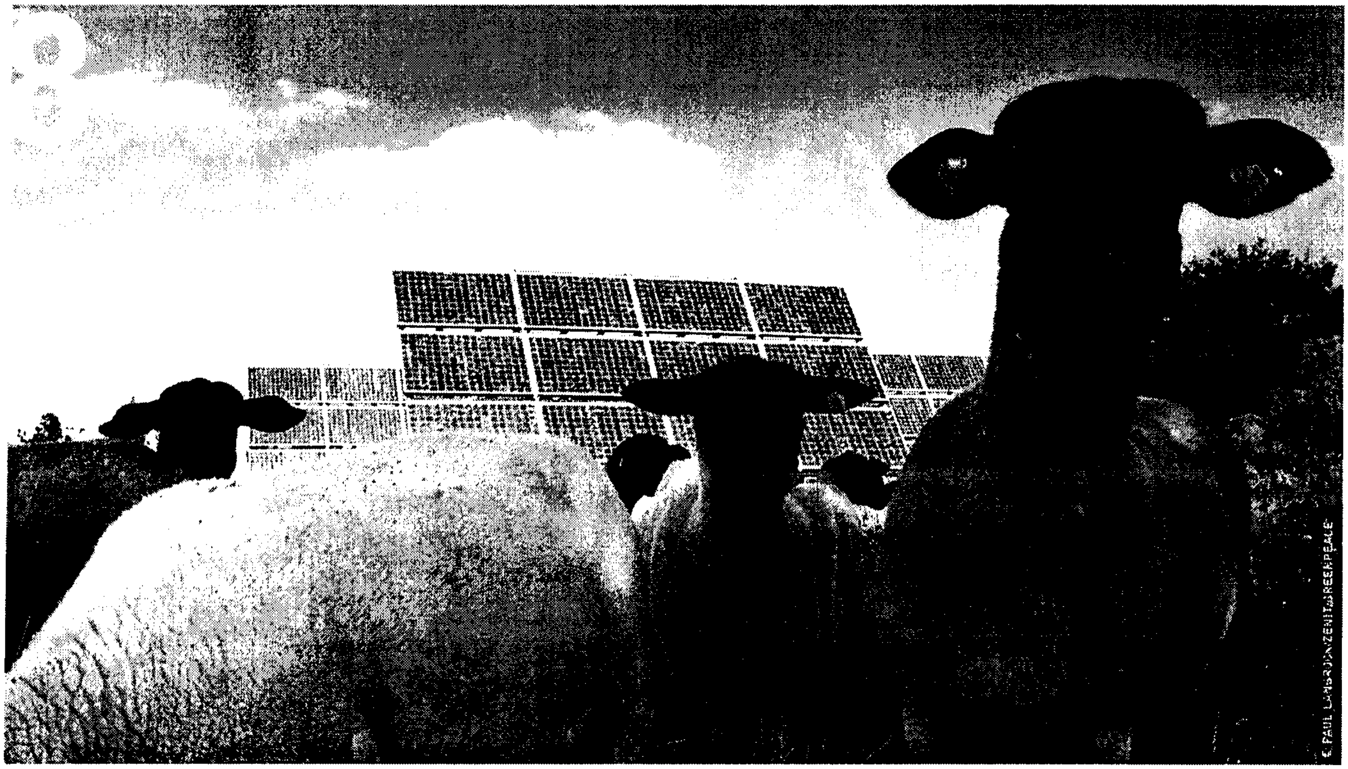


image image PHOTOVOLTAICS FACILITY AT 'WISSENSCHAFTS UND TECHNOLOGIEZENTRUM ADLERSHOF' NEAR BERLIN, GERMANY. SHEEP BETWEEN THE 'MOVERS' KEEPING THE GRASS SHORT.

the renewable energy act of germany

Worldwide, people are surprised by the fact that Germany has developed the most dynamic renewable electricity market and renewable industry world-wide. How could this happen? Many different kind of programmes in many countries have been started in the past in order to accelerate the markets for renewable energies, but none has been as successful over such a short period of time as the feed-in tariff in Germany. The idea of the feed-in tariff has been adapted in several countries and of course each country adjusted it to its specific needs. The basic idea behind it is very simple:

feed-in tariff: the driver of the success story in germany

It is evident that without the support of suitable instruments the expansion of renewable electricity markets worldwide will not happen at sufficient speed. In order to accelerate the reconstruction of our electricity supply it is necessary to implement powerful and efficient tools supporting the use of renewable electricity. The premium feed-in tariff has proved its power and efficiency during the previous years. Producers of renewable electricity:

- Have the right to feed renewable electricity into the public grid
- Receive a premium tariff per generated kWh reflecting the benefits of renewable electricity compared to electricity generated from fossil fuels or nuclear power
- Receive the premium tariff over a fixed period of time

All three aspects are simple but it took significant effort to establish them. For many years the utilities did not allow the feeding of renewable electricity into their grid (and this is still the case in many countries even today). The right to feed electricity into the public grid cannot be taken for granted and in most countries the utilities fight this idea very strongly once it comes up.

feed-in tariff: who pays for it?

In the past many programmes intended to push renewable electricity were financed through the budget of a ministry. This implies the disadvantage that lack of state money could lead to the programme being stopped. Therefore the feed-in tariff model takes a completely different approach.

In Germany in 2006 the utilities pay a fixed premium tariff for renewable electricity - the tariff varies with the size and the technology of the installation. Therefore the utilities, as a first step, have higher costs due to the premium tariff. The utilities are authorised to charge this extra cost, spread equally to all electricity consumers via their usual electricity bill. With this system the programme works independently of the financial situation of the state and is not in permanent danger of being stopped due to the financial situation at the state level. At the same time, the extra cost that each electricity consumer has to pay in order to increase the share of renewable energy in the national electricity portfolio is very small. In Germany the monthly extra costs per household due to the feed-in tariff for renewable electricity was less than €1 per month - or €12 per year. So every electricity consumer contributes to the restructuring of the national electricity supply structure from a fossil-based one towards a sustainable and independent electricity supply structure.

feed-in tariff: the driver of cost reduction

The costs for renewable electricity have been reduced constantly since the technology was introduced to the markets. But it is evident that today in most cases renewable electricity cannot yet compete with grid electricity generated from fossil fuels. While it is expected that prices for electricity generated from fossil fuels will keep rising constantly, at the same time it is very important to keep a high pace in bringing the cost of renewable electricity down. For this reason the feed-in tariff in Germany is reduced each year by 5%, but only for newly installed systems. Once a system is connected to the grid the feed-in tariff remains constant over the complete period of 20 years. The reduction by 5% each year places pressure on the industry to bring the costs for renewable electricity down by 5% each year in order to keep the market alive. This planning security is an essential element of the success story of the feed-in tariff.

feed-in tariff: the driver of high quality renewable electricity systems

With the investment subsidy approach there is little incentive to maintain the system properly over its whole lifetime. Maintenance is linked to a moderate degree of investment, but if the customer received the complete financial incentive up-front, there is no incentive to operate the system at the highest possible level.

feed-in tariff: the driver of easier financing

The up-front costs of renewable electricity systems are a clear barrier to a wider market penetration. A feed-in tariff guaranteed by law over a sufficient period of time serves as an excellent security for the customer's bank in order to finance the system.

the feed-in tariff needs a strong co-driver: simple and quick administration as well as guaranteed grid access for renewable electricity

The feed-in tariff needs a strong partner in order to be able to unfold its full power and this is a simple and quick approval process from the administration. Even if an excellent feed-in tariff is in place, but procedures for the approval of the installation of a system and for its connection to the grid takes many months, the number of potential customers will remain limited.

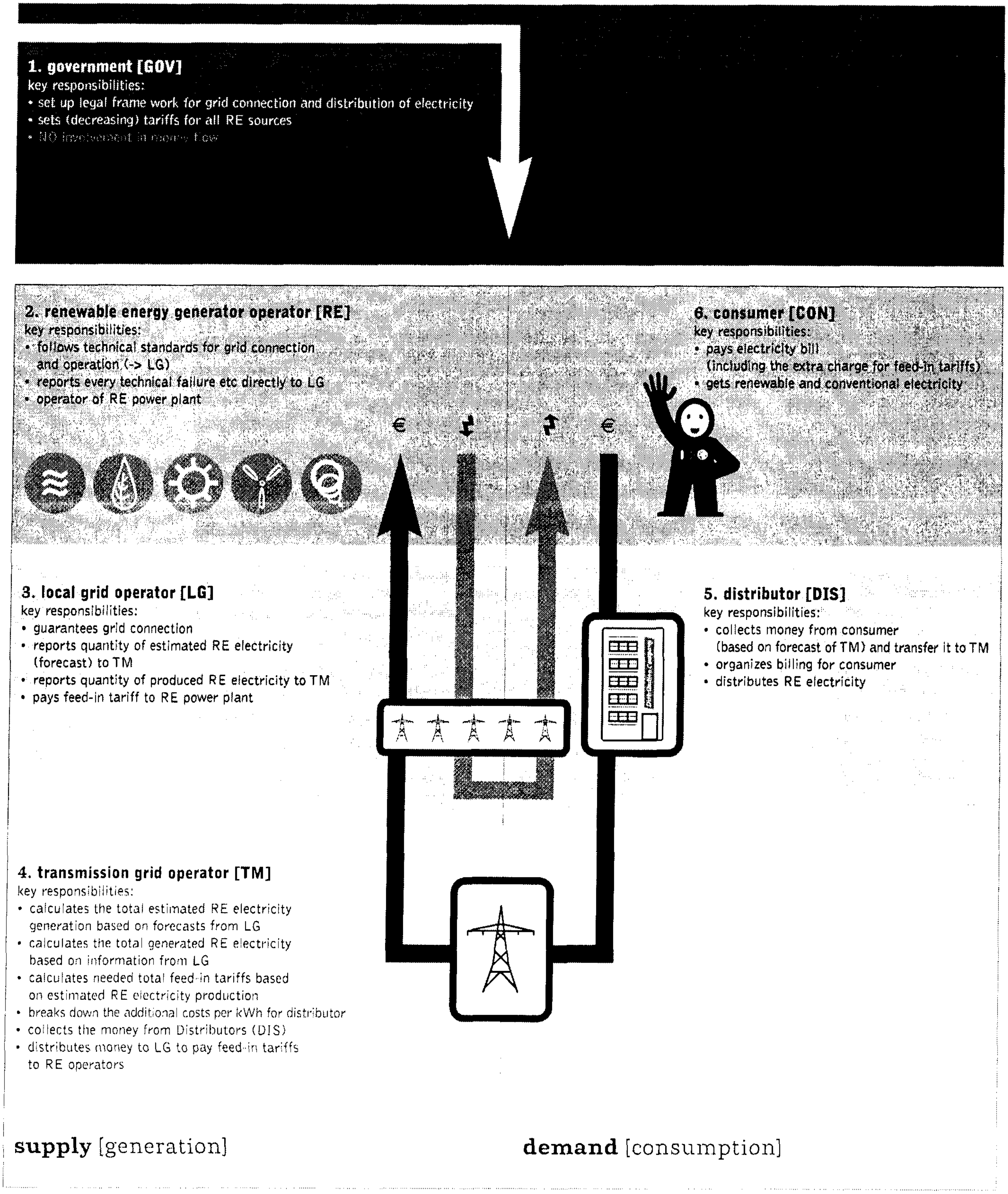
table 22: **key data on renewable energies in germany 2005/2006**

	2005[1]	2006[1]	CHANGES
Share RE in total primary energy consumption	4.7%	5.3%	+12.8%
Share RE in total final energy consumption	6.6%	7.4%	+12.2%
Share RE electricity in total gross electricity consumption	10.4%	11.8%	+13.4%
Share RE heating in total heat consumption	5.3%	5.9%	+11.3%
Share RE in total fuel consumption of road traffic	3.8%	4.7%	+23.7%
CO_2 emissions avoided through RE[3]	ca. 86m t	ca.97m t	+12.7%
- of which through EEG	ca. 37m t	ca. 44m t	+18.9%
Total turnover from RE of which:	ca. 18.1bn	ca. 21.6bn	+19.3%
- turnover from constructing plants	ca. 10.3bn	ca. 11.3bn	+9.7%
- turnover from operating plants	ca. 7.8bn	ca. 10.3bn	+32.1%
Employees in RE sector	ca. 157,000 (2004)	ca. 214,000	+ca. 36% compared with 2004

1 RE = RENEWABLE ENERGIES
2 PROVISIONAL DATA
3 CALCULATED ACCORDING TO SUBSTITUTION OF OTHER ENERGY FORMS

source BMU 2007

figure 18: **how does it work? the german feed-in tariff law for renewable energies (EEG)**



renewable portfolio standards - texas

In 1999 George Bush signed the Texas RPS into law as governor. Today, Texas generates more electricity from wind than any other state, and wind development is booming. Texas accounted for nearly a third of the new wind power installed in 2006 in the United States, and three of the five largest wind farms in the nation are located in Texas. This year the American Wind Energy Association (AWEA) believes as much as 2,000 MW of new wind power could be installed in Texas, potentially a full two-thirds of wind development in the United States. This would bring the total wind power in Texas to over 5,000 MW effectively reaching the state RPS goal set for 2015 only two years ago.

The original state RPS was passed in 1999 under then Governor Bush, the policy was so successful that it was increased in 2005 to 5,880 MW by 2015 (roughly 5 percent of electricity demand). It also includes a requirement that at least 500 MW of non-wind renewable energy be developed. The RPS includes strong penalties for failure to meet the RPS mandate ($50 per MWh or double the average cost of credits).

The common view of the success of the wind industry in Texas is that the RPS jumpstarted the market, but now wind competes well on the open market with fossil fuels. Also, the industry development has continued in part because of the creation of a proactive planning process to drive investment in necessary power line upgrades and extensions. The wind industry recently announced that it would invest $10 billion in wind projects if the necessary infrastructure investments were made.

The Texas RPS requires a renewable energy capacity on the following schedule:

- 2,280 MW by 1/1/2007
- 3,272 MW by 1/1/2009
- 4,264 MW by 1/1/2011
- 5,256 MW by 1/1/2013
- 5,880 MW by 1/1/2015

Qualifying renewable energy sources include solar, wind, geothermal, hydroelectric, wave or tidal energy, or biomass or biomass-based waste products, including landfill gas. Qualifying systems are those installed after September 1999. The RPS applies to all retail energy providers including municipal and cooperative utilities.

The state established a renewable energy credit (REC-trading program) that began in July 2001 and will continue through 2019. Under PUCT rules, one REC represents one megawatt-hour (MWh) of qualified renewable energy that is generated and metered in Texas. A Capacity Conversion Factor (CCF) is used to convert MW goals into MWh requirements for each retailer in the competitive market. The CCF is administratively set and equal to 35% for the first two compliance years, thereafter based on the actual performance of the resources in the REC-trading program.

Each retailer in Texas is allocated a share of the mandate based on that retailer's pro rata share of statewide retail energy sales. The program administrator will maintain a REC account for program participants to track the production, sale, transfer, purchase, and retirement of RECs. Credits can be banked for 3 years, and all renewable additions have a minimum of 10 years of credits to recover over-market costs. A penalty system has been established for providers that do not meet the RPS requirements. The penalty is the lesser of $50 per MWh or 200% of the average cost of credits traded during the year.

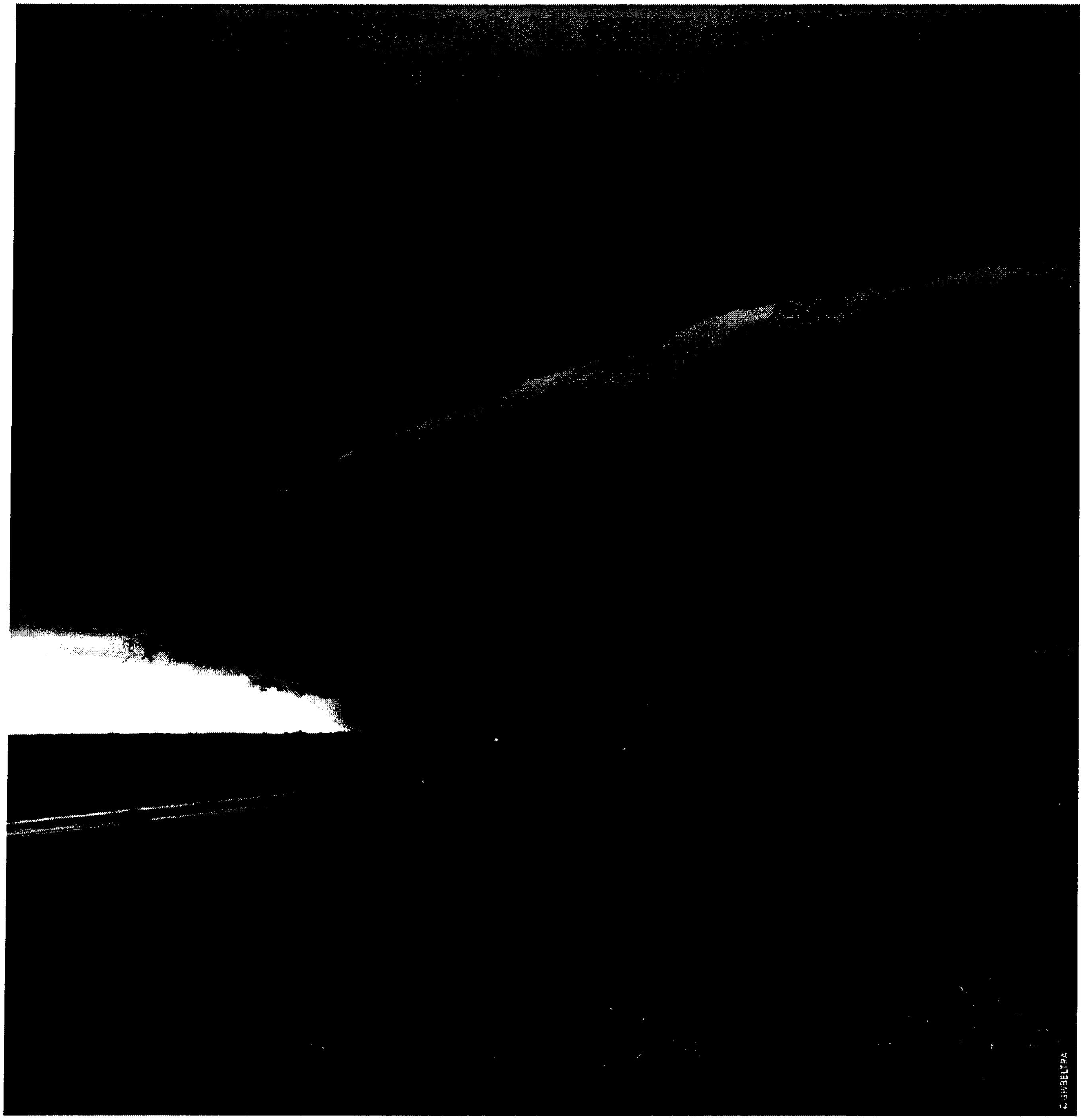
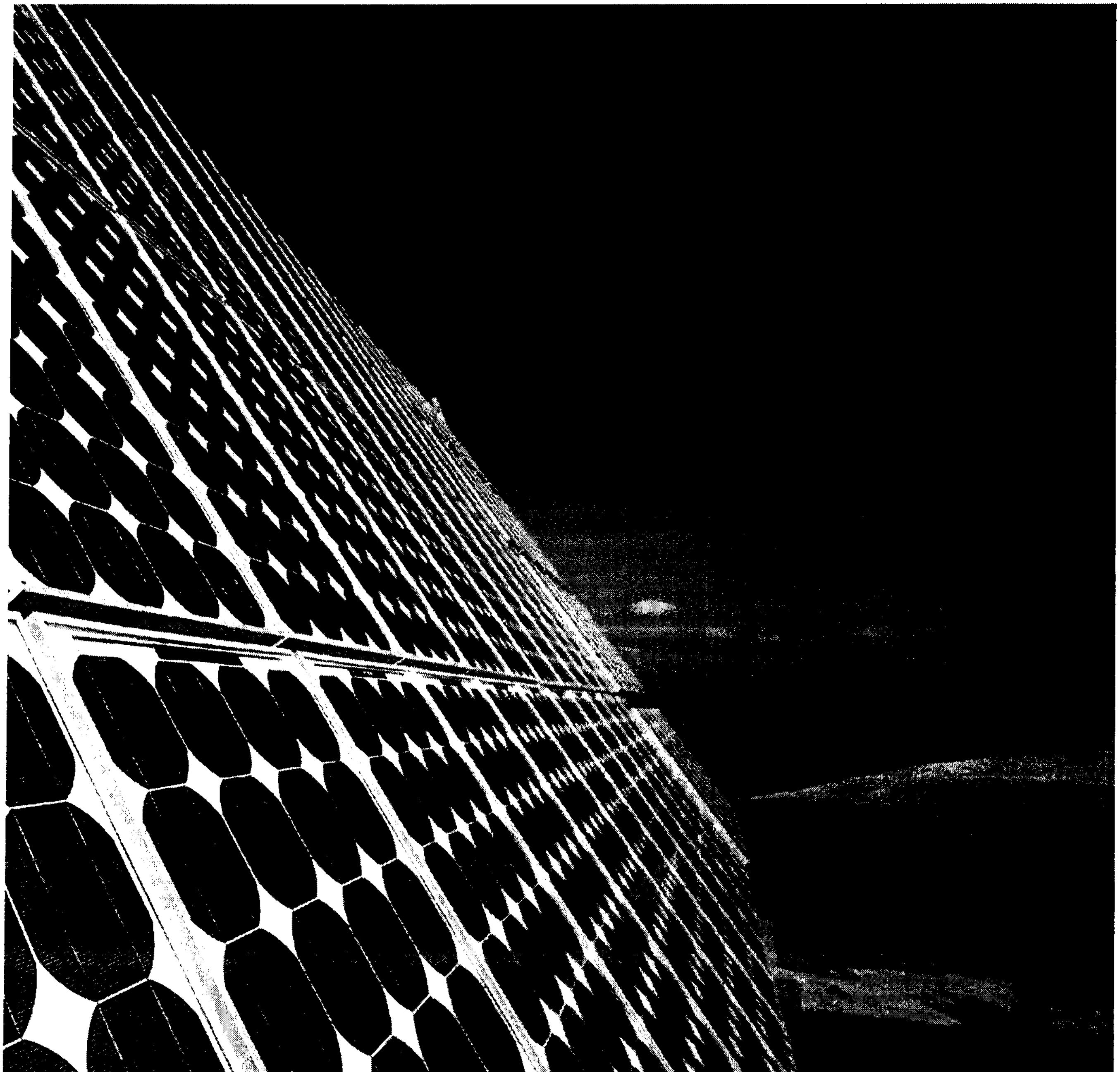


image STORM STUDIED AND FILMED BY THE CENTER OF SEVERE WEATHER RESEACH (CSWR) WITH DOPPLER ON WHEELS, NEAR BEATRICE, NEBRASKA, USA.

appendix

table 23: **investment in renewable energies in billion $2000**

		AFRICA	CHINA	EAST ASIA	LATIN AMERICA	MIDDLE EAST	OECD EUROPE	OECD NORTH AMERICA	OECD PACIFIC	SOUTH ASIA	TRANS. ECONS.
PHOTOVOLTAIC											
2004-2010	REF	0.0	0.0	0.0	0.0	0.	5.0	4.0	14.0	0.0	0.0
	E[R]	2.4	2.9	2.9	3.5	1.1	40.4	8.2	19.9	2.7	0.4
2011-2020	REF	0.0	0.0	0.0	0.0	0.0	12.7	7.5	10.6	0.0	0.0
	E[R]	19.0	47.0	20.5	24.1	12.0	76.8	56.2	57.0	20.7	3.4
2021-2030	REF	1.7	1.8	0.9	0.0	1.3	17.8	10.3	10.0	0.8	0.0
	E[R]	54.9	132.5	41.2	39.3	57.4	84.3	94.9	35.7	53.9	46.9
CONCENTRATED SOLAR POWER											
2004-2010	REF	0.0	0.0	0.0	0.0	0.0	0.0	1.6	0.6	0.0	0.0
	E[R]	0.4	0.8	0.4	0.0	1.1	0.7	1.6	0.7	0.8	0.0
2011-2020	REF	0.0	0.0	0.0	0.0	0.0	0.0	1.7	1.8	0.0	0.0
	E[R]	21.8	12.4	5.2	2.6	16.0	5.3	20.0	4.2	5.5	0.0
2021-2030	REF	0.5	0.0	0.0	0.0	0.5	0.0	5.5	3.9	0.0	0.0
	E[R]	74.2	80.1	11.8	22.2	83.3	19.1	69.9	21.3	21.1	0.0
WIND POWER											
2004-2010	REF	1.3	5.1	2.6	3.4	1.6	65.6	13.5	2.4	4.2	2.1
	E[R]	0.8	7.7	2.6	3.4	1.6	81.6	34.5	5.0	17.6	2.1
2011-2020	REF	0.8	6.6	2.6	2.6	1.1	71.4	27.7	3.4	2.5	4.6
	E[R]	15.6	109.1	65.7	76.9	22.2	153.0	209.3	83.4	44.5	11.0
2021-2030	REF	4.0	16.9	4.6	6.7	2.7	108.9	57.5	8.9	6.5	5.3
	E[R]	27.7	174.0	67.7	68.4	22.0	162.7	191.8	51.5	70.6	78.6
GEOTHERMAL											
2004-2010	REF	0.3	0.0	19.5	3.5	0.0	1.0	47.9	2.8	0.0	1.8
	E[R]	1.6	0.0	18.2	3.5	2.6	1.0	40.0	3.2	0.0	1.8
2011-2020	REF	0.4	0.0	16.3	2.9	0.0	1.9	15.5	3.1	1.1	0.7
	E[R]	2.5	0.0	22.6	2.9	3.2	4.1	15.8	3.9	1.1	0.7
2021-2030	REF	0.4	0.0	17.1	8.5	0.0	5.8	35.0	5.4	0.0	2.9
	E[R]	3.3	0.0	21.3	2.2	5.0	8.7	39.2	5.2	0.9	2.9
BIOMASS											
2004-2010	REF	0.8	2.2	0.8	6.6	0.0	5.1	5.4	5.7	3.1	0.4
	E[R]	0.5	0.4	1.7	2.7	0.4	5.2	8.1	4.2	0.4	0.4
2011-2020	REF	0.0	2.7	2.3	6.5	0.0	8.0	7.6	4.2	0.7	0.1
	E[R]	0.7	1.0	5.9	2.4	0.3	4.7	7.6	4.9	1.0	9.8
2021-2030	REF	2.1	5.1	3.0	8.7	1.4	6.5	6.4	8.3	5.8	1.2
	E[R]	2.8	0.5	7.1	1.5	1.1	7.9	8.6	5.7	1.2	10.2



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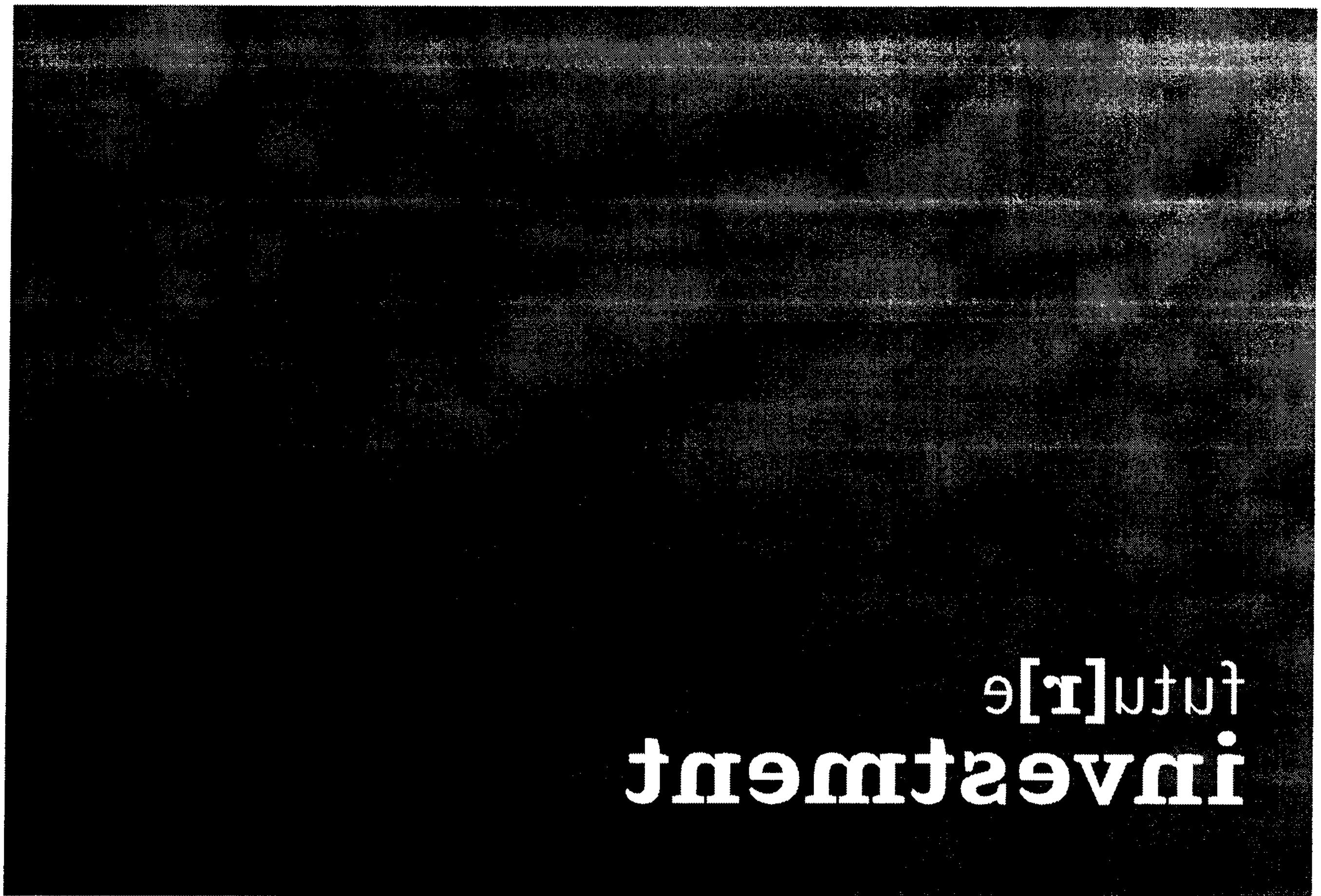

GREENPEACE

Greenpeace is a global organisation that uses non-violent direct action to tackle the most crucial threats to our planet's biodiversity and environment. Greenpeace is a non-profit organisation, present in 40 countries across Europe, the Americas, Asia and the Pacific. It speaks for 2.8 million supporters worldwide, and inspires many millions more to take action every day. To maintain its independence, Greenpeace does not accept donations from governments or corporations but relies on contributions from individual supporters and foundation grants.

Greenpeace has been campaigning against environmental degradation since 1971 when a small boat of volunteers and journalists sailed into Amchitka, an area west of Alaska, where the US Government was conducting underground nuclear tests. This tradition of 'bearing witness' in a non-violent manner continues today, and ships are an important part of all its campaign work.

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EREC

european renewable energy council - [EREC]

EREC is an umbrella organisation of the leading European renewable energy industry, trade and research associations active in the sectors of photovoltaic, wind energy, small hydropower, biomass, geothermal energy and solar thermal:

AEBIOM (European Biomass Association)
EGEC (European Geothermal Energy Council)
EPIA (European Photovoltaic Industry Association)
ESHA (European Small Hydropower Association)
ESTIF (European Solar Thermal Industry Federation)
EUBIA (European Biomass Industry Association)
EWEA (European Wind Energy Association)
EUREC Agency (European Association of Renewable Energy Research Centers)

EREC represents the European renewable energy industry which has an annual €20 billion turnover. It provides jobs to around 300.000 people!

EREC european renewable energy council
Renewable Energy House, 63-65 rue d'Arlon,
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t +32 2 546 1933 f+32 2 546 1934
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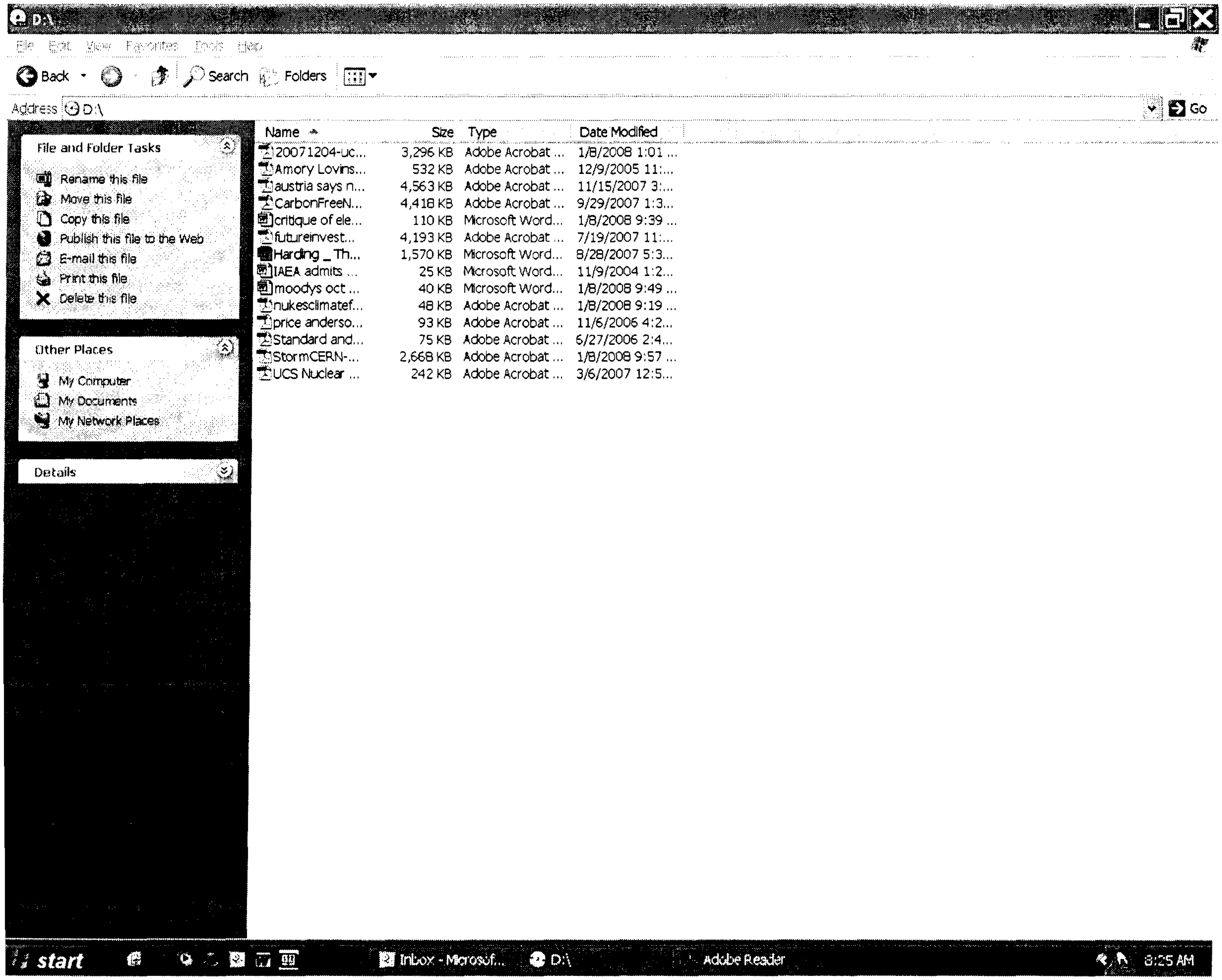
www.erec.org

image WIND TURBINES AT SUNSET.



Thursday, Jan 24, 2008 08:25 AM

Economics of New Nuclear Power and Proliferation Risks in a Carbon Constrained World
Jim Harding
June 2007

Introduction

Climate change, growth in electricity demand, and persistently higher fossil fuel prices have reignited the debate over nuclear power, and whether it is a competitive and proliferation-resistant resource inside the United States or internationally.

Estimating new US reactor costs is a daunting exercise. Recent construction cost experience with advanced reactors is confined to a small number of plants completed in Asia in the 1990s. Accounting practices, labor rates, exchange rates, licensing and regulatory procedures differ from country to country. There has been significant real escalation in worldwide materials costs since 2002, and a growing nuclear industry faces key supply chain challenges. While the Japanese supply chain capacity is intact, the US, Western European, and Russian industries have been largely moribund since the Three Mile Island and Chernobyl accidents.

Other factors are also important, including finance and capital cost recovery, both of which are affected by changes in the structure and regulation of electricity markets. Prices in the thinly traded uranium spot market have risen by a factor of ten in five years.

This report estimates costs of 9-12 cents per kilowatt-hour (in 2007 discounted levelized life cycle costs) for new reactors. Other traditional alternatives, including wind, coal, and gas combined cycles, have also risen in cost. Even with carbon taxes of $30/ton of CO2, or requirements for sequestration, nuclear power does not show an economic advantage that would lead to substantial near term worldwide growth – a "renaissance."

Over the longer term, it will challenging and difficult to replace existing nuclear capacity in the US and Europe with low carbon resources, including new reactors. For new reactors to make a significant incremental contribution to the global warming problem, many new plants must be built in the developing world, and associated bulk fuel handling facilities (enrichment, reprocessing, and mixed oxide fuel fabrication) involve significant risk of weapons proliferation.

Capital Cost

To estimate the cost of new reactors in the US, the best place to turn might be US experience, but the data is old and not easy to interpret. Plants increased in cost at rates far exceeding general inflation.[1] The more plants we built, the more they cost, but that explanation is too simple – we had rising inflation and rising interest rates in the 1970s and 1980s, supply chain imbalances for key components and skilled labor, state and

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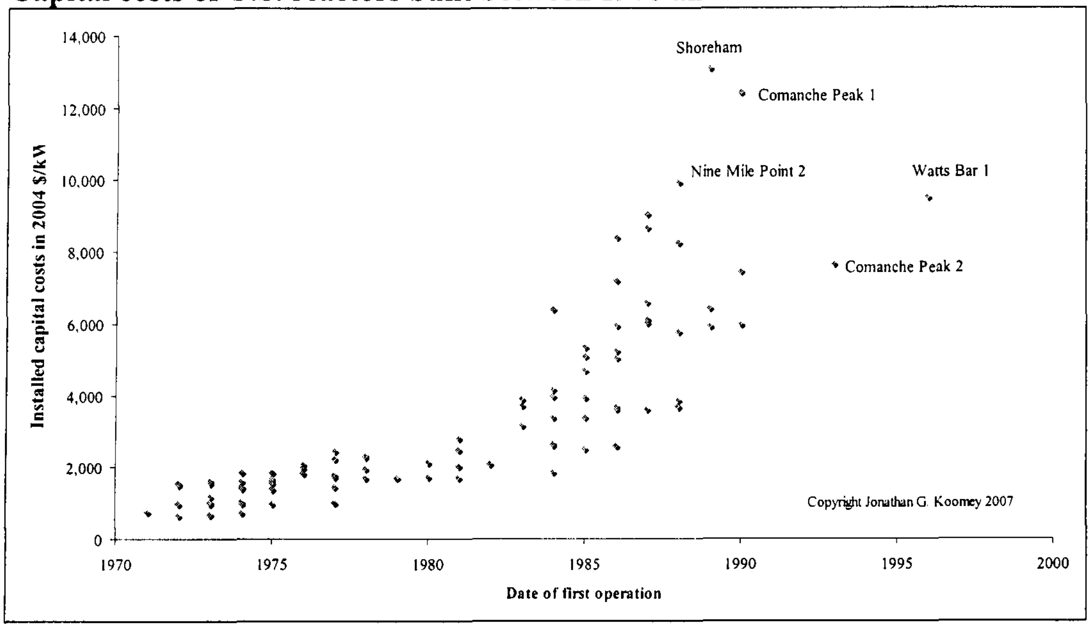
[1] Koomey, Jonathan, and Nate Hultman. 2007. "A Reactor-Level Analysis of Busbar Costs for U.S nuclear plants, 1970-2005." *Energy Policy* (accepted, conditional on revisions).

federal regulatory issues, design-as-you-build construction, siting and financing challenges, growing public opposition, and declining rates of electricity growth.

Capital costs of U.S. reactors built between 1970 and 2000



Today, the industry predicts a better future. There are government and vendor estimates for nuclear construction in the $1,500-2,100/kW range, expressed in various year dollars.[2] The Nuclear Regulatory Commission can issue a combined license for construction and operation; utilities will want most design work completed before construction starts; and advanced designs are more standardized. Recent experience in Asia suggests that construction times can be shortened with the use of more large cranes, batch concrete plants, and maintaining an open containment during construction.

In its assessment of future nuclear costs, the 2003 MIT study, rejected these lower cost estimates as based on software, rather than real construction experience, and for failing to include key owner's costs, including land, construction oversight, and project contingencies. The report instead relied on estimates for recently complete (1993-2002) advanced light water reactors in Japan and South Korea. Overnight costs (a common convention), not including either escalation or interest during construction are shown below at date of commercial operation in real 2002 dollars.[3] We have not included the South Korean units in computing the average, based on lower South Korean labor rates, though the average inclusive of these units is provided below.

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[2] This covers the range estimated in studies by the University of Chicago and MIT, as well the US Energy Information Administration estimate for advanced US light water reactors.

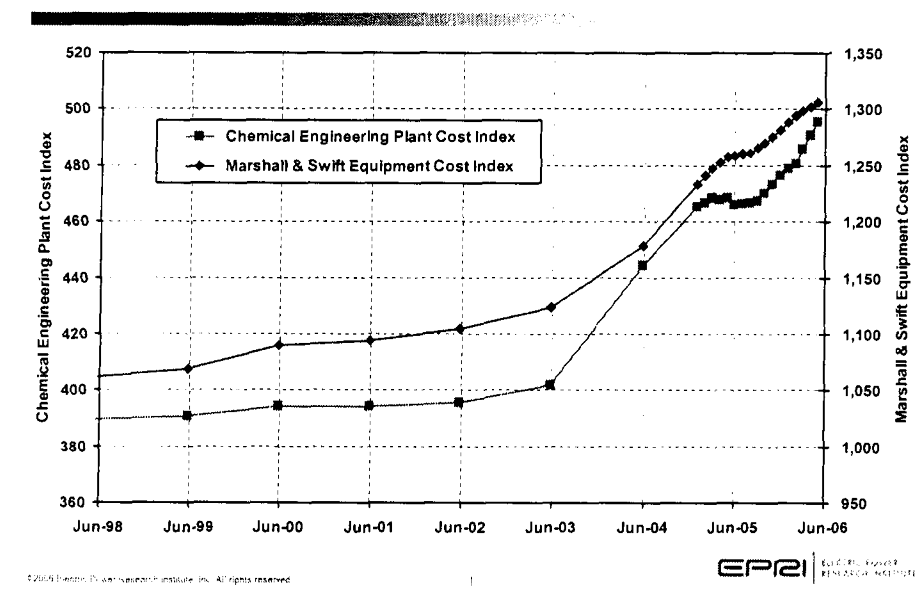
[3] John Deutch and Ernest Moniz, et al, The Future of Nuclear Power – An Interdisciplinary MIT Study, 2003.

Plant	Megawatts	Commercial Operation (COD)	Yen@COD	2002$s/kW	2007$s/kW
Onagawa 3	825	Jan-02	3.14E+11	2409	3332
Genkai 3	1180	Feb-94	3.99E+11	2643	3656
Genkai 4	1180	Jul-97	3.24E+11	1960	2711
KK3	1000	Jan-93	3.25E+11	2615	3617
KK4	1000	Jan-94	3.33E+11	2609	3608
KK6	1356	Jan-96	4.18E+11	2290	3167
KK7	1356	Jan-97	3.67E+11	1957	2707
Y5	1000	Jan-04	NA	1700	2352
Y6	1000	Jan-05	NA	1656	2290
Average				2354	3257

The chart below, provided by the Electric Power Research Institute, shows recent cost trends for large engineered projects. After a number of years with little or no real escalation in costs, the curve has steepened to roughly 4 percent real escalation per year, mainly driven by higher costs for steel, copper, concrete, and other materials. If we take the average of the recently completed Japanese reactors and escalate at from 2002-2007 at four percent real per year, overnight costs for 2007 would be approximately $3250/kW, not including either interest during construction or further real escalation.

Construction Cost Indices

Source: Chemical Engineering Magazine, August 2006



It is very difficult to determine whether real cost escalation will continue into the future, and it clearly affects all generating options, though is most acute for capital intensive resources. As described earlier, nuclear power faces some specific supply-chain challenges that argue against a low number. Twenty years ago, the U.S. had about 400 suppliers and 900 nuclear or N-stamp certificate holders (sub-suppliers) licensed by the American Society of Mechanical Engineers. The numbers today are 80 and 200.[4]

Worldwide forging capacity for pressure vessels, steam generators, and pressurizers is limited to two qualified companies - Japan Steel Works and Creusot Forge – and the reactors builders will be competing with each other as well as with simultaneous demand for new refinery equipment. Japan Steel Works prices have increased by 12% in 6 months, with a new 30% down payment requirement.[5]

Other long lead-time components, including reactor cooling pumps, diesel generators, and control and instrumentation equipment have six year manufacturing and procurement requirements. In the near term, reliance on foreign manufacturing capacity could complicate construction and licensing. NRC Chairman Dale Klein recently indicated that reliance on foreign suppliers would require more time for quality control inspections, to ensure that substandard materials are not incorporated in U.S. plants.[6]

Skilled labor and experienced contractors present another problem. A recent study by GE-Toshiba identified a potential shortage of craft labor within a 400-mile radius of the Bellefonte site, forcing the adoption of a longer construction schedule.[7] Other sources have pointed to the potential for skilled labor shortages if nuclear construction expands.[8]

Several of these problems have clearly surfaced at the Olkiluoto 3 site, where the French vendor Areva is building a 1600 megawatt advanced European pressurized reactor (EPR). Areva originally estimated a four year construction period, but the plant has fallen 18 months behind schedule, and is substantially over budget. Analysts estimate that Areva's share of the loss on the "turnkey" contract will be between $700-900 million. Concrete poured for the foundation of the nuclear island was found to be more porous than the Finnish regulator would accept. Hot and cold legs of the reactor cooling system required reforging.

At a recent conference in Nice, Areva NP President Luc Oursel indicated that the company had underestimated what it would take to reactivate the global supply chain for a new nuclear plant. In particular, they were not "100 percent assured to have a good quality of supply," were not sufficiently familiar with the "specific regulatory context" in Finland, and began building without a complete design. Some 1,360 workers from 28 different nations are now at work at the site. The project manager for STUK, the Finnish

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[4]"Supply Chain Could Slow the Path to Construction, Officials Say," *Nucleonics Week*, February 15, 2007. Comments of Ray Ganthner, Areva.

[5]*Ibid.*

[6]*Ibid.*

[7]"GE/ Toshiba, Advanced Boiling Water Reactor Cost and Schedule at TVA's Bellefonte Site," Aug. 2005, pp. 4.1-2 and 4.1-23.

[8]"A Missing Generation of Nuclear Energy Workers," NPR Marketplace, April 26, 2007. "Vendors Relative Risk Rising in New Nuclear Power Markets," *Nucleonics Week*, January 18, 2007. http://marketplace.publicradio.org/shows/2007/04/26/PM200704265.html.

regulator, added that "a complete design would be the ideal. But I don't think there's a vendor in the world who would do that before knowing whether they would get a contract. That's real life."[9]

The industry believes that standardization and "learning curves," coupled with clearing supply chain imbalances will drive costs lower over time. But there are chicken-and-egg problems with this conclusion. Utilities may not order new plants and equipment if capacity is limited and costs are uncertain. Suppliers may not expand production capacity if orders are not immediately forthcoming. As suggested in the comment above, vendors may not be willing to complete engineering designs before contracts are awarded. Moreover, given the structure of the US utility industry, learning curves may be hard to achieve, with different utilities, in different parts of the country, considering standardized but different reactor designs.

The French experience most strongly suggests that rapid construction is best achieved with one utility ordering one basic design at a steady rate, keeping vendors, sub-suppliers, and construction crews operating near capacity and able to move smoothly from one project to the next.[10] That model of single government vendor, coordinated procurement, and single government utility is rare, if not unique and unavailable, in today's world.

Market and regulatory issues also play a role. In most restructured U.S. markets, utilities would not be able to "rate base" new nuclear generation, and would instead need to rely on sales in the wholesale market, where trades are often thin, unpredictable, and short in duration. Plants built in that environment would require a very unfavorable financing structure (e.g., 70 percent equity and 30 percent debt).

In more traditional markets, utilities will probably be required to prepare integrated resource plans, comparing all supply and demand side options, including utility and non-utility owned generation. The utility might then be required to run a competitive procurement process that might include utility-owned nuclear generation. Regulators will probably consider cost caps, and/or annual prudence reviews, as a condition of final approval. Some states may take a more supportive and pro-active position, for example by permitting utilities to recover construction work in rate base despite near-term rate impacts.[11] In other states, charging costs to customers before the plant came into service would not be acceptable or consistent with current law.[12]

The MIT study assumed a financial structure of 50% debt (at 8 percent) and 50% equity (at 15 percent), including a modest equity risk premium (3 percent) for a new nuclear plant. Those assumptions are reasonable for an investor-owned utility able to access rate base.

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[9] Lack of Complete Design Blamed for Problems at Olkiluoto 3, *Nucleonics Week*, May 17, 2007. Areva Official Says Olkiluoto 3 Provides Lessons for Future Work, *Nucleonics Week*, May 3, 2007.
[10] Jim Harding, *Caro Nucleare*, published by Amici della Terra, 1984.
[11] Florida and South Carolina have adopted legislation that permits recovery of annual construction costs in current rates following an annual prudence review.
[12] Many public utility commissions cannot by statute include investment expenses in rates until the underlying resource is "used and useful."

The 2005 National Energy Policy Act included several subsidies to jump start low carbon emission resources, the most important of which involved federal loan guarantees. In May 2007, DOE released a second draft of its loan guarantee rules. The draft rule provides for the federal government to guarantee 90% of the debt, so long as the amount does not exceed 80% of the total project cost. DOE also indicated that it was considering a significant minimum equity stake on the part of any developer, and that guarantees should be limited to five projects that use the same technology.

Three features of the program diminish its value: first, the government backed debt cannot be stripped from the total debt; second, the non-guaranteed fraction of debt is subordinated to the covered piece; and finally, DOE's fiscal 2008 budget proposes $9 billion in total loan guarantees of which $4 billion would be allocated to nuclear plants and coal with carbon sequestration. A banker contacted by the trade journal Nucleonics Week commented that the first two features devalue the debt from a possible AAA rating to "single B or double D."[13] Four billion dollars in loan guarantees also might cover one or two new units.

In general, most prospective nuclear builders regard these provisions as potentially valuable, but uncertain, unlikely to be sustained over the long term, and not a tipping point for a nuclear investment. Finally, it is important to emphasize that government subsidies do not reduce the cost of nuclear power; they spread risk and cost to taxpayers and reduce prices to ratepayers.

Interest during construction depends on several key factors – duration of construction, shape of outlays, the debt to equity ratio, and returns on both debt and equity. The US Energy Information Administration assumes a six year construction period for a new reactor. Some vendors believe it can be done in four years. The MIT base case was five years.

Further real escalation for nuclear reactors, or other supply options, should not be ruled out. In fact, some real escalation should be assumed, based on tight supply-demand imbalances in metals, component costs and lead times, and skilled construction crew availability. If we assume a continuation of this trend, real discounted overnight costs, not including interest during construction are roughly $4200/kW in 2007 dollars. If the rate falls to 2.5 percent real, this value drops to $3850/kW. Interest during construction adds between $500-900 million in real 2007 dollars. Final construction costs in real 2007 dollars range from $4300-4550/kW. This is not far from a May 2007 estimate of $4000/kW from Standard & Poor's, but it is also probably too narrow, given construction time and real escalation uncertainties.[14]

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[13] "DOE's Loan Guarantee Proposal Raises Questions About Viability," *Nucleonics Week*, May 17, 2007. Production tax credits of 1.8 cents/kWh, for eight years, are also available for low emissions technologies, though these benefits do not start until commercial operation.

[14] Which Power Generation Technologies Will Take the Lead in Response to Carbon Controls?" Standard & Poor's Viewpoint, May 11, 2007.

Operating, Maintenance, and Fuel Costs

One of the most important parameters affecting lifecycle cost is reactor performance, or capacity factor. U.S. average nuclear capacity factors have increased from below 60% during most of the 1980s to nearly 90% in the post-2000 period.[15] Some of the increase is attributable to changes in technical specifications that equipment to operate within a wider range and to higher fuel enrichments. The first reduces the number of equipment related reactor trips and shutdowns. The second reduces the number of refueling outages. It may also be true that outages are more frequent in early years ("teething") and later years ("aging"). Seventy five to eighty five percent is a reasonable lifetime range for future units.

Advanced light water reactors may have lower operations and maintenance costs than current units, based on the use of more passive safety systems. Including capital additions (essentially capitalized operations and maintenance), the current US average is about $100-$120/kW-year, inclusive of A&G (essentially pension and insurance) costs. There is no recent history of real escalation in the value, and it is probably appropriate for both a low and high estimate.

Nuclear fuel costs have many components—uranium mining and milling, conversion to UF6, enrichment, reconversion, fuel fabrication, shipping costs, interest costs on fuel in inventory, and spent fuel management and disposition. The 2003 MIT study calculated a 5 mill (half a cent) per kilowatt hour cost for all these steps, based on then-current uranium prices of $13.60/lb. Spot market prices for uranium in early June 2007 were $135/lb, tripling since October 2006. The reasons for the price increase are somewhat complicated.

Uranium prices have been volatile over the past three decades. Real spot prices almost sextupled from 1973 to 1976, then dropped steeply through 2002, but have risen dramatically since that time. The problem is not declining physical supplies of uranium, cost of production, or growth in demand for nuclear fuel. The key problem is that much uranium demand over the past two decades has been met by inexpensive "secondary supplies," including surplus inventories from cancelled or shut-down units (1980s-1990s) in the US, Western Europe, and Russia, purchase of surplus Russian and US government stockpiles (mid-1990s), and diluting highly enriched uranium from surplus Russian nuclear weapons (1998-2013) with natural uranium.

Worldwide uranium production is about 60 % of current uranium demand.[16] Existing spot uranium prices clearly support enhanced production, both in the US and abroad, but lead times for new mines are long. The same situation applies to enrichment. Uranium

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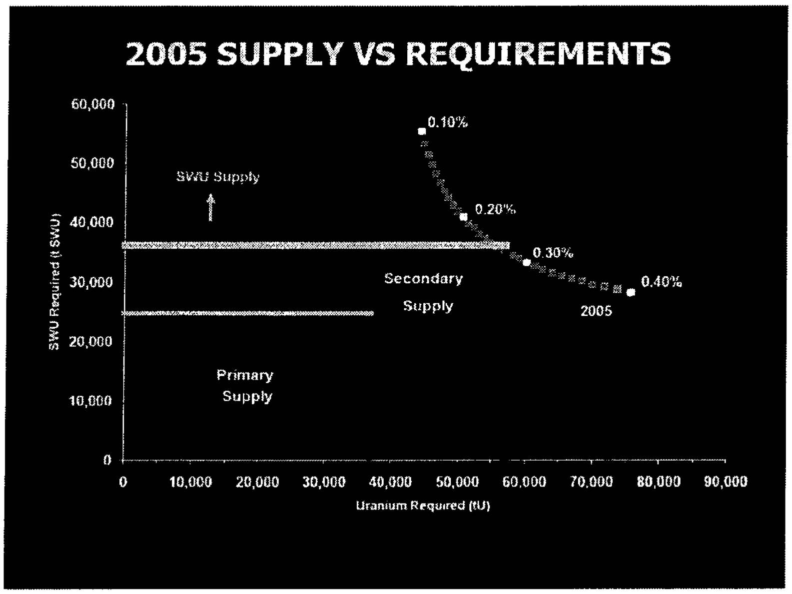
[15] MIT, "The Future of Nuclear Power," 2003; and Joskow, "Future Prospects for Nuclear-A US Perspective," Presentation at University of Paris, Dauphine, May 2006.

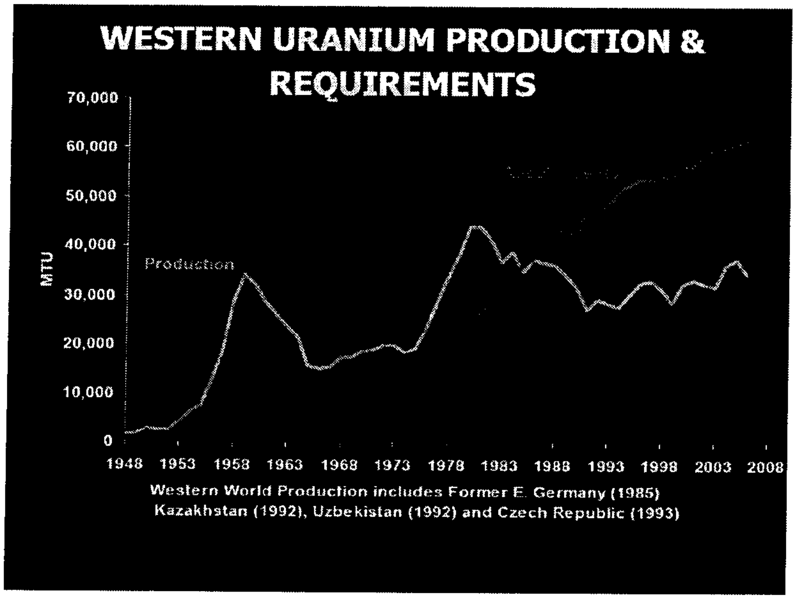
[16] Dr Thomas Neff, Center for International Studies, MIT, "Dynamic Relationships Between Uranium and SWU Prices: A New Equilibrium, Building the Nuclear Future: Challenges and Opportunities."

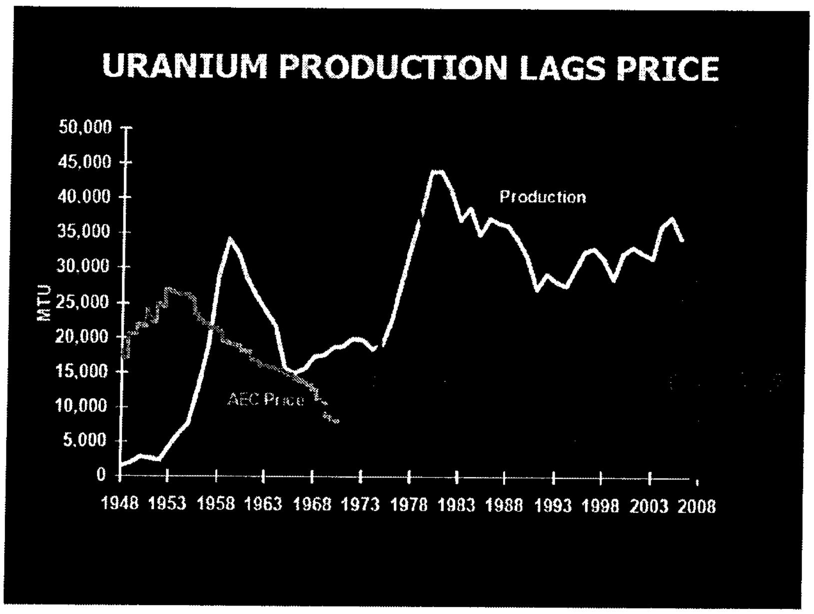
mining expansion will need to be better than 1980s rates of expansion to meet 2015 demands, particularly with limited enrichment capacity worldwide.

The following four charts from Tom Neff at MIT illustrate the history and the challenge.[17] The first chart shows demand for uranium and enrichment services (SWUs or separative work units) in 2005. Regardless of how enrichment facilities are operated (the green curve, and associated "tails assay"), current demand could not be met without secondary supplies. The second and third charts show growth in uranium demand and the lag between price and increased production. The final chart shows how much mining and enrichment capacity must be added to make up for lost secondary supply and meet the needs of a growing industry.



[17] Dr Thomas Neff, Center for International Studies, MIT, "Uranium and Enrichment – Supply, Demand, and Price Outlook," presentation to the Winter Energy Conference, Banff, January 2007.


WESTERN URANIUM PRODUCTION & REQUIREMENTS
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
MTU
Production
1948 1953 1958 1963 1968 1973 1978 1983 1988 1993 1998 2003 2008
Western World Production includes Former E. Germany (1985)
Kazakhstan (1992), Uzbekistan (1992) and Czech Republic (1993)


URANIUM PRODUCTION LAGS PRICE
50,000
45,000
40,000
35,000
30,000
25,000
20,000
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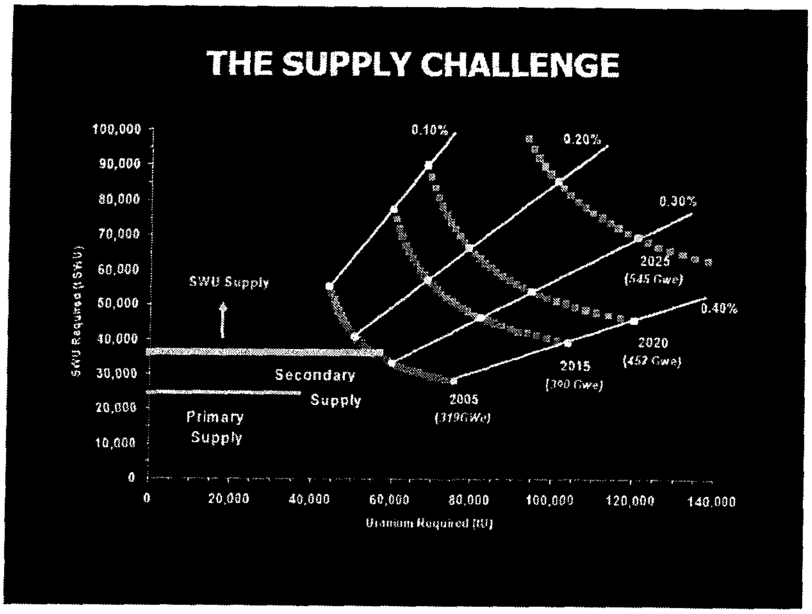
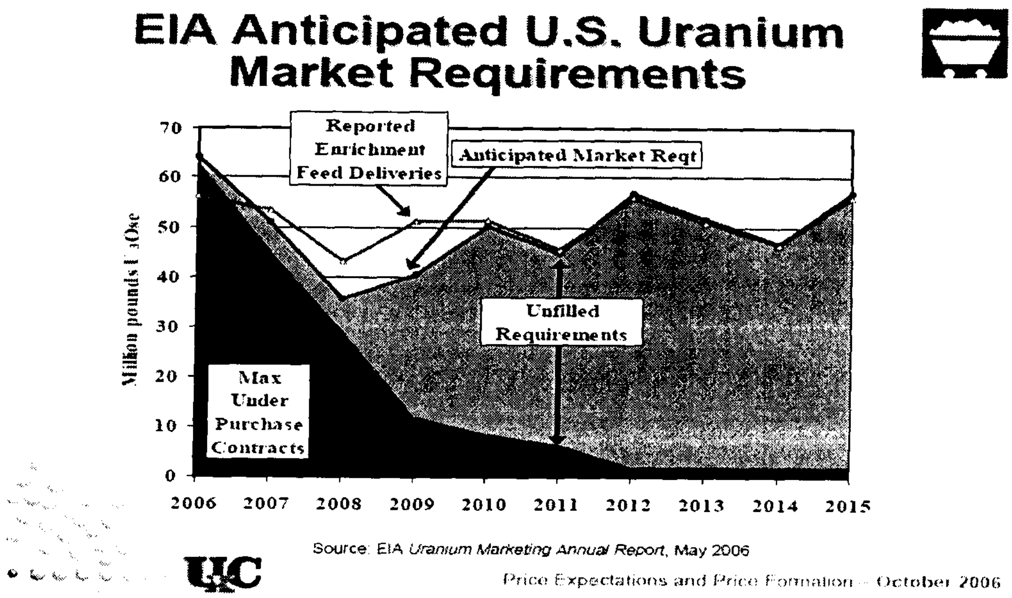
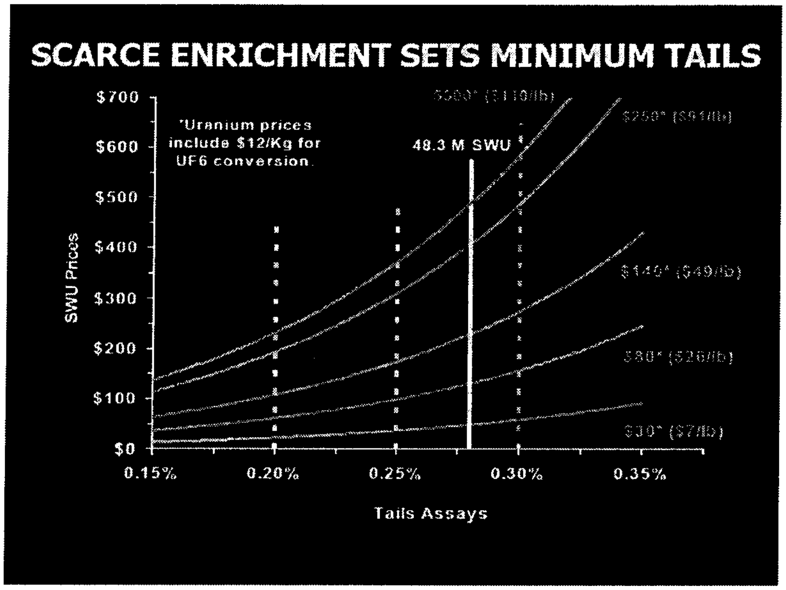
Production
AEC Price
1948 1953 1958 1963 1968 1973 1978 1983 1988 1993 1998 2003 2008



Nuclear plant owners, and utility customers, are not currently facing strikingly higher fuel prices, mainly because current contracts were written during a period of surplus, and include price ceilings. The same basic situation applies to enrichment cost and supply. Most current long-term contracts expire by 2012, and secondary supplies decline rapidly during that period. The price ceilings in long-term contracts also mean that those parties that might pursue new mines or enrichment plants have not benefited substantially from price signals in the spot market. It also means that utilities with uranium and enrichment contracts largely expiring in 2012-2013 must enter the market this year or next to ensure adequate supplies going forward.



Neff and Jeff Combs from UX Consulting suggested that uranium prices may continue to increase beyond its historical peaks. It already has. This problem is complicated by the fact that uranium and enrichment are partial substitutes for each other. When utilities actually pay a high price for uranium, they will want a much lower "tails assay" at the enrichment facility, saving uranium, but also cutting the capacity of existing enrichment plants by 30 percent, whereupon demand cannot be met. With limited enrichment capacity, utilities are forced to settle for a higher than optimal tails assay. Prices equilibrate when the cost of substituting one product for the other is equal.



Assuming current prices for uranium and enrichment ($135/lb and $140/kgSWU), nuclear fuel cycle costs are about three times the value calculated in the MIT analysis (1.6 cents/kWh). If we assume the same value for uranium, but derive SWU price from Neff's analysis, nuclear fuel cycle costs reach 2.6 cents/kWh. A midpoint of $340/kgSWU yields about 2 cents/kWh. No real cost increases are considered for other fuel cycle steps, including conversion, fabrication, and waste management and disposition.

While these price increases are dramatic, they do not justify reprocessing to recover plutonium from spent fuel for subsequent recycling as mixed oxide fuel (MOx) in light water reactors. The 2003 MIT study compared this choice with $13.60/lb uranium and $100/kgSWU enrichment prices. This yielded a 5 mill/kWh fuel price; using very conservative estimates for reprocessing and mixed oxide fuel fabrication yielded closed cycle fuel costs that were more than a factor of four higher. With $2000/ton reprocessing and $1500/kg mixed oxide fuel prices, a closed fuel cycle costs about twice the MIT value, or 4.3 cents/kWh.

Summary of Nuclear Costs without Carbon Controls

Main Assumptions (2007$)	**Low Case**	**High Case**
Overnight Cost	$3,250/kW	$3,250/kW
Plant Life	40 years	30 years
Capital Cost, Including Real Interest	$4,300/kW	$4,550/kW
Capacity Factor	90%	75 %
Financial	8% debt, 12% equity, 50/50 ratio	8% debt, 15% equity, 50/50 ratio
Depreciation	15-year accelerated	15-year accelerated
Fixed O&M	$100/kW/year	$120/kW/year
Variable O&M	0.5 cents/kWh	1 cent/kWh
Fuel	1.6 cents/kWh	2.0 cent/kWh
Grid Integration	$20/kW/year	$20/kW/year

Lifecycle Costs
(Cents/kWh)

Cost Category	**Low Case**	**High Case**
Capital Costs	6.0	7.9
Fuel	1.6	2.0
Fixed O&M	1.3	1.8
Variable O&M	0.5	0.5
Total (Levelized Cents/kWh)	9.4	12.2

Carbon Constraints

With carbon constraints (specified as taxes or a cap-and-trade approach), nuclear power's competitive position improves. Standard & Poor's recently released an economic analysis on the sensitivity of generation technologies to carbon controls.[18] Only plant – rather than full fuel cycle – emissions were considered, albeit insignificant. The base case capital cost estimate for nuclear power was $4000/kW, which is generally in line with the values calculated here. O&M costs were in line with the values calculated here, but nuclear fuel price was estimated at 0.7 cents/kWh – roughly 2-3 times too low. The price of natural gas was estimated at $7 per million BTU.

Coal price estimates ranged from $1-1.80 per million BTU for Wyoming and eastern coal respectively. Direct comparison with the values calculated here can be somewhat tricky, mainly because S&P does not show all financial assumptions. The first row of bold

[18] Which Power Generation Technologies Will Take the Lead in Response to Carbon Controls?" Standard & Poor's Viewpoint, May 11, 2007.

numbers shows internal costs, without carbon capture or taxes. The second bold row shows costs with capture and sequestration, and the final bold row shows costs with carbon credits or taxes of $10-30/ton. As shown, nuclear power only has a modest advantage over coal (either pulverized or IGCC) if carbon sequestration is required. It is significantly less competitive with carbon taxes or credits, if they are available in a range of $10-30/ton of CO2.

	Pulverized Coal	**Gas CCCT**	**Western IGCC**	**Wind**	**Nuclear**
Capital Cost ($/kW)	2438	700	2925	1700	4000
Capacity Factor (%)	85	65	80	33	85
Fixed O&M ($/kW-yr)	45	20	60	25	100
TonsCO2/MWh	0.87	0.37	0.94	NA	NA
Total cost (cents/kWh)	***5.8***	***6.8***	***6.5***	*7.1*	***8.9-9.8***[19]
Carbon Capture					
Capital Cost ($/kW)	940	470	450	NA	NA
Energy penalty (%)	25	13	15	NA	NA
TonsCO2/MWh	0.09	0.04	0.09	NA	NA
Cost for capture and sequestration (cents/kWh)	6.2	2.8	3.6	NA	NA
Total cost (cents/kWh)	***12.0***	***9.6***	***10.1***	*7.1*	***8.9-9.8***
Total cost with carbon credits at $10-30/ton	***6.2-7.9***	*7-7.7*	***6.5-8.4***	*7.1*	***8.9-9.8***

The S&P estimates for carbon capture appear pessimistic, and for pulverized coal, unrealistic. A recent International Energy Agency analysis of new and existing energy technologies found incremental costs ranging from 2-3 cents/kWh, depending on the fuel (natural gas or coal) and technology used. The IEA values for gas and coal IGCC are only slightly below S&P estimates, while the values for pulverized coal are less than half the S&P estimate, driven mainly by a much lower estimate for efficiency loss. The reasoning behind the pulverized coal analysis is not clear.

Technologies under development might reduce these values to 1.5-2.25 cents/kWh, not including CO2 transportation and storage (both relatively minor elements). They also do not take credit for possible beneficial use of the carbon dioxide in enhanced oil recovery.

[19] The higher value uses the fuel cost estimate provided above.

For example, at 0.1-0.5 metric tonnes of oil per tonne of CO2 injected, the credit would range from $30-160 per tonne of CO2, substantially diminishing, and perhaps offsetting entirely, costs for capture, transport, and storage.[20] Finally, if carbon is taxed or credits are available for $10-30/ton in national or international markets, coal and gas plant developers may pursue projects without sequestration. This implies that other carbon mitigation options – throughout the economy – may be cheaper than sequestration.

It is important to add that costs for all these technologies can vary widely from nation to nation, based on market structure, degree of government involvement (e.g., subsidies or nationalized grid), and access to gas or wind resources. In summary, at foreseeable levels of carbon taxes or cap-and-trade credit approaches ($10-30 per ton of CO2), nuclear power may be advantaged, but not to the point where it is a compelling choice.

Princeton scientists Stephen Pacala and Rob Socolow have proposed the concept of "stabilization wedges" for coping with the climate change problem for the next fifty years with current technologies.[21] Pacala and Socolow proposed fifteen possible wedges, covering all sectors of the economy, including agriculture, deforestation, electricity generation, transport efficiency, and fuel supply, among others. Full implementation of seven wedges – or a larger number of partial wedges – would be needed to stabilize atmospheric concentrations of CO2 at 500 parts per million – a little less than twice pre-industrial levels (280 ppm). One of the possible wedges involved worldwide expansion of nuclear power, essentially doubling current capacity from 370 GWe to 700 GWe over fifty years.

The authors assumed that this capacity would displace efficient coal generation. Over the same period of time, essentially all existing reactors are retired, so 1070 GWe must be built to achieve a wedge.

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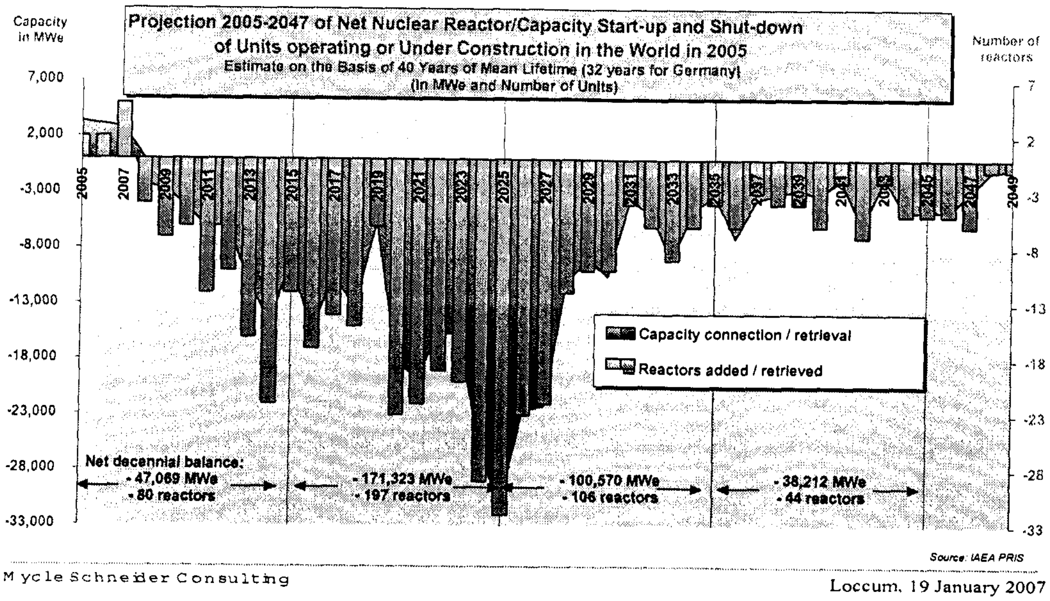
[20] International Energy Agency, Energy Technology Perspectives in Support of the G8 Plan of Action – Scenarios and Strategies to 2050, 2006. This credit can be geographically and temporally limited.
[21] Pacala and Socolow, "Stabilization Wedges: Solving the Climate Problem for the Next 50 Years with Current Technologies," *Science*, 13 August 2004, Vol. 305. no. 5686, pp. 968 – 972.]



A number of nuclear fuel cycle facilities would either be required, or need to be considered.[22]

- 23 new centrifuge enrichment plants the size of the proposed American Centrifuge Plant in Piketon, Ohio
- 18 new fuel fabrication plants
- 10 new repositories the size of the proposed Yucca Mountain facility in Nevada
- 36 new spent fuel reprocessing plants, if all spent fuel were reprocessed

In addition, if fuel is reprocessed and fabricated into a mixed oxide for use in reactors, a large number of mixed oxide fuel fabrication facilities would be required. The design capacity of the UK Sellafield mixed oxide fuel fabrication plant was 120 tonnes of heavy metal per year, but 40 tonnes/year appears to the achievable limit. Potentially, several hundred Sellafield-sized mixed oxide fabrication plants would be required to support extensive worldwide use of plutonium fuel.[23]

Pacala and Socolow did not directly examine the question of whether 1070 GWe of nuclear capacity and associated fuel cycle facilities could be built over fifty years. National and international forecasts of future nuclear capacity typically do not go beyond existing utility planning horizons of 10-20 years.

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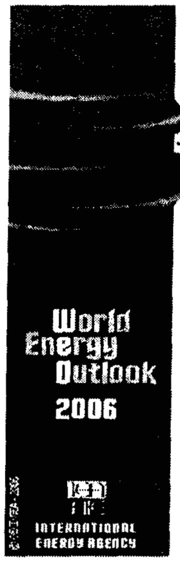
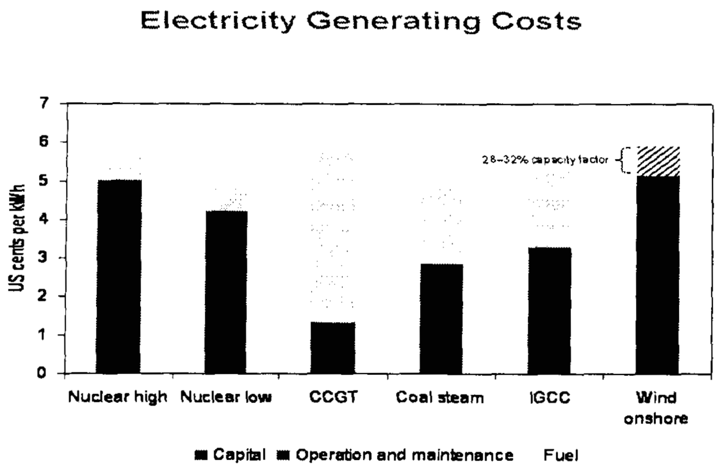
[22] These calculations were performed by Tom Cochran, senior scientist and nuclear program director, Natural Resources Defense Council, in connection with a Keystone Center joint fact finding effort examining the future of nuclear power. The report will be released in early June 2007.

[23] The French Melox mixed oxide fuel fabrication plant is licensed for 170 tonnes of fuel production per year.

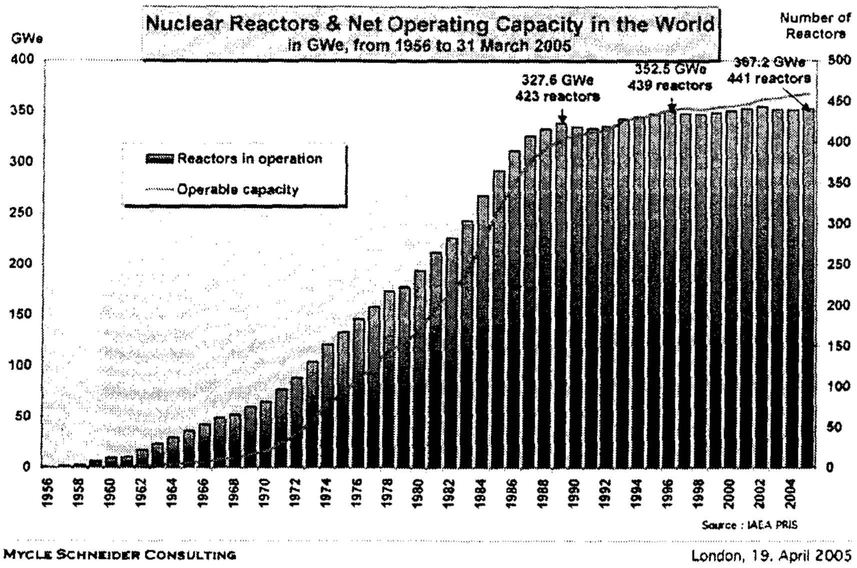
A recent analysis by the International Energy Agency (World Energy Outlook 2006) estimates that global nuclear capacity in their "Reference" scenario would grow from current levels (about 370 GWe) to 415 GWe by 2030. This implies a net rate of growth of about 2 GWe per year, and is based on optimistic capital ($2000-2500/kW construction cost) and lifecycle costs (4.9-5.7 cents/kWh). It assumes that existing government policies remain largely unchanged.





The World Energy Outlook also includes an "Alternative Policy" scenario, with widespread efforts to combat global warming and encourage new nuclear construction. This leads to a global capacity of 519 GWe in 2030, for a net growth rate of about 6.5 GWe per year.

As the chart below shows, growth rates much higher than 2-6.5 GWe per year have been sustained in the past. The circumstances were different – higher estimated rates of growth in demand, substantial margin between estimated cost of nuclear power and alternatives (mainly limited to coal and oil at that time), and greater industrial capacity. It is also not clear that the rate of peak additions was sustainable at the time. Additions since 1996 have been at less than 0.5 GWe per year.



IEA's World Energy Outlook 2006 acknowledges several important challenges facing scale-up: "the expansion of nuclear capacity may, however, face several constraints, such as limits to global capacity to build major components of nuclear power plants, for example pressure vessels and valves, especially for very large reactors. Similar to other industries, short-term constraints that may limit new construction include the cost of raw materials, the difficulty of finding engineering, procurement, and construction contractors and the shortage of key personnel."

In the Reference case, nuclear capacity increases at 0.7 percent per year, compared with estimated worldwide electricity demand growth of 2.6 percent per year, so nuclear power's share of generation drops from about 15% to 10%. The largest drop occurs in OECD Europe – from 28 to 12 percent in 2030. This does not necessarily mean that OECD Europe CO2 emissions increase; seven of the ten largest markets for wind generation are in Europe – the 27 member European Union accounted for 65 percent of global wind capacity at the end of 2006. Most of the decline is driven by phase-outs (rather than retirements) planned in Germany, Sweden, and Belgium. Increases are calculated for China, Japan, India, the US, Russia, and Korea. Most strikingly, of the net global increase of 48 GWe, 47 GWe occurs outside the OECD (including Japan and Korea) and Russia, in China, India, other Asian nations, the Middle East and Latin America.

In the Alternative Policy case, OECD Europe phase-outs remain in place, but are deferred ten years. Nuclear power share of total electricity demand in the OECD stays constant, with Pacific and North American increases offset by European declines. Developing country additions are significant – 74 GWe of net additions, ninety percent of which occur in China and India. These additions result in nuclear's share of total generation rising from 2% to 6% in China and 2% to 9% percent in India, relative to 2005. The report adds that China has set a target to build 40 GW of nuclear capacity by 2020, though an earlier target of 20 GWe by 2010 will not be met. In addition, while India announced in May 2006 a new target of 40 GWe nuclear by 2030, India's record of meeting targets is poor. The 10 GWe by 2000 target, set in 1984, was missed by a factor of four.

Similarly, while Russia has announced ambitious plans to complete 10 GWe of new nuclear capacity by 2015, there are many infrastructure challenges associated with this target. Russia has increased nuclear generation by 3 GWe since 1991. In addition to supply-chain challenges like those in the US, nuclear power tariffs are much lower than for fossil-fired generation, leaving the industry without sufficient funds to complete new reactors on schedule.

The US Energy Information Administration also forecasts global electricity demand, and projected nuclear capacity by nation and region. Estimates for 2030 generally fall between IEA's Reference and Alternative Policy scenarios, with a total of 481 GWe projected for that year. Europe falls off less steeply; OECD Asia expands less quickly, primarily because of lower estimated growth in demand; US capacity rises from 100 GWe in 2004 to 113 GWe in 2030.

Source	*GW 2030*	*GW/yr*	*% world electricity*	*Net additions*	*% Net Additions Outside OECD and Russia*
IEA Reference (WEO)	*415*	*2 GW*	*10%*	*45*	*~100*
IEA Advanced	*519*	*6.5 GW*	*15%*	*149*	*50*
US EIA	*481*	*4.7 GW*	*12%*	*110*	*72*

The short story is that between 2007-2030, forecasts for OECD + Russia show almost no net growth in nuclear capacity. Retirements are roughly offset by additions. In base cases, 72-100 percent of net growth occurs elsewhere, mainly India and China. Even so, by 2030, nuclear represents from 3-6 percent (from 2 percent today) of electric generation in those two nations. By 2030, net additions are at best about 1/7th of one wedge.[24] In IEA's advanced case, with delayed retirements in Europe, about 20% of a wedge is completed by 2030. The pace of scheduled retirements quickens rapidly in the ensuing years, however, requiring more than a quadrupling of annual additions to achieve a full wedge by the late 2050s.

[24] Seven full wedges are needed over 50 years to stabilize atmospheric concentrations of CO2 at twice pre-industrial levels.

Stated differently, it is extremely difficult to achieve a full nuclear wedge by the late 2050s, and may be impossible without expanding nuclear power to a very large number of nations that are short on internal capacity (e.g., Vietnam, Indonesia, Egypt, Saudi Arabia, Iran, Nigeria, Turkey, Mexico, Venezuela, Yemen), including safety culture. Many may want bulk fuel handling facilities (enrichment and perhaps reprocessing and mixed oxide fuel fabrication) that pose enormous risks of weapons proliferation. Neither the Non Proliferation Treaty, as currently interpreted, nor the IAEA safeguards regime, as currently implemented, are capable of meeting this challenge.

Conclusion

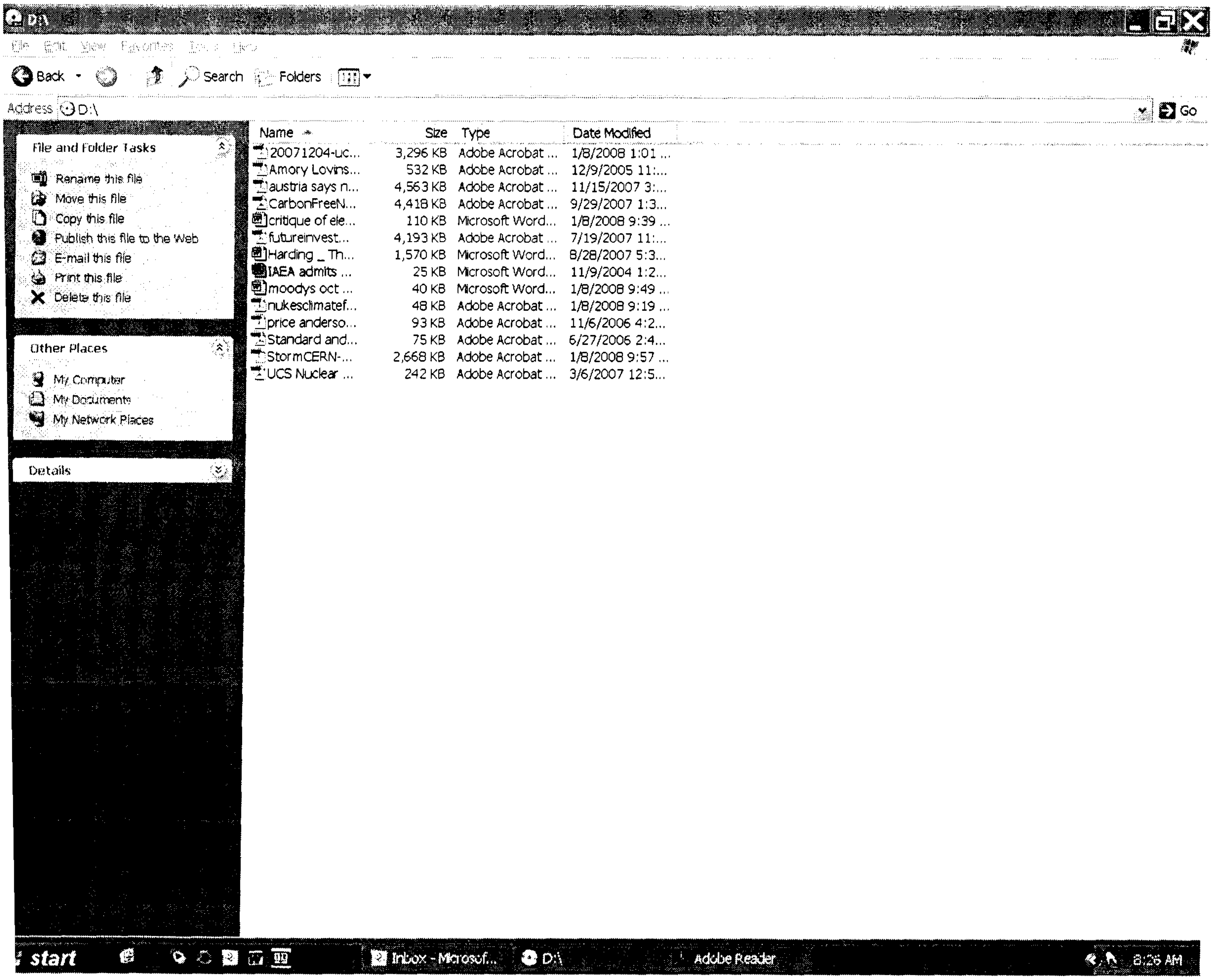
In light of these analyses, what is likely? In the near term, utilities, vendors, sub-suppliers, uranium miners, and enrichment plant operators, among others, are caught in a classic chicken and egg problem. Do utilities dare order if capacity does not exist; do vendors expand if orders are not forthcoming? Between now and 2030, some increase in the US nuclear industry appears probable, given life extensions of existing capacity, high fossil fuel prices, uncertain costs for carbon capture and sequestration technologies, and the incentives or subsidies in NEPAct 2005. That increase in capacity, however, is likely to be quite modest, even in the face of significant, and politically difficult, controls on carbon. Other resources – including coal with purchase of carbon credits, wind, efficiency improvements, gas, and, perhaps, other emerging renewables are broadly competitive.

Looking internationally is perhaps more complicated. Clearly we will have new net capacity additions in Asia, particularly in India and China. Many other nations (e.g., Vietnam) have expressed interest in new nuclear capacity. But expressions of interest do not necessarily imply sufficient domestic capacity to pursue this option, or vendor willingness to invest the time and money to pursue it.

Infrastructure in the major nuclear nations – France, the US, Russia, Germany, and the UK – has fallen off steeply since TMI and Chernobyl. French confidence and expertise led to a relatively inexpensive turnkey contract with Finland, but it is certainly not a money-maker and could be a major loss leader. Vendors, in general, have less capacity for absorbing losses than utilities.

In essence, the most likely case is that US net nuclear capacity will rise very slightly over the next 15 years. EU nuclear capacity will in all likelihood fall. Growth in China and India will be significant, but may also fall short of either EIA or IEA expectations, primarily because both use extremely optimistic cost estimates. After 2030, the problem becomes more complicated, because the pace of nuclear retirements accelerates. But it is also difficult to predict the future of other low carbon emitting technologies twenty years hence. All will benefit from carbon controls, and it is not at all clear that nuclear power will re-emerge as an economically attractive resource worldwide.

One can only get to that conclusion by assuming that near-term orders will be driven by major orders in India and China that lead to infrastructure expansion worldwide; that this expansion alleviates supply-chain imbalances in key equipment, contractors, and crews; can respond successfully to a huge ramp-up to replace existing capacity after 2020; and is not eclipsed by improvements in energy efficiency and renewables in the interim.



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Nuclear power 'can't stop climate change'

By Geoffrey Lean, Environment Editor

Independent on Sunday 27 June 2004

Nuclear power cannot solve global warming, the international body set up to promote atomic energy admits today.

The International Atomic Energy Agency (IAEA), which exists to spread the peaceful use of the atom, reveals in a new report that it could not grow fast enough over the next decades to slow climate change - even under the most favourable circumstances.

The report - published to celebrate yesterday's 50th anniversary of nuclear power - contradicts a recent surge of support for the atom as the answer to global warming.

That surge was provoked by an article in The Independent last month by Professor James Lovelock - the creator of the Gaia theory - who said that only a massive expansion of nuclear power as the world's main energy source could prevent climate change overwhelming the globe.

Professor Lovelock, a long-time nuclear supporter, wrote: "Civilisation is in imminent danger and has to use nuclear - the one safe, available, energy source - now or suffer the pain soon to be inflicted by our outraged planet."

His comments were backed by Sir Bernard Ingham, Lady Thatcher's former PR chief, and other commentators, but have now been rebutted by the most authoritative organisation on the matter.

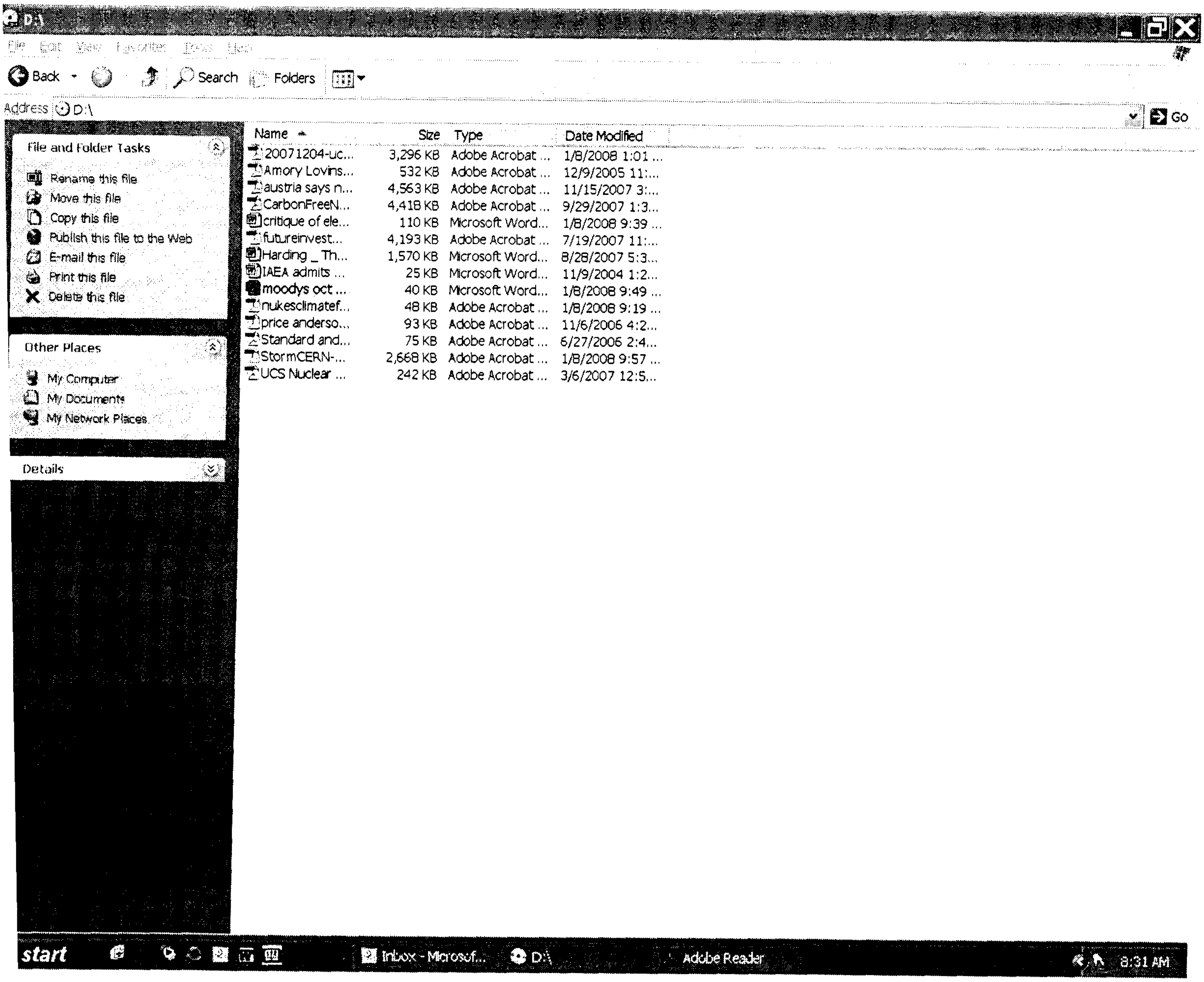
Unlike fossil fuels, nuclear power emits no carbon dioxide, the main cause of climate change. However, it has long been in decline in the face of rising public opposition and increasing reluctance of governments and utilities to finance its enormous construction costs.

No new atomic power station has been ordered in the US for a quarter of a century, and only one is being built in Western Europe - in Finland. Meanwhile, Germany, Belgium, the Netherlands and Sweden have all pledged to phase out existing plants.

The IAEA report considers two scenarios. In the first, nuclear energy continues to decline, with no new stations built beyond those already planned. Its share of world electricity - and thus its relative contribution to fighting global warming - drops from its current 16 per cent to 12 per cent by 2030.

Surprisingly, it made an even smaller relative contribution to combating climate change under the IAEA's most favourable scenario, seeing nuclear power grow by 70 per cent over the next 25 years. This is because the world would have to be so prosperous to afford the expansions that traditional ways of generating electricity from fossil fuels would have grown even faster. Climate change would doom the planet before nuclear power could save it.

Alan McDonald, an IAEA nuclear energy analyst, told The Independent on Sunday last night: "Saying that nuclear power can solve global warming by itself is way over the top." But he added that closing existing nuclear power stations would make tackling climate change harder.



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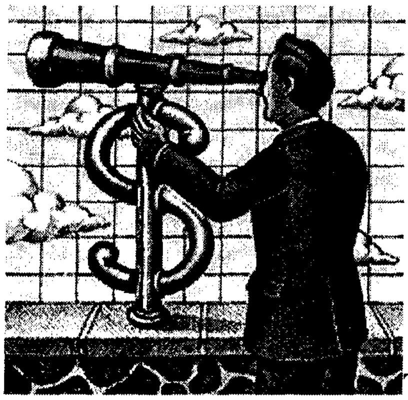
http://djysrv.blogspot.com/2007/11/moodys-nuclear-plant-costs-may-double.html

Tuesday, November 13, 2007

Moody's - Nuclear plant costs may double


The "all in" total could be $6,000/Kw! Wow. Is this number for real?
[updated 12/01/07, 12/17/07]

In a report issued to clients last month Moody's Investors Service said the outlook on on new U.S. nuclear generation is "a sensible if risky path. Moody's looks on nuclear generation as a critical component in the US' current supply mix. Currently, Moody's views the average credit rating it has on the regulated utilities with nuclear generation at the Baa-level, or low investment grade. According to the NRC, there are approximately 12 companies developing 17 Construction and Operating License applications for 31 new reactors.

There's not much new in the report, especially for those who follow the industry. However, for Wall Street, which still may not be used to the idea of the capital requirements for a nuclear power plant in the current era, the report offers some welcome news and some cautions. The first one is a whopper.

The rating service also said the cost of new plants may double. In the report, "New Nuclear Generation in the United States: Keeping Options Open vs. Addressing an Inevitable Necessity," Moody's said that the potential reactors could cost as much as $6,000/kW of capacity to build.

Moody's said it expects new plants to cost $5,000-$6,000/kW of capacity to build, compared with market estimates of $3,000-$4,000/kW of capacity. It noted that a proposed American Electric Power integrated gasification combined-cycle coal-fired power plant in West Virginia is expected to cost $3,500/kW of capacity.

NRG's two new plants in Texas are estimated to come in at a much lower price closer to

$2,000/Kw. So there is a considerable gap between NRG's current estimate as a "first mover" and the costs that could be encountered by plants that come in at later dates. *Even so Moody's estimates seem to be way off the mark and open to serious question.*

Moody's said that, when assessing the cost of a new plant, it is concerned with the "all-in costs" of the facility, adding in capitalized interest, other owner's costs – such as site preparation — and transmission upgrades. It compared its assessment of the costs to the difference between the basic purchase price of a house and the "all-in" price including the cost of appliances, furnishings and landscaping.

Moody's said it believes that "many of the current expectations regarding new nuclear generation are overly ambitious," citing the amount of time it will take to bring new plants online and under estimating the cost of building the new reactors.

Moody's believes nuclear generation is a "critical component" in the energy supply mix, it said, but it does not believe more than one or two new nuclear plants will be online by 2015.

Moody's foresees five potential areas of bottleneck for construction of new nuclear generation: lead times for "ultra heavy/ultra large" forgings, especially given the lack of forges around the globe capable of the work; large manufactured components; engineering resources; logistics; and labor. These last items are on everyone's list and are also the things that must be keeping nuclear utility executives awake at night.

The one bring spot is that the demand for large forgings and other nuclear power plant components, such as turbines, will stimulate new suppliers to bring manufacturing capabilities to the market. For instance, Alstom is planning a new turbine plant for the U.S.

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NUCLEAR POWER AND CLIMATE: WHY NUKES CAN'T SAVE THE PLANET

TOO MANY REACTORS; NOT ENOUGH CARBON REDUCTIONS

Major studies (from MIT, Commission on Energy Policy, and International Atomic Energy Agency, for example) agree that about 1,500-2,000 large new atomic reactors would have to be built for nuclear power to make any meaningful dent in greenhouse emissions. Operation of that many new reactors (currently about 440 exist worldwide) would cause known uranium reserves to run out in just a few decades and force mining of lower-grade uranium, which itself would lead to higher greenhouse emissions. If all of these reactors were used to replace coal plants, carbon emissions would drop by about 20% worldwide. If used entirely as new capacity, in the place of sustainable technologies like wind power, solar power, energy efficiency, etc., carbon emissions actually would increase.

TOO MUCH MONEY

Construction of 1,500 new reactors would cost trillions of dollars (U.S. reactors going online in the 1980s and 90s averaged about $4 billion apiece). Use of resources of this magnitude would make it impossible to also implement genuinely effective means of addressing global warming. Energy efficiency improvements, for example, are seven times more effective at reducing greenhouse gases, per dollar spent, than nuclear power. Yearly costs per 1000 kg avoided CO2 emissions are $68.9 for wind and $132.5 for nuclear power.

TOO MUCH TIME

Construction of 1,500 new reactors means opening a new reactor about once every two weeks, beginning today, for the next 60 years—an impossible schedule. The world's nuclear reactor manufacturers currently are capable of building about half that amount. Since reactors take 6-10 years to build (some U.S. reactors that began operation in the 1990s took more than 20 years), we are already that long behind schedule and will fall farther behind. Addressing the climate crisis cannot wait for nuclear power.

TOO MUCH WASTE

Operation of 1,500 or more new reactors would create the need for a new Yucca Mountain-sized radioactive waste dump somewhere in the world every 3-4 years. Yucca Mountain has been under study for nearly 20 years, has been vigorously opposed by the State of Nevada for just as long, and remains at least a decade from completion. The odds of identifying numerous new scientifically-defensible and publicly-acceptable waste dumps are slim. International efforts to site radioactive waste facilities are similarly behind schedule and face substantial public opposition. For this reason, the U.S. and other countries are attempting to increase reprocessing of nuclear fuel as a waste management tool—a dangerous and failed technology that increases worldwide nuclear proliferation risks.

TOO LITTLE SAFETY

Odds of a major nuclear accident are on the order of 1 in 10,000 reactor-years. Operation of some 2,000 reactors (1500 new plus 440 existing) could result in a Chernobyl-scale nuclear accident as frequently as every five years—a price the world is not likely to be willing to pay. Reactors of similar designs likely would close following a major accident, making nuclear power a risky proposition as a climate solution. And more reactors means more potential terrorist targets.

TOO MUCH PLUTONIUM

Operation of 1,500 or more new reactors would require a dozen or more new uranium enrichment plants, and would result in the production of thousands of tons of plutonium (each reactor produces about 500 pounds of plutonium per year), posing untenable nuclear proliferation threats.

NUKES EMIT CARBON TOO!

While atomic reactors themselves are not major emitters of greenhouse gases, the nuclear fuel chain produces significant greenhouse emissions. Besides reactor operation, the chain includes uranium mining, milling, processing, enrichment, fuel fabrication, and long-term radioactive waste storage, all of which are essential components of nuclear power. At each of these steps, construction and operation of nuclear facilities results in greenhouse gas emissions. The uranium enrichment plant at Paducah, Kentucky, for example, is the largest U.S. emitter of ozone-destroying ChloroFluoroCarbons (CFCs)—banned by the Montreal Protocol (the Paducah plant was grandfathered by this treaty).

Taken together, the fuel chain greenhouse emissions approach those of natural gas—and are far higher than emissions from renewable energy sources, not to mention emissions-free energy efficiency technologies.

NOT SUITED FOR WARMING CLIMATES

Unlike solar power, nuclear power does not work well in warming climates. The summer of 2004's heat wave across Europe not only killed thousands of people, but because of dwindling river levels caused many reactors to reduce power levels and even shut down entirely. Reactors require vast quantities of water to keep the core cool; changes in water levels, and even water temperatures, can greatly affect reactor operations. Reactors in the U.S. have similarly been forced to close during heat waves.

CAN"T TAKE US TO THE MALL

Nuclear power, which can only produce electricity, does not address emissions from automobiles and other components of the transportation sector—probably the largest source of carbon emissions.

WHAT WE *CAN* DO: 30 TERRAWATTS BY 2050

Major investment in energy supply will be needed to meet growing energy demand and address the climate crisis at the same time—perhaps even as much as building 1,500 new reactors would cost.

But investing the money differently gives us much more bang for the buck: instead of a 20% reduction in carbon emissions, we can get an 80% reduction!

By 2050, the world will need about 25-30 Terrawatts of energy, or the equivalent of 25-30,000 nuclear reactors. Clearly it is not possible or affordable to build that many reactors. But it *is* possible to build that much capacity through energy efficiency improvements, and sustainable energy sources including wind, biomass, geothermal, and especially solar power—if we start making the necessary investments now.

It won't be cheap or easy, but the payoff is huge: safe, clean energy that helps alleviate rather than contribute to the climate crisis.

Our choice is stark: we can choose nuclear power, or we can address global warming. We can't do both. Fortunately, the choice is an easy one.

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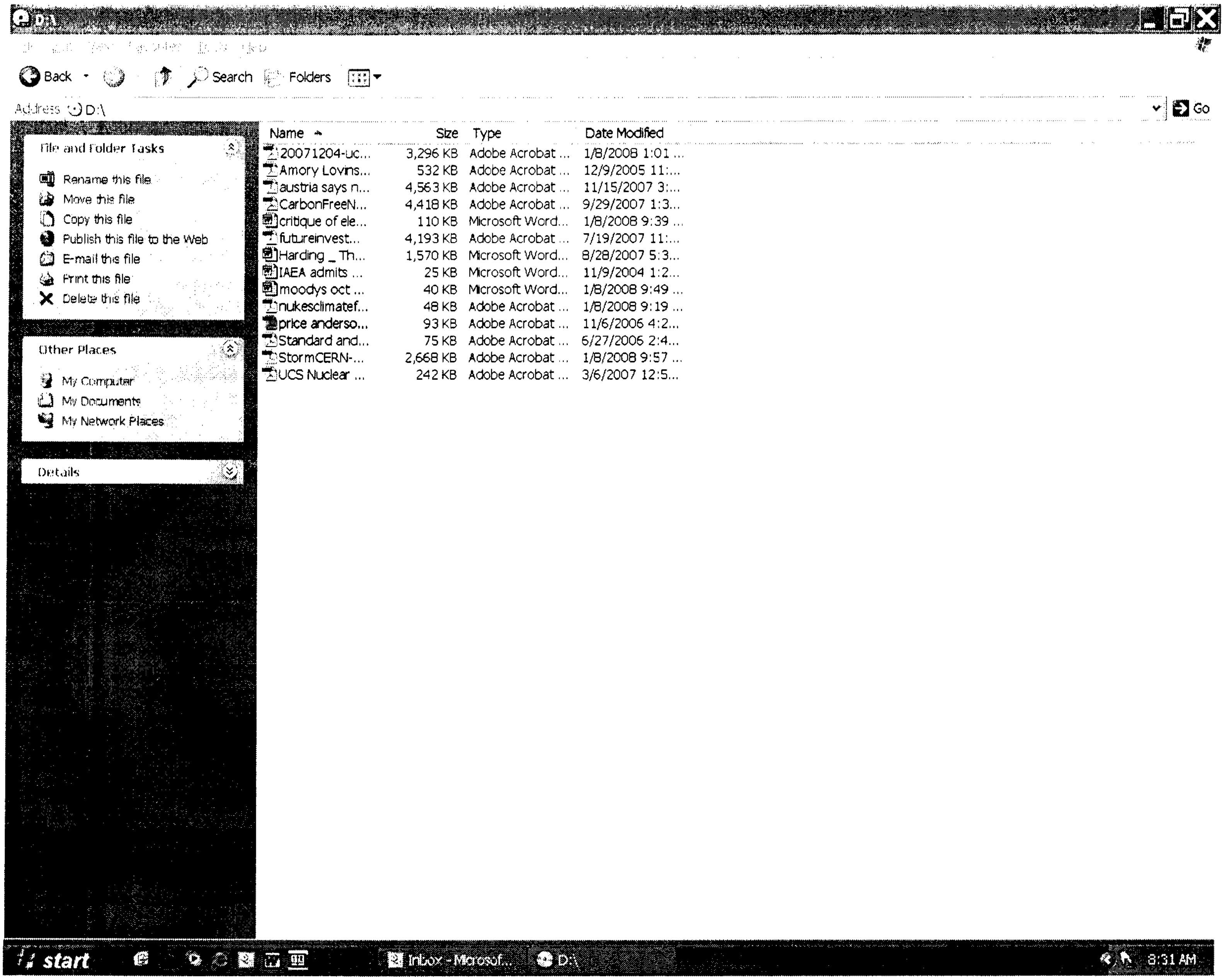

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January 10, 2006

Questions on Nuclear Liability and (unintended) Consequences of War:

There is a growing national debate about the declaration by the President and the Vice President that the United States is in a War on Terror that is not only figurative, but rather an actual ongoing state of battle. The invocation of the War Powers Act and the status of the President as Commander and Chief have sweeping consequences; some of these may be in the arena of liability and insurance. At issue is whether terrorist acts on US soil will be determined to be "acts of war" – what body would make that determination, and what the consequences are.

By declaring the United States in a war with terrorists, it is possible that the Administration has nullified the Price-Anderson Act (and therefore any insurance coverage) in the event that a nuclear power reactor is attacked.

Background: The Price-Anderson act was crafted in the 1960's to facilitate the development of commercial nuclear power. Since no private insurance company was willing to cover the operation of nuclear rectors that have the potential to cause billions of dollars of damage in the event of a catastrophic event, congress stepped in. The legislative "fix" known as the Price-Anderson Act is an ingenious scheme that essentially binds all nuclear reactor owners together in a single yoke.

In the event of a reactor "incident" that exceeds the $300 million in insurance coverage, the Act establishes a "retrospective premium pool" into which every reactor owner pays, until the liability cap has been reached. When the Price-Anderson Act was reauthorized by Congress in 2005, this liability cap was raised to reflect inflation to $15 billion. Since the Act was primarily designed to cover accidents at reactors, this "all pay, for all to play" approach mirrors other human activities where team members bear the consequences for one member's short falls, in an effort to recruit the team to police its members.

Throughout the Price-Anderson Act (42USC2010), the term used is "nuclear incident." It is clear from the Act that congress intends that at least "one terrorist attack" would be covered by the scheme of collective liability. Nonetheless, the definitions section of the Act (42UCS2014) makes it clear that a terrorist attack is not the same thing as an act of war, which is expressly disallowed any coverage under Price-Anderson:

[42USC2014 emphasis added]

(w) The term ``public liability'' means any legal liability arising out of or resulting from a nuclear incident or precautionary evacuation (including all reasonable additional costs incurred by a State, or a political subdivision of a State, in the course of responding to a nuclear incident or a precautionary evacuation), except: (i) claims under State or Federal workmen's compensation acts of employees of persons indemnified who are employed at the site of and in connection with the activity where the nuclear incident occurs; **(ii) claims arising out of an act of war;** and (iii) whenever used in subsections (a), (c), and (k) of section 2210 of this title, claims for loss of, or damage to, or loss of use of property which is located at the site of and used in connection with the licensed activity where the nuclear incident occurs. ``Public liability'' also includes damage to property of persons indemnified: Provided, That such property is covered under the terms of the financial protection required, except property which is located at the site of and used in connection with the activity where the nuclear incident occurs.

The Nuclear Regulatory Commission is the entity designated in the Act to declare an event an "extraordinary nuclear occurrence" – triggering the Price-Anderson coverage. This has, to date, never happened. It is not clear how the determination would be made as to whether the attack was a "terrorist attack" or an "act of war." It is likely that this would rest with the Commander and Chief. The unfolding of the national dialogue on this matter may (or may not) make this clearer in time. The difference is significant in terms of recovering costs associated with a catastrophic release of radioactivity.

If the event is found to be an act of war, then all the reactor owners are off the hook. The initial $300 million in insurance would also be void. In the event of an act of war, all the costs are born by the victims and the US government, wherein it would fall to the taxpayers (assuming of course, that we "win" the "war").

The $15 billion relief for nuclear reactor owners, may be another intentional transfer of liability to the public by an administration with a long track record of protecting certain corporate allies. On the other hand, this may be an unintended consequence of the War on Terror. Either way, it would have significant impact on the federal budget in the event of a nuclear catastrophe.

From another perspective, it is highly unlikely that any catastrophic attack on a reactor would be interpreted in any way except, as an act of war – unless it could be traced to a demented individual. Hollywood embodied this insight in the movie "Meltdown" that aired on FX channel in 2005. This insightful script showed a fictional national security team ready to launch nuclear weapons in retaliation against anyone that could be identified as attackers. This story gives credence to the idea that nuclear power stations are, in fact, an arsenal of pre-deployed nuclear weapons waiting for anyone mean enough or mentally ill enough to blow one up.

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RESEARCH

U.S. Is Looking At A Paced Reemergence Of The Nuclear Power Option

Publication date: 26-Jun-2006
Primary Credit Analyst: Richard W Cortright, Jr., New York (1) 212-438-7665; richard_cortright@standardandpoors.com

A sustained interest in adding new nuclear power plants to the U.S. electric generation fleet's resource mix has gained considerable momentum in the past year. The last nuclear plant was ordered more than 30 years ago, in 1973. But several influences have combined to generate a clear resurgence of interest in adding new nuclear capacity beyond the modest repowering efforts and 20-year license extensions of recent years. This interest ranges across an array of political and industrial constituents.

This is sparked in large measure by:

- Supportive federal and state legislation,
- Concern over the reliability and capacity of rail transportation infrastructure and carbon dioxide emissions related to coal, which fuels about 50% of the country's power generation,
- An increased dependence on natural gas (which fuels about 20%) and its volatile prices, and
- Appeal of operating economics.

Moreover, the country continues to need additional electric generating capacity simply to meet ever-increasing demand for power, which grows at a relatively steady 1.5% to 2% annual pace, and ratepayers are anxious to limit volatility in their electric bills, which is a direct consequence of a heavy dependence on gas.

The passage last August of the Energy Policy Act of 2005, among many other things, sought to reduce the cost and riskiness associated with nuclear investments. The act included a 1.8-cent per kilowatt-hour tax credit for 6,000 MW of new nuclear capacity, as well as standby support to offset the financial effect of construction delays due to regulatory lag or litigation. The act extended the Price-Anderson Act, which provides the framework for limiting operator liability associated with nuclear accidents, and it modified the tax treatment of certain nuclear decommissioning trusts, particularly those related to nonrate-based facilities.

Regional Factors Come Into Play

While there is no national consensus on the willingness to increase nuclear capacity, certain regions appear much more receptive than others, specifically, the Southeast and Midwest. Others, most notably the Northeast and the West Coast, remain generally opposed to the idea, despite the clear need for more base load resources.

Recognizing this, several states have already taken steps to ease the permitting and construction process. Florida passed its own energy legislation that enables utilities to recover their nuclear-related preconstruction and licensing costs. It also excludes nuclear plants from the state's competitive bidding rules related to new capacity. In South Dakota, the state legislature passed a bill that encourages research and development related to advanced design reactors and, and generally fosters consideration of the nuclear option for power generation. Several other states are considering similar bills.

Long Lead Times For Approval And Construction

Placing any plant into operation is a long-term proposition, with new facilities unlikely to enter service before 2015-2016, or about five years following receipt of all relevant permits. Recognizing the lead time necessary for approving and building a nuclear plant, several partnerships and consortia are moving forward today with preparing to file applications with the NRC for a combined construction and operating license (COL), in many cases for multiple units. The NRC has indicated that 16 utilities have noted serious interest in as many as 25 new facilities. For instance, Duke Energy Corp. and Southern Co. expect to submit COLs within the next year-and-a-half for one or two 1,000 MW units to be built in South Carolina.

Such a filing does not commit either company to actually construct the facilities, which is a decision they could make in several years depending on the prevailing market, political, and regulatory dynamics. Duke has estimated the total cost to put the two plants in service to be between $4 billion and $6 billion.

Perhaps the single greatest hurdle to licensing the next nuclear facility, and funding it, is public acceptance of the technology. There are two principal considerations in this regard: operational safety and waste disposal. On the operational front, nuclear plants have demonstrated a strong history since the mid-1990s of safety and operational performance. The performance of safety systems has achieved very high standards, and the absence of headline news and the reduction of forced outages have added to the relative comfort that the public has generally achieved with nuclear technology, until the threat of terrorism injected a whole new risk element into the equation. However, this last consideration does not appear to be deterring companies in the Southeast and Midwest.

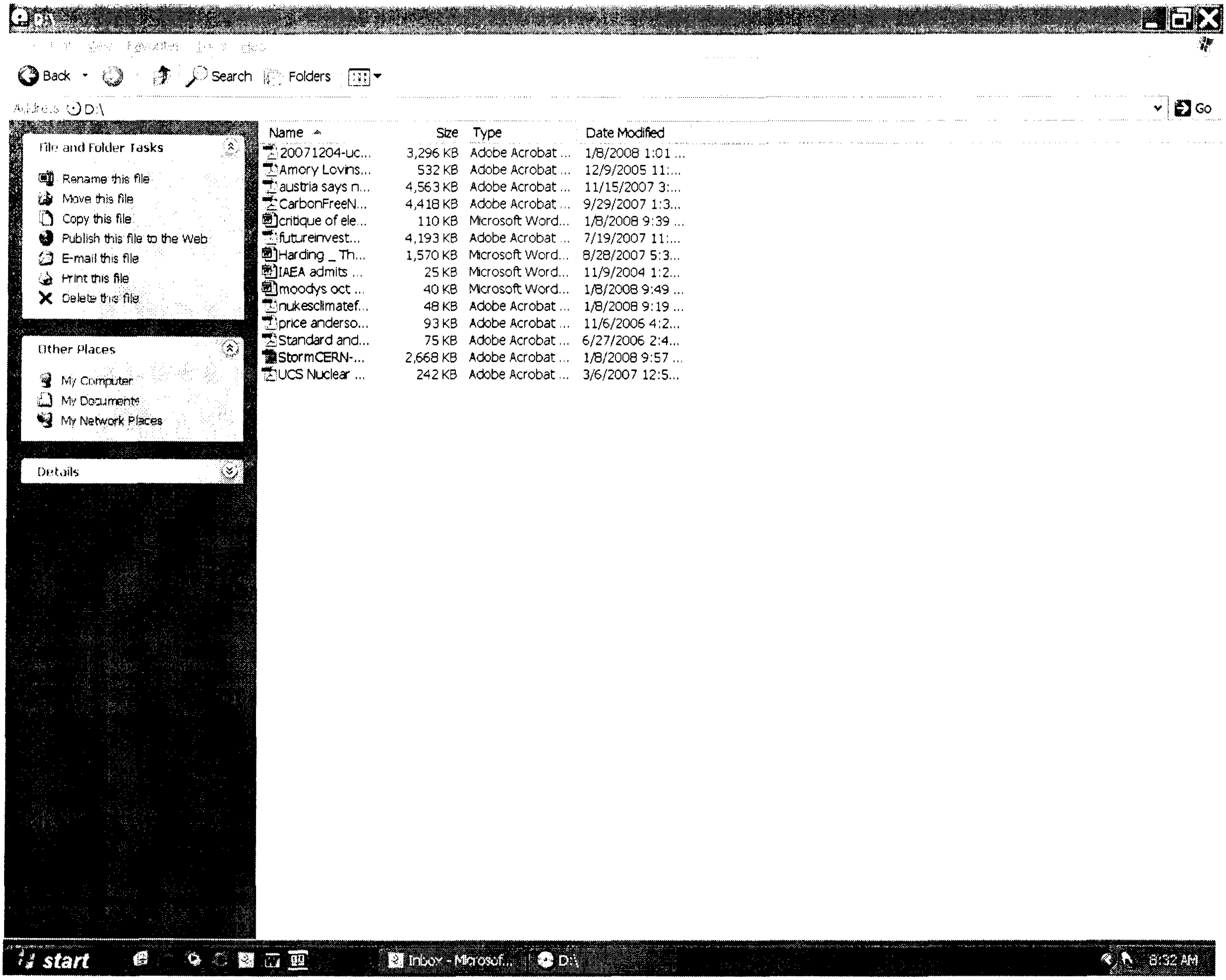
Standard & Poor's Rating Services believes the waste issue will remain a very challenging political problem, but will not be sufficiently disruptive to prevent the licensing of new plants.

Financial Considerations Remain Daunting

From an investor's perspective, the legacy of the unpredictable and prolonged construction period of the last nuclear build cycle and the mixed operating performance of the industry until about 10 years ago remains graphically inked in a collective consciousness. The sheer amount of capital necessary to bring a new plant on line is daunting, so the design of capacity payment structures in 10 years will be a critical consideration. The price of natural gas 10 years hence is also a considerable uncertainty.

At the same time, we recognize that the federal government is initiating numerous structural changes designed to prevent a repeat of the extremely negative and financially ruinous experience of the last nuclear construction cycle, such as standardizing reactor designs, providing tax breaks and loan guarantees, and creating a combined construction and operating license, while the industry itself has demonstrated an ability to operate safely and efficiently in recent years.

So, while slow and steady, the return of the nuclear option has considerable momentum that is not likely to wane.



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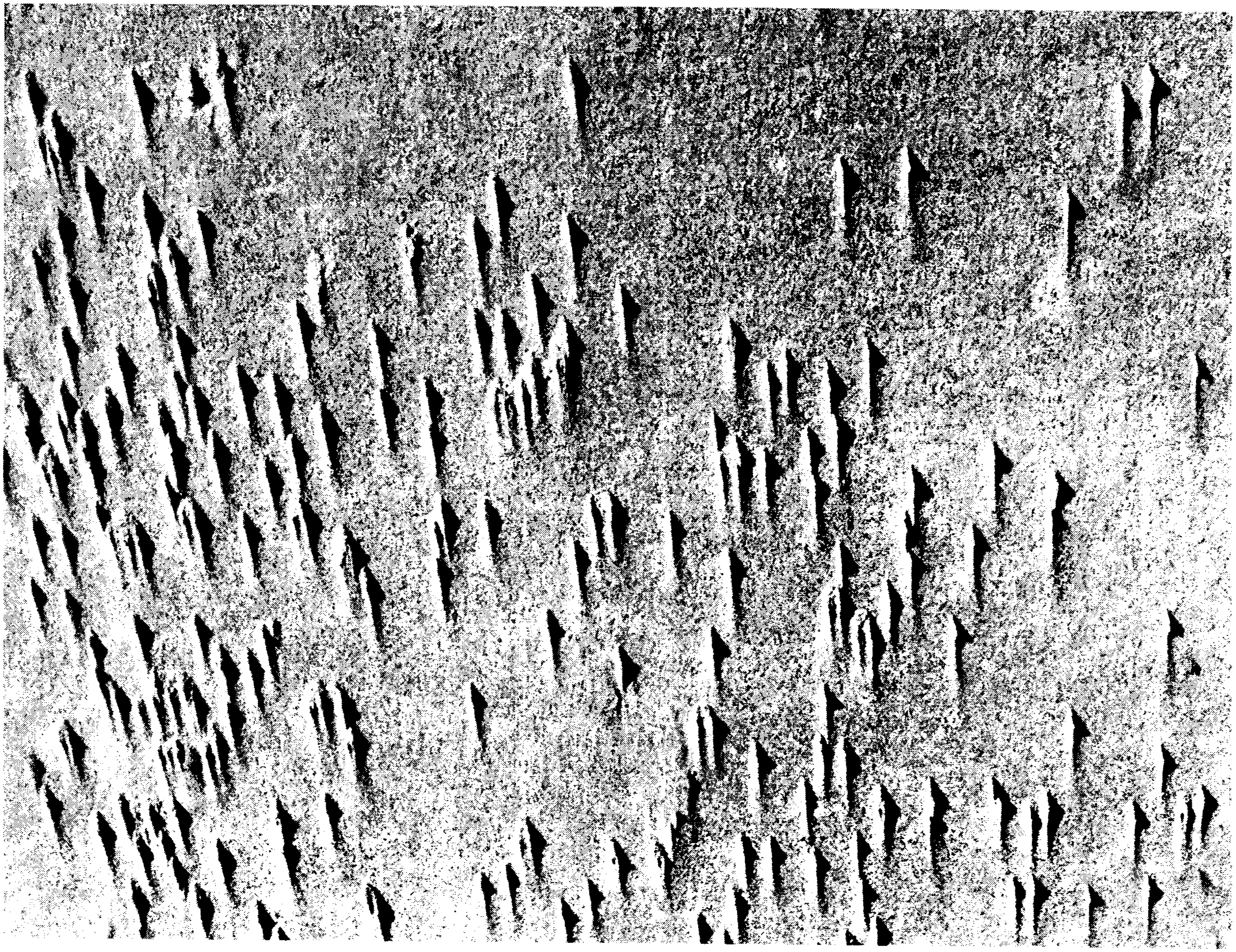

J.W. Storm van Leeuwen 2006

Climate change and nuclear power

J.W. Storm van Leeuwen

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2006

Nuclear power – the energy balance

by

J.W. Storm van Leeuwen and P.B. Smith

August 2005

www.stormsmith.nl

Nuclear power – the energy balance

History of the study

About the study

Data:

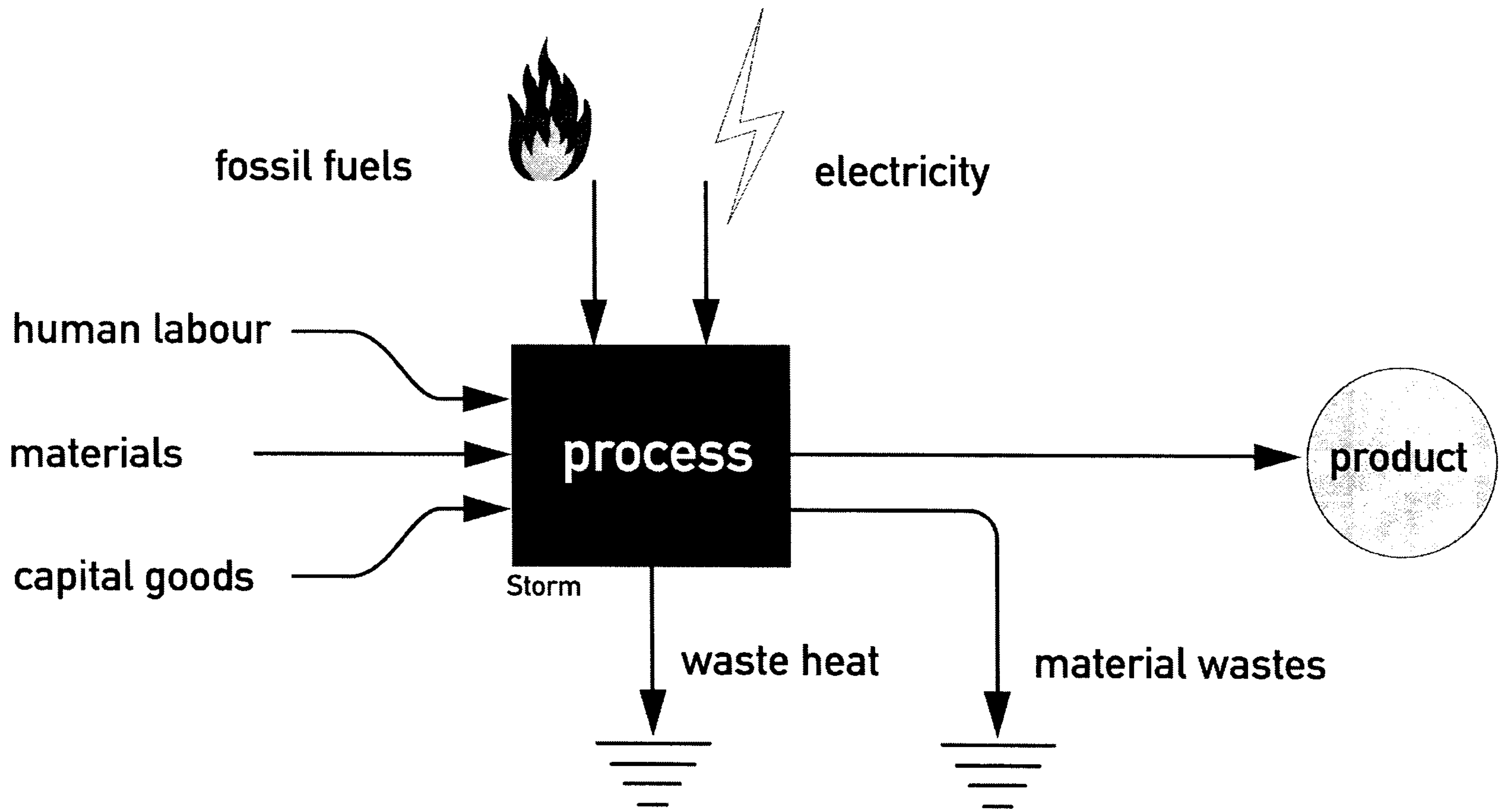
exclusively from nuclear industry itself

About the study

Methodology:

- physical relationships and quantities:
  mass and energy
- life cycle assessment (LCA)
- process analysis
- energy analysis of complex systems
  methods validated during the 1970s and 1980s

Process analysis



Unique features of our study

- Exhaustive analysis
- Energy debt
  - construction
  - dismantling
- Ore grade - energy relationship
- Empirical figures where possible
- Large database, recent data

Key points

- Nuclear and greenhouse gases

- Nuclear share
- Uranium: how much energy?

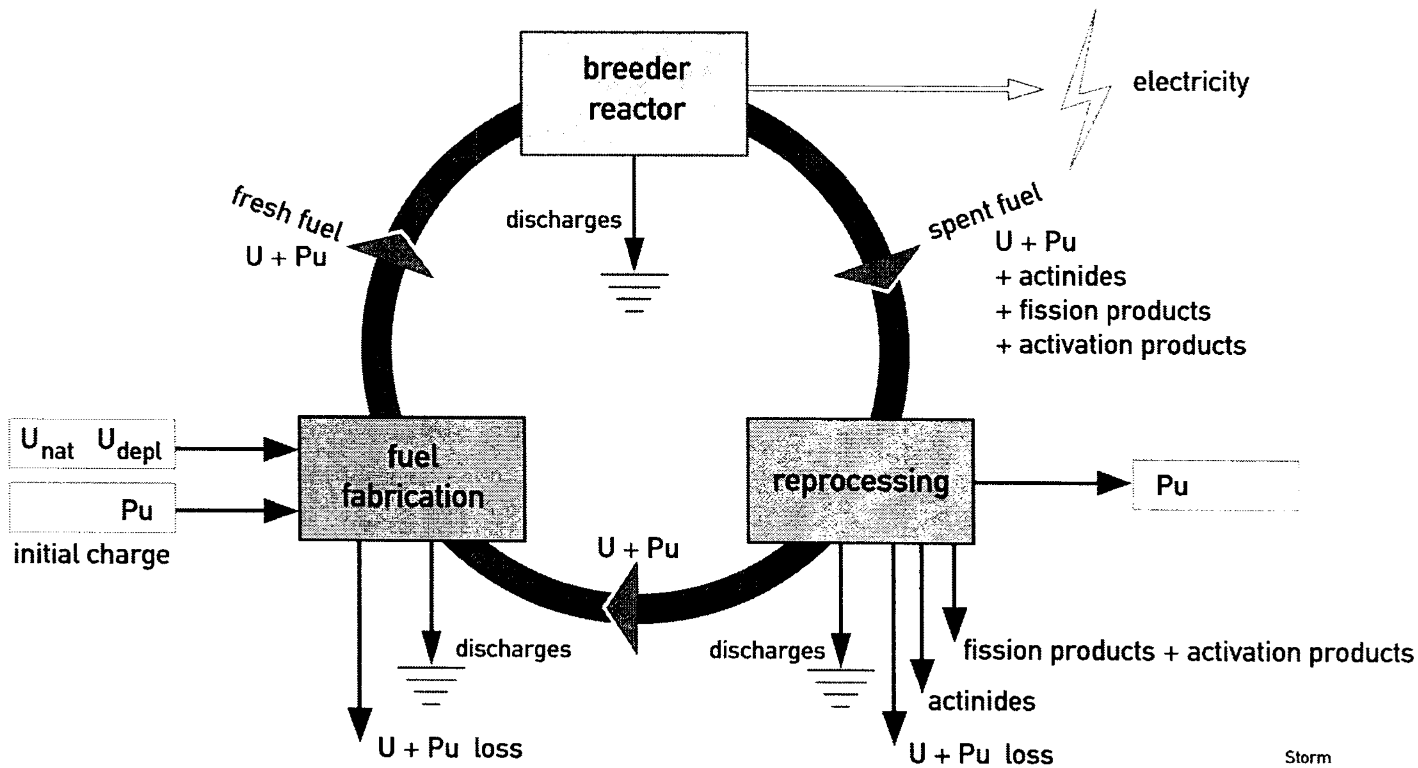
Contents

- Reactor technology
- Energy for energy
- Greenhouse gases
- Nuclear share
- Energy from uranium
- Conclusions

Reactor technology

- Thermal neutron reactors
  LWR
  other ('advanced')
- U-Pu breeder
- Th-U breeder

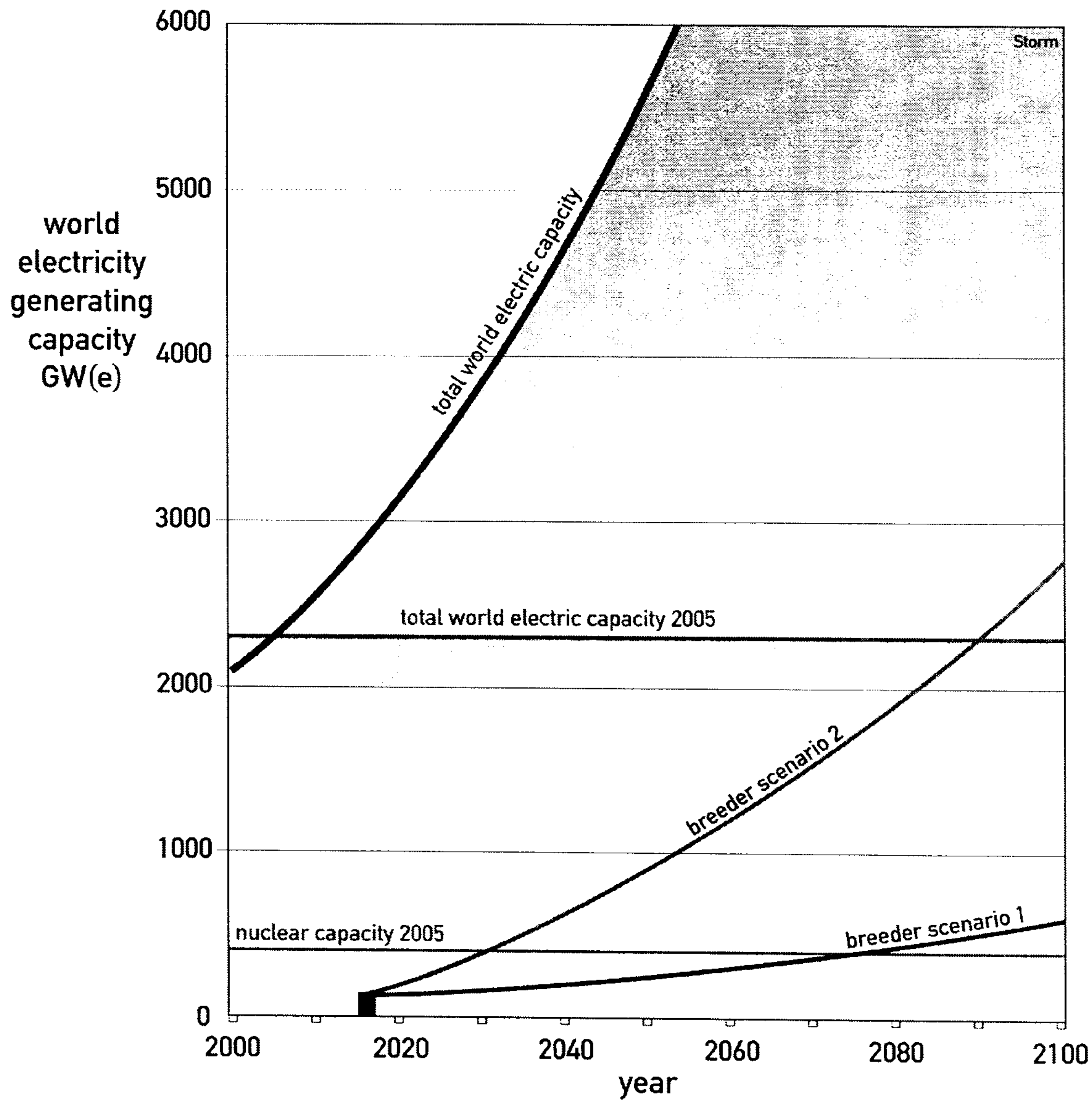
Breeder cycle



Breeder scenarios: assumptions

- textbook operation
- in 2016 140 breeders on line
- plutonium-limited
- doubling time 40 years

Breeder scenarios



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Thorium breeder

- based on Th-232 -> U-233
- Th-U breeder system more remote
- no U-233 in stock

Choice for the next decades

Thermal neutron reactors:
mainly LWR

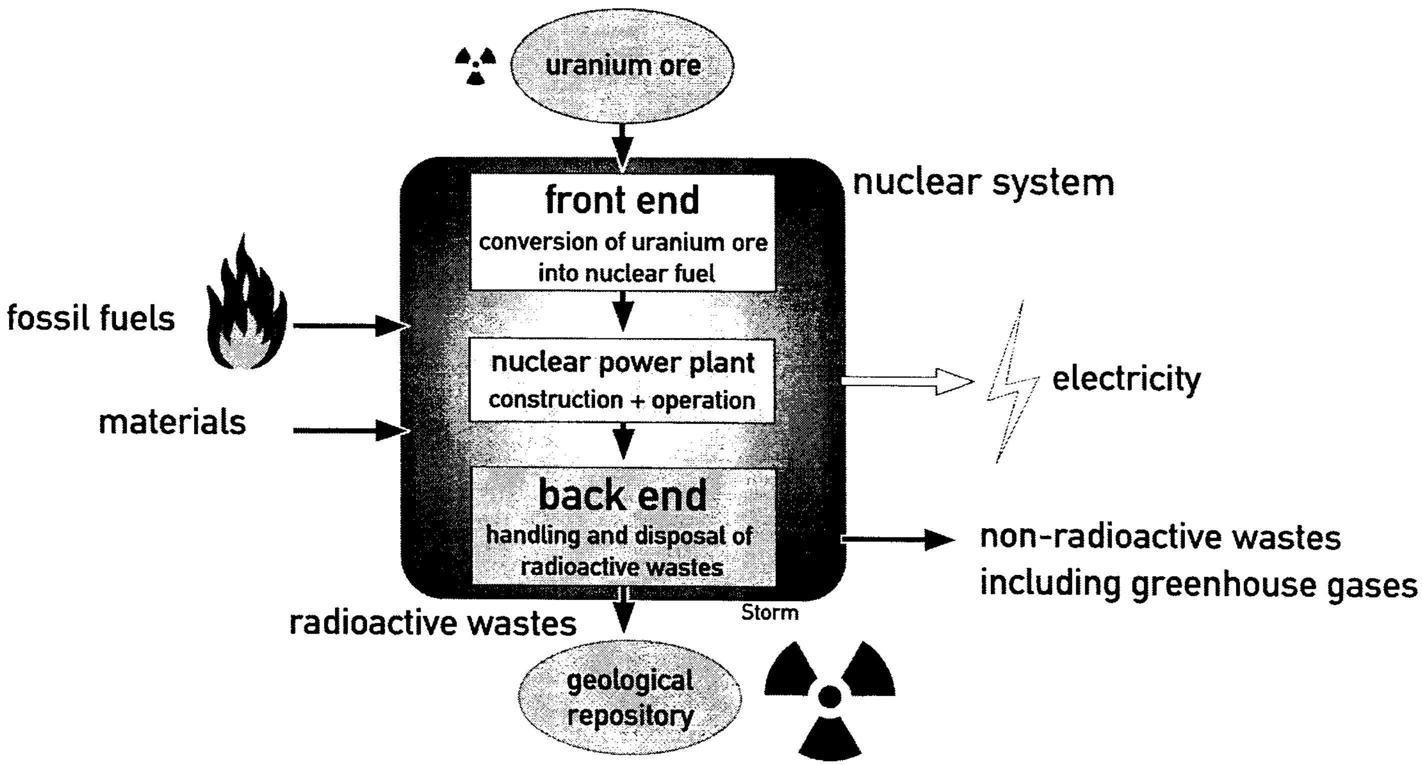
Once-through fuel cycle

Energy for energy

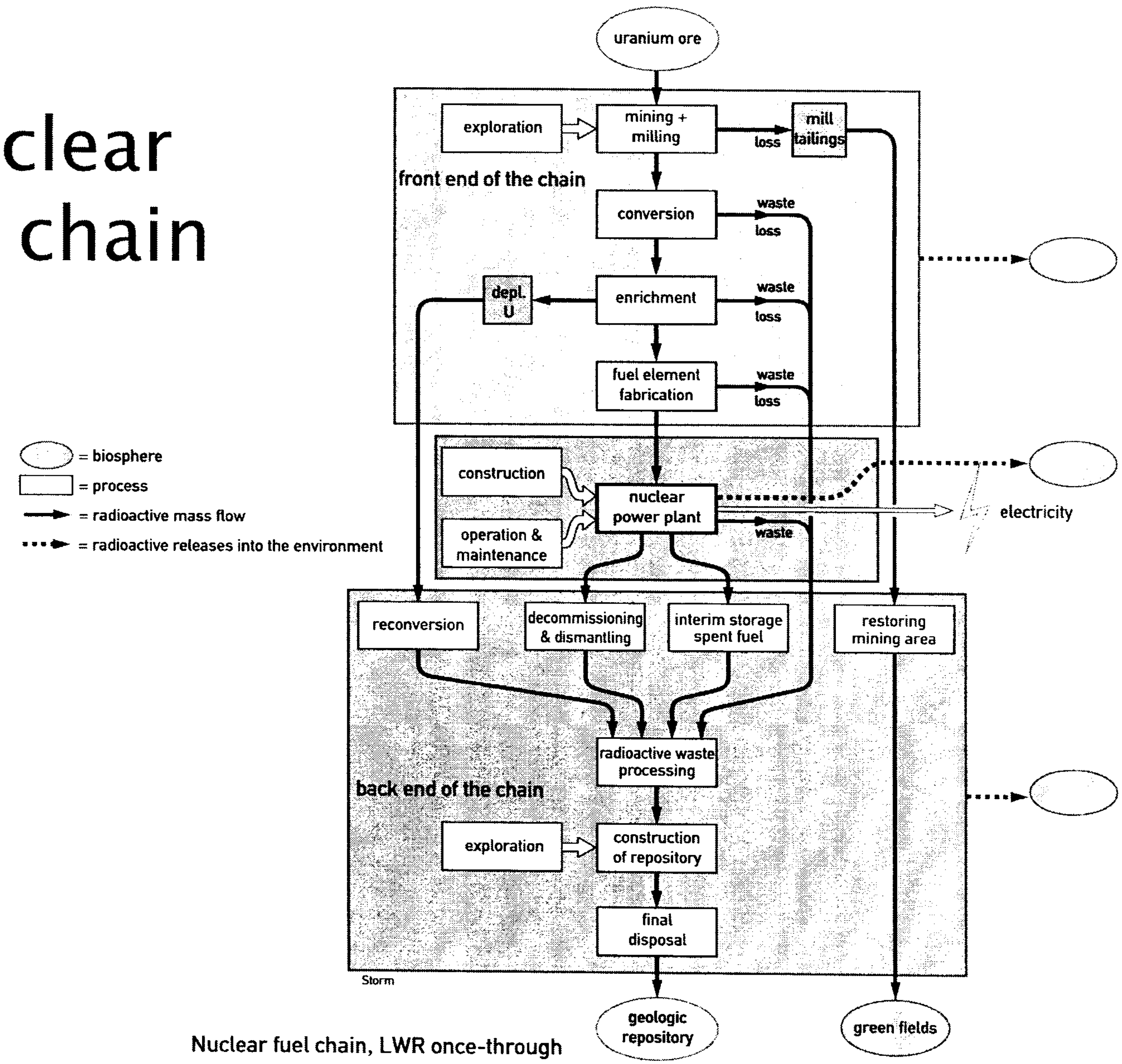
- Releasing useful energy from uranium costs energy
- Nuclear reactor part of a complex system

- Nuclear process chain: conventional industrial and nuclear operations

Basic nuclear process chain



Full nuclear process chain



Nuclear fuel chain, LWR once-through

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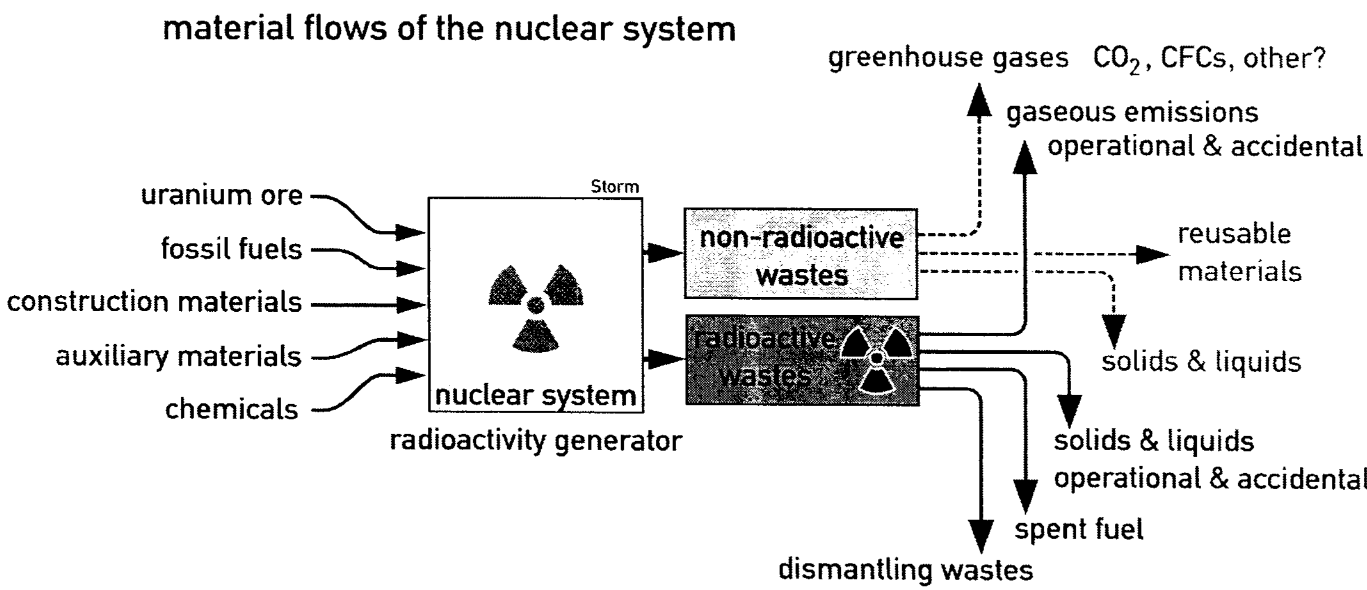
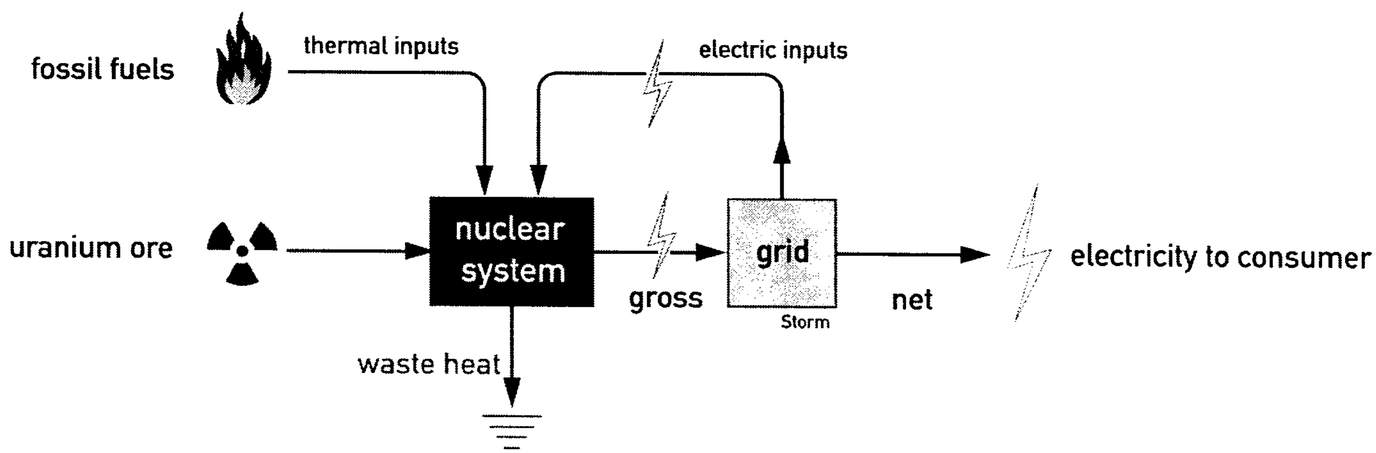
Waste flows of the nuclear system

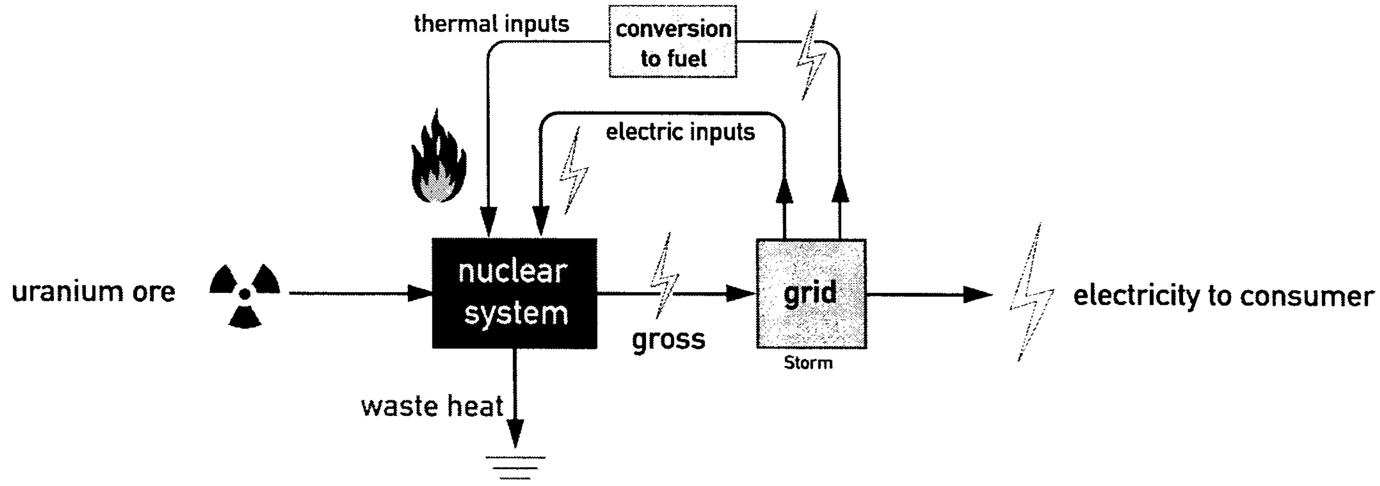


Energy flows of the nuclear system



Fossil fuel-assisted system (current situation)

Energy flows of the nuclear system



All-nuclear system (comparable to renewables)

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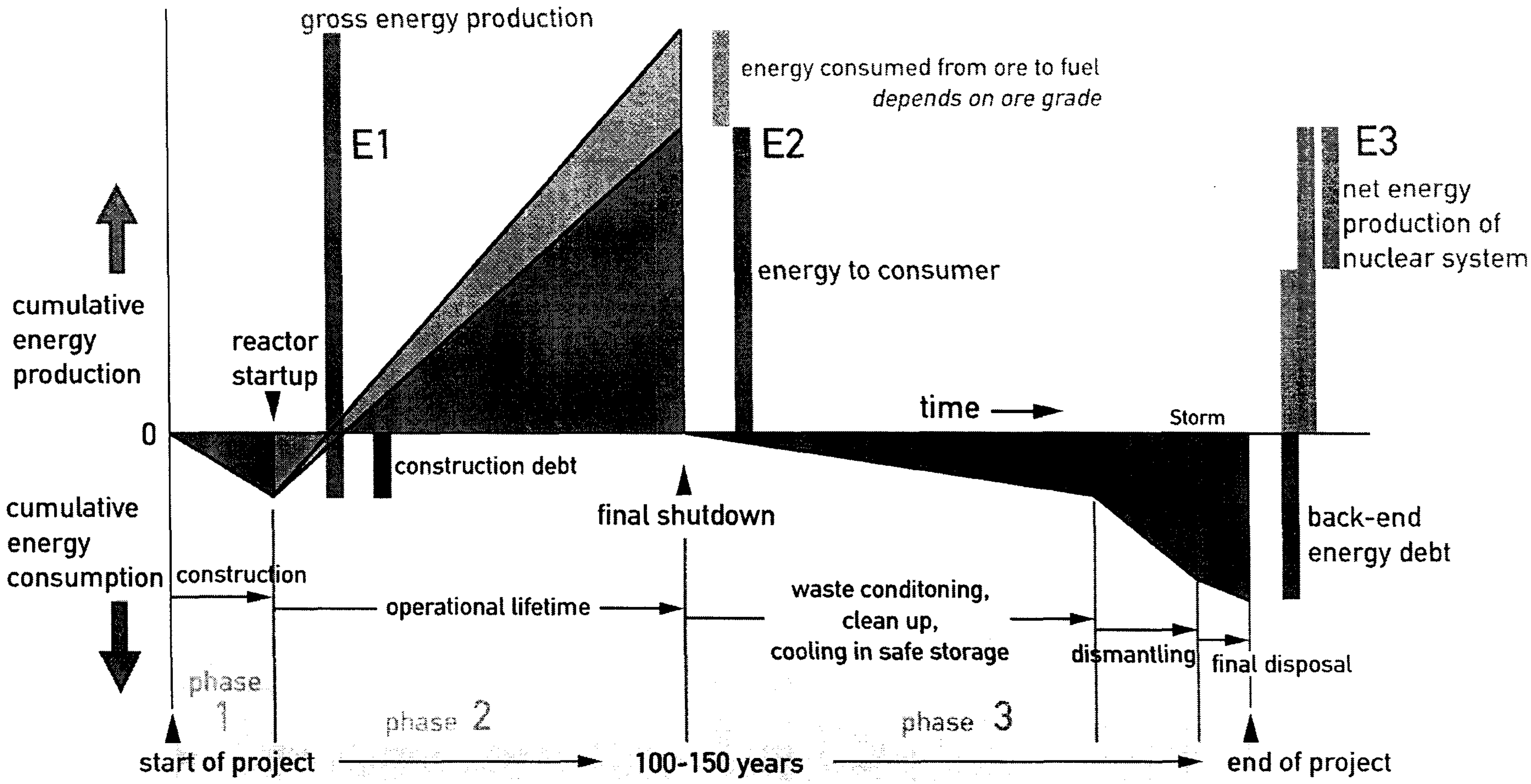
Energy debt



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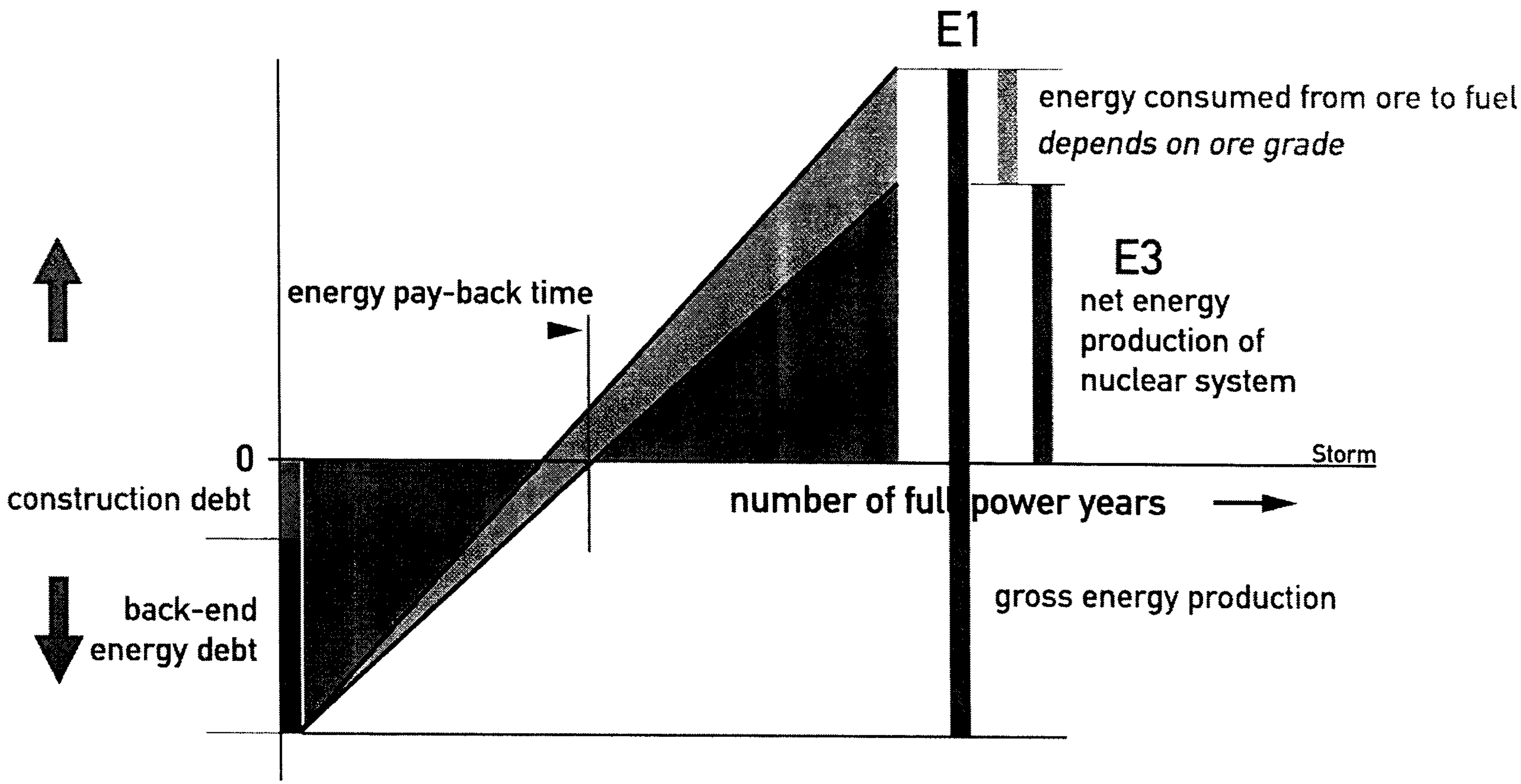
Energy debt 'capitalized'



Greenhouse gases

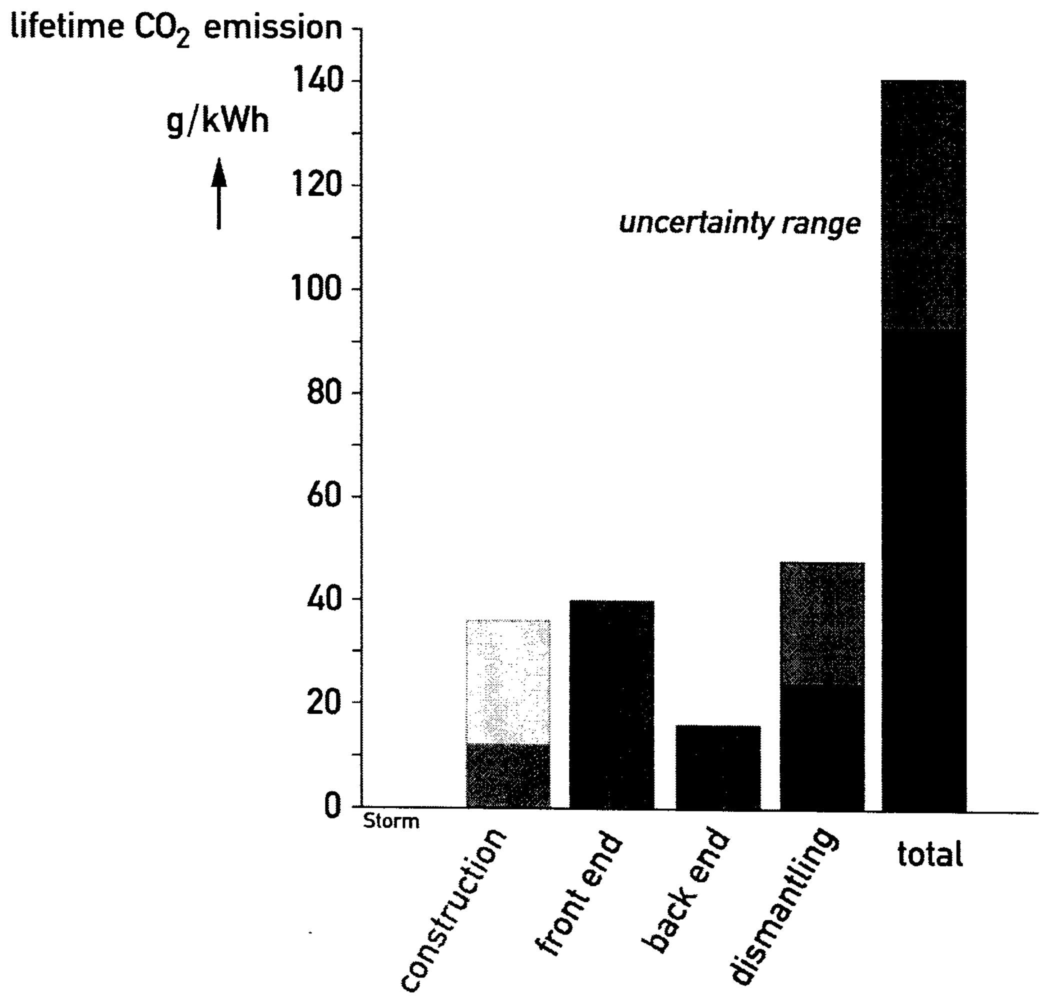
- Carbon dioxide CO_2
- Other greenhouse gases

Only
carbon dioxide emisions analyzed

CO_2 emission from construction

	our study		Sizewell B
	low	high	
total CO_2, Tg	2.5	7.5	3.74
spec CO_2, g/kWh	12	35	14

CO_2 emissions



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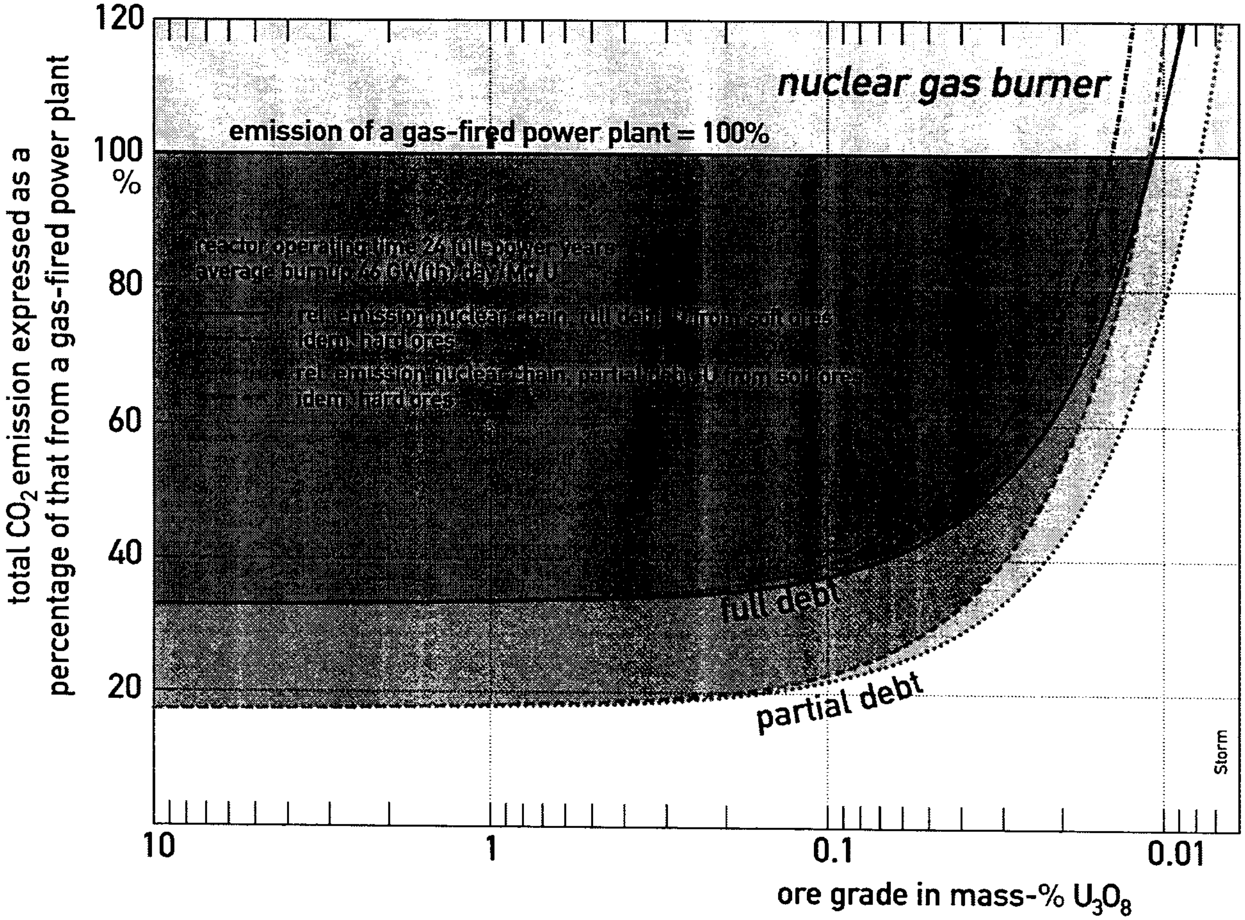
Specific emission of CO_2 vs ore grade



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Emission of other greenhouse gases

- Enrichment ~5 g CO2-eq/kWh freon-114.

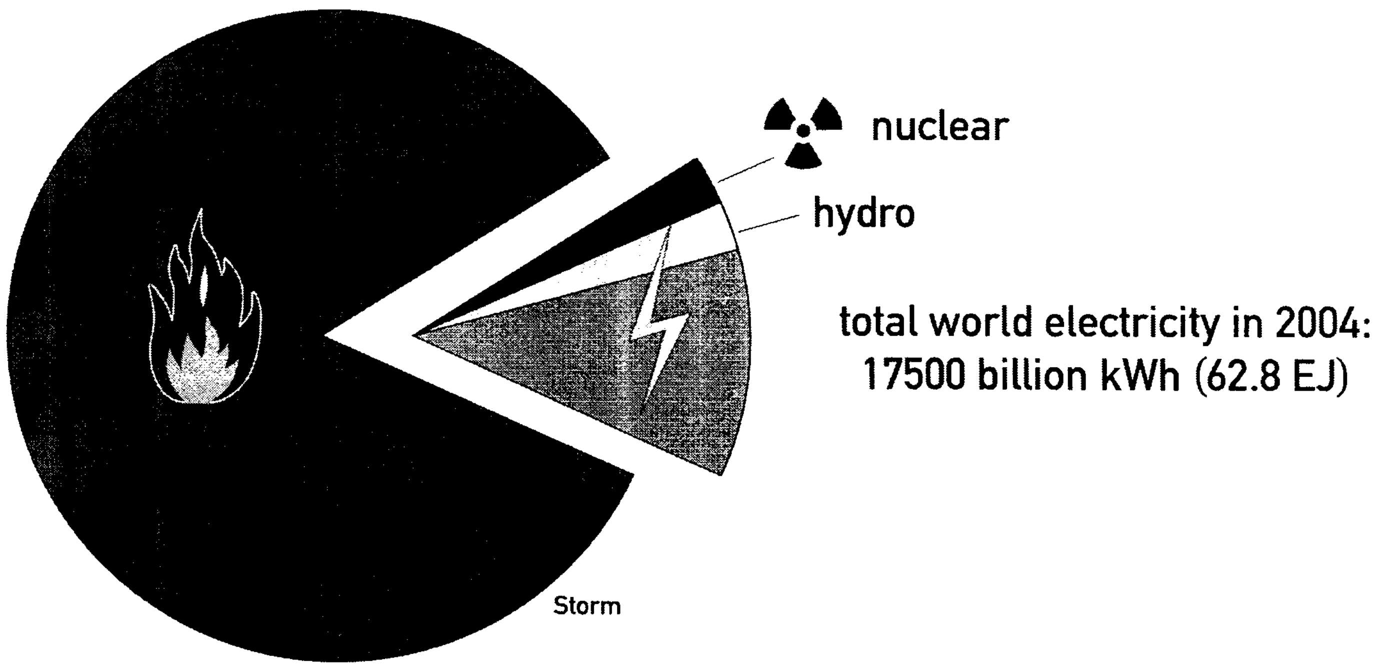
- Other greenhouse gases?
- All nuclear-related processes?

- Ever investigated and/or published?

Nuclear share in the future

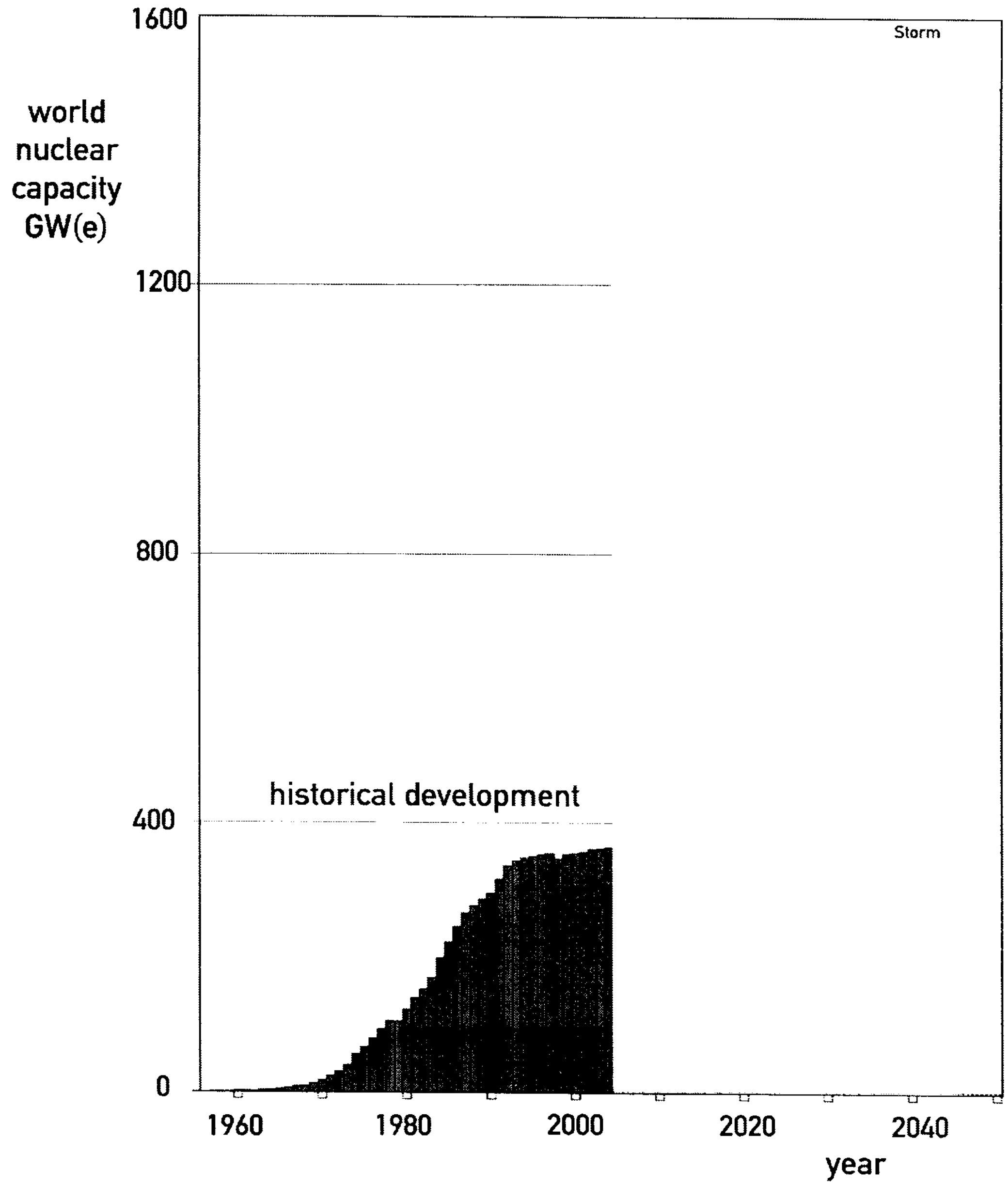
- Current share
- Nuclear scenarios
- World energy scenarios
- Uranium requirements

Current nuclear share



total world final energy consumption in 2004: ~400 EJ

Nuclear scenarios



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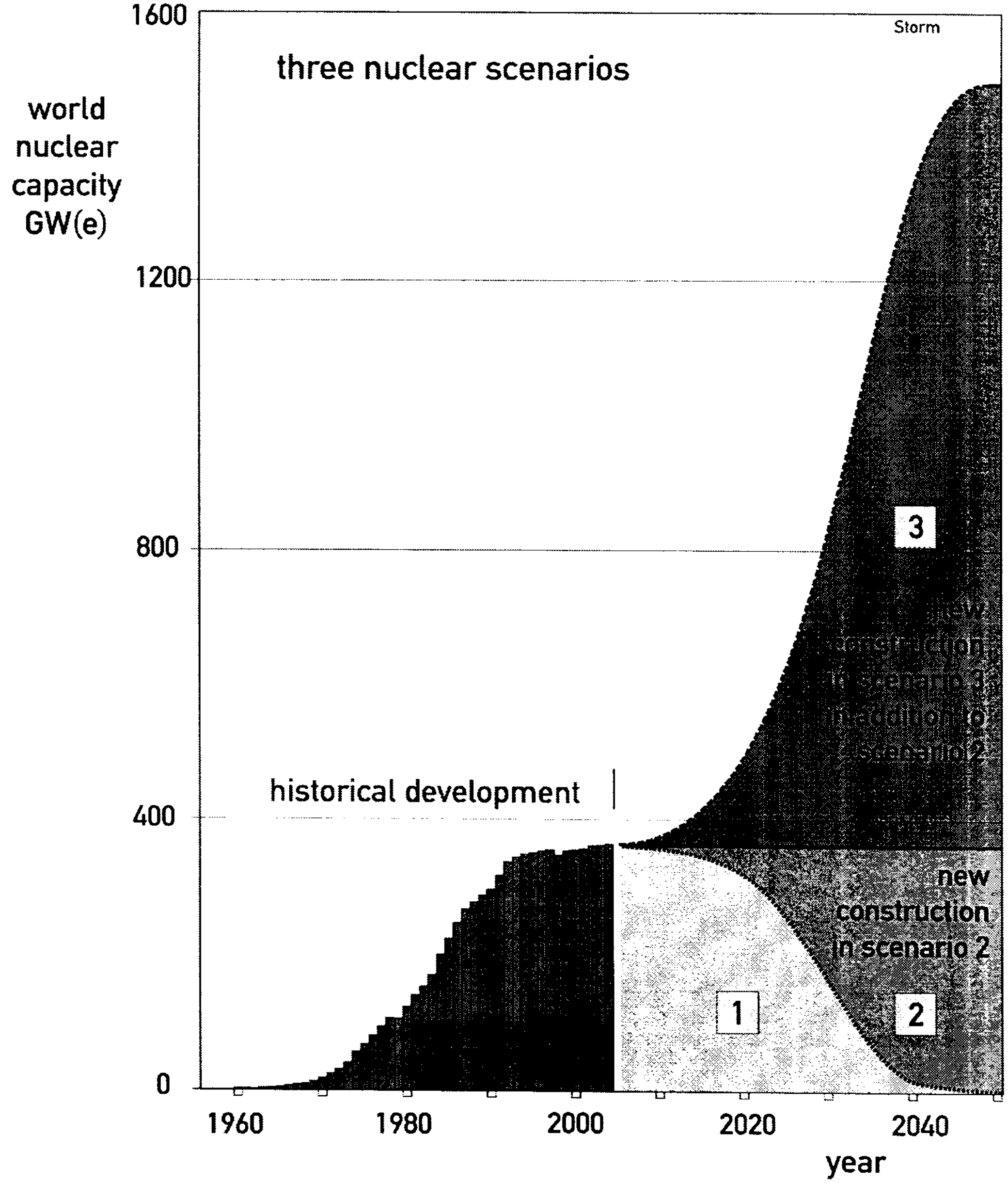
Nuclear scenarios



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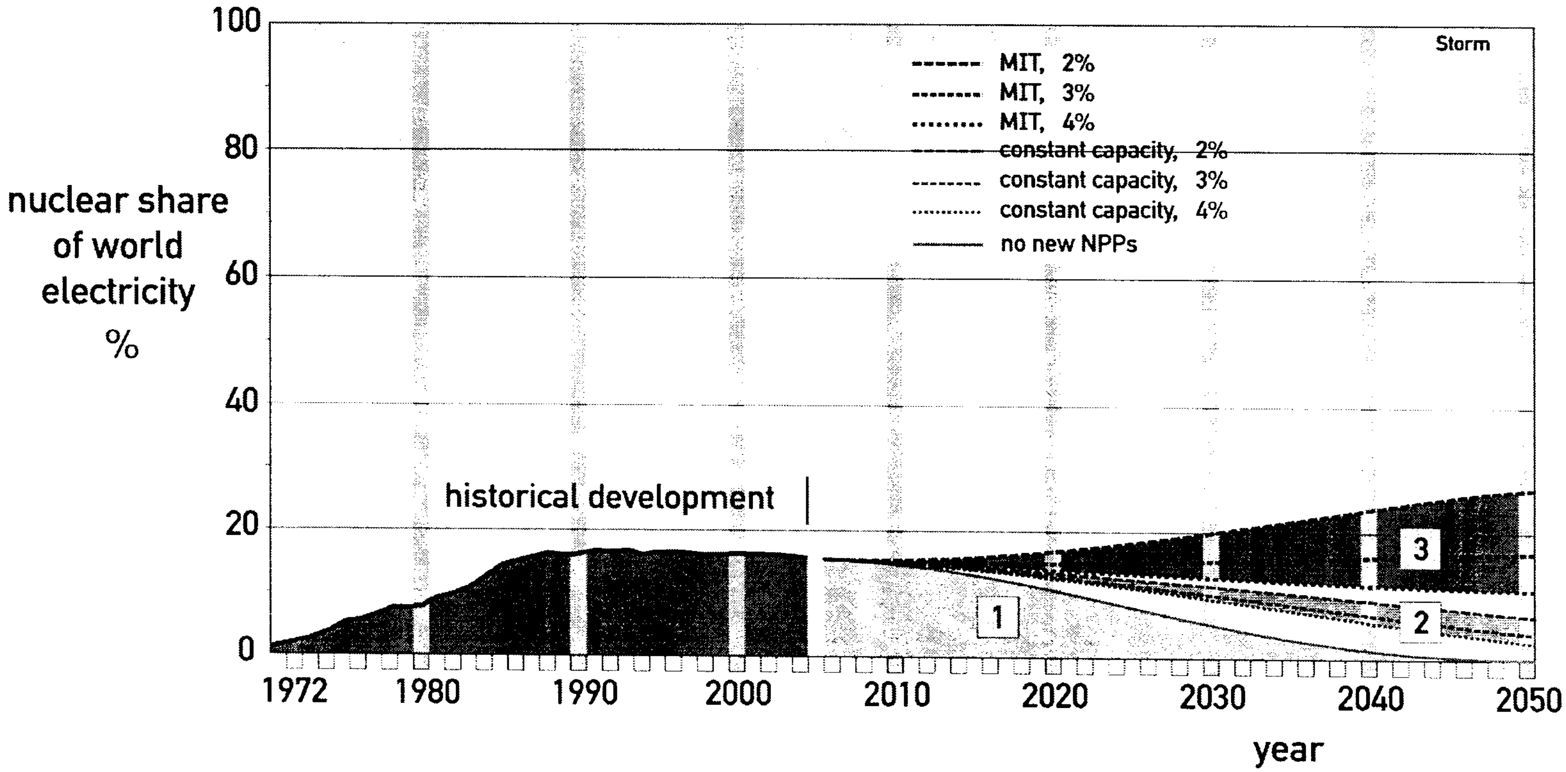
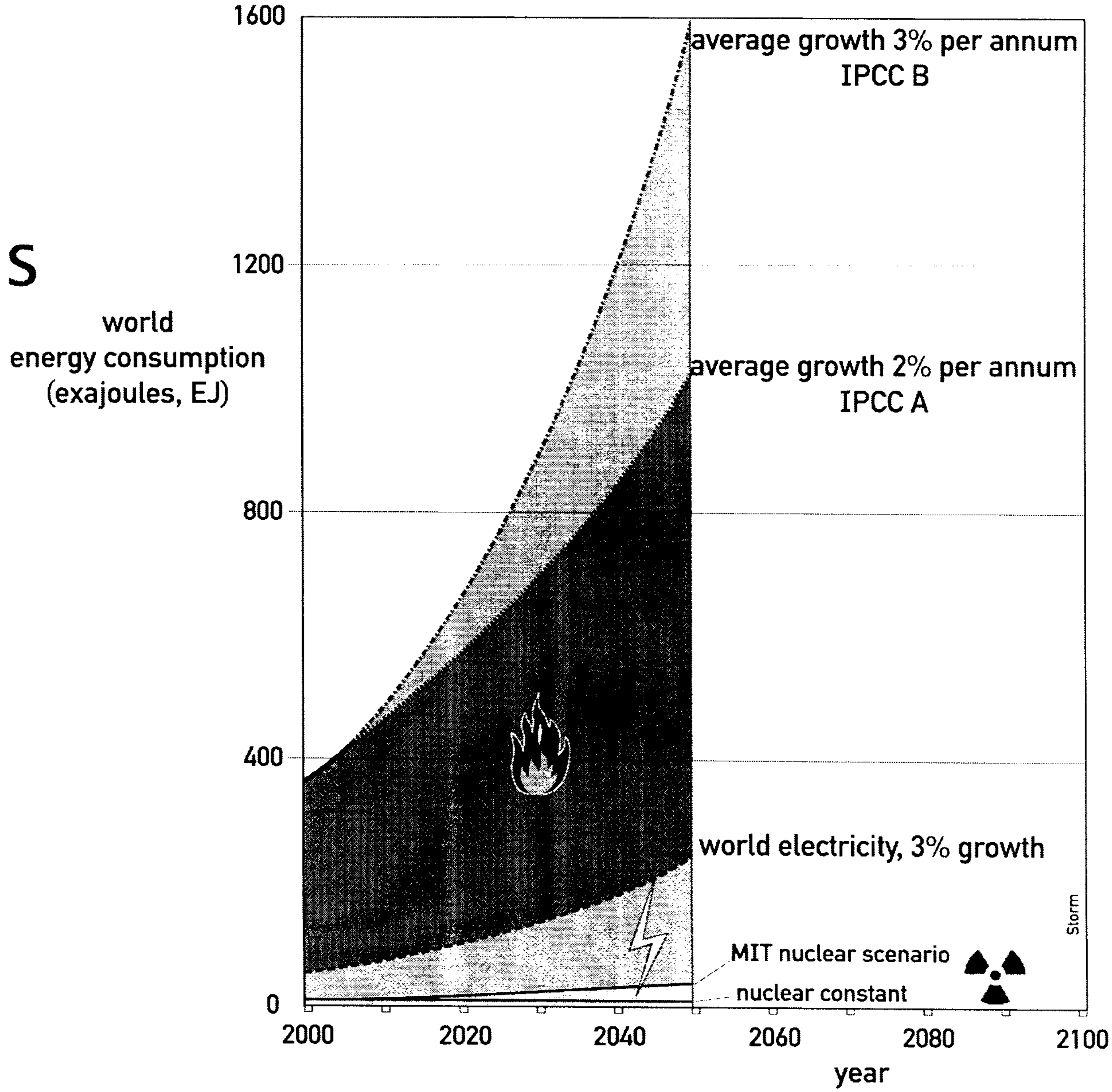
Nuclear share of world electricity



World energy scenarios



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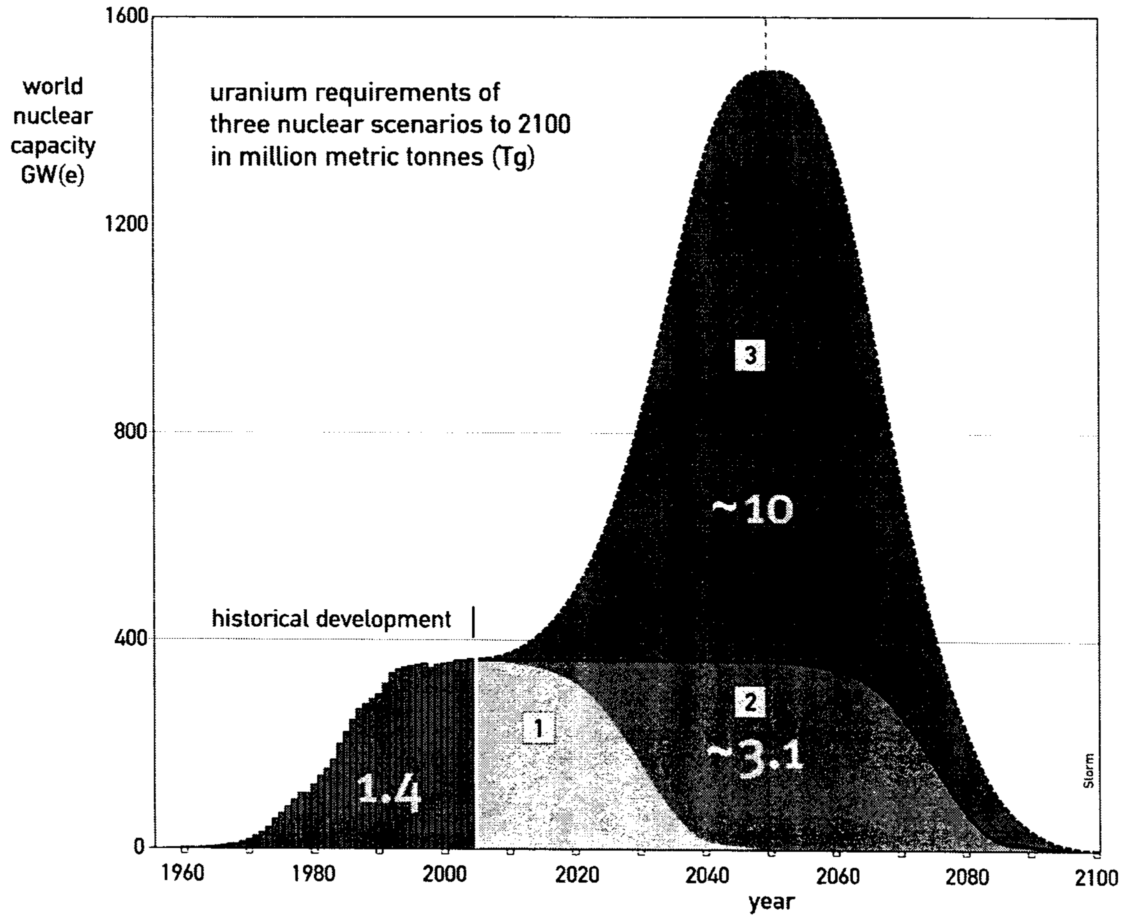
Uranium requirements



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Energy from uranium

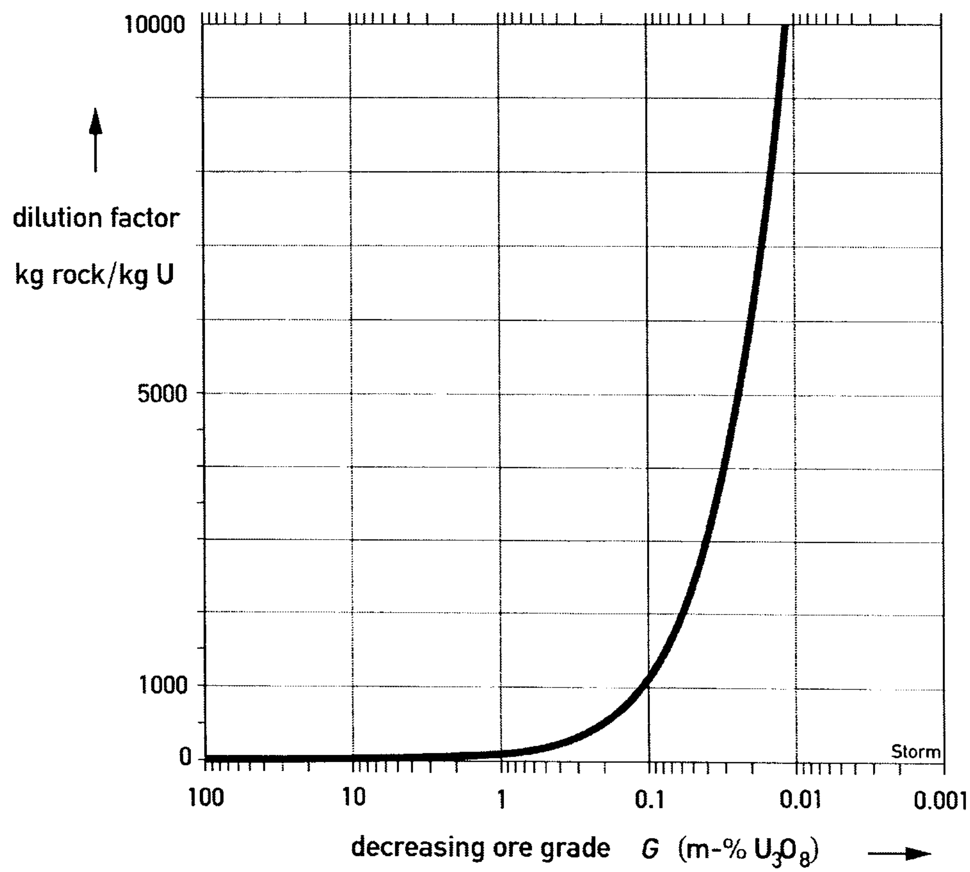
- Uranium extraction from ore:
  - dilution factor
  - extraction yield

- Energy cliff
- Uranium resources
- Nuclear energy resources

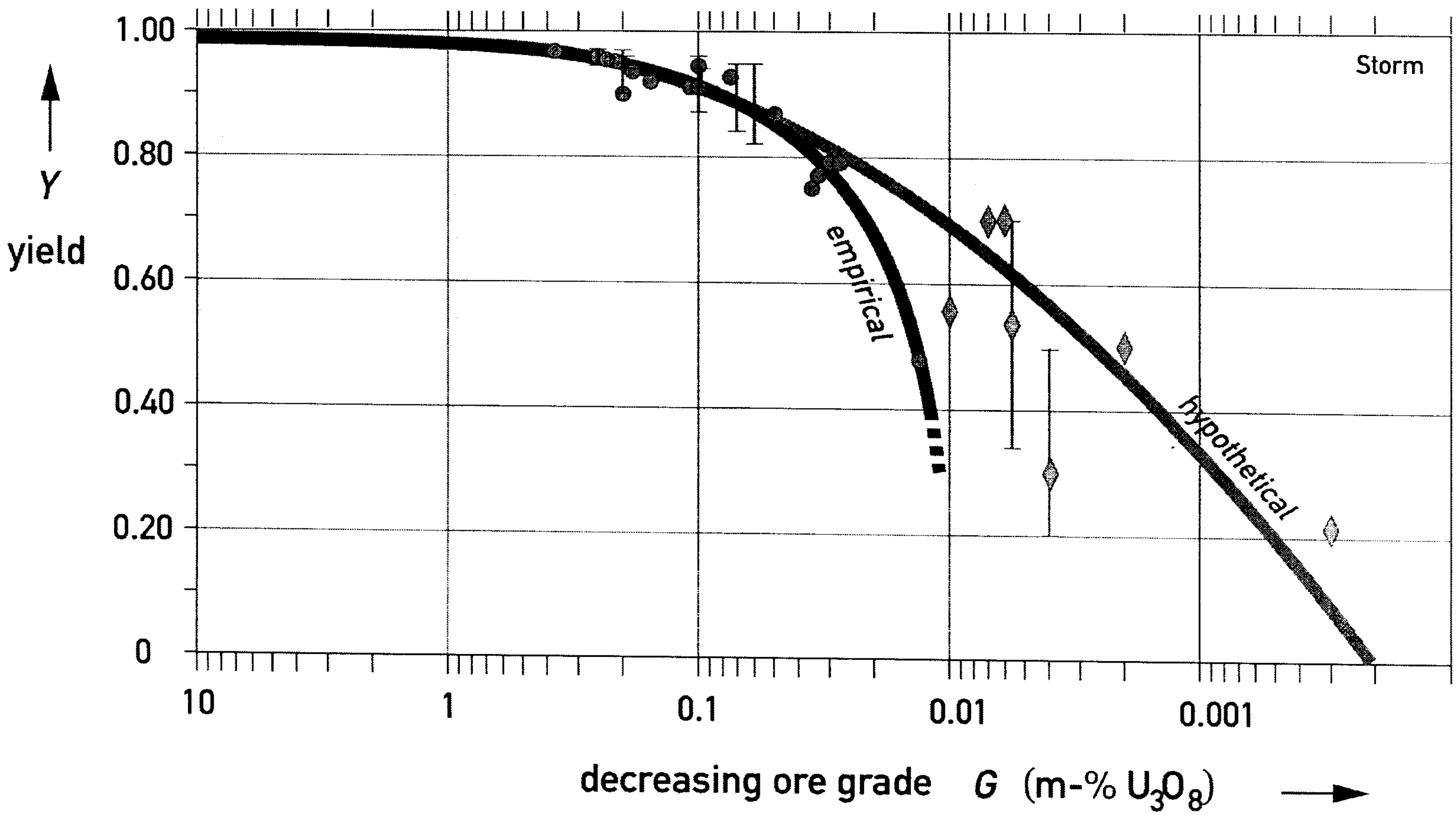
Extraction of uranium from ore

- excavation of rock
- transport
- grinding
- leaching (chemical processing)
- extraction
- purification
- concentration

Dilution factor = kg(rock)/kg(U)



Extraction yield $\boldsymbol{Y} = \boldsymbol{m}U_{ex} / \boldsymbol{m}U_{rock}$



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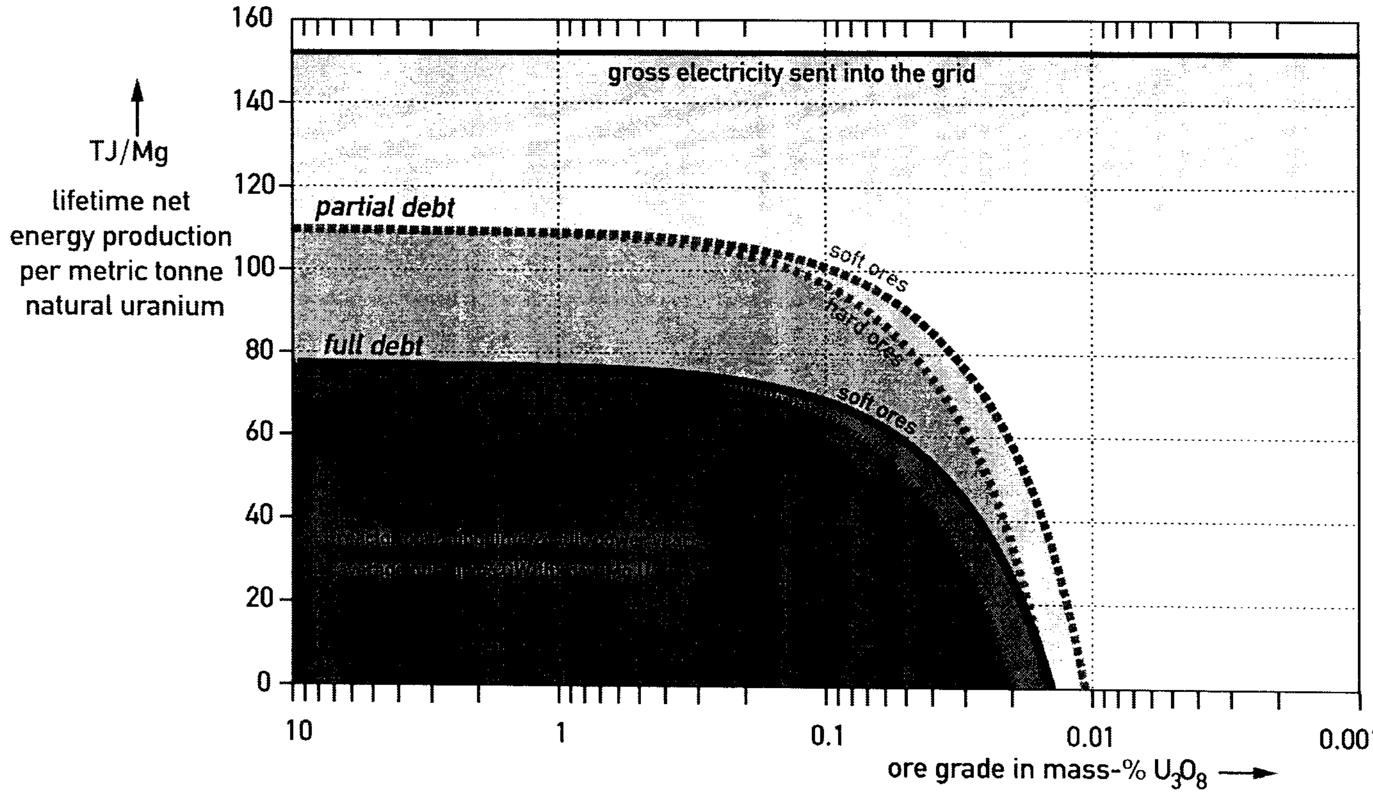
Energy cliff



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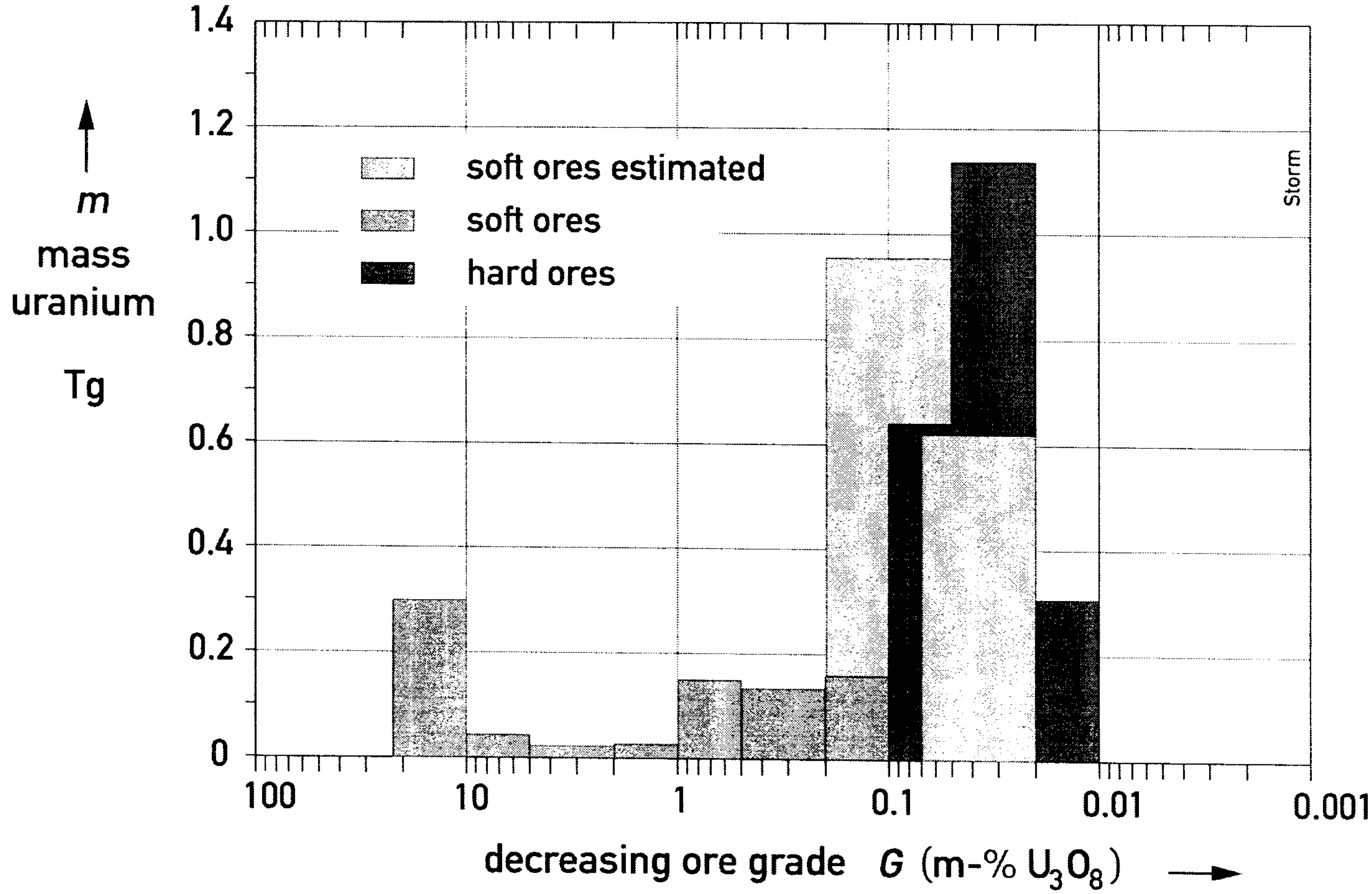
Quantities of available uranium depend on ore grade



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Uranium in the future: *economic view by WNA*

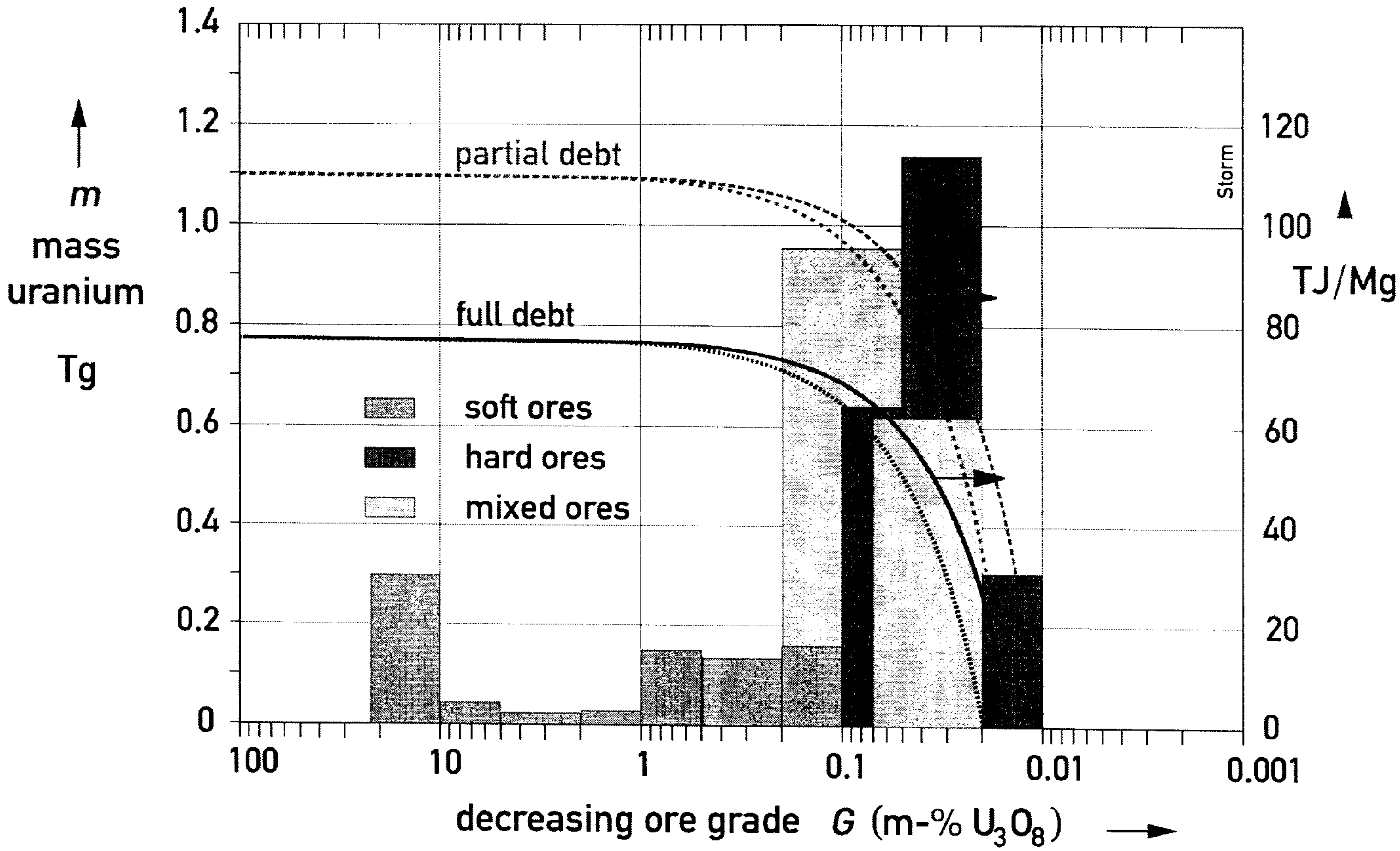
- Higher prices ->
- More exploration, advanced techniques ->
- More discoveries, lower costs ->
- More resources.

- Conclusion: uranium is a sustainable energy resource

Uranium in the future: ***physical facts***

- The larger amount of U in rock, the lower its grade.
- Easily discoverable and mineable uranium resources are already in production.
- Physical laws stay in force, cannot be circumvented by economics.

Nuclear energy resources



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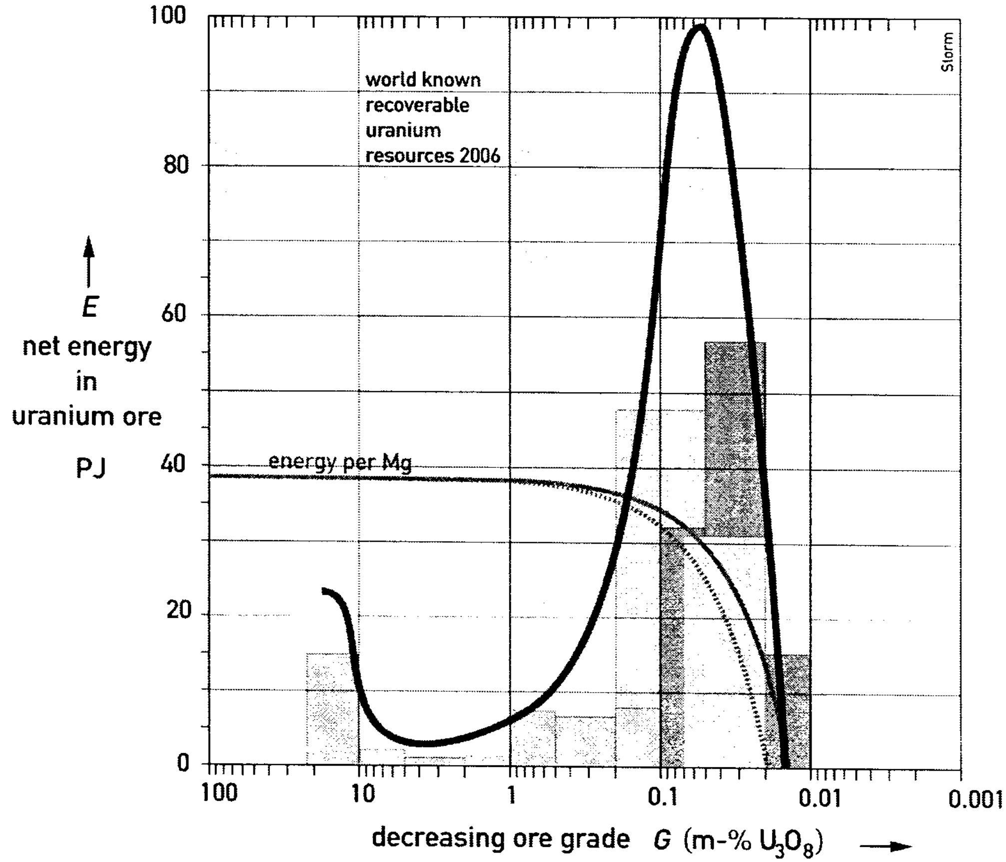
Uranium peak



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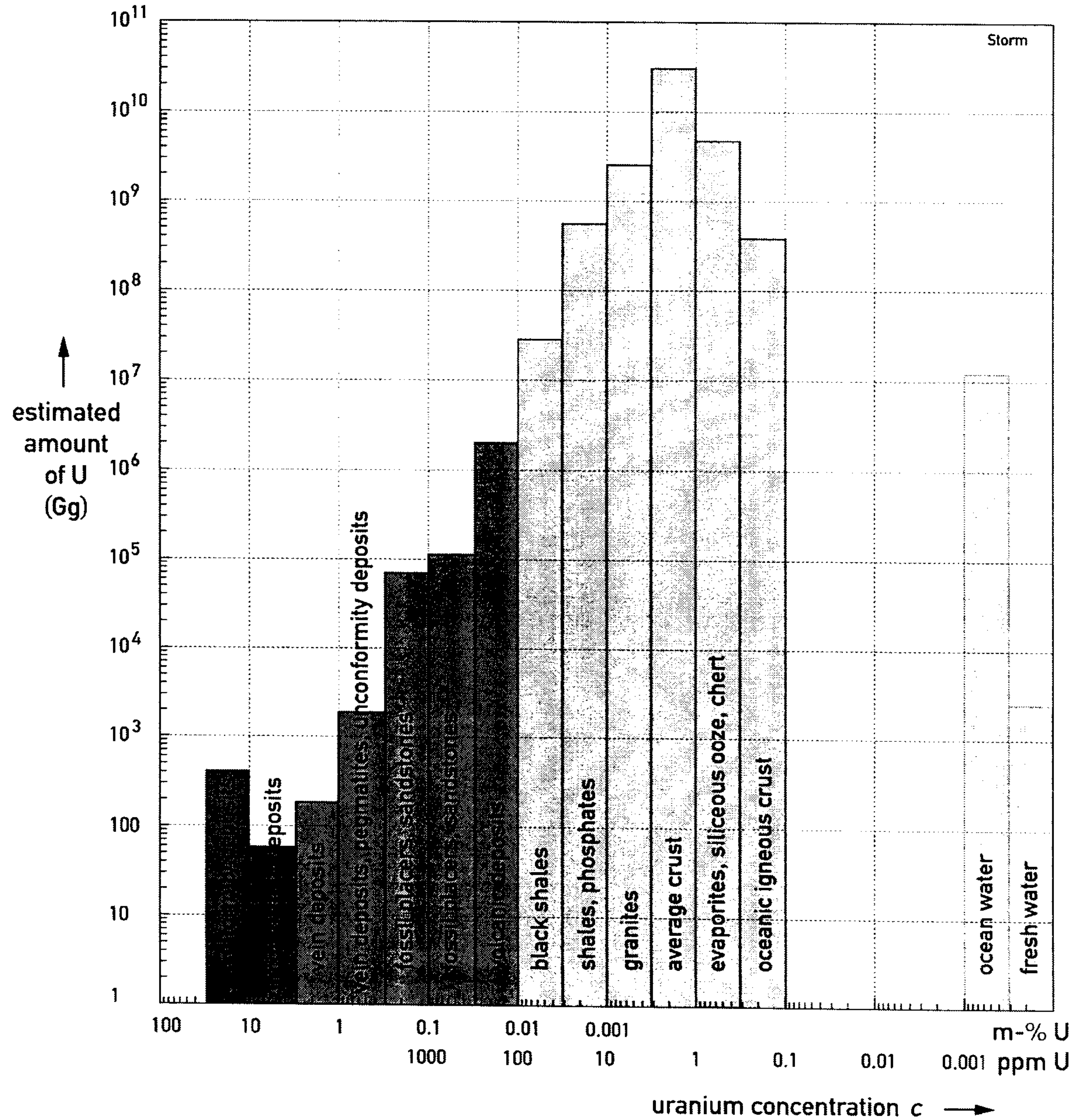
Uranium in the earth's crust

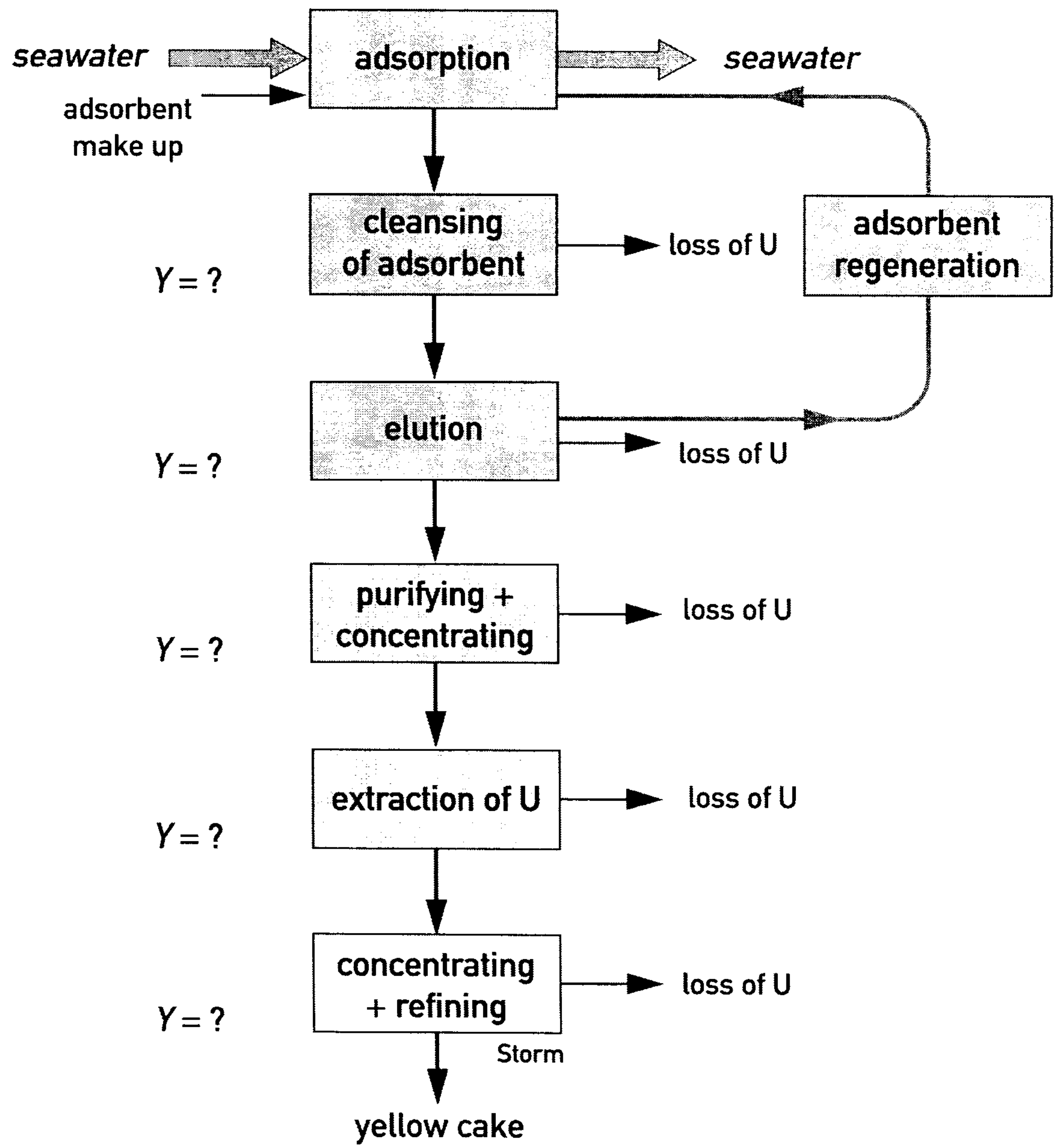


Uranium in seawater

- Dissolved uranium in seawater:
  3.34 milligram per cubic meter
- 1.37 billion km^3 seawater
- 4.5 billion metric tonnes uranium in the oceans

- ***A net energy resource?***

Uranium extraction from seawater



Uranium extraction from seawater

- 162 Mg natural uranium per year per GW
- Overall extraction yield = 17% (excluding the first stage)
- 285 km^3 seawater per year per GW = = 90400 m^3 per second per GW
- 428000 km^3 per year in MIT scenario = = 14 million m^3 per second

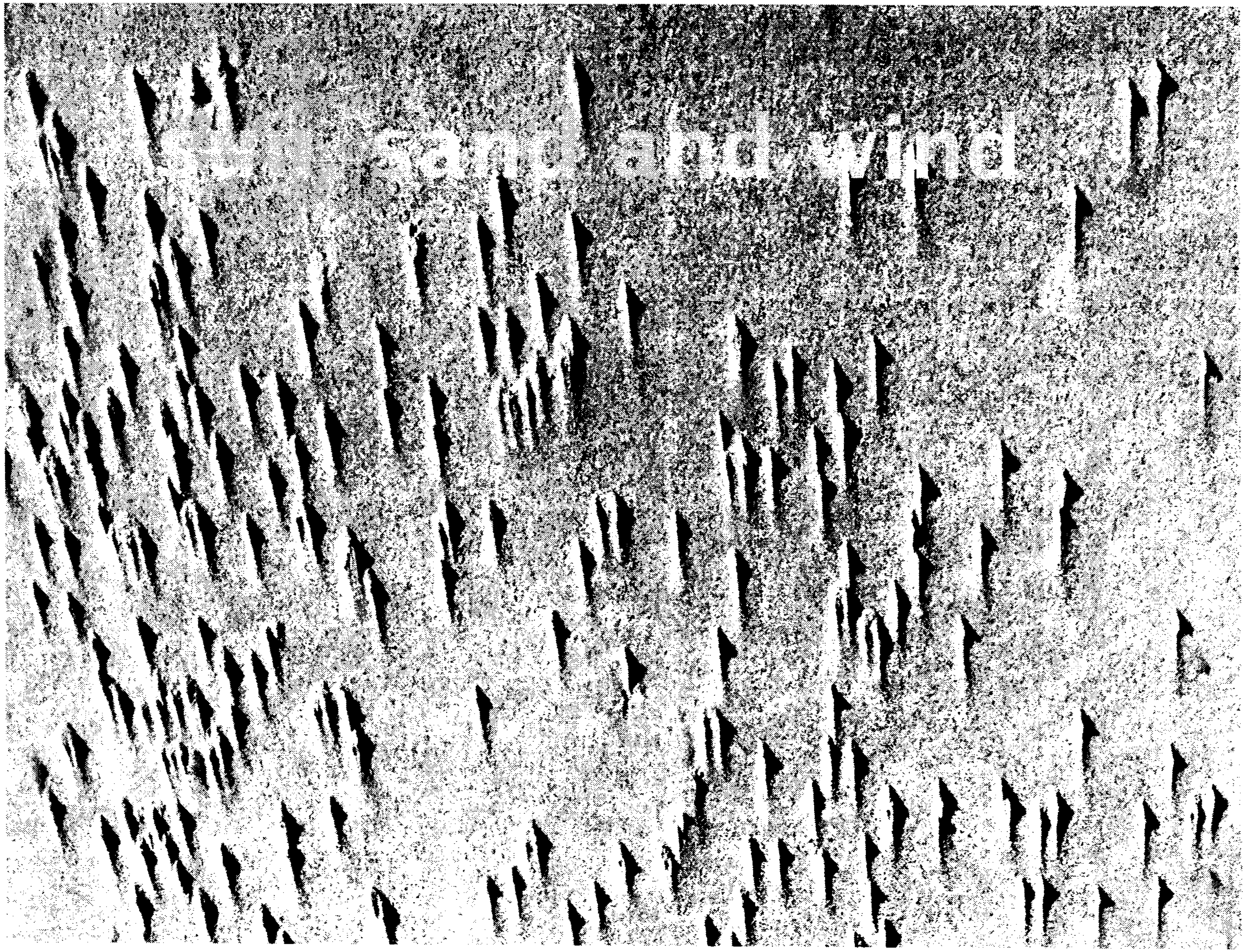
Conclusions

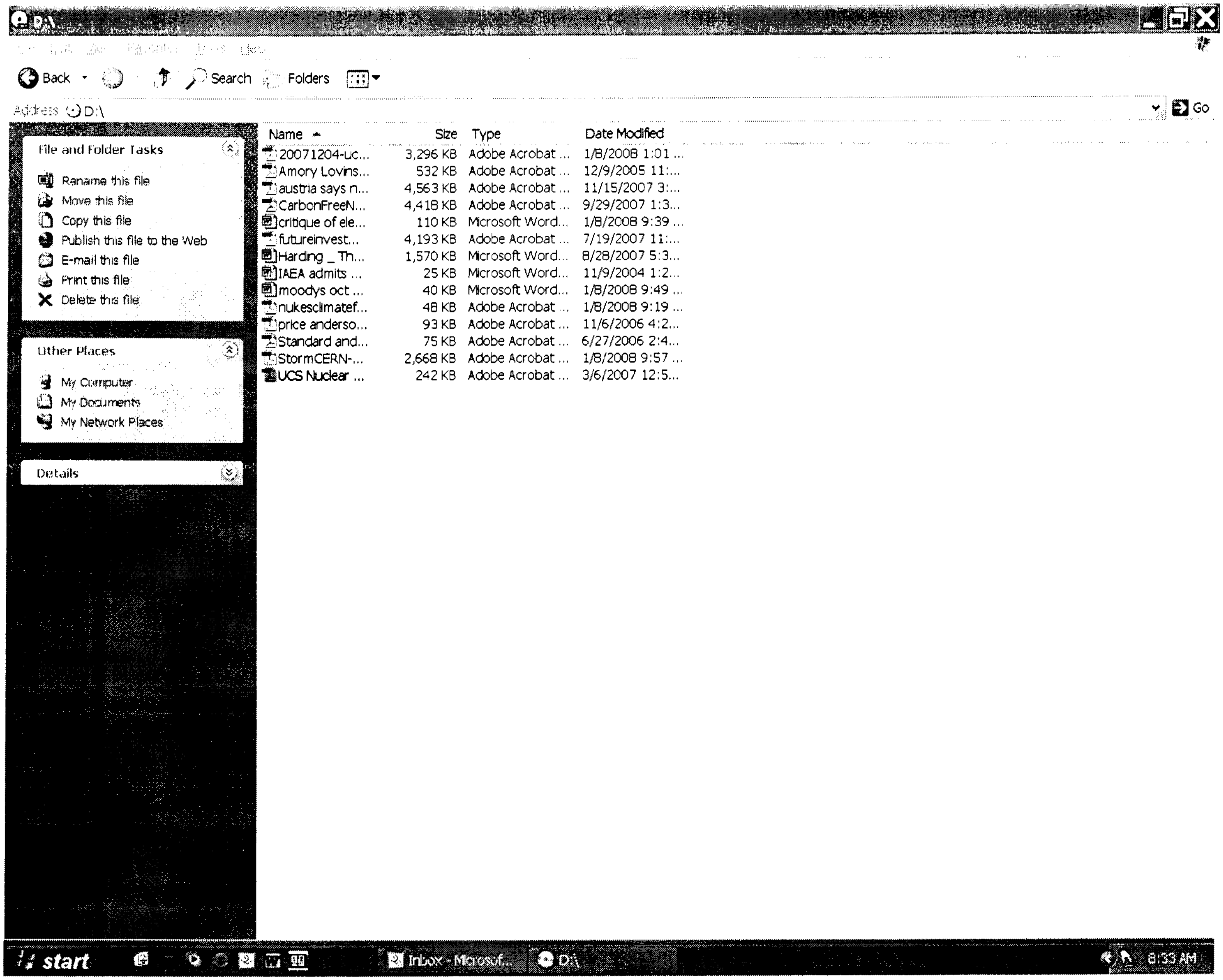
- Greenhouse gas emissions by nuclear?
  Yes, carbon dioxide and other
- Nuclear share in the future?
  Marginal
- Availability of nuclear energy from uranium?
  Serious misconceptions
  Very large uncertainties

Concluding remarks

The industrial society meets the thermodynamic limits in drawing its energy needs from mineral resources.

The time has come to divert to the only entropy-free energy source: the sun.


sand and wind



Thursday, Jan 24, 2008 08:33 AM

Union of Concerned Scientists
Citizens and Scientists for Environmental Solutions

position paper

Nuclear Power and Global Warming

Global warming poses a profound threat to humanity and the natural world, and is one of the most serious challenges humankind has ever faced. We are obligated by our fundamental responsibility to future generations and our shared role as stewards of this planet to confront climate change in an effective and timely manner.

THE SCOPE OF THE PROBLEM

The atmospheric concentration of carbon dioxide (the heat-trapping gas primarily responsible for global warming) has reached levels the planet has not experienced for hundreds of thousands of years, and the global mean temperature has risen steadily for over a century as a result. The U.S. National Academy of Sciences, the Intergovernmental Panel on Climate Change, and scientific academies of 10 leading nations have all stated that human activity, especially the burning of fossil fuels, is a major driver of this warming trend. The window for holding global warming emissions to reasonably safe levels is closing quickly. Recent studies have concluded that avoiding dangerous climate change will require the United States and other industrialized countries to reduce their global warming emissions to approximately 20 percent of current levels by mid-century.

WHAT CAN BE DONE

A profound transformation of the ways in which we generate and consume energy must begin now. The urgency of this situation demands that we be willing to consider all possible options for coping with climate change, but in examining each option we must take into account its impact on public health, safety, and security, the time required for large-scale deployment, and its costs.

While there are currently some global warming emissions associated with the nuclear fuel cycle and plant construction, when nuclear plants operate they do not produce carbon dioxide. This fact is used to support proposals for a large-scale expansion of nuclear power both in the United States and around the world. The Union of Concerned Scientists (UCS) has monitored the use of nuclear power in this country for over three decades, and has been deeply engaged in the related issues of nuclear weapons and proliferation. UCS recognizes the need for a fresh examination of all possible options for coping with climate change, but it must be borne in mind that a large-scale expansion of nuclear power in the United States or worldwide under existing conditions would be accompanied by an increased risk of catastrophic events—a risk not associated with any of the non-nuclear means for reducing global warming.

These catastrophic events include a massive release of radiation due to a power plant meltdown or terrorist attack, or the death of tens of thousands due to the detonation of a nuclear weapon made with materials obtained from a civilian—most likely non-U.S.—nuclear power system. Expansion of

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2397 Shattuck Ave., Ste. 203 • Berkeley, CA 94704-1567 • TEL: 510.843.1872 • FAX: 510.843.3785

nuclear power would also produce large amounts of radioactive waste that would pose a serious hazard as long as there remain no facilities for safe long-term disposal.

In this context, the Union of Concerned Scientists contends that:

1. Prudence dictates that we develop as many options to reduce global warming emissions as possible, and begin by deploying those that achieve the largest reductions most quickly and with the lowest costs and risk. Nuclear power today does not meet these criteria.

2. Nuclear power is not the silver bullet for "solving" the global warming problem. Many other technologies will be needed to address global warming even if a major expansion of nuclear power were to occur.

3. A major expansion of nuclear power in the United States is not feasible in the near term. Even under an ambitious deployment scenario, new plants could not make a substantial contribution to reducing U.S. global warming emissions for at least two decades.

4. Until long-standing problems regarding the security of nuclear plants—from accidents and acts of terrorism—are fixed, the potential of nuclear power to play a significant role in addressing global warming will be held hostage to the industry's worst performers.

5. An expansion of nuclear power under effective regulations and an appropriate level of oversight should be considered as a longer-term option if other climate-neutral means for producing electricity prove inadequate. Nuclear energy research and development (R&D) should therefore continue, with a focus on enhancing safety, security, and waste disposal.

PROBLEMS WITH U.S. NUCLEAR POWER TODAY

Nuclear power currently provides eight percent of the nation's total energy supply, and is now used only to generate electricity. To address global warming we have to address all sources of emissions including transportation.

Since its birth, the nuclear power industry has benefited from major government subsidies. Nevertheless, no new nuclear plants have been ordered since 1978, primarily because the industry has been unable to attract investors after cost overruns and large financial losses.

The Nuclear Regulatory Commission (NRC) has not properly enforced safety regulations at existing plants; such negligence nearly led in 2002 to a catastrophic accident at the Davis-Besse plant in Ohio. Furthermore, NRC security requirements still assume that terrorists targeting a nuclear facility will not use aircraft, will not attack with more than a handful of individuals, and will not use widely available weapons such as rocket-propelled grenades.

The disposal of spent nuclear fuel also remains an unresolved issue. Spent fuel rods can, however, be stored safely in aboveground steel cylinders ("dry casks") for at least 50 years. Permanent storage should be in deep underground "geological" sites, but the Yucca Mountain geological facility in Nevada may never be licensed.

Compounding matters is the fact that no new nuclear plants could be completed before 2014 according to government estimates, and plants with genuinely advanced designs no earlier than 2025.

APPROPRIATE STRATEGIES FOR COMBATING GLOBAL WARMING

A truly effective and timely response to the risk posed by global warming would take the form of a comprehensive national policy covering the entire spectrum of technologies and practices that could reduce global warming emissions. The following strategies would set the nation on a cost-effective and prudent path toward that end:

- The government should adopt policies that maximize energy efficiency and conservation, increase the use of renewable energy resources, and eliminate barriers to existing technologies that can reduce global warming emissions without the risks associated with nuclear power. Such policies provide the best prospect for the large near-term reductions in global warming emissions that are needed to stabilize the global average temperature at a reasonably safe level.

- The government should create conditions under which energy prices would reflect the full cost of global warming emissions, by setting emission targets and establishing a mandatory revenue-neutral carbon tax or cap-and-trade system. A constraint on carbon will make nuclear power more competitive with fossil fuels; how well it would then compete with other technologies that do not generate global warming emissions remains to be seen. Of course, nuclear power's safety, security, nuclear terrorism, and waste problems would still need to be addressed for it to be an acceptable option for reducing global warming emissions.

- Nuclear power should not receive the disproportionate direct and indirect subsidies currently provided by the Bush administration and Congress. Start-up subsidies, licensing shortcuts, and liability limits made available through the Price-Anderson Act (which shift financial risk from investors to taxpayers and customers) should not be provided for new nuclear plants.

- Government and industry should recognize that an expansion of nuclear power is contingent on public confidence, and taking shortcuts in either safety or security measures increases the chance of catastrophic events. A serious accident or successful terrorist attack would hobble expansion, as did the accidents at Three Mile Island and Chernobyl, or might even result in the closure of many existing plants.

- Because Yucca Mountain may not be licensed, preliminary assessment of other geological sites should begin. The federal government should take possession of spent fuel (at least at decommissioned reactor sites) and upgrade security of on-site storage. Centralized dry-cask storage should be investigated.

- The government's current investment in energy R&D is less than half its 1979 level, and is minuscule compared with its investment in defense and homeland security R&D. The nation's energy R&D effort should be raised to a level commensurate with the threat to national security posed by global warming.

CHANGES NEEDED IN U.S. NUCLEAR POWER

Whether or not there is a major expansion of nuclear power in the United States, the following measures are long overdue, and should be considered prerequisites to any expansion:

- Thorough reform of the NRC; for example, public access to NRC proceedings should be restored to the level that prevailed when nuclear plants were last being licensed.

- Realistic definition of the terrorist threat facing nuclear power plants, and rigorous testing of their readiness for an attack.

- Unambiguous definition of the government's and plant owners' responsibilities for defense against terrorism and sabotage.

Congress should exercise close oversight of the NRC and of the practices employed by the government and industry to protect nuclear plants against terrorism.

WEAPONS IMPLICATIONS OF EXPANDED NUCLEAR POWER

A major global expansion of nuclear power would require the United States to adopt domestic and foreign policies that deal effectively with the potential threats to national and global security that would result. Under the existing non-proliferation regime, such an expansion would be irresponsible because it would entail a corresponding growth in facilities for producing nuclear fuels—facilities that can readily produce the materials needed to build nuclear weapons.

The government should, therefore, commit itself to reinforcing the non-proliferation regime so that it can provide reliable control over nuclear fuels.

A nuclear fuel of paramount concern is plutonium, which can serve as a highly effective material for nuclear weapons. For that reason, U.S. policy has long barred the extraction ("reprocessing") of plutonium from spent power reactor fuel. The Bush administration broke with this policy by proposing the Global Nuclear Energy Partnership (GNEP), which includes reprocessing as its central component.

Contrary to the administration's claims, GNEP shows no prospect of creating a proliferation-resistant nuclear fuel cycle or of solving the waste disposal problem. The technologies required for turning this vision into reality do not exist, while the proposed waste disposal scheme is considerably more costly and substantially less proliferation-resistant than the current practice of direct disposal of spent fuel. Furthermore, the administration's high-profile advocacy of reprocessing as an integral part of GNEP is encouraging other nations to engage in dangerous plutonium fuel operations.

Congress should therefore restore the U.S. commitment to direct disposal of spent reactor fuel and bar reprocessing. Any congressional commitment to GNEP should await a favorable outcome of a thorough and independent assessment of the program's prospects for success and its implications for national security.

CONCLUSION

How we address global warming will be the lasting legacy of this generation. The enormity of the challenge demands that no option for reducing global warming emissions be left permanently off the table. However, the most sensible strategy is to first deploy those options that achieve the largest reductions most quickly and with the lowest costs and risk. As this paper has demonstrated, nuclear power today does not meet these criteria.

A major expansion of nuclear power in the United States is not feasible in the near term. Even under an ambitious deployment scenario, new plants could not make a substantial contribution to reducing U.S. global warming emissions for at least two decades.

Long-standing problems regarding the security of nuclear plants must be adequately addressed. A single major accident or successful act of terrorism would likely stop any industry expansion, and could even lead to a contraction that would undermine efforts to address global warming.

The administration's Global Nuclear Energy Partnership (GNEP), which includes extraction of plutonium from spent reactor fuel ("reprocessing") as its central component, shows no prospect of creating a proliferation-resistant nuclear fuel cycle and is encouraging other nations to engage in dangerous plutonium fuel operations. Congress should therefore restore the long-standing U.S. policy barring reprocessing.

An expansion of U.S. nuclear power—under effective regulations and an appropriate level of oversight—should be considered as a longer-term option if other climate-neutral means for producing electricity prove inadequate. Nuclear energy R&D should therefore continue, with a focus on enhancing safety, security, and waste disposal.

Appendix: SUPPORTING MATERIAL

ENERGY USE AND ELECTRICITY IN THE UNITED STATES

The extent to which nuclear power could be a climate solution in the United States is related to how energy is now produced and consumed here. Today, 86 percent of the energy we consume is generated from fossil fuels (and is therefore accompanied by global warming emissions). Nuclear power supplied eight percent of the total energy consumed by the United States in 2005 and slightly over 20 percent of the electricity consumed.

The figures below show that the required reductions in global warming emissions will only be possible if our energy production infrastructure and modes of energy consumption undergo a profound transformation. In other words, the majority of the now-dominant technologies for producing and distributing energy must either be modified or replaced, or shrunk to a much smaller share of the market. Alternatives to fossil fuels will not, however, grow to the levels required for a successful response to global warming until energy prices and policies reflect the true cost of climate change.

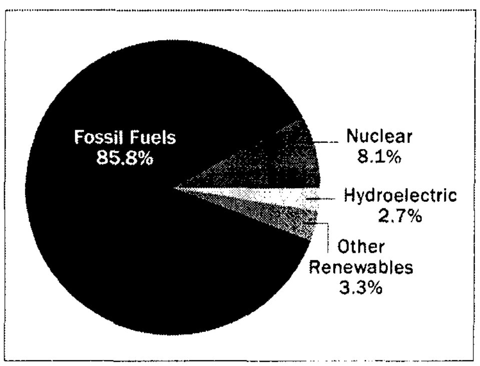
U.S. NUCLEAR POWER TODAY AND TOMORROW

As of now, 103 nuclear power plants are operating in the United States, supplying 21 percent of our electricity. For fuel, they use "low-enriched" uranium, four to five percent of which is the fissionable isotope U-235 (compared with less than one percent in uranium ore). The spent fuel, which is lethally radioactive, is stored on-site pending decisions by the federal government.

By the government's own estimates, the first new nuclear plant in the United States could not be completed before 2014, and the first of the advanced designs ("Generation IV") no earlier than 2025. As a result, nuclear power could not make a substantial contribution to emission reductions in the United States for at least two decades—even under an ambitious deployment scenario.

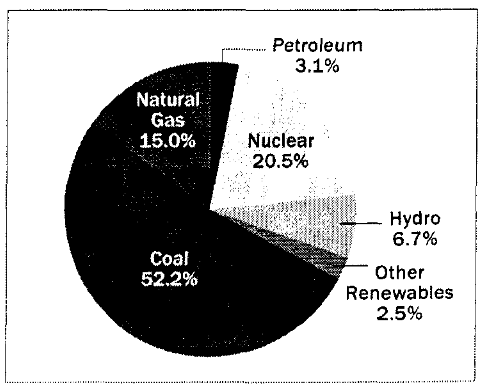
Nuclear power historically has received large government subsidies. Nevertheless, construction cost overruns incurred in building the last generation of nuclear power plants exceeded $150 billion in 2005 dollars (excluding expensive changes required after the Three Mile Island accident). These cost overruns led to nuclear plants being uneconomic compared with other electricity generation choices. As a result, no nuclear plants have been ordered since 1978, and none of those ordered after 1974 were completed. Large financial losses from both completed reactors and reactors abandoned during construction were incurred by utility customers, investors, and taxpayers.

Total U.S. Energy Consumption by Source, 2005



Source: U.S. Energy Information Administration. 2006. *Annual Energy Review 2005*.

U.S. Electricity Consumption by Source, 2005



Source: U.S. Energy Information Administration. 2006. *Annual Energy Review 2005*.

Current forecasts regarding the cost of nuclear power are based on assumptions about the reliability and capital costs of new plants, many of which are still in the design phase. Knowing that past estimates of nuclear plant construction times and financing costs often proved grossly optimistic, forecasts assuming great improvements in new plant construction should be viewed with skepticism.

FACTORS AFFECTING EXPANSION OF U.S. NUCLEAR POWER

2005 Energy Policy Act. In the 2005 Energy Policy Act, the Bush administration and Congress have already legislated subsidies for nuclear power even though this is not the public investment that would provide the most cost-effective near-term response to global warming or energy security. These subsidies include start-up support in the form of loan guarantees and production tax credits for a handful of plants, and a 20-year extension of the Price-Anderson Act, which limits plant owners' liability for accidents to an amount far below the potential costs of a serious accident.

Liability protection. Applying the Price-Anderson Act to new plants removes the financial incentive for plant owners to develop reactor designs that would have safety margins large enough so the owners could buy insurance and not need federal liability protection. The act also functions as an indirect subsidy that puts less risky technologies at a disadvantage.

New designs. While some argue that new plant designs will be much safer than current-generation reactors, these claims are difficult to evaluate because they are based largely on probabilistic safety assessments that in most cases have not been validated by actual operational experience. While certain design features would correct major safety deficiencies in current plant designs, the associated benefits could be offset by other factors such as cost-cutting actions that reduce safety margins, lack of operating experience, and the need in some cases to develop advanced materials that will have to perform under punishing conditions.

NRC policy and safety oversight. New NRC policies include licensing process shortcuts that prevent meaningful public participation in proceedings related to the siting of new reactors (by taking away the intervener's rights of discovery and cross-examination). The NRC's focus on schedules is reducing the number of NRC inspections, making it more likely that the practice of allowing reactors to start up with known but unresolved safety problems will persist.

In addition, serious safety problems continue to arise at operating plants because the NRC does not adequately enforce existing safety standards. In the last decade alone, nine reactors have been shut down for at least a year in order to rectify safety problems. An effective regulator would be neither unaware nor tolerant of safety problems so extensive that a year is needed to fix them.

Unfortunately, the NRC has tended to act more like a protector of the nuclear power industry than a guardian of the public welfare. An internal NRC survey in 2002 revealed that almost half of the agency's employees feared that their careers would suffer if they raised safety concerns. Regarding the near-accident at Ohio's Davis-Besse plant in 2002, the NRC inspector general reported:

"The fact that [the licensee] sought and [NRC] staff allowed Davis-Besse to operate past December 31, 2001, without performing these inspections was driven in large part by a desire to lessen the financial impact [on the licensee] that would result from an early shutdown."

Had a loss-of-coolant accident occurred at Davis-Besse, it is doubtful that an expansion of U.S. nuclear power would even be under discussion now.

Protection against terrorism and sabotage. Regardless of whether any new plants are built, it is essential for the government to ensure that all plants have the ability to withstand acts of terrorism. The NRC, however, requires nuclear power plants to be protected against a "design basis threat" that remains far less severe than the actual threat demonstrated by the 9/11 attack. In addition, the responsibilities of the government and plant owners for defending against acts of terrorism and sabotage must be clearly defined—which they are not now—and a system must be in place to ensure that both the government and plant owners fulfill those responsibilities.

In short, Congress should recognize that thorough reform of the NRC is long overdue whether or not new plants are built, and that such reform is a prerequisite to any expansion of U.S. nuclear power.

Waste disposal. With increased nuclear power comes increased nuclear waste. While the problem of waste disposal can (from a technical and safety standpoint) be postponed for decades by storing waste in aboveground "dry casks," the political challenge of expanding our nuclear capacity without a long-term disposal plan is another matter.

The best available means of dealing with radioactive waste is to place it underground in a permanent geologic repository, where it will remain isolated from the environment anywhere from tens of thousands of years to a million years or more. The location of such a repository must be chosen based on a high degree of scientific and technical consensus; no such consensus currently exists on the proposed Yucca Mountain facility in Nevada.

There is no immediate need to begin operating a permanent repository to store waste from existing plants. However, whether or not there is an expansion of nuclear power in this country, the United States needs to demonstrate a technically and politically viable process for identifying and licensing geologic repositories.

WEAPONS IMPLICATIONS OF EXPANDED NUCLEAR POWER

The energy released by both nuclear power and nuclear weapons is ultimately due to the fission of uranium or plutonium nuclei. Therefore, nuclear power and nuclear weapons are inextricably linked.

For uranium to be used in weapons, the ore must be modified into "highly enriched" uranium (HEU), more than 20 percent of which is the isotope U-235. While all HEU can be used to build weapons, the most suitable material contains 93 percent or more U-235 and is referred to as "weapon-grade HEU." Plutonium does not exist in nature.

The acquisition of plutonium or HEU is the biggest obstacle to any group or nation seeking to build a nuclear weapon. While HEU may be more attractive to terrorist groups because the simplest weapon design uses HEU, a sophisticated group could also be capable of making a simple plutonium-based weapon. These materials can be the objective or the by-product of a civilian nuclear power program.

Uranium enrichment at civilian facilities. Uranium enrichment facilities have an inherent "dual-use" character because the repetitive process that yields the "low-enriched" uranium (LEU) needed for power plant fuel can simply be continued to produce HEU. Once an enrichment facility has produced LEU for reactor fuel (which is four to five percent U-235), it has already completed about two-thirds of the work required to produce weapon-grade HEU.

This is why the current Iranian enrichment effort, ostensibly for power reactors, is suspected to be the prelude to a weapon program. The Iranian crisis illustrates the limitations of the current international safeguards system in controlling proliferation threats.

Extracting plutonium from spent fuel. Plutonium is inevitably produced in any power plant that uses uranium as fuel. It is a component of the plant's large and heavy spent fuel assemblies, which remain lethally radioactive for 100 years or more. Left in this state, plutonium is resistant to theft or use by a nation or terrorist group seeking nuclear weapons. It can, however, be extracted from the spent fuel using special "reprocessing" equipment and then used to manufacture new reactor fuel. Plutonium itself is only mildly radioactive and could be handled without protection by thieves or terrorists after reprocessing.

Presidents Ford and Carter, seeking to impede the proliferation of nuclear weapons, decided to stop reprocessing in the United States and advocated this step abroad. The Reagan administration rescinded this policy, but did not succeed in restarting reprocessing in the United States because the technology was far too expensive and ample uranium supplies existed to fuel existing plants. This is still the case today.

The proposed Global Nuclear Energy Partnership (GNEP). In 2006 the Bush administration announced its plan to promote the global expansion of nuclear power. To those ends, GNEP is to develop new reprocessing technologies and a new "fast burner" nuclear reactor that would consume plutonium fuel. GNEP would also create an international arrangement in which "supplier" nations (including the United States) would lease nuclear fuel to other nations; in exchange, these "recipient" nations would agree to not pursue their own nuclear fuel production facilities. Under this arrangement, the recipient nations would return their spent fuel to the supplier nations.

GNEP faces formidable problems. The "fast burner" power plants only exist as untested conceptual designs, and the net cost of nuclear power with reprocessing is projected to be considerably higher than the continued use of uranium fuel without reprocessing. There is also no reason to expect that "states of concern" such as Iran would be willing to accept the proposed plan for controlling nuclear fuels.

Furthermore, the GNEP fuel cycle would be substantially less proliferation-resistant than the existing cycle in which plutonium remains embedded in lethally radioactive wastes. Rather than supporting nonproliferation, the Bush administration's advocacy of GNEP is encouraging other countries to reprocess their spent fuel. The nationally owned French firm Areva, for example, recently declared its intention to develop new reprocessing plants for export to a dozen countries.

This problem is compounded by the fact that it is very difficult for reprocessing facilities that handle large amounts of nuclear waste to keep accurate track of small amounts of plutonium—amounts sufficient to build multiple nuclear bombs. Consider the amount of plutonium unaccounted for at a Japanese reprocessing facility over a five-year period: a total of 70 kilograms—enough for some 10 nuclear weapons.

Before Congress makes any further commitments to GNEP, it should conduct a thorough and independent review to evaluate the program's compatibility with the stated goals of U.S. nuclear proliferation policy, and to assess its prospects for fostering a more economical and safer domestic nuclear power industry.

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To the Florida Public Service Commission
Submission of Documents to the Public Record With Reference to the Florida Power and Light Certificate of Need for Proposed New Nuclear Power Reactors at Turkey Point
Docket 070650-EI

Nuclear Information and Resource Service (NIRS) is a national educational organization with members in all 50 states of the USA. We submit the following documents to the Florida Public Service Commission proceedings on the proposed Turkey Point nuclear power station expansion certificate of "need" for new nuclear power reactors in Florida on behalf of NIRS members in Florida and all those who will be impacted by this decision.

The following documents have bearing on this matter on a number of bases. NIRS Southeast Office will be happy to assist the Florida PSC in contacting any of the authors of these documents if that would be helpful. Please contact the Southeast Office.

1) With respect to the matter that nuclear energy CANNOT solve the climate crisis and therefore should in no way receive public subsidy in the form of money, or in regulatory privilege on that basis or justification, we submit the following (where electronic, file names are given first; actual document title second):

- Energy ~ Climate ~ Security: Nuclear Power is Not a Solution to the Climate Crisis, 2007 (hard copy)
- Climate of Hope, 2007 DVD (30 minutes, disk)
- Storm CERN 3April2006; "Climate Change and Nuclear Power" (electronic on disk)
- Austria Says No to Nuclear Power as a Climate Solution; "Nuclear Power, Climate Policy and Sustainability: An Assessment by the Austrian Nuclear Advisory Board" 2007 (electronic on disk)
- Amory Lovins SciAm 0905; "More Profit With Less Carbon" (electronic on disk)
- USC Nuclear Power and Climate March 2007; "Nuclear Power and Global Warming: Union of Concerned Scientists Position Paper" (electronic on disk)
- IAEA Admits Nuclear Power Cant Solve Climate Change; "Nuclear Power 'Can't Stop Climate Change'" 2004 (electronic on disk)
- nukesclimatefact606; "Nuclear Power and Climate: Why Nukes Can't Save the Planet" (electronic on disk)

Note, where the reduction in greenhouse gas emissions is cited as a value, benefit or justification for a new nuclear power generating site, or the expansion of an existing site, this claim must be substantiated, not assumed.

2) With respect to the need to consider reducing total energy demand through the smarter use of power (efficiency) as a more cost-effective approach to serving Florida electric power consumers compared to making them pay up-front (pre-pay) for electric power from new nuclear power reactors that will cost more than instituting (providing) systemic efficiency. Efficiency must be valued specifically because unlike nuclear energy, it does not bear an intrinsically higher risk to the public health, safety and the common defense AND is qualified as a remedy to the overarching problem of the climate crisis. These documents also bear on a full consideration of investment in a portfolio of sustainable, renewable power generating sources:

- Amory Lovins SciAm 0905; "More Profit With Less Carbon" 2005 (electronic on disk)
- CarbonFree NuclearFree; "Carbon Free, Nuclear Free: A Roadmap for US Energy Policy" (electronic on disk, in entirety – summary hard copy)
- Futureinvestment; "Futu[r]e Investment: A Sustainable Investment Plan for the Power Sector to Save the Climate" (electronic on disk)

NIRS particularly recommends close attention be given to the scenario presented in Carbon Free Nuclear Free: A Roadmap for US Energy Policy as a credible basis for comparing a non-nuclear path to the FPL proposal.

3. With respect to fuel diversification and the reliability of electric power based on uranium – a limited resource that either has, or will soon hit its "peak" production, NIRS submits:

- Storm CERN 3April2006; "Climate Change and Nuclear Power" 2006 (electronic on disk)
- Climate of Hope, 2007 DVD (30 minutes, disk)

4. With respect to underreported loop-holes in insurance coverage in the event of a terror attack on a nuclear power reactor:

- Price Anderson and War; "Questions on Nuclear Liability and the (unintended) Consequences of War" 2006 (electronic on disk)

5. In service of this investigation, we also offer several documents relevant to the determination of the cost of nuclear power – stipulating that unfortunately no one has yet factored the TRUE costs and liability of nuclear energy including all the health impact including loss of life – including on those impacted by the mining and processing of uranium, the production of fuel, all the transport steps, the fission, and the long-term impacts (or cost of averting) over the entire radiological "life" time of the resulting waste (both so-called "low-level" and high-level). Nonetheless these documents represent significant additional data points for consideration.

- Harding_the Economics of Nuclear Power3; "Economics of New Nuclear Power and Proliferation Risks in a Carbon-Constrained World" 2007 (electronic on disk)
- Standard and Poors 2 page 2006; "U.S. Is Looking At A Paced Reemergence of the Nuclear Power Option" 2006 (electronic on disk)

- moodys oct 2007 projected cost per Kw new nukes; "Moodys – Nuclear Plant Costs May Double" 2007 (electronic on disk)
- Amory Lovins SciAm 0905; "More Profit With Less Carbon" (electronic on disk)
- Storm CERN 3April2006; "Climate Change and Nuclear Power" (electronic on disk)
- Austria Says No to Nuclear Power as a Climate Solution; "Nuclear Power, Climate Policy and Sustainability: An Assessment by the Austrian Nuclear Advisory Board" 2007 (electronic on disk)

Please note: it is no longer credible to dismiss the climate crisis as a "side issue" that does not need to be factored in a pure economics discussion. Climate IS the driver at this juncture – if the climate crisis is not stabilized and reversed, real significant costs will be born by the people of this state; any misapprehension of that fact will result in miscarriage of the responsibility of the Florida PSC to protect the financial interests of the consumers of this fine state.

These documents combine to support the finding that the Florida Public Service Commission should fulfill its mandate by **rejecting** Florida Power and Light's proposed expansion of the Turkey Point Nuclear Power Station – and recognize that while FPL may "need" it – the people of Florida do not – and further, that such an investment of the consumer's dollar will set them back on any real credible progress toward a sustainable energy path that will help reverse the climate crisis and therefore in the truest sense, **serve the public** --as this Commission is bound to do.

Respectfully submitted in Miami, Florida on January 9, 2008

Mary Olson
Southeast Regional Coordinator
Nuclear Information and Resource Service

VOLUME 15, NUMBER 1 August 2007

Science for Democratic Action

AN IEER PUBLICATION Published on the Web as Énergie et Sécurité and Энергетика и Безопасность No. 39

Carbon-Free and Nuclear-Free

A Roadmap for U.S. Energy Policy

BY ARJUN MAKHIJANI, Ph.D.[1]

A three-fold global energy crisis has emerged since the 1970s; it is now acute on all three fronts:

1. *Climate disruption:* Carbon dioxide (CO_2) emissions due to fossil fuel combustion are the main anthropogenic cause of severe climate disruption, whose continuation portends grievous, irreparable harm to the global economy, society, and current ecosystems.
2. *Insecurity of oil supply:* Rapid increases in global oil consumption and conflict in and about oil exporting regions make prices volatile and supplies insecure.
3. *Nuclear proliferation:* Non-proliferation of nuclear weapons is being undermined in part by the spread of commercial nuclear power technology, which is being put forth as a major solution for reducing CO_2 emissions.

After a decade of global division, the necessity for drastic action to reduce CO_2 emissions is now widely recognized, including in the United States, as indicated by the April 2007 opinion by the U.S. Supreme Court[2] that CO_2 is a pollutant and by the plethora of bills in the U.S. Congress. Many of the solutions offered would point the United States in the right direction, by recognizing and codifying into law and regulations the need to reduce CO_2 emissions. But much more will be needed. Moreover, most of the solutions being offered are likely to be inadequate to the task and some, such as the expansion of nuclear power or the widespread use of food crops for making fuel, are likely to compound the world's social, political, and security ills. Some, like production of biofuels from Indonesian palm oil, may even aggravate the emissions of CO_2.

Our report, which this issue of SDA summarizes, examines the technical and economic feasibility of achieving a U.S. economy with zero-CO_2 emissions without nuclear power. This is interpreted as an elimination of all but a few percent of CO_2 emissions or complete elimination with the possibility of removing from the atmosphere some CO_2 that has already been emitted. We set out to answer three questions:

- Is it possible to physically eliminate CO_2 emissions from the U.S. energy sector without resort to nuclear power, which has serious security and other vulnerabilities?
- Is a zero-CO_2 economy possible without purchasing offsets from other countries – that is, without purchasing from other countries the right to continue emitting CO_2 in the United States?
- Is it possible to accomplish the above at reasonable cost?

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U.S. Navy 750 kW Parking Lot Solar PV Installation near San Diego

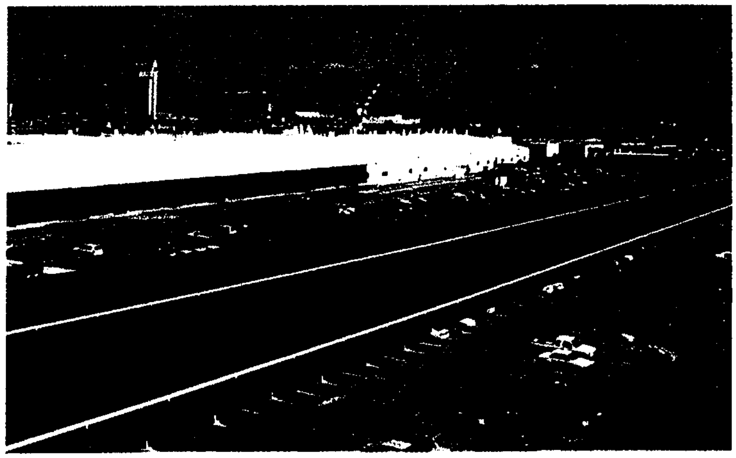

Figure 1 *Courtesy PowerLight Corporation*

CENTRAL FINDING

The overarching finding of the study on which this issue of SDA is based is that a zero-CO_2 U.S. economy can be achieved within the next thirty to fifty years without the use of nuclear power and without acquiring carbon credits from other countries. In other words, actual physical emissions of CO_2 from the energy sector can be eliminated with technologies that are now available or foreseeable. This can be done at reasonable cost while creating a much more secure energy supply than at present. Net U.S. oil imports can be eliminated in about 25 years. All three insecurities – severe climate disruption, oil supply and price insecurity, and nuclear proliferation via commercial nuclear energy – will thereby be addressed. In addition, there will be large ancillary health benefits from the elimination of most regional and local air pollution, such as high ozone and particulate levels in cities, which is due to fossil fuel combustion.

INSIDE

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The achievement of a zero-CO_2 economy without nuclear power will require unprecedented foresight and coordination in policies from the local to the national, across all sectors of the energy system. Much of the ferment at the state and local level, as well as some of the proposals in Congress, are already pointed in the right direction. But a clear long-term goal is necessary to provide overall policy coherence and establish a yardstick against which progress can be measured.

A zero-CO_2 U.S. economy without nuclear power is not only achievable—it is necessary for environmental protection and security. *Even the process of the United States setting a goal of a zero-CO_2, nuclear-free economy and taking initial firm steps towards it will transform global energy politics in the immediate future and establish the United States as a country that leads by example rather than one that preaches temperance from a barstool.*

A zero-CO_2 U.S. economy without nuclear power is not only achievable—it is necessary for environmental protection and security.

The tables on pages 8–10 provide a sketch of the roadmap to a zero-CO_2 economy with estimates of dates at which technologies can be deployed as well as research, development, and demonstration recommendations.

A summary of our main findings can be found on the back page.

Editor's note: The Institute for Energy and Environmental Research has boldly gone where none other has gone before. In partnership with the Nuclear Policy Research Institute, IEER will publish in August 2007 a groundbreaking scientific study: A roadmap to how the United States can achieve CO_2 reductions – down to zero – while phasing out nuclear power. This special issue of *Science for Democratic Action* serves as the Executive Summary of that report which will be published as a book in October. Additional resources, including a guide for elected officials to a zero-CO_2, non-nuclear U.S. economy, will be available on IEER's web site, www.ieer.org, in the near future.

Author's note: I would like to thank the Nuclear Policy Research Institute for having sponsored the project that will result in the book on which this issue of *Science for Democratic Action* is based. Helen Caldicott was the star who raised the funds, provided critical comments and suggestions, and had the vision that this study should be done because it is urgently needed. Helen's and S. David Freeman's presentations at NPRI's 2006 energy conference and our private discussions afterwards inspired me to write the book.

Thank you to Julie Enszer for smoothly shepherding this project from beginning to end. I also wish to thank Hisham Zerriffi, Jenice View, and Paul Epstein, who, as members of the Advisory Board of the project (in addition to Helen and Dave and others), contributed valuable insights and criticisms of the draft manuscript and this summary. However, they may or may not agree with the recommendations or conclusions in this summary. The book will contain statements from Board members who wish to comment. Full acknowledgements will appear in the book.

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Science for Democratic Action

Science for Democratic Action is published quarterly by the Institute for Energy and Environmental Research:

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The Institute for Energy and Environmental Research (IEER) provides the public and policy-makers with thoughtful, clear, and sound scientific and technical studies on a wide range of issues. IEER's aim is to bring scientific excellence to public policy issues to promote the democratization of science and a healthier environment.

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Thank You to Our Supporters

We gratefully acknowledge our funders whose generous support makes possible our project to provide technical assistance to grassroots groups working on nuclear-weapons related environmental and security issues, our global outreach work, and our efforts to promote sound energy policy.

Colombe Foundation
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Thanks also to the SDA readers who have become donors to IEER. Your support is deeply appreciated.

Credits for this Issue

Thanks to the Nuclear Policy Research Institute (NPRI) for sponsoring the project that will result in the book on which this issue of SDA is based. NPRI and IEER thank the following individuals and foundations for their support of this project:

The Park Foundation
The Lear Family Foundation
The Lintilhac Foundation

And many individual donors who wish to remain anonymous.

Production: KS Graphic Design
Printing: Ecoprint
Editor: Lisa Ledwidge
Science for Democratic Action is free to all readers.

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FROM PAGE 2

Main Findings

Finding 1: *A goal of a zero-CO_2 economy is necessary to minimize harm related to climate change.*

According to the Intergovernmental Panel on Climate Change, global CO_2 emissions would need to be reduced by 50 to 85 percent relative to the year 2000 in order to limit average global temperature increase to 2 to 2.4 degrees Celsius relative to pre-industrial times. A reduction of 80% in total U.S. CO_2 emissions by 2050 would be entirely inadequate to meet this goal. It still leaves U.S. emissions at about 2.8 metric tons per person.

A global norm of emissions at this rate would leave worldwide CO_2 emissions almost as high as in the year 2000.[3] In contrast, if a global norm of approximately equal per person emissions by 2050 is created along with a 50 percent global reduction in emissions, it would require an approximately 88 percent reduction in U.S. emissions. An 85 percent global reduction in CO_2 emissions corresponds to a 96 percent reduction for the United States. An allocation of emissions by the standard of cumulative historical contributions would be even more stringent.

A U.S. goal of zero-CO_2, defined as being a few percent on either side of zero relative to 2000, is both necessary and prudent for the protection of global climate. It is also achievable at reasonable cost.

Finding 2: *A hard cap on CO_2 emissions—that is, a fixed emissions limit that declines year by year until it reaches zero—would provide large users of fossil fuels with a flexible way to phase out CO_2 emissions. However, free allowances, offsets that permit emissions by third party reductions[4], or international trading of allowances, notably with developing countries that have no CO_2 cap, would undermine and defeat the purpose of the system. A measurement-based physical limit, with appropriate enforcement, should be put into place.*

A hard cap on CO_2 emissions is recommended for large users of fossil fuels, defined as an annual use of 100 billion British thermal units (Btu) or more—equal to the delivered energy use of about 1,000 households. At this level, users have the financial resources to be able to track the market, make purchases and sales, and evaluate when it is most beneficial to invest in CO_2 reduction technologies relative to purchasing credits. This would cover about two-thirds of fossil fuel use. Private vehicles, residential and small commercial use of natural gas and oil for heating, and other similar small-scale uses would not be covered by the cap. The transition in these areas would be achieved through efficiency standards, tailpipe emissions standards, and other standards set and enforced by federal, state and local governments. Taxes are not envisaged in this study, except possibly on new vehicles that fall far below the average efficiency or emissions standards. The hard cap would decline annually and be set to go to zero before 2060. Acceleration of the schedule would be possible, based on developments in climate impacts and technology.

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RECOMMENDATIONS
THE CLEAN DOZEN

The 12 most critical policies that need to be enacted as urgently as possible for achieving a zero-CO_2 economy without nuclear power are as follows.

1. Enact a physical limit of CO_2 emissions for all large users of fossil fuels (a "hard cap") that steadily declines to zero prior to 2060, with the time schedule being assessed periodically for tightening according to climate, technological, and economic developments. The cap should be set at the level of some year prior to 2007, so that early implementers of CO_2 reductions benefit from the setting of the cap. Emission allowances would be sold by the U.S. government for use in the United States only. There would be no free allowances, no offsets and no international sale or purchase of CO_2 allowances. The estimated revenues – approximately $30 to $50 billion per year – would be used for demonstration plants, research and development, and worker and community transition.
2. Eliminate all subsidies and tax breaks for fossil fuels and nuclear power (including guarantees for nuclear waste disposal from new power plants, loan guarantees, and subsidized insurance).
3. Eliminate subsidies for biofuels from food crops.
4. Build demonstration plants for key supply technologies, including central station solar thermal with heat storage, large- and intermediate-scale solar photovoltaics, and CO_2 capture in microalgae for liquid fuel production.
5. Leverage federal, state and local purchasing power to create markets for critical advanced technologies, including plug-in hybrids.
6. Ban new coal-fired power plants that do not have carbon storage.
7. Enact at the federal level high efficiency standards for appliances.
8. Enact stringent building efficiency standards at the state and local levels, with federal incentives to adopt them.
9. Enact stringent efficiency standards for vehicles and make plug-in hybrids the standard U.S. government vehicle by 2015.
10. Put in place federal contracting procedures to reward early adopters of CO_2 reductions.
11. Adopt vigorous research, development, and pilot plant construction programs for technologies that could accelerate the elimination of CO_2, such as direct solar hydrogen production (photosynthetic, photoelectrochemical, and other approaches), hot rock geothermal power, and integrated gasification combined cycle plants using biomass with a capacity to sequester the CO_2.
12. Establish a standing committee on Energy and Climate under the U.S. Environmental Protection Agency's Science Advisory Board.

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The annual revenues that would be generated by the government from the sale of allowances would be on the order of $30 billion to $50 billion per year through most of the period, since the price of CO_2 emission allowances would tend to increase as supply goes down. These revenues would be devoted to ease the transition at all levels – local, state and federal – as well as for demonstration projects and research and development.

Finding 3: *A reliable U.S. electricity sector with zero-CO_2 emissions can be achieved without the use of nuclear power or fossil fuels.*

The U.S. renewable energy resource base is vast and practically untapped. Available wind energy resources in 12 Midwestern and Rocky Mountain states equal about 2.5 times the entire electricity production of the United States. North Dakota, Texas, Kansas, South Dakota, Montana, and Nebraska *each* have wind energy potential greater than the electricity produced by all 103 U.S. nuclear power plants. Solar energy resources on just one percent of the area of the United States are about three times as large as wind energy, if production is focused in the high insolation areas in the Southwest and West.

Just the parking lots and rooftops in the United States could provide most of the U.S. electricity supply. This also has the advantage of avoiding the need for transmission line expansion, though some strengthening of the distribution infrastructure may be needed. A start has been made. The U.S. Navy has a 750 kW installation in one of its parking lots in San Diego that provides shaded parking spots for over 400 vehicles, with plenty of room to spare for expansion of electricity generation (see cover photo).

One possible future U.S. electricity grid configuration without coal or nuclear power in the year 2050

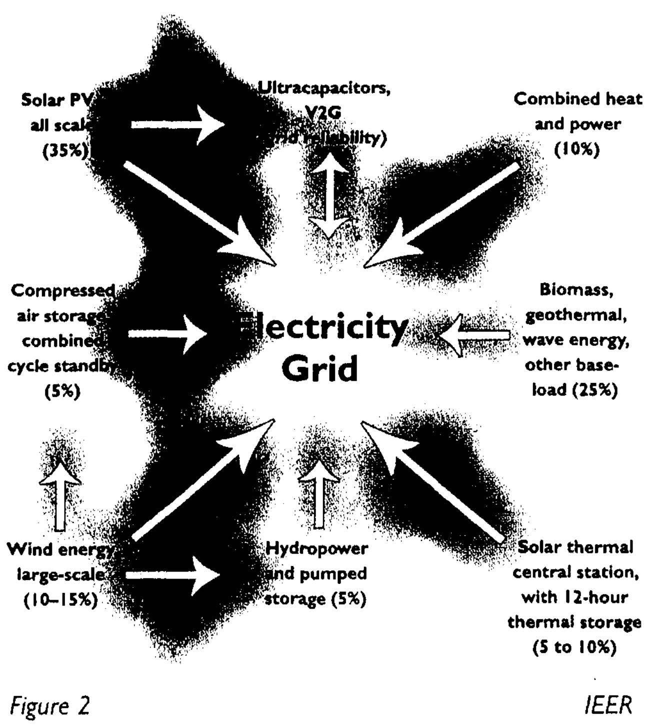

Figure 2 *IEER*

Complete elimination of CO_2 could occur as early as 2040. Elimination of nuclear power could also occur in that time frame.

Wind energy is already more economical than nuclear power. In the past two years, the costs of solar cells have come down to the point that medium-scale installations, such as the one shown in the cover photo, are economical in sunny areas, since they supply electricity mainly during peak hours.

The main problem with wind and solar energy is intermittency. This can be reduced by integrating wind and solar energy together into the grid – for instance, wind energy is often more plentiful at night. Geographic diversity also reduces the intermittency of each source and for both combined. Integration into the grid of these two sources up to about 15 percent of total generation (not far short of the contribution of nuclear electricity today) can be done without serious cost or technical difficulty with available technology, provided appropriate optimization steps are taken.

Solar and wind should also be combined with hydropower – with the latter being used when the wind generation is low or zero. This is already being done in the Northwest. Conflicts with water releases for fish management can be addressed by combining these three sources with natural gas standby. The high cost of natural gas makes it economical to use combined cycle power plants as standby capacity and spinning reserve for wind rather than for intermediate or baseload generation. In other words, given the high price of natural gas, these plants could be economically idled for some of the time and be available as a complement to wind power. Compressed air can also be used for energy storage in combination with these sources. No new technologies are required for any of these generation or storage methods.

Baseload power can be provided by geothermal and biomass-fueled generating stations. Intermediate loads in the evening can be powered by solar thermal power plants which have a few hours of thermal energy storage built in.

Finally, new batteries can enable plug-in hybrids and electric vehicles owned by fleets or parked in large parking lots to provide relatively cheap storage. Nanotechnology-based lithium ion batteries, which Altairnano has begun to produce, can be deep discharged far more times than needed simply to operate the vehicle over its lifetime (10,000 to 15,000 times compared to about 2,000 times respectively).

Since the performance of the battery is far in excess of the cycles of charging and discharging needed for the vehicle itself, vehicular batteries could become a very low-cost source of electricity storage that can be used in a vehicle-to-grid (V2G) system. In such a system, parked cars would be connected to the grid and charged and discharged

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according to the state of the requirements of the grid and the charge of the battery in the vehicle. Communications technology to accomplish this via wires or wireless means is already commercial. A small fraction of the total number of road vehicles (several percent) could provide sufficient backup capacity to stabilize a well designed electricity grid based on renewable energy sources (including biomass and geothermal).

Figure 2 on page 4 shows one possible configuration of the electric power grid. A large amount of standby power is made available. This allows a combination of wind and solar electricity to supply half or more of the electricity without affecting reliability. Most of the standby power would be supplied by stationary storage and/or V2G and by combined cycle power plants for which the fuel is derived from biomass. Additional storage would be provided by thermal storage associated with central station solar thermal plants. Hydropower use would be optimized with the other sources of storage and standby capacity. Wind energy can also be complemented by compressed air storage, with the compressed air being used to reduce methane consumption in combined cycle power plants.

With the right combination of technologies, it is likely that even the use of coal can be phased out, along with nuclear electricity. However, we recognize that the particular technologies that are on the cutting edge today may not develop as now appears likely. It therefore appears prudent to have a backup strategy. The carbon dioxide from coal-fired power plants can be captured at moderate cost if the plants are used with a technology called integrated gasification combined cycle (IGCC). Carbon capture and sequestration may also be needed for removing CO_2 from the atmosphere via biomass should that be necessary.[5]

The tables on pages 8–10 provide the details and estimated technological schedules along with some cost notes for key components of the IEER reference scenario. The IEER reference scenario describes the overall combinations of technologies and policies that would enable the achievement of a zero-CO_2 economy without any fossil fuels or nuclear power by 2050. We recommend that new coal-fired power plants without carbon capture be banned because constructing new plants at this stage would create pressures to increase CO_2 emission allowances and/or higher costs for capturing the CO_2 later.

Complete elimination of CO_2 could occur as early as 2040. Elimination of nuclear power could also occur in that time frame. An early elimination of CO_2 emissions and nuclear power depends on technological breakthroughs, for instance in efficient solar hydrogen production. If there are major obstacles in the technological assumptions – for instance, if V2G cannot be implemented in the time frame anticipated here (on a large scale after about 15 to 20 years) – then technologies such as co-firing of natural gas with biomass or even some coal with biomass and CO_2 sequestration may be needed. In that case, a zero-CO_2 economy may be delayed to about 2060.

Figure 3 below shows the delivered energy to end uses in the IEER reference scenario (losses in electricity and biofuels production are not included), indicating the approximate pattern of phasing in new fuels and phasing out fossil fuels and nuclear power. It also shows the role of

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Delivered Energy, IEER Reference Scenario

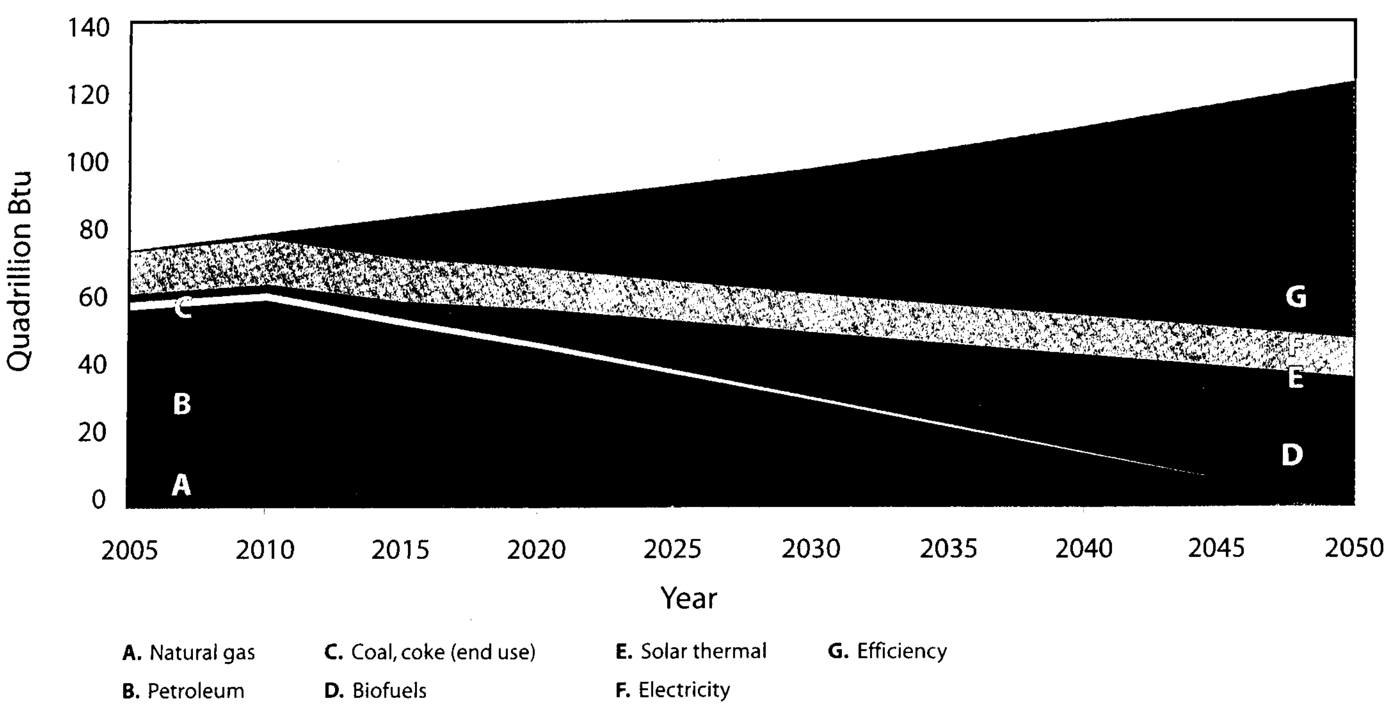

Figure 3 *IEER*

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energy efficiency relative to a business-as-usual approach. The reference scenario envisages a zero-CO_2, non-nuclear economy by 2050.

Figure 4 below shows the corresponding structure of electricity production. The slight decreases followed by increases reflect the faster increase in efficiency envisioned by large-scale introduction of electric cars.

Finding 4: *The use of nuclear power entails risks of nuclear proliferation, terrorism, and serious accidents. It exacerbates the problem of nuclear waste and perpetuates vulnerabilities and insecurities in the energy system that are avoidable.*

Commercial nuclear technology is being promoted as a way to reduce CO_2 emissions, including by the U.S. government. With Russia, the United States has also been promoting a scheme to restrict commercial uranium enrichment and plutonium separation (reprocessing) to the countries that already have it. (These are both processes that can produce nuclear-weapons-usable materials.) This is a transparent attempt to change the Nuclear Non-Proliferation Treaty (NPT) without going through the process of working with the signatories to amend it. The effort will undermine the treaty, which gives non-nuclear parties an "inalienable right" to commercial nuclear technology. In any case, non-nuclear-weapon states are unlikely to go along with the proposed restrictions.

It is not hard to discern that the increasing interest in nuclear power is at least partly a route to acquiring nuclear weapons capability. For instance, the Gulf Cooperation Council (Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates), pointing to Iran and Israel, has stated that it will openly acquire civilian nuclear power technology. In making the announcement, the Saudi Foreign Minister Prince Saud Al-Faisal was quoted in the press as saying "It is not a threat....We are doing it openly." He also pointed to Israel's nuclear reactor, used for making plutonium for its nuclear arsenal, as the "original sin." At the same time he urged that the region be free of nuclear weapons.[6]

Interest in commercial reprocessing may grow as a result of U.S. government policies. The problems of reprocessing are already daunting. For instance, North Korea used a commercial sector power plant and a reprocessing plant to get the plutonium for its nuclear arsenal.

Besides the nuclear weapon states, about three dozen countries, including Iran, Japan, Brazil, Argentina, Egypt, Taiwan, South Korea, and Turkey, have the technological capacity to make nuclear weapons. It is critical for the United States to lead by example and achieve the necessary reductions in CO_2 emissions without resorting to nuclear power. Greater use of nuclear power would convert the problem of nuclear proliferation from one that is difficult today to one that is practically intractable.

Even the present number of nuclear power plants and infrastructure has created tensions between nonproliferation and the rights countries have under the NPT to acquire nuclear technology. Increasing their number

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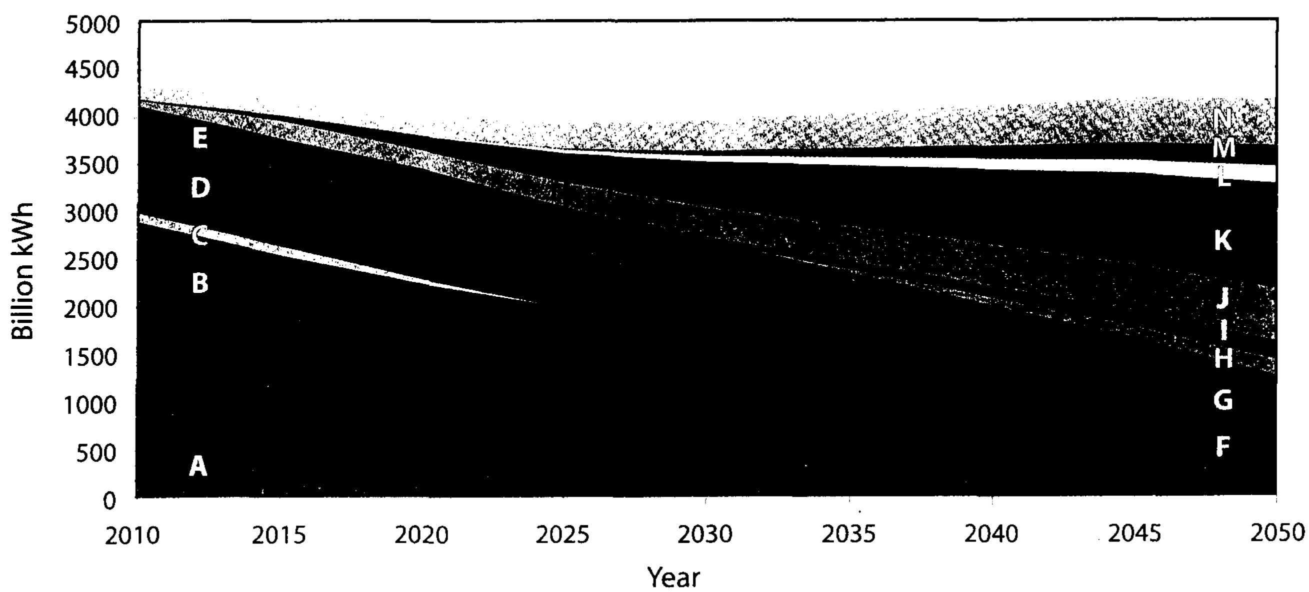
Electricity Supply, IEER Reference Scenario



A. Coal
B. Natural gas
C. Oil
D. Nuclear
E. Hydropower
F. Geothermal, wood waste, landfill gas, etc.
G. Biomass (solid)
H. Biomass-derived gas standby
I. Geothermal hot rock
J. Wind
K. Solar PV central station & intermediate
L. Solar PV small scale
M. Solar thermal & other
N. Combined heat & power

Figure 4 *IEER*

would require more uranium enrichment plants, when just one such plant in Iran has stoked global political-security tensions to a point that it is a major driver in spot market oil price fluctuations. In addition, there are terrorism risks, since power plants are announced terrorist targets. It hardly appears advisable to increase the number of targets.

The nuclear waste problem has resisted solution. Increasing the number of power plants would only compound the problem. In the United States, it would likely create the need for a second repository, and possibly a third, even though the first, at Yucca Mountain in Nevada, is in deep trouble. No country has so far been able to address the significant long-term health, environmental and safety problems associated with spent fuel or high level waste disposal, even as official assessments of the risk of harm from exposure to radiation continue to increase.[7]

Finally, since the early 1980s, Wall Street has been, and remains, skeptical of nuclear power due to its expense and risk. That is why, more than half a century after then-Chairman of the Atomic Energy Commission, Lewis Strauss,

Wall Street has been, and remains, skeptical of nuclear power due to its expense and risk.

proclaimed that nuclear power would be "too cheap to meter," the industry is still turning to the government for loan guarantees and other subsidies. The insurance side is no better. The very limited insurance that does exist is far short of official estimates of damage that would result from the most serious accidents; it is almost all government-provided.

Finding 5: *The use of highly efficient energy technologies and building design, generally available today, can greatly ease the transition to a zero-CO_2 economy and reduce its cost. A two percent annual increase in efficiency per unit of Gross Domestic Product relative to recent trends would result in a one percent decline in energy use per year, while providing three percent GDP annual growth. This is well within the capacity of available technological performance.*

Before the first energy crisis in 1973, it was generally accepted that growth in energy use and economic growth, as expressed by Gross Domestic Product (GDP), went hand in hand. But soon after, the U.S. energy picture changed radically and economic growth was achieved for a decade without energy growth.

Since the mid-1990s, the rate of energy growth has been about two percent less than the rate of GDP growth, despite the lack of national policies to greatly increase energy efficiency. For instance, residential and commercial buildings can be built with just one-third to one-tenth of the present-day average energy use per square foot with existing technology. As another example, we note that industrial energy use in the United States has stayed about the same since the mid-1970s, even as production has increased.

Our research indicates that annual use of delivered energy (that is, excluding energy losses in electricity and biofuels production) can be reduced by about one percent per year while maintaining the economic growth assumed in official energy projections.

Finding 6: *Biofuels, broadly defined, could be crucial to the transition to a zero-CO_2 economy without serious environmental side effects or, alternatively, they could produce considerable collateral damage or even be very harmful to the environment and increase greenhouse gas emissions. The outcome will depend essentially on policy choices, incentives, and research and development, both public and private.*

Food crop-based biodiesel and ethanol can create and are creating social, economic, and environmental harm, including high food prices, pressure on land used by the poor in developing countries for subsistence farming or grazing, and emissions of greenhouse gases that largely or completely negate the effect of using the solar energy embodied in the biofuels. While they can reduce imports of petroleum, ethanol from corn and biodiesel from palm oil are two prominent examples of damaging biofuel approaches that have already created such problems even at moderate levels of production.

For instance, in the name of renewable energy, the use of palm oil production for European biodiesel use has worsened the problem of CO_2 emissions due to fires in peat bogs that are being destroyed in Indonesia, where much of the palm oil is produced. Rapid increases in ethanol from corn are already partly responsible for fueling increases in tortilla prices in Mexico. Further, while ethanol from corn would reduce petroleum imports, its impact on reducing greenhouse gas emissions would be small at best due to energy intensity of both corn and ethanol production, as well as the use of large amounts of artificial fertilizers, which also result in emissions of other greenhouse gases (notably nitrous oxide). All subsidies for fuels derived from food crops should be eliminated.

In contrast, biomass that has high efficiency solar energy capture (~five percent), such as microalgae grown in a high-CO_2 environment, can form a large part of the energy supply both for electricity production and for providing liquid and gaseous fuels for transport and industry. Microalgae have been demonstrated to capture over 80 percent of the daytime CO_2 emissions from power plants and can be used to produce up to 10,000 gallons of liquid fuel per acre per year. Some aquatic plants, such as water hyacinths, have similar efficiency of solar energy capture and can be grown in wastewater as part of combined water treatment and energy production systems.

Figures 5 and 6 on page 11 show two critical biomass examples that have the potential for about 5 percent solar energy capture – about ten times that of the corn plant, including the grain and the crop residues. The NRG Energy

SEE **CARBON-FREE** ON PAGE 11, ENDNOTES PAGE 14

TABLE 3: TECHNOLOGY ROADMAP TO 2025—SUPPLY & STORAGE TECHNOLOGIES

Technology	Status	Deployable for large-scale use	Next steps	CO_2 abatement cost; obstacles; comments
Solar PV—intermediate-scale	Near commercial with time-of-use pricing	2010 to 2015	Orders from industry and government; time-of-use electricity pricing	$10 to $30 per metric ton; no storage; lack of large-scale PV manufacturing (~1 GW/yr/plant); some manufacturing technology development needed.
Solar PV—large-scale	Near commercial	2015 to 2020	Large-scale demonstration with transmission infrastructure, ~5,000 MW by 2015–2020	$20 to $50 per metric ton; no storage; transmission infrastructure may be needed in some cases.
Concentrating solar thermal power plants	Near commercial; storage demonstration needed	2015 to 2020	~3,000 to 5,000 MW needed to stimulate demand and demonstrate 12 hour storage, by 2020	$20 to $30 per metric ton in the Southwest. Lack of demand main problem.
Microalgae CO_2 capture and liquid fuel production	Technology developed, pilot-scale plants being built	2015	Large-scale demonstrations—1,000 to 2,000 MW by 2012; nighttime CO_2 storage and daytime CO_2 capture pilot plants by 2012. Large-scale implementation thereafter. Demonstration plants for liquid fuel production: 2008–2015	Zero to negative at oil prices above $30 per metric ton or so for daytime capture; nighttime capture remains to be characterized. Liquid fuel potential: 5,000 to 10,000 gallons per acre (compared to 650 for palm oil).
Wind power—large-scale, land-based	Commercial	Already being used	Transmission infrastructure and rules need to be addressed; optimize operation with existing natural gas combined cycle and hydropower plants	Negative to $46 per metric ton for operation with combined cycle standby. Areas of high wind are not near populations. Transmission development needed.
Solar PV—intermediate storage	Advanced batteries and ultracapacitors are still high-cost	~2020	Demonstration of vehicle-to-grid using stationary storage (ultracapacitors and lithium-ion nanotechnology batteries) —several ~1 MW-scale parking lot installations	Five-fold cost reduction in ultracapacitors and lithium ion batteries needed. Main problems: lack of large-scale manufacturing and some manufacturing technology development needed.
Solar PV—intermediate scale with Vehicle -to-Grid	Planning stage only. Technology components available. Integration needed.	~2020 to 2025	By 2015, several 5,000 to 10,000 vehicle demonstration V2G technology	V2G could reduce the cost of solar PV electricity storage from several cents to possibly ~1 cent per kWh.
Biomass IGCC	Early demonstration stage	~2020	Pilot- and intermediate-scale plants (few MW to 100 MW) with various kinds of biomass (microalgae, aquatic plants), 2015 to 2020	Baseload power.
High solar energy capture aquatic biomass	Experience largely in the context of wastewater treatment; some laboratory and pilot plant data	~2020	2010 to 2015 pilot plant evaluations for liquid fuel and methane production with and without connection to wastewater treatment	May be comparable to microalgae biofuels production. 50 to 100 metric tons per acre.

TABLE 3 (continued)

Technology	Status	Deployable for large-scale use	Next steps	CO_2 abatement cost; obstacles; comments
Hot rock geothermal energy	Concept demonstrated; technology development remains	2025?	Build pilot and demonstration plants: 2015–2020 period	Baseload power.
Wave energy	Concepts demonstrated	2020 or 2025?	Pilot and demonstration plants needed	Possible baseload power.
Photolytic hydrogen	Laboratory development	Unknown—possibly 2020 or 2025	Significantly increased R&D funding, with goal of 2015 pilot plants	Potential for high solar energy capture. Could be a key to overcoming high land area requirements of most biofuels.
Photoelectro-chemical hydrogen	Concept demonstrated; technology development remains	Possibly 2020 or 2025	Significantly increased R&D funding, with goal of 2015 pilot plants	High solar energy capture. Could be a key to overcoming problems posed by agricultural biofuels (including crop residues).
Advanced batteries	Nanotechnology lithium ion batteries; early commercial stage with subsidies	2015	Independent safety certification (2007?); large-scale manufacturing plants	Large-scale manufacturing to reduce costs. Could be the key to low-cost V2G technology.
Carbon sequestration	Technology demonstrated in context other than power plants	Unknown. Possibly 15 to 20 years	Long-term leakage tests. Demonstration project ~2015 to 2020	For use with biomass, plus back-up, if coal is needed.
Ultracapacitors	Commercial in certain applications but not for large-scale energy storage	2015 to 2020?	Demonstration test with intermediate-scale solar PV. Demonstrate with plug-in hybrid as a complement to battery operation for stop-and-start power	Complements and tests V2G technology. About a five-fold cost reduction needed for cost to be ~$50/metric ton CO_2. Lower CO_2 price with time-of-use rates.
Nanocapacitors	Laboratory testing of the concepts	Unknown.	Complete laboratory work and demonstrate the approach	Has the potential to reduce costs of stationary electricity storage and take ultracapacitor technology to the next step.
Electrolytic hydrogen production	Technology demonstrated	Depends on efficiency improvements and infrastructure development	Demonstration plant with compressed hydrogen vehicles needed ~2015 to 2020	Could be used in conjunction with off-peak wind power.

TABLE 4: TECHNOLOGY ROADMAP TO 2025—DEMAND SIDE TECHNOLOGIES

Technology	Status	Deployable for large-scale use	Next steps	CO_2 price; obstacles; comments
Efficient gasoline and diesel passenger vehicles	Commercial to ~40 miles per gallon or more	Being used	Efficiency standards needed	Efficiency depends on the vehicle. Can be much higher.
Plug-in hybrid vehicles	Technology has been demonstrated	2010	Efficiency standards, government and corporate orders for vehicles	Large-scale battery manufacturing needed to reduce lithium ion battery cost by about a factor of five.
Electric cars	Technology with ~200 mile range has been demonstrated; low volume commercial production in 2007 (sports car and pickup truck)	2015 to 2020	Safety testing, recycling infrastructure for battery materials, large-scale orders, solar PV-V2G demonstration	One of the keys to reducing the need for biofuels and increasing solar and wind power components.
Internal combustion hydrogen vehicles	Technology demonstrated	Depends on infrastructure development	10,000 psi cylinder development and testing of vehicles. Demonstration project.	
Biofuels for aircraft	Various fuels being tested	2020?	Fuel development, safety testing, emissions testing	
Hydrogen-fuel aircraft	Technology has been demonstrated	2030?	Aircraft design, safety testing, infrastructure demonstration	In combination with solar hydrogen production, could reduce need for liquid biofuels.
Building design	Commercial, well known	Already being used	Building standards, dissemination of knowledge, elimination of economic disconnect between building developers and users	Residential and commercial building energy use per square foot can be reduced 60 to 80 percent with existing technology and known approaches. CO_2 price, negative to $50 per metric ton.
Geothermal heat pumps	Commercial	Already being used	Building standards that specify performance will increase its use	Suitable in many areas; mainly for new construction.
Combined heat and power (CHP), commercial buildings and industry	Commercial	Already being used	Building performance standards and CO_2 cap will increase use	CO_2 price negative to <$30 per metric ton in many circumstances.
Micro-CHP	Semi-commercial	Already being used	Building performance standards will increase use	
Compact fluorescent lighting (CFL)	Commercial	Being used currently	Appliance and building regulations needed	Negative CO_2 price. Mercury impact of disposal needs to be addressed.
Hybrid solar light-pipe and CFL	Technology demonstrated; beta-testing being done in commercial establishments	2012 to 2015?	Government and commercial sector orders	Solar concentrators focus light indoors; work in conjunction with CFL. Five-fold cost reduction needed.
Industrial sector: examples of technologies and management approaches: alternatives to distillation, steam system management, CHP, new materials, improved proportion of first pass production	Constant development of processes	Various	Hard cap for CO_2 with annual assured decreases and no free allowances will lead to increase in efficiency	Variable. Negative to possibly $50 per metric ton, possibly more in some cases. Great potential for economical increases in efficiency exists at present costs, since energy costs have gone up suddenly. Successful reductions of energy use indicate that overall cost ill be modest, with possible reduction in net cost of energy services.

coal-fired power plant in Louisiana shown in Figure 5 is being used by GreenFuel Technologies Corporation for field tests. The plant is a potential site for a commercial-scale algae bioreactor system that would recycle the plant's CO_2 emissions into biodiesel or ethanol.

Water hyacinths, shown in Figure 6, have been used to clean up wastewater because they grow rapidly and absorb large amounts of nutrients. Their productivity in tropical and subtropical climates is comparable to microalgae – up to 250 metric tons per hectare per year. They can be used as the biomass feedstock for producing liquid and gaseous fuels.

Prairie grasses have medium productivity, but can be grown on marginal lands in ways that allow carbon storage in the soil. This approach can therefore be used both to produce fuel renewably and to remove CO_2 from the atmosphere.

Finally, solar energy can be used to produce hydrogen; this could be very promising for a transition to hydrogen as a major energy source. Techniques include photoelectrochemical hydrogen production using devices much like solar cells, high-temperature, solar-energy-driven splitting of water into hydrogen and oxygen, and conversion of biomass into carbon monoxide and hydrogen in a gasification plant. Tailored algae within a highly controlled environment and fermentation of biomass can also be used to produce hydrogen. In some approaches, energy, food, and pharmaceuticals can be produced simultaneously. Progress has been far slower than it could be for lack of money. Figure 7 on page 12 shows direct hydrogen production from sunlight using algae deprived of sulfur in their diet.

Finding 7: *Much of the reduction in CO_2 emissions can be achieved without incurring any cost penalties (as, for instance, with efficient lighting and refrigerators). The cost of eliminating the rest of CO_2 emissions due to fossil fuel use is likely to be in the range of \$10 to \$30 per metric ton of CO_2.*

Operating demonstration algae bioreactor at a coal-fired power plant in Louisiana

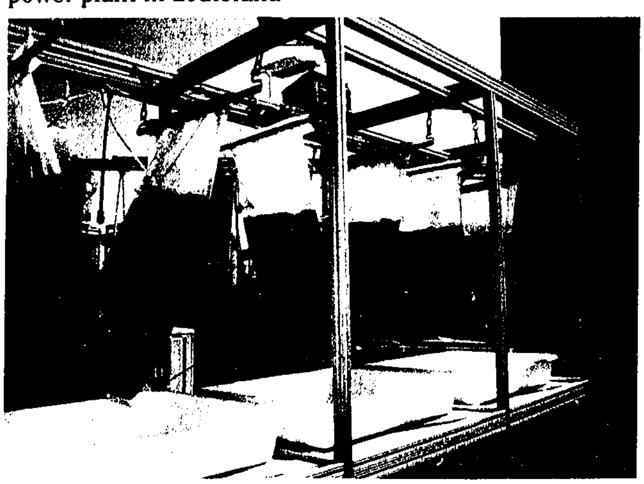


Figure 5 *Courtesy Greenfuel Technologies Corporation*

Water hyacinths can yield up to 250 metric tons per hectare in warm climates

Figure 6 *Courtesy Center for Aquatic and Invasive Plants, Institute of Food and Agricultural Sciences, University of Florida*

Table 1 on page 12 shows the estimated costs of eliminating CO_2 from the electricity sector using various approaches. It is based on 2004 costs of energy. At 2007 prices (about \$8 per million Btu of natural gas and almost 9 cents per kilowatt-hour (kWh) electricity, averaged over all sectors) the costs would be lower.

Further, the impact of increases in costs of CO_2 abatement on the total cost of energy services is low enough that the overall share of GDP devoted to such services would remain at about the present level of about 8 percent or perhaps decline. It has varied mainly between 8 and 14 percent since 1970, hitting a peak in 1980. It dropped briefly to about 6 percent in the late 1990s when oil prices tumbled steeply, hitting a low of about \$12 per barrel in 1998.

Table 2 on page 12 shows the total estimated annual energy and investment costs for the residential and commercial sectors in terms of GDP impact. The lower energy use per house and per square foot, higher needed investment, and somewhat higher anticipated costs of electricity and fuels under the IEER reference scenario are taken into account. The net estimated GDP impact of reducing residential and commercial sector energy use by efficiency improvements and converting entirely to renewable energy sources is small and well within the range of the uncertainties in the calculations.

The total GDP for energy services in all sectors under the IEER reference scenario is estimated to remain at about 8 percent or less. For an individual new home owner, the net increased cost, including increased mortgage payments, would be between about \$20 and \$100 per month; the latter is less than 0.7 percent of projected median household income in 2050.

SEE **CARBON-FREE** ON PAGE 13, ENDNOTES PAGE 14

TABLE 1: SUMMARY OF COSTS FOR CO_2 ABATEMENT (AND IMPLICIT PRICE OF CO_2 EMISSION ALLOWANCES)—ELECTRICITY SECTOR (BASED ON 2004 COSTS OF ENERGY)

CO_2 source	Abatement method	Phasing	Cost per metric ton CO_2, $	Comments
Pulverized coal	Off-peak wind energy	Short-term	A few dollars to $15	Based on off-peak marginal cost of coal.
Pulverized coal	Capture in microalgae	Short- and medium-term	Zero to negative	Assuming price of petroleum is >$30 per barrel.
Pulverized coal	Wind power with natural gas standby	Medium- and long-term	Negative to $46	Combined cycle plant idled to provide standby. Highest cost at lowest gas price: $4 per million Btu.
Pulverized coal	Nuclear power	Medium- to long-term	$20 to $50	Unlikely to be economical compared to wind with natural gas standby.
Pulverized coal	Integrated Gasification Combined Cycle (IGCC) with sequestration	Long-term	$10 to $40 or more	Many uncertainties in the estimate at present. Technology development remains.
Natural gas standby component of wind	Electric vehicle-to-grid	Long-term	Less than $26	Technology development remains. Estimate uncertain. Long-term natural gas price: $6.50 per million Btu or more.

Notes:
1. Heat rate for pulverized coal = 10,000 Btu/kWh; for natural gas combined cycle = 7,000 Btu/kWh.
2. Wind-generated electricity costs = 5 cents per kWh; pulverized coal = 4 cents per kWh; nuclear = 6 to 9 cents per kWh.
3. Petroleum costs $30 per barrel or more.
4. CO_2 costs associated with wind energy related items can be reduced by optimized deployment of solar and wind together.

TABLE 2: ANNUAL RESIDENTIAL (R) AND COMMERCIAL (C) ENERGY AND INVESTMENT COSTS IN 2050, IN BILLIONS OF CONSTANT 2005 DOLLARS

Item	IEER Reference Scenario	Business-as-Usual Scenario
R + C Electricity	$326	$442
R + C Fuel	$150	$247
Sub-total energy cost	*$476*	*$689*
Added annual investment for efficiency	$205	$0
Total GDP-basis amount (rounded)	**$681**	**$689**
GDP in 2050	***$40,000***	***$40,000***
GDP fraction: residential and commercial energy services	**1.70%**	**1.72%**

Notes:
1. Business-as-Usual (BAU) fuel and electricity prices: about $12 per million Btu and 9.6 cents per kWh. IEER prices: $20 per million Btu and 14 cents per kWh respectively. BAU electricity price is from January 2006.
2. Added efficiency investments: existing residences: $20,000 per residence each time, assumed to occur in one of every three sales of existing buildings between 2010 and 2050; new = $10 per square foot (about $20,000 per house, approximate LEED-certified house added cost); plus cost of replacing appliances every 15 years with then-prevailing advanced appliances. Investments for solar thermal heating, combined heat and power, and geothermal heat pumps added to these figures for the proportion of residential area using them. LEED stands for Leadership in Energy and Environmental Design; it is a building certification program.
3. Commercial efficiency investments: $10 per square foot; this is more than examples of platinum level LEED investment. Investments for solar thermal heating, combined heat and power, and geothermal heat pumps have been added to these figures.
4. GDP = consumption expenditures + investment + government spending (on goods and services) + exports − imports.

Direct Solar Production of Hydrogen Using Algae

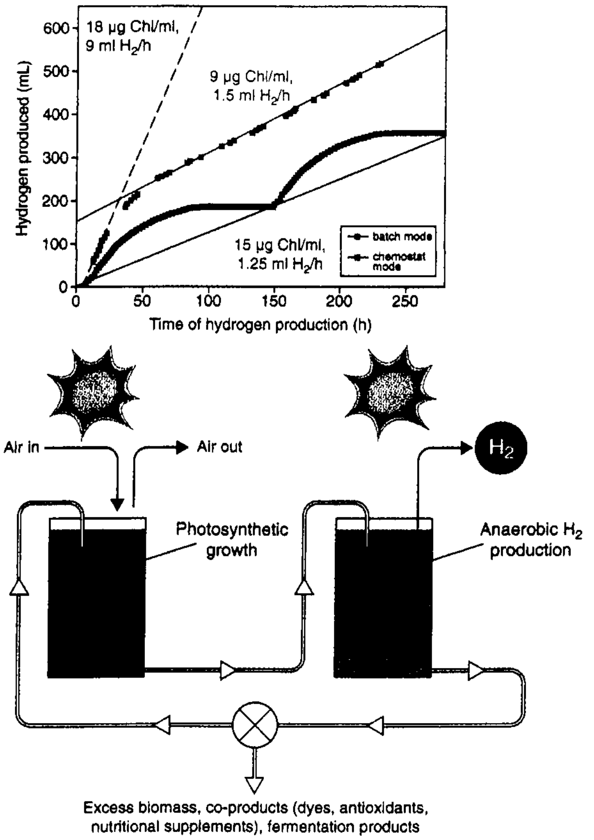


Figure 7 This diagram/graph was developed by the National Renewable Energy Laboratory for the U.S. Department of Energy.

Note: In the "batch mode" the production is stopped periodically to replenish the nutrients. In the "chemostat mode" nutrients are supplied continuously to maintain production. "Chl" stands for chlorophyll.

CARBON-FREE
FROM PAGE 11

Finding 8: *The transition to a zero-CO_2 system can be made in a manner compatible with local economic development in areas that now produce fossil fuels.*

Fossil fuels are mainly produced today in the Appalachian region, in the Southwest and West and some parts of the Midwest and Rocky Mountain states. These areas are also well-endowed with the main renewable energy resources—solar and wind. Federal, state and regional policies, designed to help workers and communities transition to new industries, therefore appear to be possible without more major physical movement or disruption of populations than has occurred in post-World War II United States. It is recognized that much of that movement has been due to dislocation and shutdown of industries, which causes significant hardship to communities and workers. Some of the resources raised by the sale of CO_2 allowances should be devoted to reducing this disruption. For instance, the use of CO_2 capture technologies, notably microalgae CO_2 capture from existing fossil fuel plants, can create new industries and jobs in the very regions where the phaseout of fossil fuels would have the greatest negative economic impact. Public policy and direction of financial resources can help ensure that new energy sector jobs that pay well are created in those communities.

ANSWERS TO ATOMIC PUZZLER, SDA VOL. 14, NO. 4

Calculating CO_2 Emissions from a Natural Gas Fired Plant

1. 36,410 Btu per cubic meter x 1055 joules per Btu = 38,410,000 joules per cubic meter = 3.841 x 10^7 joules per cubic meter

2. 1 kilowatt-hour = 1,000 joules per second per kilowatt x 3600 seconds per hour = 3,600,000 joules per kilowatt-hour = 3.6 x 10^6 joules per kilowatt-hour

3. 3.841 x 10^7 joules per cubic meter / 3.6 x 10^6 joules per kilowatt-hour = 10.67 kilowatt-hours (thermal) per cubic meter

4. 800 grams = 800/1000 kilograms = 0.8 kilograms → 10.67 kilowatt-hours per cubic meter / 0.8 kilograms per cubic meter = 13.34 kilowatt-hours (thermal) per kilogram

5. System efficiency from thermal to electrical energy = 50% = 0.50

Thermal output per kilogram of natural gas = 13.34 kilowatt-hours (thermal)

Electrical output per kilogram of natural gas = 13.34 kilowatt-hours (thermal) x 0.50 = 6.67 kilowatt-hours (electrical) per kilogram of natural gas

Kilograms of natural gas per kilowatt-hour of electricity = 1/6.67 = 0.150 kilograms per kilowatt-hour of electricity

6. 0.1500 kilograms of natural gas per kilowatt-hour of electricity x 0.734 kilograms carbon per kilogram of natural gas = 0.110 kilograms of carbon per kilowatt-hour of electricity

7. 0.110 kilograms of carbon per kilowatt-hour of electricity x 3.67 kilograms of CO_2 per kilogram of carbon = 0.404 kilograms of CO_2 per kilowatt-hour of electricity

GLOSSARY

Baseload generation: A large-scale power plant designed to generate electricity on a continuous basis.

Biofuel: Fuel derived from biomass.

Biomass: Organic material produced by photosynthesis.

Carbon capture: Capture of carbon dioxide when fuels containing carbon are burned for their energy.

Carbon sequestration: Deep geologic storage of carbon for long periods (thousands of years) to prevent it from entering the atmosphere.

CFL: Compact fluorescent lamp, which is a high-efficiency light bulb.

CHP: Combined heat and power. In this arrangement, some of the energy derived from burning a fuel is used as heat (as for instance in heating buildings or for industrial processes), and some is used for generating electricity.

Combined cycle power plant: Power plant in which the hot gases from the burning of a fuel (usually natural gas) are used to run a gas turbine for generating electricity. The exhaust gas from the turbine is still hot and is used to make steam, which is used to drive a steam turbine, which in turn generates more electricity.

Electrolytic hydrogen production: The use of electricity to separate the hydrogen and oxygen in water.

Geothermal heat pump: A heat pump that uses the relatively constant temperature a few feet below the earth's surface in order to increase the efficiency of the heat pump.

IGCC: Integrated Gasification Combined Cycle plant. This plant gasifies coal or biomass and then uses the gases in a combined cycle power plant.

LEED: Leadership in Energy and Environmental Design – a rating system used for building efficiency. The platinum level is the highest rating.

Microalgae: Tiny algae that grow in a variety of environments, including salty water.

Nanocapacitor: A capacitor that has the surface area of its electrodes increased greatly by the use of nanotechnology.

Photolytic hydrogen: Hydrogen produced by plants, for instance, algae, in the presence of sunlight.

Photoelectrochemical hydrogen: Hydrogen produced directly using devices similar to some solar photovoltaic cells that generate electricity. In this arrangement, hydrogen is produced instead of electricity.

Pumped storage: Using electricity at off-peak times to pump water into a reservoir and then using a hydroelectric power plant to generate electricity with the stored water during peak times (or, when used with wind energy, when the wind is not blowing).

Solar light pipe: A fiber optic cable that conveys light from the sun along its length without leaking it out of the sides, much like a wire carries electricity. It can be used to light the interiors of buildings during the daytime.

Solar PV: Solar photovoltaic cells – devices that turn incident sunlight into electricity.

Solar thermal power plant: A power plant that uses reflectors to concentrate solar energy and heat liquids that are then used to produce steam and generate electricity.

Spinning reserve: The capacity of electric power plants that are kept switched on ("spinning") but idle in order to be able to meet sudden increases in electricity demand.

Standby capacity: Power plants that are kept on standby to meet increases in electric demand.

Ultracapacitor: A capacitor that can store much more electricity per unit volume than normal capacitors.

V2G: Vehicle to grid system. Parked cars are connected to the grid. When the charge on the batteries is low, the grid recharges them. When the charge is sufficient and the grid requires electricity, a signal from the grid enables the battery to supply electricity to the grid.

Endnotes

1. This issue of SDA is a summary of a report of the same title that will be web-published in August 2007 and published as a book in October 2007 by RDR Books. References can be found in the report at www.ieer.org/carbonfree. The study is a joint project of the Nuclear Policy Research Institute and the Institute for Energy and Environmental Research. For their support of this project, NPRI and IEER wish to thank The Park Foundation, The Lear Family Foundation, The Lintilhac Foundation, and many individual donors who wish to remain anonymous.
2. On the Internet at www.supremecourtus.gov/opinions/06pdf/05-1120.pdf.
3. Based on a global population of 9.1 billion and a U.S. population of 420 million in 2050.
4. Offsets allow a purchaser to continue emitting CO_2 while paying for reductions in CO_2 by the party from whom the offsets are purchased. These may or may not result in actual CO_2 reductions. Even when they do, the emissions may be immediate while reductions may be long-term. Verification is difficult and expensive.
5. Integrated gasification of coal works as follows: Coal is reacted with steam, which yields a mixture of hydrogen and carbon monoxide. When burned, this yields CO_2 and water. The process can result in removal of heavy metals prior to combustion; nearly all the sulfur in the coal can also be captured, preventing almost all sulfur dioxide emissions. When nearly pure oxygen is used for combustion, capture of CO_2 becomes far less expensive. The CO_2 can then be injected into a deep geologic formation. Since biomass draws CO_2 from the atmosphere, sequestering CO_2 when biomass is the fuel results in a reduction of atmospheric CO_2, provided the biomass production process does not involve greater CO_2 emissions.
6. Saudi-US Relations Information Service, "27th GCC Supreme Council Summit Wrapup," December 13, 2006, online at www.saudi-us-relations.org/articles/2006/ioi/061213-gcc-summit.html. Viewed June 20, 2007.
7. See for instance the report of the National Academy of Sciences, published in 2006, at http://books.nap.edu/openbook.php?isbn=030909156X.

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SUMMARY OF MAIN FINDINGS

1. A goal of a zero-CO_2 economy is necessary to minimize harm related to climate change.

2. A hard cap on CO_2 emissions – that is, a fixed emissions limit that declines year by year until it reaches zero – would provide large users of fossil fuels with a flexible way to phase out CO_2 emissions. However, free allowances, offsets that permit emissions by third party reductions, or international trading of allowances, notably with developing countries that have no CO_2 cap, would undermine and defeat the purpose of the system. A measurement-based physical limit, with appropriate enforcement, should be put into place.

3. A reliable U.S. electricity sector with zero-CO_2 emissions can be achieved without the use of nuclear power or fossil fuels.

4. The use of nuclear power entails risks of nuclear proliferation, terrorism, and serious accidents. It exacerbates the problem of nuclear waste and perpetuates vulnerabilities and insecurities in the energy system that are avoidable.

5. The use of highly efficient energy technologies and building design, generally available today, can greatly ease the transition to a zero-CO_2 economy and reduce its cost. A two percent annual increase in efficiency per unit of Gross Domestic Product relative to recent trends would result in a one percent decline in energy use per year, while providing three percent GDP annual growth. This is well within the capacity of available technological performance.

6. Biofuels, broadly defined, could be crucial to the transition to a zero-CO_2 economy without serious environmental side effects or, alternatively, they could produce considerable collateral damage or even be very harmful to the environment and increase greenhouse gas emissions. The outcome will depend essentially on policy choices, incentives, and research and development, both public and private.

7. Much of the reduction in CO_2 emissions can be achieved without incurring any cost penalties (as, for instance, with efficient lighting and refrigerators). The cost of eliminating the rest of CO_2 emissions due to fossil fuel use is likely to be in the range of $10 to $30 per metric ton of CO_2.

8. The transition to a zero-CO_2 system can be made in a manner compatible with local economic development in areas that now produce fossil fuels.

From *Carbon-Free and Nuclear-Free: A Roadmap for U.S. Energy Policy*, www.ieer.org/carbonfree/

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http://www.nirs.org/southeast/nukesclimatetalk092007.pdf (citation links are hot—includes section on nuclear nonproliferation as well.)

Nuclear Power is Not a Solution to the Climate Crisis

Mary Olson, Director of the Nuclear Information and Resource Service Southeast Office
Prepared as a hand-out for the Middle Powers Initiative Round Table, September 26, 2007, NYC. Updated 10/09/07.

As the world reeled in the wake of the atomic destruction of Hiroshima and Nagasaki, it is understandable that many people innocently embraced the idea that splitting atoms could be a good thing. Atoms for Peace spoke to a generation that needed to address their collective conscience and anxiety. Unfortunately atoms that are split are ***not*** peaceful: all industrial-scale fission results in massive new radioactivity with the capacity to do harm at both high levels (causing tissue and organ damage) and low levels (causing cellular damage, often to DNA resulting in mutations that cause cancer, sterility, birth defects and a host of other complications[1]). Splitting uranium atoms for energy results in the production of plutonium; this plutonium can be (and has been) used to make nuclear weapons. Even in medicine, it is the destructive force of radiation that is harnessed to attack disease or to penetrate tissue. *Radioactive atoms are not peaceful!*

Just as nuclear energy is intrinsically incapable of stopping the spread of nuclear weapons, atomic power is also intrinsically incapable of reversing – or even significantly slowing the global Climate Crisis. Nonetheless, Bush and Cheney are promoting nuclear power as a key remedy to climate change, and concomitantly listing climate as a key reason for the world to re-invest in this failed energy technology. Nuclear energy *is* failed -- it is only the considerable liability of CO2 production that creates any kind of an "economy" in which investment of either public or private funds in new nuclear infrastructure would be considered in the USA, at all – *but nuclear should be rejected as a climate "fix" since a technology that cannot compete with other options should not be the preferred strategy in the face of crisis.*[2]

Nuclear Power Will Not, and *Cannot* Solve the Climate Crisis[3]

There are multiple issues that must be considered when engaging with the issue of nuclear power. Expanding the nuclear power infrastructure worldwide will not be an effective response to the climate crisis precisely because nuclear energy is known not to be viable in non-monopoly free markets – it cannot compete. It has been three decades since any energy corporation in the United States ordered a nuclear power reactor that was not subsequently canceled. Indeed, the current rush for new reactor applications is **only** because of massive subsidies that have been signed into law under the Bush administration. Few energy corporations located in states where energy is no longer fully regulated by the state and where there are no longer monopolies of production, distribution and sale are considering participation in this nuclear welfare due, no doubt, to the fact that without such monopolies consumers are no longer hostage to the higher electric power prices that new nuclear investment will bring.[4] Wall Street analysts also noted early in this attempt at nuclear revival that trying nuclear in anything but a fully regulated market would be more than risky. [5]

The good news is that nuclear is not only expensive when compared to burning coal (which must be phased out to reduce carbon emissions) – it is significantly more expensive that truly green, sustainable energy options as well.

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- **A dollar invested in new wind generation infrastructure returns two to three times more electricity than a dollar invested in new nuclear power infrastructure will.**[6]
- **A dollar invested in energy efficiency – including technologies like cogeneration that prevent the loss of potential energy from industrial systems – will yield 7 – 10 times more avoided-energy-use (and therefore need for generation) than the dollar invested in new nuclear power generating infrastructure.**[7]

For some years now, wind has been the fastest-growing new electric power generating capacity[8] – and for honest market-based reasons! Energy efficiency is finally making a foothold as mega-corps such as DuPont Chemical are making investments that not only cut their energy consumption, but are immediately *profitable, due to the averted cost of energy not used.*[9] It is universally true that the cost of energy not-needed is less than any form of new power generation. What has taken time to comprehend is that this reduced-need can be traded as "nega-watts."[10] Energy efficiency is not a new thought, but it is a new way of thinking!

Please note that US spot-market prices quoted today for "the price of nuclear power" **do not** adequately represent the cost of new nuclear generating capacity. This is because today's reactors were built with funds that in many cases were never paid off – during the 1980's and 1990's reactors sold for a dime on the dollar – the large conglomerates that emerged have trimmed expenses in ways that likely will not be sustainable over time; let alone all the true costs that are never included, such as impacts on health and the true long-term waste costs.

So when it comes to the climate crisis, the fact that nuclear energy **cannot** compete is a crucial piece of information – for the same level of investment (of either commercial or public funds) – one gets 3 – 10 times more reduction in greenhouse gas emissions from non-nuclear energy infrastructure and programs compared to building new nuclear power reactors. Since the overall level of investment in nuclear power that would be required to take a sizable bite out of global greenhouse emissions is on the order of 1500 new power plants[11] – each projected to cost somewhere between $2 and $6 billion for **each unit**[12] this is an astronomical amount of money running in the many trillions dollars. What about *trillions* spent on wind and wave energy? The numbers say we would get more energy (turn off more coal plants) than spending it on nukes – without the health and security risks!

The climate crisis is real – and rapid action is required. News from this past week confirms that changes in Earth's systems are, unfortunately, progressing far more rapidly than previously thought. A scientist interviewed on the radio Friday warned that we have no time to delay.[13] We cannot afford to invest limited resources for dealing with this crisis in a technology that does not give a good rate of return on the money invested! New nuclear generating capacity is like a black hole when it comes to addressing this crisis. For those seeking real reduction in greenhouse gas emissions from the US "energy pig" energy efficiency is the number one option – with wind, appropriate hydro and solar all more preferable than investment in new nuclear power.

In a detailed consideration of a revival of nuclear energy, many "conventional" concerns are worthy of consideration -- including:

1. Radiological concerns:
    - routine radioactive emissions by air[14], water and solid wastes[15] (nuclear power is not clean; not healthy; not "Green")
    - potential for catastrophic accidents[16] (not safe; not secure; not healthy)
    - radioactive waste production that contains the vast majority of global source term[17] (not secure; not clean; not safe) including the biggest reservoir of plutonium -- a burden for 11,000 human generations

2. Danger of nuclear weapons proliferation:
    - "front-end" uranium enrichment can produce both low-enriched reactor fuel or highly enriched nuclear weapons production material
    - "back-end" separation of plutonium via reprocessing from waste that is an automatic by-product of electric power production from uranium fuel
    - even greater potential for nuclear weapons proliferation if plutonium fuel (including MOX) is further commercialized

These concerns are intrinsic reasons why nuclear energy has failed, and worthy of extensive study. The reader is directed to the extensive discussion of these concerns, specifically in the context of the climate crisis, in recently published works:

Dr. Helen Caldicott, "*Nuclear Power is Not the Answer*" New Press, 2007.
Dr. Brice Smith: "*Insurmountable Risks: The Dangers of Using Nuclear Power to Combat Global Climate Change*" IEER Press and RDR Books, 2006.

Two other nuclear technology issues receive less attention, but are perhaps even more potent reasons why nuclear energy CANNOT fix the climate problem:

- **Nuclear, more than any other energy source, is vulnerable to turbulent weather**
- **Nuclear reactors do not work in warming water[18]**

These two points will be taken in order.

Nuclear is Vulnerable to Climate Impacts

Extreme weather often causes loss of electric power, which in turn, causes nuclear power reactors to go off-line automatically (also called a "scram"). Reactors go off-line because they – all of them – depend on energy from the grid to operate. Since the core of a reactor continues to generate heat for ***years*** (even "off-line") it is vital that emergency cooling equipment be operable around the clock. As is sensible, every reactor site is equipped with back-up power, most often in the form of (two) diesel generators. Unfortunately these generators, in part because of intermittent use, are not terribly reliable.[19] When both the grid and the back-up power fail, the site is said to be in "station blackout." According to the US Nuclear Regulatory Commission, station blackout contributes a full one-half of the total risk of a major reactor accident at US nuclear power stations.[20]

Recent years have seen an escalation in all kinds of extreme weather: intense heat, drought, blizzards, tornados, and perhaps most compelling – hurricanes and cyclones. All of these conditions may contribute to electric grid failures. The loss of grid power will not necessarily trigger a nuclear crisis, but it elevates the risk. As overall incidence of grid blackout increases, so will the over all risk for nuclear power accidents. Nuclear energy is an enormous liability in these turbulent times.

Nuclear Power Does Not Work in Hot Water

The heat waves of 2003 were a turning point: the frequency and also the duration of periods of elevated temperatures in the rivers, lakes and even oceans, used for cooling nuclear power reactors have been increasing each summer ever since. With this have come reports of nuclear power reactors being forced to low power or off-line until the water temperatures dropped. In 2004 a number of nuclear reactors in France were impacted[21] not because of nuclear safety issues – but because of the basic design of a nuclear reactor.

Essentially an expensive, dangerous "tea pot," a nuclear power reactor harvests the heat from splitting atoms to make steam, to turn a turbine – essentially 19th century stationary steam technology with an atomic "fire." The closed-loop steam system relies on the heat differential between the temperature of the steam, and the temperature of a condenser, to turn the steam back into liquid, in order to repeat the process. When the water used to cool the condenser gets too warm, this temperature differential is lost; the steam no longer condenses back to liquid. When river and lake water gets too hot, electric power cannot be generated.[22] As temperatures rise, nuclear power will be less and less qualified as a means to even **try** to generate electric power.

To sum up, no one has said it better than my friend David Lochbaum: "We're going to have to solve the climate-change problem if we're going to have nuclear power, not the other way around." David is a nuclear engineer with the Union of Concerned Scientists; his comment was reported in the May 20, 2007 International Herald Tribune.

Nuclear power will never solve any crisis – nuclear energy **is** a crisis. The following references are offered to support your understanding of this situation.

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[1] For basic information on ionizing radiation see Nuclear Information and Resource Service fact sheets posted at: http://www.nirs.org/radiation/radiationhome.htm . Milestone work on radiation health effects was done by the late Dr. John Gofman who's many works are available via: http://www.ratical.org/radiation/CNR/CNRtitles.html

[2] The classic analysis by Amory Lovins "Nuclear Power: Economics and Climate-Protection Potential" posted at: http://www.rmi.org/images/PDFs/Energy/E05-08_NukePwrEcon.pdf

[3] For more NIRS documents on nuclear energy and climate, see: http://www.nirs.org/climate/climate.htm

[4] Olson, Mary "We Don't Need New Nukes" http://www.nirs.org/southeast/wedontneednewnukes.pdf

[5] Bradford, Peter and David Schlissel 2007. "Why A Future For the Nuclear Power Industry is RISKY" posted at: http://www.cleanenergy.org/resources/reports/WhyNewNukesAreRiskyFACTSHEET.pdf

[6] See a variety of sources including: Greenpeace France "Wind Vs Nuclear 2003" posted at: http://www.greenpeace.org/raw/content/international/press/reports/wind-vs-nuclear-2003.pdf, Amory Lovins as cited in note 27 above and also IEER's interesting comparison of wind and plutonium (MOX) fuel for Japan posted at: http://www.ieer.org/reports/wind/index.html

[7] See Lovins, Amory as cited in note 27.

[8] See for instance, US State Department press release in 2005: http://usinfo.state.gov/xarchives/display.html?p=washfile-english&y=2005&m=April&x=20050422130541lcnirellep0.9051172

[9] See 2005 press release of Alliance to Save Energy: http://www.ase.org/content/news/detail/2249 and also Amory Lovins, "More Profit With Less Carbon," Scientific American: September 2005.

[10] Amory Lovins coined the name "nega-watt" to describe energy formerly but no longer consumed. Perhaps it was his brisk business in helping corporations trade in this newly "excess capacity" during the California electric power crisis in 2001 that lead him to remove this term from his parlance.

[11] J. Deutsch and E. Moniz (co-chairs), The Future of Nuclear Power, MIT, 2003. http://web.mit.edu/nuclearpower/

[12] In recent years the media has reported that a nuclear power reactor can be built for $2 billion – however all current construction is running much higher than that –and the last reactors in the US to go on line weighed in at $4.5 -- $6 billion dollars per unit. See also: http://www.nirs.org/factsheets/quickeconfact1206.pdf

[13] See Mark Serreze cited in note # 4.

[14] Drey, Kay "Hidden Radioactive Releases from Nuclear Power Plants in the United States" posted at: http://www.nirs.org/factsheets/drey_usa_pamphlet.pdf Note: region-specific pamphlets are in the same directory.

[15] For a wealth of information on radioactive waste see: http://www.nirs.org/factsheets/fctsht.htm

[16] For a compendium of information on the 1986 Chernobyl nuclear power plant disaster and updated reports as of the 20 year mark: http://www.nirs.org/c20/c20us.htm

[17] "Source term" describes the type of radioactivity (what elements are present) and the duration of the hazard.

[18] A current, very telling editorial about the connection of electric power and water, "Water Power," September 24, 2007 Raleigh (North Carolina) "News and Observer" posted at: http://www.newsobserver.com/opinion/editorials/story/714061.html. Here is a selection of news reports of nuclear power reactors being taken off-line due to elevated temperatures of the cooling water supplies:
May 20, 2007 "Climate Change Puts Nuclear Energy in Hot Water" International Herald Tribune, http://iht.com/articles/2007/05/20/business/nuke.php?page=2
June 8, 2007 "Court Blocks Yankee's Warm Water Discharge" Rutland Herald (VT) http://www.rutlandherald.com/apps/pbcs.dll/article?AID=/20070608/NEWS04/706080387

July 31, 2007 "US Heat Wave..." Bloomberg.com
http://www.bloomberg.com/apps/news?pid=20601087&sid=aNtzVaLCaNc8&refer=home
August 17, 2007 "TVA Reactor Shut Down: Cooling Water Drawn From River Too Hot" reported on WAFF48 News http://www.waff.com/global/story.asp?s=6944527 and "Heat Wave Ignites Problems in ET" Knoxnews http://www.knoxnews.com/news/2007/aug/18/heat-wave-ignites-problems-in-et/
August 23, 2007 "Rising Temperatures Undermine Nuclear Power's Promise" Union of Concerned Scientists http://www.nirs.org/climate/background/ucsrisingtemps82307.pdf
July 30, 2006 "Heat Wave Shuts Down Nuclear Power Plants" The Observer (London)
http://observer.guardian.co.uk/world/story/0,,1833620,00.html
July 27, 2006 "Heat Wave Shows Limits of Nuclear Energy" IPS http://www.ipsnews.net/news.asp?idnews=34121
August 10, 2006 "Hot Temps Chill Nuclear Power's Appeal" Christian Science Monitor, posted at http://www.cbsnews.com/stories/2006/08/10/tech/main1881980.shtml

[19] Summary of findings given in: http://www.nirs.org/reactorwatch/mox/nirsmcguirecatawbacontentions.htm

[20] U.S. Nuclear Regulatory Commission, "Severe Accident Risks: An Assessment for Five U.S. Nuclear Power Plants," NUREG-1150, 1990.

[21] For a review of French reactors off line due to heat listen to NPR's Morning Edition August 21, 2007: http://www.npr.org/templates/story/story.php?storyId=13818689

WHY A FUTURE FOR THE NUCLEAR INDUSTRY IS RISKY

BASED IN PART ON PRESENTATIONS BY

PETER BRADFORD

Former Chair, New York State Public Service Commission,
Former Chair, Maine Public Utilities Commission,
Former Commissioner, U.S. Nuclear Regulatory Commission.

DAVID SCHLISSEL

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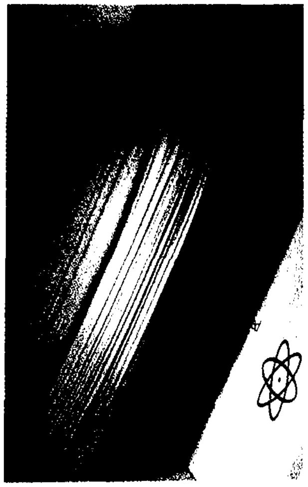

JANUARY 2007

Sponsored by a coalition of environmental, health, social investment and public interest organizations concerned about the impacts of nuclear power including:

Friends of the Earth,

Interfaith Center on Corporate Responsibility (ICCR),

North Carolina Waste Awareness and Reduction Network (NC WARN),

Nuclear Information and Resource Service (NIRS),

Public Citizen,

Southern Alliance for Clean Energy (SACE), and

U.S. Public Interest Research Group (PIRG).

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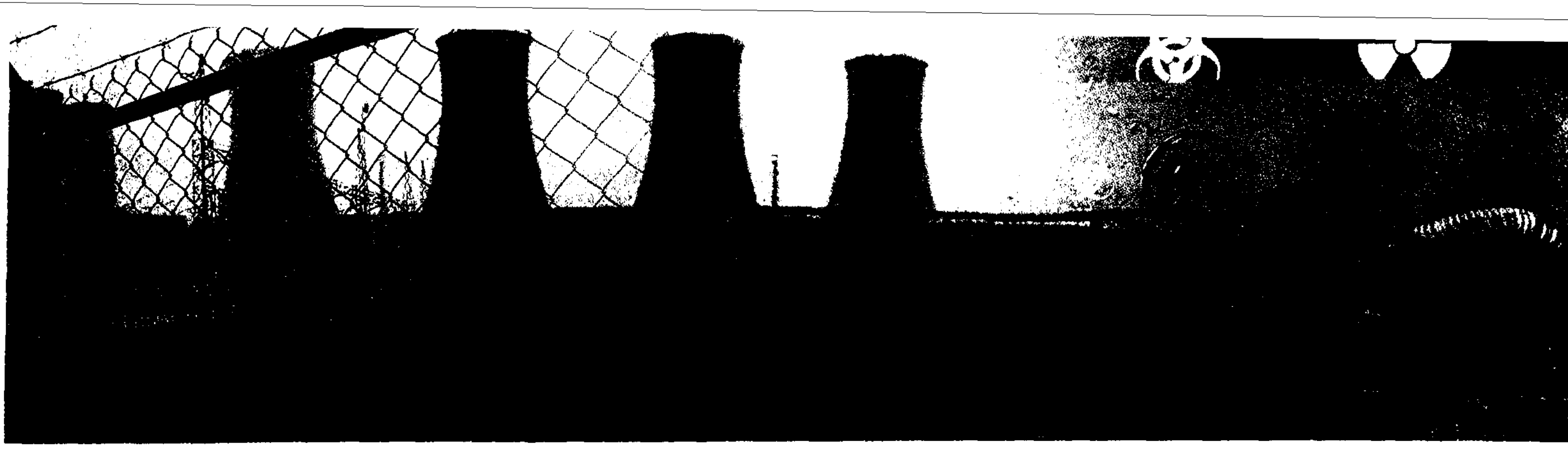


INTRODUCTION

Talk of a "nuclear renaissance" abounds. The accidents at Chernobyl and Three Mile Island are receding in public memory. Promises of improved safety and performance are coupled with billions of dollars of subsidies. However, the claims that nuclear power is a necessary energy source for displacing greenhouse gases hasn't convinced investors that new nuclear power plants will be safe and profitable investments.

New nuclear power plants will not be cost competitive with other electricity generating alternatives. Wind power and other renewable technologies, combined with energy efficiency, conservation and cogeneration can be much more cost effective and can be deployed much sooner than new nuclear power plants. Building expensive new nuclear plants will divert private and public investment from the cheaper and readily available renewable and energy efficiency options needed to protect our climate.

In competitive markets, new nuclear power plants will be bad investments. At the same time, worldwide private equity and venture capital investments in clean energy continue to grow. Worldwide investment in renewable energy capacity was almost $40 billion in 2005 and the renewable energy markets continue to grow robustly.[1]

DESPITE THE SIGNIFICANT SUBSIDIES PROVIDED IN THE ENERGY POLICY ACT OF 2005 (EPACT 2005), INVESTMENTS IN NEW NUCLEAR PLANTS REMAIN VERY RISKY

- The estimated cost of $1,500-$2,000 per KW for new nuclear plants is unlikely to be achieved and has recently been revised upward for some companies.
- The prices of recently built nuclear power plants in Japan were much higher, ranging between $1,796 and $2,827 per KW, in 2003 dollars.[2]
- The subsidies provided in EPACT 2005 are limited to a few plants and some require Congressional appropriations which are not guaranteed. Moreover, Standard & Poor's analysis of EPACT 2005 has concluded that the bill has few implications for the credit quality of nuclear developers and that the regulatory risk for new nuclear construction remains high, given the possibility that a plant for which construction has started may never actually commence operations.[3]
- None of the new nuclear power plant designs under consideration in the U.S. have actually been built. The industry's optimistic construction time and cost estimates are unproven and theoretical.
- Despite massive subsidies and R&D investments, there has not been an order for a new nuclear power plant in the U.S. for almost three decades.[4]
- Even with the subsidies in EPACT 2005, the U.S. Department of Energy has moved its target for bringing a new nuclear unit online from 2010 to 2014.[5]

1 "Renewables Global Status Report: 2006 Update," Renewable Energy Policy Network for the 21st Century, 2006, at pages 2-5, available at http://www.ren21.net/globalstatusreport/download/RE_GSR_2006_Update.pdf.

2 "Economic Future of Nuclear Power," The University of Chicago for the U.S. DOE, August 2004, at pages 2-14.

3 "Energy Policy Act 2005 has Limited Credit Implications: S&P," Nuclear Engineering International News, August 18, 2005, available at http://www.neimagazine.com/story.asp?sc=2030540&ac=7969460 and "Long-Awaited Energy Act Has Marginal Credit Implications for U.S. Utility And Oil And Gas Companies," Standard & Poor's, August 1, 2005.

4 "Nuclear Power: Economics and Climate Protection Potential," Amory Lovins, Rocky Mountain Institute, September 11, 2005, at page 9, available at http://www.rmi.org/images/other/Energy/E05-08_NukePwrEcon.pdf.

5 Statement of Samuel W. Bodman, Secretary of Energy, Before the Committee on Science, U.S. House of Representatives, Concerning the Department of Energy's FY 2007 Budget, February 15, 2006. *available at http://resourcescommittee.house.gov/science/hearings/full06/Feb15/bodman.pdf.*

- A recent article in The Energy Journal, published by the International Association for Energy Economics, concluded that in current liberalized markets, investors have no incentives to back the construction of new nuclear power plants because of their capital intensity, "engineering difficulties" and "regulatory creep."[6]

- Nuclear construction cost estimates in the U.S. have been notoriously inaccurate. In fact, the estimated costs of some existing nuclear units were wrong by factors of two or more. The total estimated cost of 75 of today's nuclear units was $45 billion (in 1990 dollars).[7] The actual cost turned out to be $145 billion (also in 1990 dollars). This $100 billion cost overrun was more than 200 percent above initial cost estimates.

  - New billion dollar mega-projects traditionally cost much more than their original estimates. As a result, a 1988 RAND Corporation study concluded that "the data on cost growth, schedule slippage and performance shortfalls of mega-projects are certainly sobering, but the most chilling statistic is that only about one in three of these projects is meeting its profit goals."[8]

  - Standard & Poor's stated that "given that construction [of new nuclear plants] would entail using new designs and technology, cost overruns are highly probable."[9]

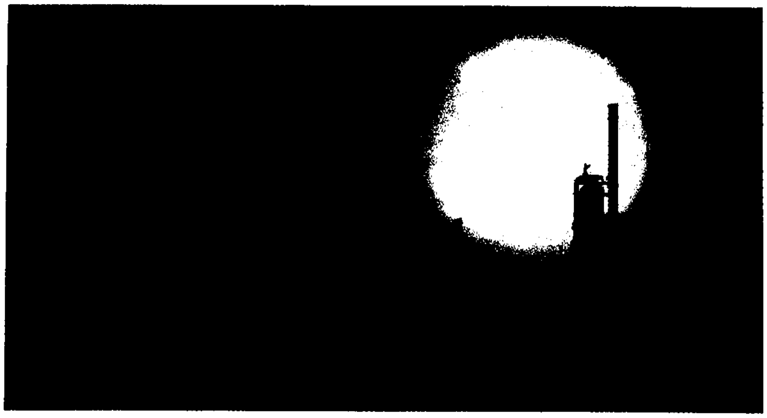
  - The DOE's Energy Information Administration has clearly and concisely stated that "new [nuclear] plants are not expected to be economical."[10]

  - A 2003 study by the Massachusetts Institute of Technology forecasted that the base case real levelized cost (present value of building and running a plant for its lifespan) of electricity from new nuclear reactors with an estimated 85 percent capacity would be $.067 per kilowatt hour over a projected forty year operating life more expensive than from pulverized coal or natural gas.[11]

  - A 2005 assessment by Synapse Energy Economics, Inc. showed that the levelized cost of electricity from a new nuclear power plant would be $.068 per kilowatt hour, which was significantly higher than obtaining the same amount of energy from a combination of wind and gas-fired capacity and energy efficiency measures.[12] Additional studies have also concluded that overnight capital costs, lead construction times and interest rate premiums are likely to place the cost of electricity from any future nuclear power plants within the range of $.06 to $.07 per kilowatt hour.[13]

- Nuclear utilities have acknowledged that there are significant economic risks associated with the operation of nuclear power plants.

  - Plant O&M and capital expenditures could increase or the nuclear plant(s) could experience outages as a result of events at other operating nuclear power plants, new rules or regulations issued by the U.S. Nuclear Regulatory Commission (NRC), or as the result of deficiencies identified by the NRC.[14]



- Restructuring of the electric utility industry brings additional uncertainty to the ownership of new nuclear power plants. Without captive customers from whom increased costs can be recovered, plant owners are exposed to the risks of higher O&M expenses, higher decommissioning costs, and the lost revenues and higher costs of extended unit outages.

  - For example, Standard & Poor's stated that "Decommissioning risk remains an important factor in determining credit quality of U.S. firms and weighs more in the analysis of competitive nuclear generators. This is the case because, again, a regulatory process cannot provide recovery for underfunding."[15]

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6 "Nuclear Power: A Hedge against Uncertain Gas and Carbon," Fabien A. Roques, William J. Nuttall, David M. Newbery, Richard de Neufville, Stephen Connor, The Energy Journal, Vol. 27, n. 4., 2006.

7 Study prepared by the Energy Information Administration of the U.S. DOE, "An Analysis of Nuclear Power Plant Construction Costs," 1986.

8 "Understanding the Outcomes of Megaprojects: A Quantitative Analysis of Very Large Civilian Projects," Edward W. Merrow, RAND Corporation, March 1988.

9 "Credit Aspects of North American and European Nuclear Power," Standard & Poor's, January 9, 2006.

10 Annual Energy Outlook 2005, Energy Information Administration, available at http://www.eia.doe.gov/emeu/plugs/plfeb05.html.

11 "The Future of Nuclear Power - Summary Report," MIT, 2003, available at http://web.mit.edu/nuclearpower/pdf/nuclearpower-summary.pdf.

12 Affidavit of Bruce Biewald, Synapse Energy Economics, in U.S. NRC Docket No. 52-007-ESP, at page 23.

13 "Insurmountable Risks: The Dangers of Using Nuclear Power to Combat Global Climate Crisis - Summary," Brice Smith, Institute for Energy and Environmental Research, 2006, at page 6, available at http://www.ieer.org/reports/insurmountablerisks/summary.pdf.

14 For example, see the Testimony of Thomas Aller, in Iowa Utility Board Docket No. SPU-05-15, at page 15.

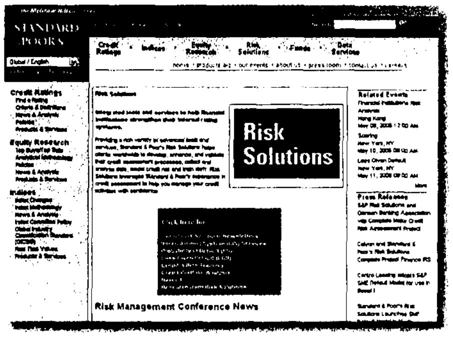
15 "Credit Aspects of North American and European Nuclear Power," Standard & Poor's, January 9, 2006.

WALL STREET HAS EXPRESSED SERIOUS CONCERNS ABOUT THE CREDITWORTHINESS OF COMPANIES THAT PURSUE NEW NUCLEAR PLANTS

- Standard & Poor's Ratings Services found that "an electric utility with a nuclear exposure has weaker credit than one without and can expect to pay more on the margin for credit. Federal support of construction costs will do little to change that reality. Therefore, were a utility to embark on a new or expanded nuclear endeavor, Standard & Poor's would likely revisit its rating on the utility." [16]

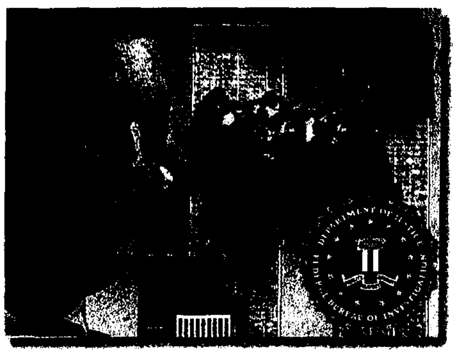
- Standard & Poor's has also expressed concern that "from a credit perspective, [2005 Energy Policy Act] provisions may not be substantial enough to sustain credit quality and make [nuclear generation] a practical strategy."[17]

- The credit rating service Fitch reminds potential investors that "the overarching concern [regarding nuclear power generation] is the financial effect of an extended outage, forcing the generating company to buy potentially more expensive replacement power on the spot market to honor any existing supply commitments."[18]



NUCLEAR POWER PLANTS ARE STATED TERRORIST TARGETS: A SUCCESSFUL ATTACK COULD HALT NEW CONSTRUCTION EVEN AFTER SIGNIFICANT EXPENDITURE

In testimony before the Select Committee on Intelligence in the U.S. Senate in February 2005, FBI director Robert S. Mueller stated that, "Another area we consider vulnerable and target rich is the energy sector, particularly nuclear power plants. Al-Qa'ida planner Khalid Sheikh Mohammed had nuclear power plants as part of his target set and we have no reason to believe that Al-Qa'ida has reconsidered."[19]



- In October 2001, the Federal Aviation Administration temporarily restricted all private aircraft from flying over 86 nuclear facilities due to threats of terrorist attacks.[20]

- Over 53,000 metric tons of highly radioactive spent nuclear fuel is stored at commercial reactors in the U.S. Nearly 90% of this fuel is stored in cooling pools without adequate protection.[21] According to a recent study by the National Academy of Sciences, a terrorist attack on a spent fuel pool could lead to the release of large quantities of radioactive materials to the environment.[22] Such an event could result in thousands of cancer deaths and economic damages in the range of hundreds of billions of dollars.

- In the event of a major radioactive release from a nuclear power plant, public opinion would likely react strongly against nuclear power (as occurred after the Chernobyl and Three Mile Island accidents), resulting in the halting of construction of any new planned reactors.

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16 Ibid.

17 Ibid.

18 "Fitch's Approach to Rating U.S. Wholesale Energy Companies," October 2004.

19 "Testimony of Robert S. Mueller, III, Director, Federal Bureau of Investigation Before the Senate Committee on Intelligence of the United States Senate," February 16, 2005, available at http://www.fbi.gov/congress/congress05/mueller021605.htm.

20 "FAA Restricts All Private Aircraft Flying Over Nuclear Facilities," October 30, 2001, available at http://www.faa.gov/news/press_releases/news_story.cfm?newsId=5446.

21 "Spent Nuclear Fuel Storage Locations and Inventory," Anthony Andrews, Congressional Research Service, updated 2004.

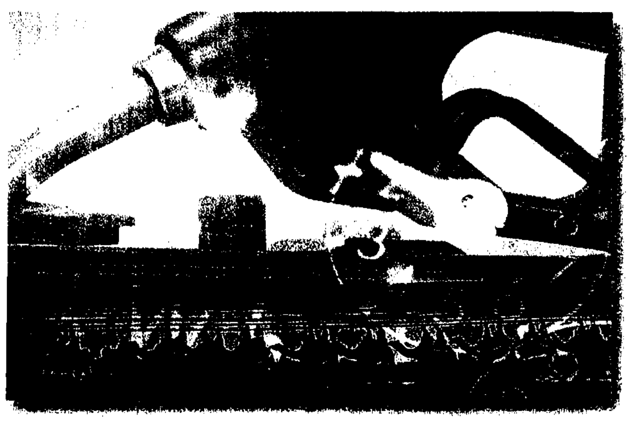
22 "Safety and Security of Commercial Spent Fuel Storage: Public Report," Committee on the Safety and Security of Commercial Spent Fuel Storage, National Research Council, 2006, available at http://newton.nap.edu/catalog/11263.html#toc.

WEAKNESSES IN NUCLEAR REGULATORY COMMISSION (NRC) OVERSIGHT OFFER TROUBLESOME INDICATIONS THAT THE NRC IS PUTTING THE NUCLEAR INDUSTRY AHEAD OF SAFETY AND PUBLIC CONFIDENCE

- In recent years, the NRC appears to have retreated into a similar pro-industry mindset that was described in the assessment of the March 1979 accident at the Three Mile Island nuclear power plant that was prepared by a Presidential Commission: "We find that the NRC is so preoccupied with the licensing of plants that it has not given primary consideration to overall safety issues. [...] With its present organization, staff and attitudes, the NRC is unable to fulfill its responsibility for providing an acceptable level of safety for nuclear power plants."[23]
- For example, shortcomings in the U.S. nuclear regulatory process were clearly implicated in the 2001 near-accident at the Davis-Besse plant in Ohio. The NRC Inspector General's report on that incident found that there was a clear connection between cost considerations and NRC laxity in the fact that the licensee sought and the NRC staff allowed the Davis-Besse plant to operate without performing important inspections, and that this situation was driven in large part by a desire to lessen the financial impact that would result from an early shutdown.[24] A loss of coolant accident at Davis-Besse might well have eliminated all discussion of a nuclear revival in the U.S.
- NRC surveys have showed that almost half of all NRC employees thought that their careers would suffer if they raised safety concerns and nearly one-third of those who had raised safety concerns felt they had suffered harassment and/or intimidation as a result. [25]
- Streamlined licensing processes for construction and operating permits eviscerate public involvement as a check on laxity in the licensing process.

NUCLEAR POWER WILL NOT REDUCE U.S. DEPENDENCE ON ENERGY SUPPLIES FROM ABROAD

- The U.S. is importing more oil each year – most of it from the world's most unstable regions – increasing our country's economical and political vulnerability and making oil dependency among the largest threats to our economy and national security.
- Increasing reliance on nuclear power will not reduce our nation's dependency on foreign sources of oil – only about 3% of the electricity produced in the U.S. is from petroleum and almost none of that petroleum comes from the Middle East.[26]
- Nuclear power's only substantial contribution to oil displacement in the U.S. comes in regions in which natural gas displaced by nuclear power can penetrate further into oil's share of the markets, such as space heating in New England. [27]
- Indeed, transportation is the sector that accounts for most of U.S. oil consumption – about two-thirds of the country's oil consumption is used by vehicles, which corresponds to roughly 13 millions barrels a day.[28] Thus, possible nuclear power development would not have any influence over these statistics.



23 "Report of the President's Commission on the Accident at Three Mile Island: The Need for Change," October 1979, pages 51, 56.

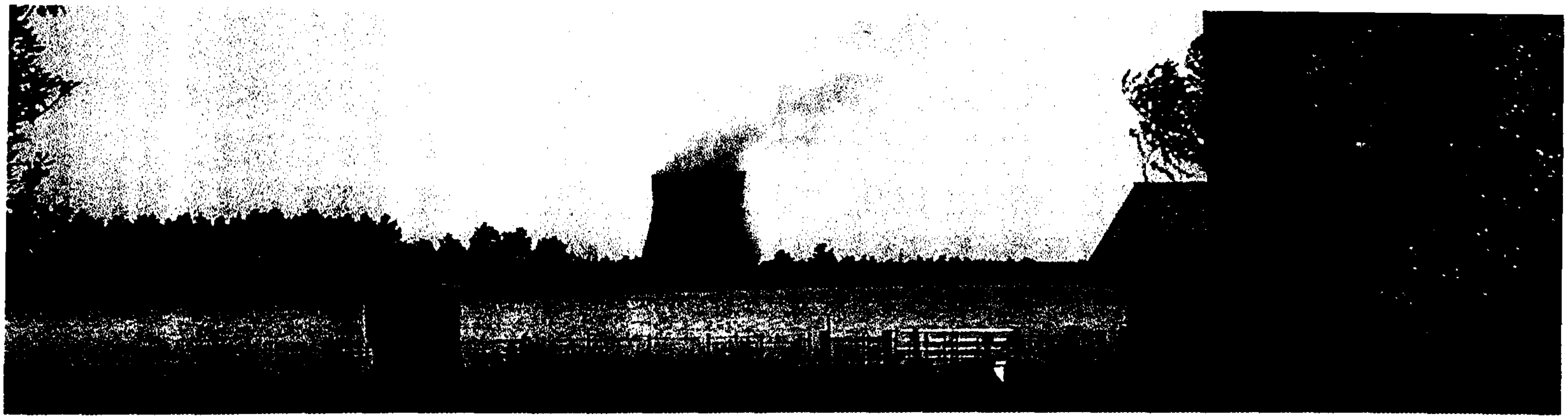
24 "NRC's Regulation of Davis Besse Regarding Damage to the Reactor Vessel Head," NRC Inspector General, Case No. 02-03S, December 30, 2002, at page 23.

25 "Special Evaluation: OIG 2002 Survey of NRC's Safety Culture and Climate," Office of the Inspector General, U.S. Nuclear Regulatory Commission, December 11, 2002, OIG-03-A-03; "Audit Report: Review of NRC'S Differing Professional View/Differing Professional Opinion Program," Office of the Inspector General, U.S. Nuclear Regulatory Commission, September 20, 2000, OIG-00-A-07.

26 U.S. Energy Information Administration, Electric Power Generation by Fuel Type (2004), available at http://www.eia.doe.gov/fuelelectric.html.

27 "Nuclear Power's Prospects in the Power Markets of the 21st Century," Peter A. Bradford, Nonproliferation Education Center, February 2005, available at: http://www.npec-web.org/Essays/Essay050131%20NPT%20Bradford%20Nuclear%20Powers%20Prospects.pdf.

28 "Peaking of World Oil: Impacts, Mitigation and Risk Management," Hirsch et al, Science Applications International Corporation, Department of Energy, February 2005, available at http://www.netl.doe.gov/publications/others/pdf/Oil_Peaking_NETL.pdf.



PERMANENT STORAGE OF SPENT NUCLEAR FUEL REMAINS UNRESOLVED

One of the riskiest elements of building new nuclear plants is that the long-term disposition of the waste is far from being resolved. The planned Yucca Mountain repository in Nevada is almost 20 years behind schedule and may never open. The projected opening date for this permanent spent fuel repository has been delayed countless times and, according to the Department of Energy, the current target date of 2017 is a "best-achievable schedule."[29]

A plan proposed by the Bush Administration, the Global Nuclear Energy Partnership (GNEP), that would allow the reprocessing of spent nuclear fuel, will face significant technical, legal, and political challenges and cannot be counted on as a realistic solution. Reprocessing results in large amounts of waste still needing disposal, and much of the technology essential to GNEP is unproven and undeveloped. Indeed, similar attempts to reprocess spent fuel in the past have been unsuccessful and the DOE does not have a lifecycle cost analysis for the program.

Interim storage of waste at Idaho National Engineering & Environmental Laboratory

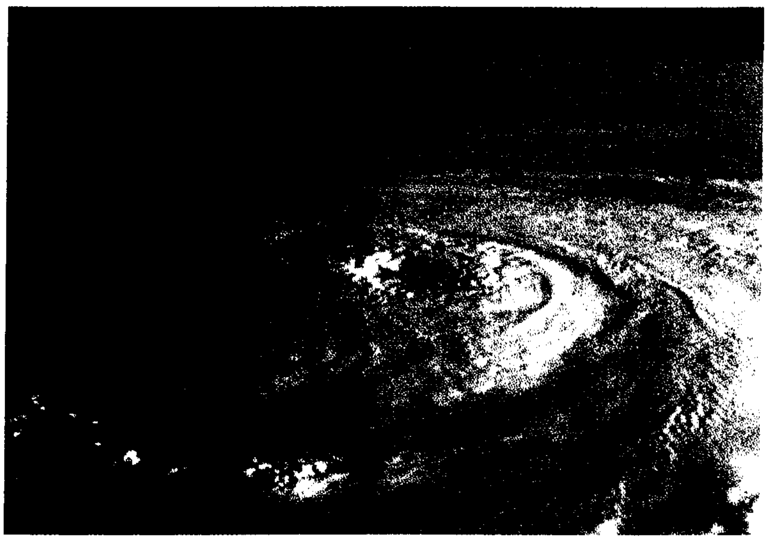
- Reprocessing would be a dangerous shift in U.S. global nonproliferation policy and would increase the likelihood that a terrorist could obtain fissile material to build a nuclear bomb. Moreover, DOE is trying to build momentum for the program before deliberations have been conducted by Congress to determine whether this path is in the best interests of U.S. national and energy security, as well as fiscally sound, even if it should eventually prove technically feasible.
- Reprocessing would increase the number of nuclear waste streams to be managed and secured and is the most polluting part of the nuclear fuel cycle. It would not alleviate the problem of used (spent) fuel storage on reactor sites or the need for a permanent waste repository.[30]
- U.S. taxpayers are still paying several billion dollars each year to clean up contamination from reprocessing programs in the 1960s and 1970s for nuclear weapons at the Hanford Site (WA) and the Savannah River Site (SC), as well as the reprocessing of naval irradiated fuel at the Idaho National Laboratory (ID) and commercial reprocessing at West Valley (NY), which all make this new reprocessing push unlikely and illogical.

29 Statement of Edward F. Sproat, III, Director for the Office of Civilian Radioactive Waste Management, U.S. Department of Energy, Before the Subcommittee on Energy and Air Quality, Committee on Energy and Commerce, U.S. House of Representatives. September 13, 2006, available at http://www.ocrwm.doe.gov/info_library/program_docs/testimonies/SPROAT9-13Testimony_FINAL.pdf.

30 Spent fuel rods must remain in on-site cooling pools for at least five years until they have cooled sufficiently to be transported. Reprocessing waste does not eliminate long-lived radioactive elements that necessitate secure storage for hundreds of thousands of years. GNEP proposes to transmute much of the nuclear waste, but this technology as yet to be proven.

WHAT ABOUT GLOBAL GLOBAL WARMING? BETTER SOLUTIONS EXIST

- Climate change is one of the most pressing threats of our time and it is imperative that we take swift and decisive action to avert its most severe impacts. However, building more nuclear power plants is not the answer.
- The claim that "we need all energy options" to face growing energy needs is disingenuous. On the contrary, we cannot afford all energy options. Further investment in nuclear power would squander the limited financial resources that are available to implement meaningful climate change mitigation policies.
- Nuclear power's role in mitigating climate change (and in reducing oil dependence) is constrained because its impact is limited to the electric sector.



Wind power and other renewables, such as solar and bioenergy, coupled with energy efficiency, conservation and cogeneration are much more cost effective and can be deployed much faster. Building new nuclear power plants will divert private and public investment from the cheaper, readily available options needed to protect our climate. Each dollar invested in electric efficiency in the U.S. displaces nearly seven times as much carbon dioxide as a dollar invested in nuclear power, and nuclear power saves as little as half as much carbon per dollar as wind power and cogeneration.[31]

- Recent studies analyzing the potential of nuclear power to combat global warming have concluded that between 1,000 and 2,000 new nuclear reactors would have to be built around the globe in the next decades to achieve a meaningful impact on CO_2 emissions.[32] These projections point to a clearly infeasible schedule, as new reactors would have to come online every few weeks.
- A 2005 study by Synapse Energy Economics, Inc. showed that the U.S. can substantially reduce global warming pollution through efficiency improvements in power generation. In fact, the report concludes that modest investments in efficiency and renewable energy would reduce global warming pollutants from the electricity sector by 47% by 2025.[33]

IMPACTS OF GLOBAL WARMING INCREASE RISKS OF OPERATING NUCLEAR POWER PLANTS

- Heat waves in the summer of 2006 forced U.S. and European utilities to shut down some reactors and reduce operations at others. Some companies in Europe also had to secure exemptions from regulations in order to discharge overheated water into the environment and others were forced to buy electricity on the spot market.[34]
- Rise in frequency and intensity of catastrophic weather events pose additional risks to nuclear plants' safety because reactors are particularly vulnerable to the effects of flooding, hurricanes, and tornados, as severe storms can disable the on and off-site power systems necessary to operate the plants' safety mechanisms.

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31 "Return of the Nuclear Salesmen: Global Warming Gives Them a New Sales Pitch," Dave Reed, Rocky Mountain Institute Newsletter, Vol. XVI, #1, Spring 2000, pages 25 and 15, available at http://www.rmi.org/images/other/Newsletter/NLRMIspring20.pdf.

32 "The Future of Nuclear Power - Summary Report," MIT, 2003 and "Insurmountable Risks: The Dangers of Using Nuclear Power to Combat Global Climate Crisis - Summary," Brice Smith, Institute for Energy and Environmental Research, 2006, at page 6, available at http://www.ieer.org/reports/insurmountablerisks/summary.pdf.

33 "A Responsible Electricity Future: An Efficient, Cleaner and Balanced Scenario for the US Electricity System," Bruce Biewald et al. Synapse Energy Economics, Inc. and National Association of State PIRGS, May 2005, available at http://www.uspirg.org/uploads/w7/OS/w70S27rKo2G0kOLMyQqBNg/AResponsibleElectrictyFuture.pdf.

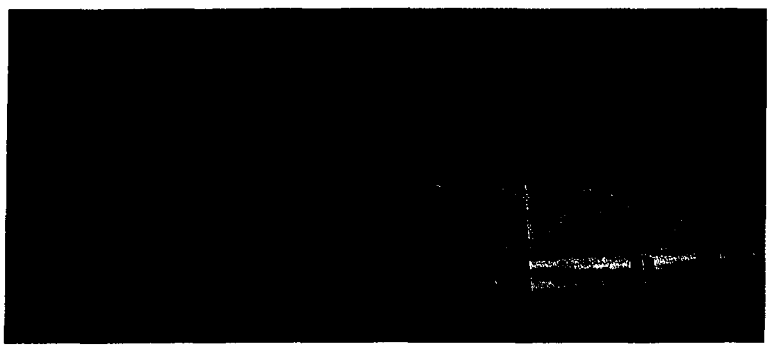
34 "Nuclear Power's Green Promise Dulled by Rising Temps," Susan Sachs, The Christian Science Monitor, August 10, 2006, available at http://www.csmonitor.com/2006/0810/p04s01-woeu.html; and "U.S. Heat Wave Heads to Northeast, May Break Records," update to Bloomberg News, July 31 2006, available at http://www.bloomberg.com/apps/news?pid=20601087&sid=aNtzVaLCaNc8&refer=home.

RENEWABLE ENERGY INVESTMENTS ARE BOOMING WHILE PRICES FOR CONSUMERS KEEP DROPPING

- Worldwide investment in renewable energy capacity was almost $40 billion in 2005. In the U.S., renewable power capacity expanded to 23 GW.[35]
- In 2005, wind energy in the U.S. grew by almost 2,500 MW of installed capacity – a 35% increase in just one year.[36] Total wind-generating capacity in the United States now stands at over 9,000 MW, enough to power more than 2.3 million average American homes.[37]
- Venture capital investment in U.S. based solar companies totaled more than $150 million in 2005 – double the investment from the previous year.[38]
- The International Energy Agency predicts a cost reduction up to 25% for wind power and 50% for solar photovoltaics from 2001 to 2020.[40]
- In the global marketplace, nuclear power is already losing to its faster, cheaper, less financially risky competitors that are NOT centralized power stations.
  - In 2005, micropower (low-carbon fossil-fueled cogeneration, 2/3 of it gas-fired, plus decentralized renewables) added 4 times as much output and 8 times as much capacity as nuclear power.
  - These alternatives have eclipsed nuclear power in both capacity (in 2002) and output (in 2006) .
  - In 2005, micropower provided 32% of the additional global electrical output and was mostly financed by private risk capitol. Thus, investors focusing on actual market behavior must conclude that nuclear power is not preferred.[39]

HOW THE EVOLUTION OF POWER SUPPLY MARKETS AFFECTS NUCLEAR POWER

Assessing the future of nuclear power begins by understanding the past. Nuclear power is a technology force fed into an unsophisticated power supply selection process at a pace too fast for the nuclear industry to assimilate the lessons of operating experience. Moreover, the evolution occurred in ways that concealed or understated the real costs and problems, assuring a series of unpleasant surprises, deepening public mistrust, and, ultimately, reform of the power supply selection processes under which nuclear power had momentarily thrived.



- A real nuclear revival will not exist until private capital is available to build plants, which will require market prices that assure competitive success and profitability. However, even with their ability to compete on the basis of operating costs, the most recent sales of nuclear units have not been at prices that would support the building of a new plant.[41]
- In short, nuclear power's asserted comeback rests not on a newfound competitiveness in power plant construction, but on an old formula: massive government subsidies and licensing shortcuts, and perhaps, guaranteed purchases with risks borne by customers. Climate change has replaced oil dependence as the bogeyman from which supposedly only nuclear power can save us.

35 "Renewables Global Status Report: 2006 Update," Renewable Energy Policy Network for the 21st Century, 2006, at pages 2-5, available at http://www.ren21.net/globalstatusreport/download/RE_GSR_2006_Update.pdf.

36 "U.S. Wind Industry Ends Most Productive Year, Sustained Growth Expected for At Least Next Two Years," American Wind Energy Association, January 24, 2006, available at http://www.awea.org/news/US_Wind_Industry_Ends_Most_Productive_Year_012406.html.

37 "Global Wind 2005 Report," Global Wind Energy Council, 2005, available at http://www.gwec.net/fileadmin/documents/Publications/Global_WindPower_05_Report.pdf.

38 Ibid, page 4.

39 "The Rise of Micropower" Armory Lovins, Rocky Mountain Institute, Updated July 2006, available at www.rmi.org/sitepages/pid171.php#E05-04.

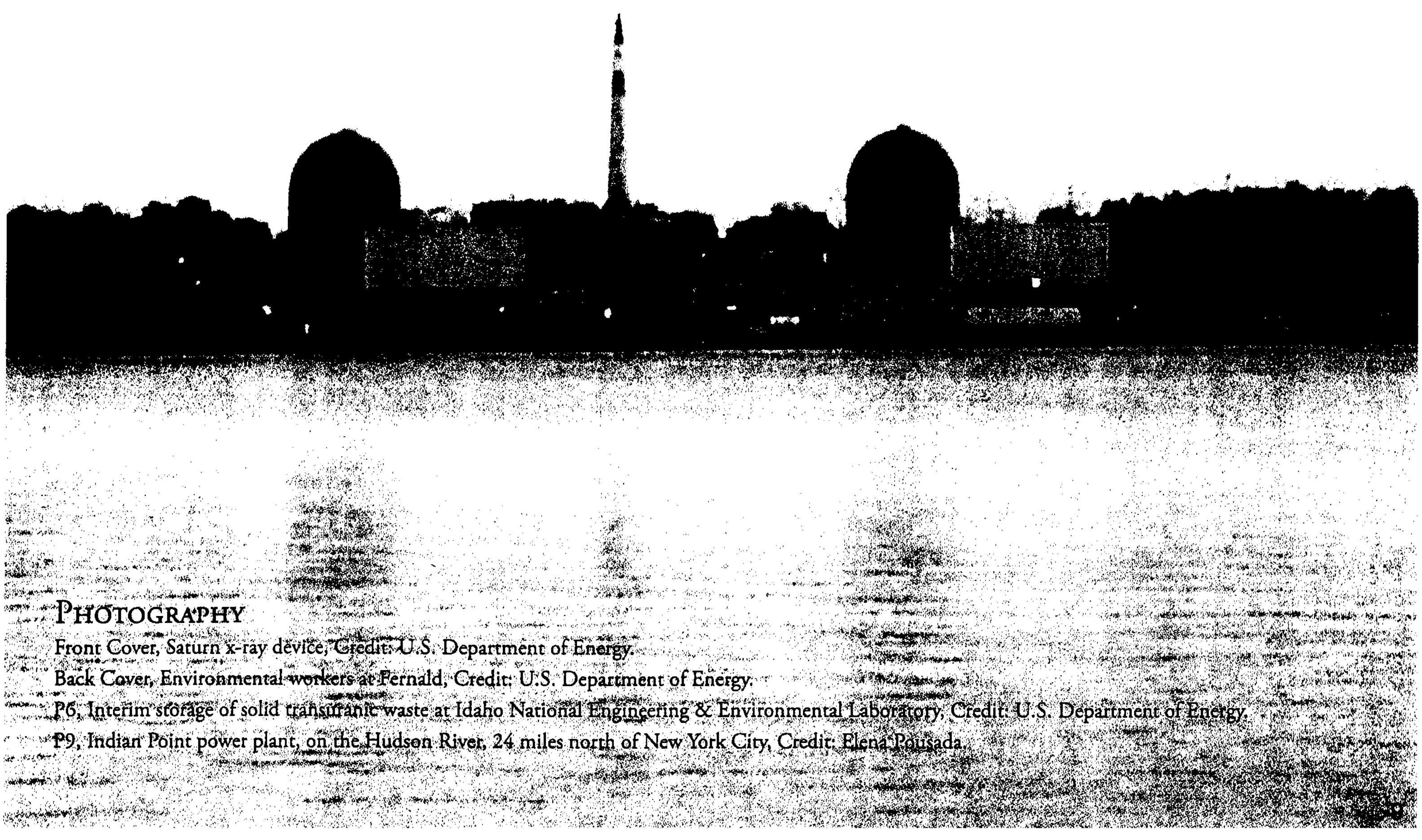
40 "Renewable Energy," International Energy Agency, available at http://www.iea.org/textbase/papers/2002/renewable.pdf.

41 The MIT study, in discussing the 2002 sale of 88% of the Seabrook station, notes that the price "implies that the market value of a fully licensed and operational nuclear power plant with a good performance record is less than half of the most optimistic cost estimates for building a new nuclear power plant....Comparable analyses of other nuclear power plant sales come to very similar conclusions. The market value of nuclear plants is far below their replacement cost, a result that is inconsistent with merchant investment in new nuclear plants." ("The Future of Nuclear Power," Appendix 5, p. 140.)

CONCLUSION

The genesis of nuclear power was the "Atoms for Peace Program" which was intended to make the public more comfortable with the horrifying destruction of the nuclear bomb. Originally, the promise was that the technology would provide energy that would be "too cheap to meter." However, in the last 50 years, nuclear energy subsidies have totaled close to $145 billion and amount to more taxpayer dollars for R&D than for all other energy sectors combined. In fact, nuclear power became the energy that is "too expensive to matter."

A nuclear revival is financially risky. The likelihood of large numbers of new nuclear units being built on the basis of favorable economics is very unlikely. Nuclear power is not competitive today and for nuclear power to succeed it must achieve major cost cuts, avoid even one serious accident, resolve the nuclear waste storage and disposal issue in an enduring way, sever its links to proliferation of nuclear weapons, and get the benefit of its status as a lower carbon-emitting power source. However, even if all of these things occur over the next decade, success will not be guaranteed. Nuclear power may still be more expensive and offset much fewer greenhouse gas emissions than a portfolio of renewable and energy efficiency options.



Photography

Front Cover, Saturn x-ray device, Credit: U.S. Department of Energy.

Back Cover, Environmental workers at Fernald, Credit: U.S. Department of Energy.

P6, Interim storage of solid transuranic waste at Idaho National Engineering & Environmental Laboratory, Credit: U.S. Department of Energy.

P9, Indian Point power plant, on the Hudson River, 24 miles north of New York City, Credit: Elena Pousada.

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4

Document #1 Docket No. 070650

Memo from a meeting, 9/7/07, with environmental groups, representatives of Miami-Dade Water and Sewer Dept. (WASD) and representatives of Miami-Dade Department of Environmental Management (DERM), hosted by Dr. Douglas Yoder, WASD.

This memo was emailed 7 days prior to the meeting and all participants in attendance arrived with copies.

As a result of this meeting, only portions of 2 questions were answered. The requirement for process water is 100,000 gallons a day and this water will be supplied by the Newton Water Treatment Plant, WASD.

Other questions were discussed but no other answers were given.

Mark Oncavage
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FLORIDA PUBLIC SERVICE COMMISSION
DOCKET NO. 070650-EI EXHIBIT 4
COMPANY Witness on behalf of the Citizens of FL
WITNESS Mark Oncavage
DATE 01/09/2008

Memo: meeting with members of the environmental community, 9/7/07
To: Dr. Yoder, WASD
From: Mark Oncavage, Sierra Club
Re: proposed nuclear units A & B at Turkey Point
Date: August 31, 2007

What is the source of
Plant process water,
Blowdown water,
Cooling water,
Fire protection water?

How much water, per unit, is required for process, cooling, and fire protection?

What chemicals, in what concentration, will be added to the process water?

What chemicals, in what concentration, will be added to the blowdown water?

What chemicals, in what concentration, will be added to the cooling water?

Where will process water, blowdown water, and cooling water be discharged?

Where will radioactive liquid wastes be discharged?

How will the cooling water be cooled?

How will plant stormwater runoff be treated and where will the runoff be discharged?

What role in monitoring or enforcement does WASD take for the 1971 District Court Judgment concerning discharges from Turkey Point?

What permits from WASD are needed for plant operations?

To what extent will the rock mining proposed by FPL affect the saltwater intrusion line?

Will the Elevated Tank, Newton, or FKAA wellfields be affected by the proposed rock mining?

What is the expected rate of rise in sea level WASD is using?

Document #2 Docket No. 070650

Memo from a meeting, 9/18/07, with several environmental groups and Florida Power & Light (FPL). Barbara Linkiewicz, FPL, was the lead speaker.

The questions were submitted in writing. The only question that was answered was that cooling water would be cooled in low-rise cooling towers.

FPL refused to answer all other questions.

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Mark Oncavage
Sierra Club, Miami Group
305-251-5273
oncavage@bellsouth.net

September 18, 2007

Questions pertaining to Turkey Point

For uprating units 3 & 4, what components will be replaced or modified?

For uprating units 3 & 4, will the reactors need a higher concentration of fissile fuel?

For uprating, will the reactors operate at a higher temperature? How much higher?

For uprating, which components will operate with a higher risk of problems?

For uprating, how many more megawatts of electricity will be produced by unit 3? Unit 4?

For uprating, will additional cooling capacity be needed?

For the proposed units A & B in normal operation, how many gallons a day will be released to the cooling canals?

For units A & B, how will the cooling water be cooled?

For units A & B, how often will blowdown occur?

For units A & B, what dissolved solids will be in the blowdown stream? At what concentrations?

Will the addition of the blowdown stream from A & B impact the operations of units 3 & 4? What are the impacts?

Document #3 Docket No. 070650

This document was submitted, in writing, as public comment at a public hearing on 11/14/07 to the Miami-Dade County Development Impact Committee. This Committee consists of directors of Miami-Dade County agencies, such as Planning & Zoning, Water and Sewer, Environmental Management, and others. The purpose of the Committee is to advise the County Commission. This Committee was chaired by Susanne Torriente.

None of the questions were answered.

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SIERRA CLUB
FOUNDED 1892

MIAMI GROUP
P.O. Box 43-0741
South Miami, FL 33243-0741

MIAMI-DADE COUNTY WATER AND SEWER DEPARTMENT

Sierra Club is the oldest and largest environmental organization in the United States having a membership of approximately 750,000 people. The Sierra Club urges the Miami-Dade Development Impact Committee and the Miami-Dade Board of County Commissioners to deny the six unusual use permits and variances requested for the construction and operation of the proposed nuclear units at Turkey Point. The application suffers from both poor planning and the lack of adequate planning.

There are concerns that plant operations will deny Miami-Dade County an adequate supply of water. Rock mining will be damaging to the restoration and rehydration of Biscayne National Park. There will be a significant loss of coastal wetlands, loss of habitat for protected species, and major disruptions to the natural flow of water in the region.

The following questions illustrate the lack of information and the lack of adequate planning. Sierra Club urges denial of all permits and variances.

<u>Water Consumption</u>

Miami-Dade County anticipates that water consumption, for the next 20 years, will increase by 74 million gallons a day (MGD). Cooling water consumption for Turkey Point is presumed to be 70 MGD.

1. Where will Miami-Dade County find the additional 144 MGD of water needed to support expected growth and operate the proposed nuclear units at Turkey Point?

<u>Lake Okeechobee</u>

Lake Okeechobee is the back-up water supply for Miami-Dade County. The Lake level is approximately 5 feet below its 41 year average. This equates to a deficit of 1.94 million acre-feet or 632 billion gallons of water.

2. What is the contingency plan for back-up water if low lake levels persist?

<u>Newton Water Treatment Plant</u>

The Newton WTP provides potable water, from the Biscayne Aquifer, for the unincorporated areas in the C-103 Basin and Model Land tract. Population estimates from the Watershed Study show that 20,300 new housing units will be built in this area by 2025. The average potable water consumption for low-density housing units is 350 gallons per day (GPD) for a total consumption of 7,100,000 GPD. The estimated consumption of potable water for the proposed nuclear units at Turkey Point, from the Newton WTP is 150,000 GPD. FPL has not yet stated the increased consumption of potable water it will be requesting for the uprates of the current nuclear units

Estimated Increased Consumption for Newton WTP

New housing units	7,100,000	GPD
Turkey Point service and process water	150,000	GPD
Uprates of currently operating nuclear units	?	GPD
Total Increased Consumption	7,250,000	GPD

3. How far west will salt water intrusion occur with the withdrawal of 7,250,000 GPD from the Newton WTP Wellfield?

4. Will the Newton, Elevated Tank, Leisure City, Naranja, Florida City, Everglades, Homestead, or Florida Keys Wellfields be damaged by increased salt water intrusion from the Newton withdrawals?

5. How many private wells will be damaged by increased salt water intrusion from the Newton withdrawals?

6. What are the contingency plans for Newton wellfield damage and what are the costs?

7. Will the City of Homestead, Florida City, and Monroe County have equal representation with Miami-Dade County for water consumption decisions concerning Turkey Point?

Water Re-use

The proposed wastewater re-use treatment plant for south Miami-Dade County is expected to treat 100 MGD of sewage and reclaim 60 MGD of re-used water. The cost is expected to be $1.6 billion. Additional cooling water needed for the proposed nuclear units at Turkey Point is estimated to be 70 MGD.

8. Will taxpayers have to pay $1.6 billion to provide re-use water infrastructure for Turkey Point at the South Miami-Dade WWTP?

9. Will taxpayers have to pay for other schemes to deliver additional re-used water for Turkey Point?

Upper Floridan Aquifer

Turkey Point Unit 5 is currently withdrawing approximately 14 MGD from the Upper Floridan Aquifer. The proposed new nuclear units will require approximately 70 MGD of additional cooling water. Withdrawals of 14 MGD and 70 MGD may draw heavily mineralized water or high chloride water to the wellfields that are already using Upper Floridan water. Water from the proposed

Miami-Dade wellfields may require additional capital investments due to the Turkey Point withdrawals.

10. Who is financially responsible for wellfield damage to the current users of Upper Floridan Aquifer water due to the Turkey Point water withdrawals?

11. Will taxpayers have to pay additional costs for poor water quality at the new Miami-Dade wellfields due to the Turkey Point water withdrawals?

<u>ASR Wells</u>

Water storage at aquifer storage and recovery (ASR) sites are supposed to store excess surface water in the Upper Floridan Aquifer in an underground fresh water bubble. There are 4 ASR sites in Miami-Dade County and 4 sites in Broward County.

12. Which ASR site operations will be damaged due to the Turkey Point water withdrawals?

13. How much damage to the ASR fresh water bubbles will occur, due to the Turkey Point water withdrawals?

October 22, 2007

Contact Person:

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oncavage@bellsouth.net

Document #4 Docket No. 070650

This document was submitted in writing, 12/20/07, to the Miami-Dade Board of County Commissioners. It was a quasi-judicial hearing and oral and written statements were given under oath.

There were 8 questions embedded in the statement.

None were answered.

Mark Oncavage
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Statement of Mark Oncavage
Miami-Dade Board of County Commissioners
December 20. 2007

I am Mark Oncavage, I live at 12200 SW 110th Avenue in Miami, which is about 14 miles from Turkey Point. This is a bad place to put new reactors. The land is practically at sea level, protected natural areas are not compatible with heavy industry, problems with terrorism, sabotage, radiation leaks, routine releases of radioactive materials, and no safe place to put the all the hot reactor wastes.

This creates a dis-amenity for homeowners like me. Any one of these problems gets out of control and all housing values plummet. I am concerned. Twice in the past I challenged safety problems at Turkey Point and have achieved legal standing both times.

I am also the Conservation Chair of the Miami Group of the Sierra Club. We have about 2,700 members in Miami-Dade and about 300 members in Monroe County. Our Club is the oldest and largest environmental organization in America. Our organizational mission is to explore, enjoy, and protect the wild places on the planet. We also work to protect natural resources and the human environment. We also offer outings to natural areas for our members and the public.

The recommendations of the County staff have utterly failed to protect the County's most valuable resource, its water supply.

On Tuesday, Mr. Chip Merriam of the South Florida Water Management District gave an overview of the consumptive use permit recently obtained by the County. County government asked for, I believe, an additional 77.5 million gallons of water a day for the next 20 years.

But now Florida Power & Light wants an additional 90 million gallons a day from the County. This is an excessive demand for water and it is a substantial reason to deny the zoning variance for the 2 nuclear reactors.

Section 33-311 of the CDMP warns that no zoning variance should be approved if it would have an unfavorable effect on the economy of Miami-Dade County Florida. Yes, Miami would be like Atlanta and watch its water supply drain away only for the benefit of power plants. There would be economic hardship. The second criterion, that it would cause undue or excessive burden on public facilities including water, sewer, solid waste, and other facilities. This must include over-pumping our water supply aquifers. The County Commission has an obligation to protect its vital resources.

Mr. Merriam, in his presentation on Tuesday, briefly mentioned Turkey Point. He said the District could allow an additional 70 million gallons a day of re-used water to go there. But FPL wants 90 million gallons a day. Where can the County find these missing 20 million gallons a day?

Then there are the costs. The County has committed for a South Miami-Dade water re-use plant that will cost an estimated 1.6 billion dollars for approximately 65 million gallons a day. But that water has already been assigned for other uses. Will Florida Power & Light pay 1.6 billion dollars for a second water re-use plant?

And if they do pay for this second plant, the next closest place that has that much sewage is Virginia Key. So is Florida Power & Light going to pay to drill a 22 mile tunnel from Virginias Key, under Biscayne Bay, and under Biscayne National Park to South Miami-Dade to pump sewage? How many additional billions of dollars would that take? Or would you want taxpayers to pay these costs to supply FPL with water?

The criteria for denial of these variances are an unfavorable effect on the economy and undue or excessive burden on public facilities. If the County Commissioners don't have good answers, then the Commissioners should say "no."

Earlier I said that the staff utterly failed to protect the County's water supply. This is where they failed. They did not state that FPL must only use re-used water. Instead they said, and I quote,

"Should WASD be unable to provide the applicant with sufficient quality or quantity or consistency in water delivery as required by FPL for its cooling system, alternative sources may be proposed to satisfy such deficiencies." End of quote.
It sounds like staff is too eager to give away the County's aquifer quality water. Talk about giving away the store.

Please ask the County staff and Florida Power & Light these 3 questions.

1. What is the source of the 90 million gallons a day of cooling water?

2. How much will it cost? And

3. Who pays the cost?

We're all waiting for these answers.

Thank you very much.

FLORIDA PUBLIC SERVICE COMMISSION

DOCKET NO. 070650-EI EXHIBIT 5

COMPANY Witness on behalf of the Citizens of FL

WITNESS Debbie Arnason

DATE 01/09/08

5

Florida Public Service Commission, January 9, 2008
Office of Commission Clerk, 2540 Shumard Oak Blvd
Tallahassee, FL 32399-0850 Fax 800-511-0809, e-mail contact@psc.state.fl.us, 800-342-3552,

RE; Docket # 070650-EI - FPL's proposed expansion at Turkey Point Nuclear Plant

Dear Florida Public Service Commissioners:

* My name is Deborah (call me Debbie) Arnason. I reside at 12 Dill St, Alva, FL 33920.
This is my oral testimony given in Miami 1/9/08. I am an FPL customer who no longer 'donates' to so-called Green Program!

I will begin by showing a cartoon from USA Today 8/13/07 depicting a drunken Uncle Sam on his butt amidst emptied barrels of oil and a chunk of coal reaching for a nuclear canister. The balloon over his head reads, "Just what I need…a little eye-opener…"

To fill you in, I worked as an Addictions Counselor in the 90's at Outreach, teen drug and alcohol rehab in Cape Coral, FL. I am very familiar personally with 12-step recovery programs of all types.

I also have background in Sales. Although retired, I occasionally work for my brother's metals business as their SE Sales Rep. I attend power generation trade shows and have been receiving Renewable Energy World Trade Magazine www.rew-subscribe.com to receive a free copy. I highly recommend it for its incredible solar solutions to this energy crunch we are dealing with here in Florida.

On a personal basis, my husband and I have suffered many health problems living close to fossil fuel plants in northern Florida. Upon investigation, we have found that we cannot take the reassurances of for-profit energy companies as to the safety of their fossil fuels. I testified before the PSC April 16, 2007 regarding FPL's proposed coal plant for the heart of our endangered Everglades and am thrilled to say dirty coal was denied.

In the process, I have learned about other forms of energy from many sources including environmental, business and social justice groups. I discovered that nuclear was also a fossil-fuel as uranium is mined, finite, radioactive, known to cause cancer, birth defects and death. It is extremely cost and energy-intensive to mine, handle, transport and dispose of without contaminating our air, water and soil. That's scary. And, its ridiculous just to make steam. I have attached information from many sources to validate this.

We are here to give public input on the proposed expansion of nuclear energy at Turkey Point. From my background, I wish to point out the connections many others are now beginning to make regarding the question of expanding nuclear energy as the "quick fix" to our warming and energy woes:
-As President Bush said, he "is addicted to oil." Actually, he said "we" but he does not speak for me in many areas. Nuclear is a fossil-fuel, like coal, gas and oil.
-Our nation's chief scientist, Dr. James Hansen of NASA calls the problem we face with

global warming a "fossil-fuel addiction."
-Alan Greenspan, former US economist, states in his recent book, "Everyone knows the Iraq war is about oil." It is typical of addicts to go to any lengths to get their supply and woe to anyone in their way.
-Time's Global Warming catalog published in Dec 2007 can be obtained 800-327-6388 on page 72 refers to the Acceptance/Grief process so necessary for recovery from addictive illnesses as it pertains to Global Warming. "First came denial (This isn't happening), then Anger (How can this be happening?), followed by bargaining (just let us use dirty energy for one more generation, then our children will switch to alternative sources of power). The fourth Step is Depression (There's nothing we can do about this.) Finally, there is Acceptance (The world that we're moving towards is a better one).....we appear to have just about finished Bargaining and we're now facing the question of whether we can skip Depression and go straight to Acceptance."

pg 73 Solar attached

We need to do an intervention with the power companies. Switching to coal to gas to nuclear is like the alcoholic changing drinks from beer to scotch to vodka. I'd even liken nuclear to trying "hard drugs" in an effort to keep the buzz.

There is so much I can point to wrong about nuclear. For instance, France is touted as being on 80% nuclear power. No one mentions that this past summer, in the midst of a heat wave, they had to shut down ¾ of their reactors to avoid meltdown since their cooling water was too warm. Or that nuclear evaporates more water than people use.

* I haven't even gotten into the costs of building or expanding more nuclear plants. It is billions of dollars per plant for less than 10% of the energy we need. The only reason it is being considered right now by FPL and others is because OUR federal and state governments are promising THEM they won't have to pay for it....the public will, even if it fails. That's the nuclear loan guarantees without which no for-profit energy corporation would risk THEIR money. (What ever happened to PUBLIC utilities?)

We, the citizens of Florida, need to do an intervention with the power companies instead of enabling this insanity. I call it asking us to "subsidize our own demise." Why don't
** we send FPL off to the Concentrated Solar Power Summit in San Francisco Jan 28 & 29 to learn "How to build - and run - a profitable Concentrated Solar Power plant. Everything you need to know to get a CSP plant up and running. Fast." 800-814-3459. There are such rehabilitative Solar energy events all over the world, even in oil-rich Abu Dhabai. The breakthroughs in solar are dazzling and might help FPL "see the light."

We hope, once again, the PSC will act as the Higher Power for the greater good to determine whether we in Florida head down the path to nuclear destruction or into the God-given sunlight of the spirit. Star Energy is freely given and available for our recovery. I pray we choose life.

Deb Arnason

Love, Deb Arnason (and 360+ signers of my petition - No coal, no nuclear, go solar)
12 Dill St. Alva, FL 33920 239-728-3147 diamondteldeb@aol.com 386-288-4454 c

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how to save on heliostats... receivers... frames... trackers... turbines... and heat storage without compromising performance

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the inside track on getting financial backing, minimizing longer term risks and improving the ROI you can offer to investors and backers

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ENERGY CENTRAL

Organised by: CSP today

Insanity —— Cost vs productivity $ trillions to solve small portion of energy problem.

Subj: **[No_Coal] RE: [saveitnowglades] FPL wants ratepayers to cover Glades fiasco**
Date: 8/6/2007 5:48:38 A.M. Pacific Standard Time
From: marshmaid@hughes.net
Reply-to: No_Coal@yahoogroups.com
To: saveitnowglades@yahoogroups.com, COMMONS-EVERGLADES@LISTS.SIERRACLUB.ORG, no_coal@yahoogroups.com

George, Obviously they don't! They should be sued for wasting taxpayer dollars on a huge disinformation campaign instead! How about PIRG doing something with ratepayers here? We need those invoices. Rhonda

Uranium - carbon to get it out
finite vs SOLAR.

Not Planned on this tic
Cargle ~~?~~ months ago
Spoke to public counsel

-----Original Message-----
From: saveitnowglades@yahoogroups.com [mailto:saveitnowglades@yahoogroups.com] **On Behalf Of** George Cavros
Sent: Friday, August 03, 2007 6:09 PM
To: saveitnowglades@yahoogroups.com
Subject: [saveitnowglades] FPL wants ratepayers to cover Glades fiasco

* My estimate of SOLAR COSTS
Solar needs no MINING
MILLING, Special handling,
waste that none knows
how to get rid of & would
cost trillions
to live around for generations to come.

Have they no shame ...?

-gc

FPL wants to recover $34.5 million for coal plant planning

By Kristi E. Swartz

Palm Beach Post Staff Writer

Friday, August 03, 2007

* Pre-approved —
No way do we (rate payers) want to be suckered in again to pay for nukes!

Florida Power & Light Co. won't be building a coal-fired power plant in Glades County, but the utility wants to recoup the money it spent planning for the project anyhow.

The utility is asking to recover $34.5 million from consumers for permits, engineering, and equipment-contract costs. If approved by utility regulators, FPL's 4.4 million residential and business customers wouldn't be paying these costs until 2010, because of an agreement the utility struck with consumer advocates that has frozen basic electricity rates through the end of 2009.

"Even though the project was not approved, we still had a number of upfront project-related costs, and these upfront project-related costs are due to the fact that you have to ensure that the plant will be built on

FPL Choices for ALTERNATIVES —
IGCC + GAS
WHY NOT SOLAR?
VERSUS NUCLEAR
no "uncertainty" of future costs
like nuclear, coal, oil
- no carbon tax on SOLAR
Nanosolar
Paper batteries
Concentrated Solar Power
Roof tiles

* why no cost comps to Solar including Risk Mgmt
Are we not told because FPL doesn't care because they aren't paying for it anyway
WE (The Public) ARE

1/9/08

I attended this workshop. As I listened to John explein the horrors of nuclear handling, disposition and waste transport, I was appalled. Just one cannister on a truck in a bridge accident like MN this past year would be like 10X Hiroshima. This could happen on the TAMPA Bay Bridge or anywhere in FLORIDA.

As the workshop went on about half an hour, I started to GRIN There's no way the human race could be so insane as to even consider dealing with this stuff..... Just to make steam!

Deb ARNASON

More than a TAD:

A Study of the Problems With the Transport and Reprocessing of Nuclear Waste in the Carolinas

A report prepared for

Commonsense at the Nuclear Crossroads

Asheville, North Carolina

by John C. Sticpewich

nuclearcrossroads.org website
+ contact John - 8/11/07

12-step - we do not have to accept unacceptable behavior —
State Lands, money, giveaway to for-Profit Powers of people's
lands to expand FPL Power plants - Nikes No

LOCAL & STATE

WHERE'S TELL I

Melanie Payne's column will return next week. Meanwhile, if you have a news story, call Assistant Metro Editor Miriam Pereira at 335-0491.

THURSDAY, JANUARY 3, 2008 | THE NEWS-PRESS | news-press.com

FPL stands to gain from proposed bill

Utility has spent big to push tax-cut plan

BY JIM ASH
The News-Press Capital Bureau

TALLAHASSEE — Florida Power & Light, the second-largest contributor to Gov. Charlie Crist's tax-cutting campaign, would reap the benefits of legislation the industry is pushing this year, including changes that would make it easier to build transmission lines on state-owned lands and harder for local governments to block new power plants.

A draft bill, written by an FPL lobbyist and dated Dec. 5,

CRIST
Tax-cut vote set for Jan. 29

would give Crist's Department of Environmental Protection chief, as well as water management districts, the authority to grant utility easements on state-owned lands, a power now reserved for the governor and Cabinet.

The legislation also would force local governments to report zoning restrictions that bar power plants to the Public Service Commission within two years, or lose the ability to enforce them. The proposal also would give utility companies more leeway to charge customers for the cost of expanding nuclear power plants.

An FPL spokesman said Wednesday that the company did not write or propose the legislation but supports it. The company did not donate to the

■ See FPL B2

WE WANT TC FROM YOU

How will the p constitutional affect you? How wil

Let us know if defeat will make a c whether you will s home.

E-mail Assistant Editor Sheldon szoldan@news-pres your thoughts. Plea your name, phone r if you are a snowl steader, business ow tor.

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them if they would partner with us, we thought we would have to sell them on it," said Dinon, who's also a member of art celebration's board of directors. "But they told us, 'We just want to do something for the kids.'"

Some schools have had relationships with private art organizations for years. The Art League of Bonita Springs has sponsored Art Goes to School, in which artists work with south Lee students, for more than 40 years.

ArtFest Fort Myers, an outdoor art festival, is hosting its eighth annual "Art Under 20" contest on Edwards Drive in downtown Fort Myers on Feb. 2 and 3. This year, the event will have 359 works from 193 students in 15 high schools. ArtFest also sends artists to area middle schools to teach art for a day. It also gives money to public school teachers to buy art supplies for their classes, said Sharon McAllister, festival director.

"It's also about providing a venue for students to show off their work," McAllister said. "High school students who want to go to college for art have to

FPL

■ Continued from B1

tax-cutting campaign to get favorable treatment for the legislation, the spokesman said.

"We're aware of the legislation, but we didn't initiate it," said FPL spokesman Mayco Villafana. "We want to help state leadership resolve this (tax issue) in a manner that is best for our employees and the people of Florida. We have employees that are affected by the tax burden, like most Floridians."

Dec. 5, the date the draft bill was written, is nine days before the company wrote a $250,000 check to "Yes on 1," the committee that is organizing Crist's campaign for a $9.3 billion property tax cutting measure on the Jan. 29 ballot. FPL wrote another $250,000 check to the committee Dec. 21.

The $500,000 contribution makes FPL the second-largest single contributor to "Yes on 1." Only the Florida Association of Realtors, with a $1 million contribution, has given more.

Vivian Myrtetus, a spokeswoman for "Yes on 1," who formerly worked as Crist's communications chief, said FPL did not ask for any favors when it donated to the campaign.

"I'm sure, just like every business that has contributed, they know that Amendment 1 is important for Florida's economy," she said. "I'm sure that they have lots of (legislative) bills that come up every year."

Tallahassee utility lobbyist Frank Matthews said he drafted the legislation for an industry group, not for his client, FPL. He said he was not aware of the company's donation to "Yes on 1."

Utilities have been asking for some or all of the changes for years, Matthews said.

"It's kind of a bunch of issues that have been out there for four or five years," Matthews said. "It's the garden variety issues, not the big stuff like global warming."

Eric Draper, a lobbyist for Audubon of Florida, said utility companies have been trying for years to get easier access to state lands, over the strong objections of conservationists. State lands are attractive to power companies because they are remote and uninhabited, Draper said.

But they are also prime wildlife habitat, and cutting a swath through the wilderness disrupts the migration of larger animals, including panthers and bears, Draper said.

"Public lands are usually the last intact ecosystems," Draper said. "We try to buy contiguous lands whenever the public buys lands that are important for the preservation of species."

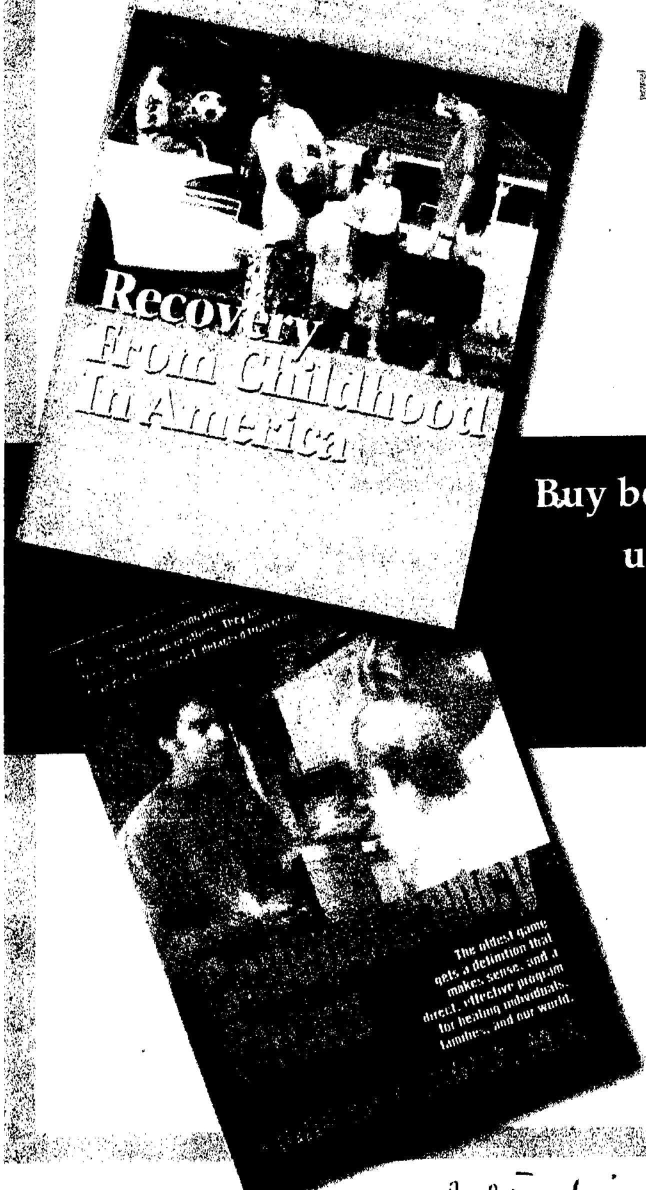
Giving the state DEP or water management districts the power to grant easements on state lands would make it harder for groups to monitor the proposals and oppose them at public meetings, Draper said.

"We have a long, well-established process in Florida for establishing power plants and power lines, and the system works. It's not broken," Draper said.

EAGLES

■ Continued from B1

She also wants to make the ordinance mandatory to pro-



Linda Meyerholz is a licensed mental health counselor.

Codependency Sucks and *Recovery From Childhood In America are available* at:

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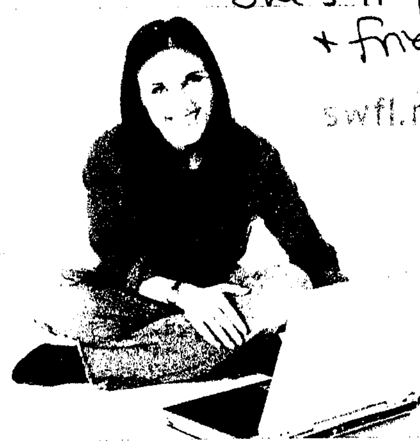

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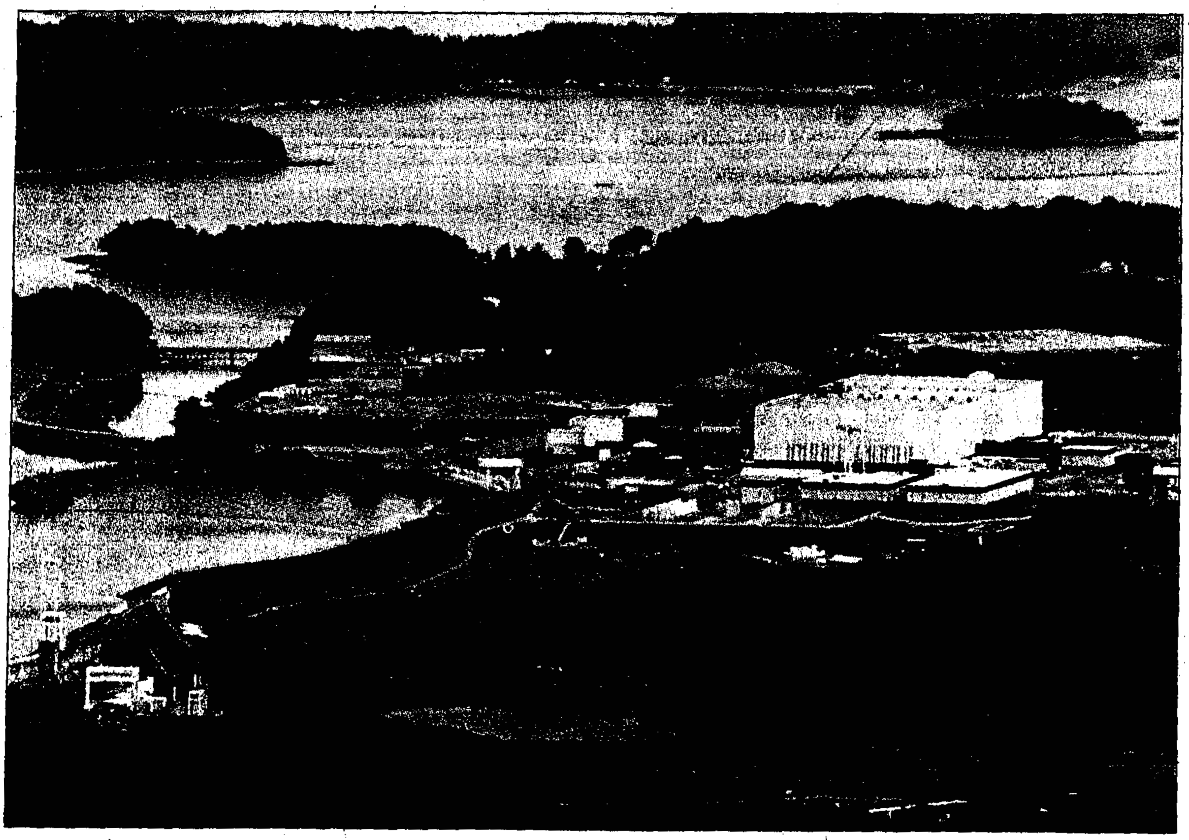
THE RACE TO UPGRADE MCGUIRE



GARY O'BRIEN – gobrien@charlotteobserver.com

For the backup safety system at Duke Energy's McGuire nuclear power plant to operate, the water level on Lake Norman must be at a certain level. The company is in the process of replacing the system so it can operate at a lower lake level.

Drought fueling power concerns

Duke facing a problem as water level drops on Lake Norman

BY CHRISTOPHER D. KIRKPATRICK
ckirkpatrick@charlotteobserver.com

At the McGuire nuclear power plant on Lake Norman, engineers race a ticking drought clock.

For one of the plant's backup safety systems to work, the lake has to be above a certain water level. But persistent drought is taxing the water supply as Duke Energy Corp. races to redesign and replace the system so it can operate at a lower lake level.

If Duke loses the race with Mother Nature, it could be forced to temporarily shut down ... cording to its op- ... he U.S. Nuclear Regulatory Commission.

At stake is the 2,200 megawatts McGuire provides at full power – nearly 12 percent of Duke's capacity in the Carolinas. Shutting down the plant could put a strain on the system as power demand soars. When Duke needs extra power, the company often buys from outside sources, passing the sometimes-higher costs on to ratepayers.

"We have put every available resource into this job," said spokeswoman Rita Sipe.

For now, Duke, through its series of 13 dams on the Catawba River, has been keeping Lake Norman at a high enough level to keep McGuire online. But the company says the water supply in the river basin is shrinking about 2 percent a week and persistent drought into March could compromise some of its operations.

The McGuire plant, near Huntersville, is about 20 miles north of uptown Charlotte. The Lake Norman area and its waterfront, once rural, have sprouted with high-end homes and communities, often developed or sold by Crescent Resources LLC, Duke's former real estate

SEE DUKE | 4D

Watching Duke

At McGuire nuclear plant, like similar plants across the country, U.S. Nuclear Regulatory Commission officials work side by side with plant employees. Two officials at McGuire watch day-to-day activities to ensure plant operations are within federal guidelines.

"It's like having a state trooper in the passenger seat while you're driving down the highway," said Duke spokeswoman Rita Sipe.

Duke's three nuclear plants are an integral part of Duke's power plant fleet, providing 46 percent of Duke's power generation. Coal accounts for 52 percent. The rest comes from hydroelectric plants and ones run on natural gas and oil.

Thurs Nov 1 2007
Charlotte Observer
Nuclear
NG
in Drought
704
358-
5040
Summer 07
Ask Observer
to look up

Nuclear will melt-down if they cannot use (waste) millions of gallons of water PER DAY!

12/29/07
cKirkpatrick
@charlotteobserver.com
req'd copy of article & date for nuclear drought concerns here info PSC next week

Go Solar, Duke!

Subj: **Radioactive Future?**
Date: 10/4/2007 12:07:51 P.M. Pacific Daylight Time
From: foe@foe.org
Reply-to: foe@mail.democracyinaction.org
To: diamondteldeb@aol.com

Friends of the Earth We champion a healthy and just world.

Deb:

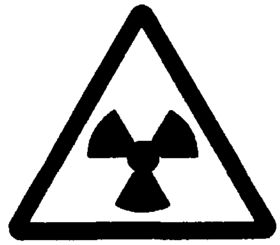
Under the guise of fighting global warming, the nuclear power industry and its allies in Congress are pushing a plan to construct the first new nuclear power plants in the U.S. in decades, and the plan's lynchpin is to make taxpayers the unwilling investors.

Amazingly, opposition to this foolish effort has been weak on Capitol Hill and in the media, which is why Friends of the Earth is launching an intense campaign over the coming weeks to balance the debate and stop this nuclear juggernaut in its tracks -- and we need your help to make it happen.

Despite having already received over $77 billion in federal government handouts, the nuclear industry is now lobbying for over $50 billion in loan guarantees to build the new plants.

Just last month, the first application for a new plant in 30 years was submitted to federal regulators. Federal regulators expect at least 21 other applications for new plants in the next two years. The arguments against nuclear power are overwhelming:

- **Nuclear power is not the answer to global warming.** Every dollar spent on nuclear power would reduce greenhouse gas emissions less than were it spent on wind power or greater energy efficiency. The U.S. would have to more than triple its number of nuclear power plants to significantly reduce global warming emissions. Nuclear plants take 10 years to build, while more effective options can take less than a year (as one expert has said, "If you worry about climate change, it is essential to buy the fastest and most effective climate solutions. Nuclear power is just the opposite").



DANGER
Radiation risk

There's a push by both the nuclear industry and its allies in Congress to pass off nuclear power as a solution to global warming.

This push is going virtually unchallenged.

If you want to fight this effort to prop up a troubled industry, put a donation behind our campaign.

Donate

- **There is no place for the waste.** Every reactor's waste remains radioactive for tens of thousands of years, yet this waste is now dumped in temporary storage pools of water next to reactors because there is no permanent location to isolate it. One study found that a fire at one of these already-full waste pools could cause as many as 28,000 cancer fatalities and $59 billion in damages, and could render 188 square miles of land unsuitable for habitation.
- **There are risks beyond our control.** Just this summer the world's largest nuclear plant, in Japan, was damaged during an earthquake and released radioactive waste into the sea.
- **Nuclear plants are an economic boondoggle.** It is estimated that new nuclear plants will

cost at least $5 billion each. Even at this conservative estimate, it would likely cost over *$1 trillion* in order to significantly reduce global warming with nuclear power. (Not surprisingly, some experts anticipate that half of new plants will result in defaults on the loans required to build them).

- **New nuclear plants create new opportunities for foreign and domestic terrorists.** [illegible] allegedly considered crashing a plane into the Indian Point nuclear [illegible] plutonium, the two types of fuels used in reactors, are necessary for a nuclear bomb -- more plants will provide more opportunity for theft of bomb making materials.

As the industry concedes, new plants will not be built without these loan guarantees. *By supporting our campaign you can help ensure that they aren't.*

Your money will mobilize political pressure, bring the public into this decision-making process, and forcefully inject the facts about nuclear power into the current debate. Thanks to the work of Friends of the Earth and others, no new plants have been built in the U.S. in the last 30 years. We need your help now to make sure the public and its elected officials know what ending the moratorium

Welcome to

Beyond Nuclear is a new initiative at Nuclear Policy Research Institute. Beyond Nuclear aims to educate and activate the public about the connections between nuclear power and nuclear weapons and the need to abandon both to safeguard our future. Beyond Nuclear advocates for an energy future that is sustainable, benign and democratic.

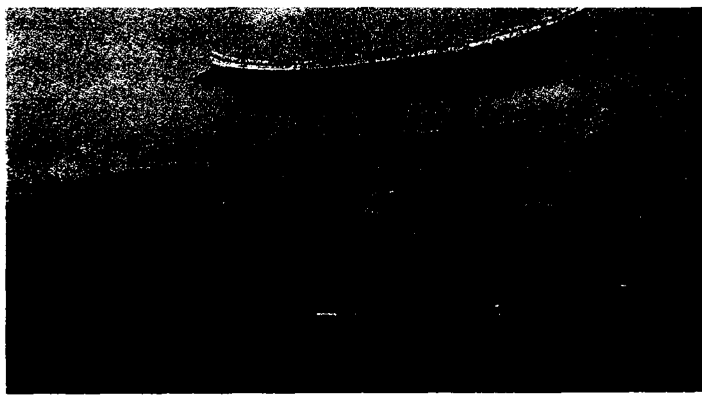
The **Beyond Nuclear** team works with diverse partners and allies to provide the public, government officials, and the media with the critical information necessary to move humanity toward a world beyond nuclear.

The Nuclear Burden

From uranium mining to waste management, nuclear power and nuclear weapons demand needless sacrifices to human health, safety and security. Furthermore, the two technologies are inextricably linked posing an unacceptable nuclear proliferation risk.

Nuclear Energy. From Three Mile Island to Chernobyl, the nuclear industry represents a litany of disasters and near-misses. Tens of thousands of people in Ukraine, Russia and Belarus – including children born after the accident – still endure the deadly health effects of the Chernobyl accident. The U.S. has hidden the true health impacts of Three Mile Island. Routine and accidental radioactive releases and spills continue at reactors in the U.S. and around the world.

Nuclear Weapons. The sickening images of Hiroshima and Nagasaki after the U.S. dropped atomic bombs on these two historic cities should serve as a permanent reminder of the horrors of nuclear war. Even so, soldiers and civilians continue to be sickened by depleted uranium used in the conflicts in the Balkans, Kuwait and Iraq. In an age of terrorism, even a commercial nuclear reactor can be used as a nuclear weapon.



1 If nuclear waste from U.S. reactors begins moving to the Yucca Mountain dump, the transports will pass within one mile of 50 million Americans every day for the next 25-40 years on our roads, rails and waterways.

2 Evacuation plans around U.S. reactors are unworkable. New Orleans was not effectively evacuated in the face of a natural disaster. A crisis involving radioactive releases would result in chaos, permanent relocation and a multitude of deaths.

3 Thirty-two U.S. reactors have radioactive fuel pools at the top level of the reactor buildings, outside of the containment structure and covered by nothing more than sheet metal – an open invitation to attack.

4 The U.S. maintains some 10,000 nuclear warheads – while the U.S. and Russia have more than [illegible] [illegible]

5 The U.S. is making new components for nuclear weapons and in fact plans to escalate its arsenal to levels even higher than during the Cold War.

7 If every U.S. home installed 20 compact fluorescent light bulbs we could displace approximately one quarter of the nuclear plants in the U.S. If we went further and updated the lighting, air conditioning, appliances, and other electrical systems across our economy, we would save more energy than all 103 U.S. nuclear plants produce annually.

The Way Forward

Conservation and Efficiency. Saving energy reduces demand, lowers emissions and cuts costs. Using energy efficient equipment in our homes and businesses is a simple step that saves money, energy and the planet. Changing a light bulb – from an incandescent to a compact fluorescent – delivers 66% greater efficiency and reduces heat emission, lowering air conditioning need as well.

Renewable Energy. Renewable energy can replace polluting and antiquated nuclear power and fossil fuels at less financial and environmental cost. Wind power is already the fastest-growing electricity source world wide and solar panels are saving home owners and businesses money across the United States.

Peaceful Conflict Resolution. Nuclear weapons invite – rather than deter – catastrophic conflict. Disarming makes everyone safer. The U.S. government must lead the way for a global abolition of nuclear weapons by creating an irreversible plan to fulfill its legal treaty obligations, rather than pursuing a dangerous and illegal pre-emptive attack posture.

Beyond Nuclear

Beyond Nuclear faces well-organized and extremely well-funded opposition. That is why we need your financial help.

To be effective, Beyond Nuclear must:

- develop first-rate educational materials
- promote its eye-catching, topical Web site
- send speakers and experts to media events and public appearances
- deliver movement-building resources and tools to our partners and colleagues

Please help **Beyond Nuclear** realize these goals by sending a donation today.

Yes I would like to contribute to Beyond Nuclear!

❑ $10 ❑ $20 ❑ $50 ❑ $100

❑ $250 ❑ Other ____________________

Name: ______________________________

Address: ____________________________

____

Tel: _________________________________

Email: _______________________________

Please visit our Web site to pay by credit card at: www.beyondnuclear.org. Please mail checks made out to Beyond Nuclear to the address shown below. **And we thank you!**

BEYOND NUCLEAR

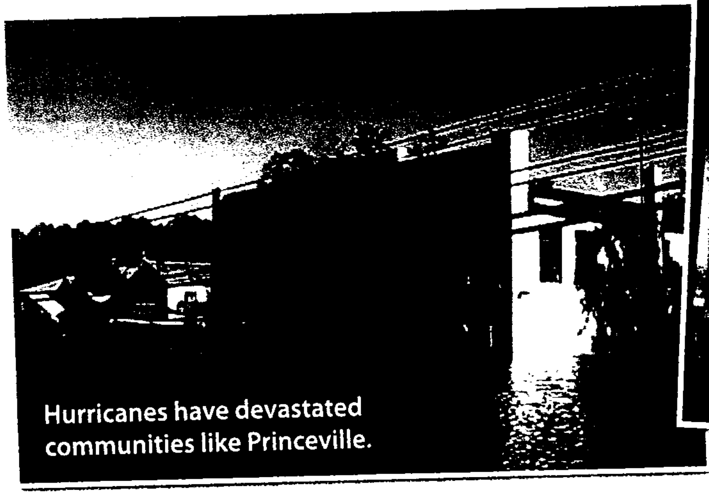
BEYOND NUCLEAR AT NPRI
6930 Carroll Avenue, Suite 400
Takoma Park, MD 20912
Tel: 301.270.2209
Fax: 301.270.4000
Email: info@beyondnuclear.org
www.beyondnuclear.org

Beyond Nuclear

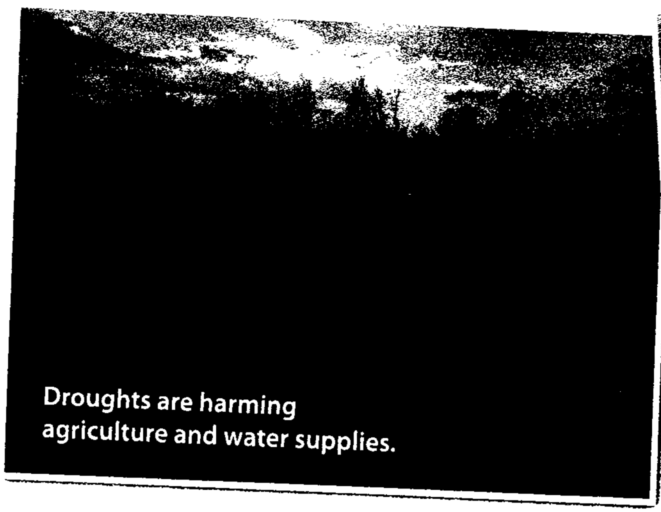
Working for a world free from nuclear power and nuclear weapons

Beyond Nuclear at Nuclear Policy Research Institute

The power companies that helped bring us a climate emergency and failing nuclear plants...



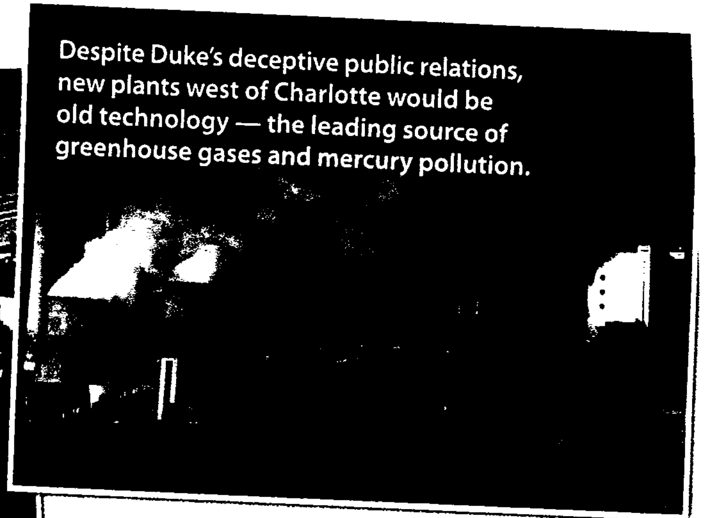
Hurricanes have devastated communities like Princeville.



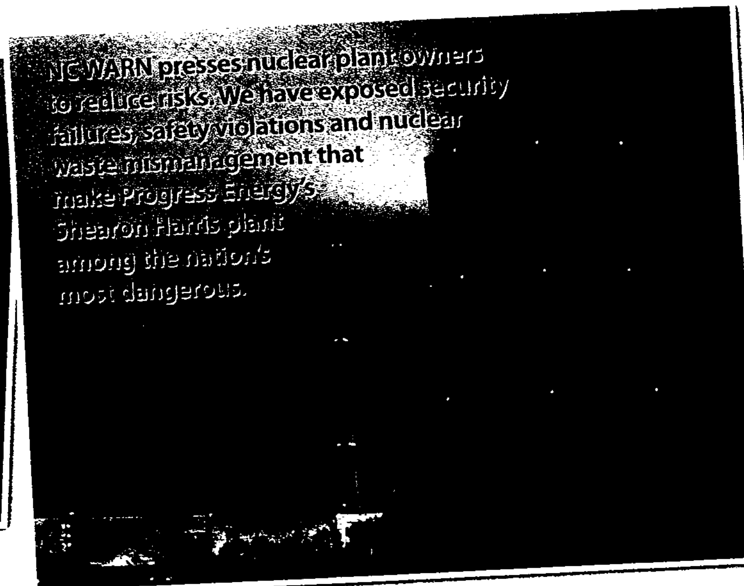
Droughts are harming agriculture and water supplies.

...want to do more of the same, by risking our money and safety.

NC WARN is fighting Duke Energy's plan to build more coal-fired plants...



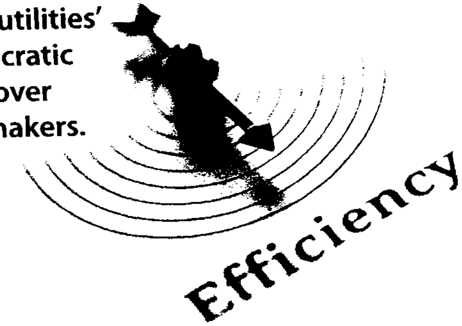
Despite Duke's deceptive public relations, new plants west of Charlotte would be old technology — the leading source of greenhouse gases and mercury pollution.



NC WARN presses nuclear plant owners to reduce risks. We have exposed security failures, safety violations and nuclear waste mismanagement that make Progress Energy's Shearon Harris plant among the nation's most dangerous.

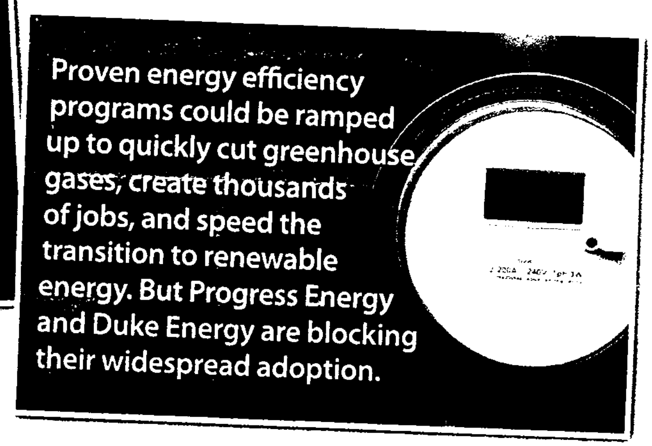
...and plans by both Duke and Progress Energy to build more nuclear plants.

NC WARN pushes for a statewide transition to smart energy, and challenges corporate utilities' anti-democratic influence over decision makers.



Planning new power plants is squandering precious time and money needed to combat global warming.

Even if nuclear power were emissions-free and safe as the utilities claim, building new plants would take too long and cost too much money to slow global warming.



Proven energy efficiency programs could be ramped up to quickly cut greenhouse gases, create thousands of jobs, and speed the transition to renewable energy. But Progress Energy and Duke Energy are blocking their widespread adoption.

Who is NC WARN?

We're a watchdog of the power companies, and we promote safe, sustainable solutions to hazardous electricity generation that harms the public and the environment.

Since the late 1980s, this member-based non-profit has used science and activism to win a string of major grassroots victories involving toxic waste and nuclear hazards.

Our Durham-based staff and volunteers work with community groups, local governments, legal and technical experts, and the news media to expose and challenge the utilities' dangerous practices and corporate influence.

We succeed by focusing our members' voices to demand good decision-making by politicians and regulators.

North Carolina will make the transition to safe, economical electricity...the time is now!

NC WARN
Waste Awareness & Reduction Network

Working for a safe, sustainable energy future for North Carolina

Phone: 919.416.5077
Fax: 919.286.3985
Email: ncwarn@ncwarn.org
Website: ncwarn.org

printed on recycled paper

Everyone has a role.

1. Become energy-smart at home, work and school. See *www.energync.net* (North Carolina Energy Office) for suggestions.
2. Urge your public officials to pass local and state-wide clean energy programs.
3. Strengthen the civic movement to offset utility influence over the media and decision-makers.

***Yes!* I want to be part of a citizens' network working for a transition to safe, economical energy in North Carolina.**

Here's my *tax-deductible* membership of $______.

Suggested Annual Membership:
Individual/Family $35
Student/Low Income $15
Give online! *www.ncwarn.org*
Additional Support is Greatly Appreciated

Name: ____________________

Address: ____________________

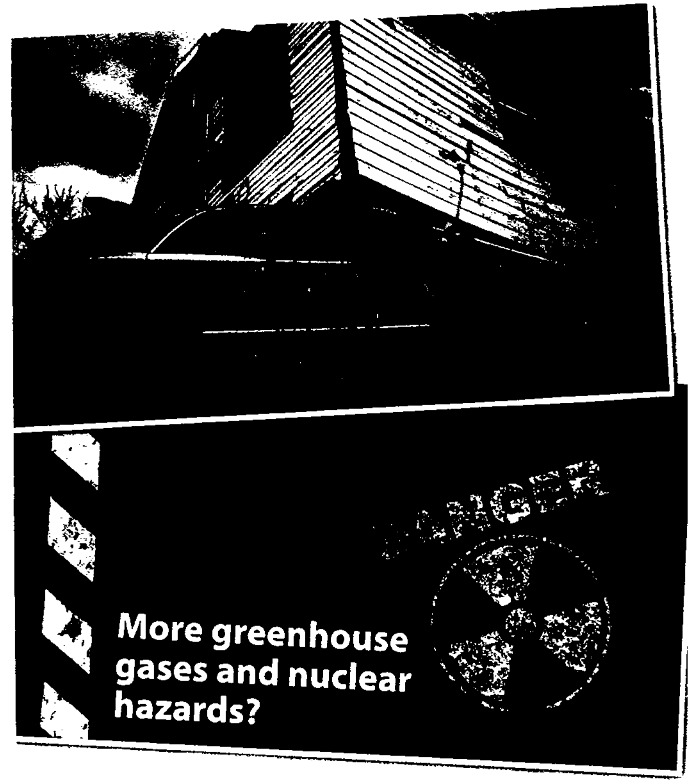
City/State/ Zip: ____________________

Phone: ____________________

Email: ____________________

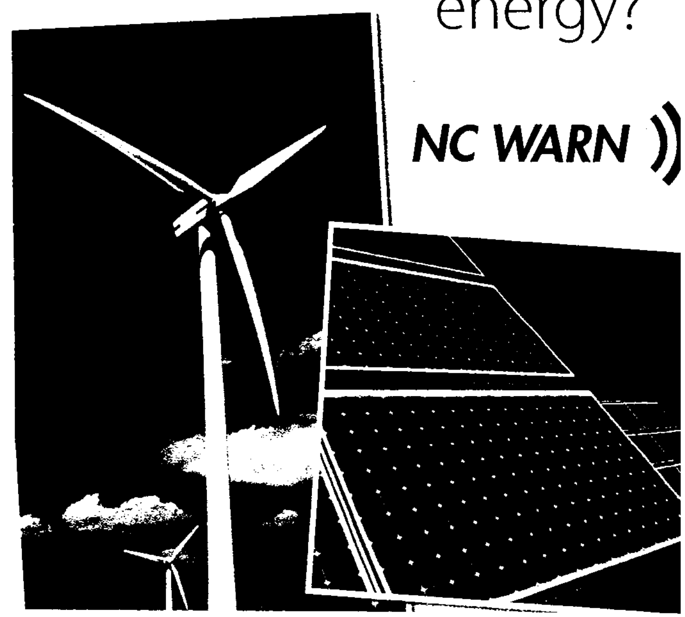
☐ Please contact me to volunteer.

Please mail to
NC WARN, PO Box 61051, Durham, NC 27715-1051



Or a shift to safe, economical energy?

NC WARN



Southern Alliance for
Clean Energy

Why it is a problem and what needs to be done to protect our communities.

Nuclear Power Fact Sheet

Nuclear Power is Expensive.

The construction of Southern Company's nuclear plant Vogtle near Waynesboro, Georgia in Burke County along the Savannah River resulted in the worst rate hike Georgians ever experienced. Original estimates ballooned from more than $600 million for four reactors to more than $8 billion for a 2-reactor plant. Now Georgia Power and its utility partners hope to build up to two more reactors at Vogtle costing billions of more dollars.

Nuclear Power Invites Terrorism.

FBI director Robert S. Mueller said, before the Select Committee on Intelligence in the US Senate in February 2005, "Another area we consider target rich and vulnerable is the energy sector, particularly nuclear power plants." Storing dangerous, highly radioactive spent nuclear fuel outside the reactors in casks or transporting it across the country presents an inviting terrorist target and puts all affected communities at risk. For instance, a 1982 Congressional report estimated that if a meltdown occurred at just one of Plant Vogtle's reactors, it could cause up to 39,000 immediate injuries with costs of over $70 billion (in 1980 dollar and Census figures). [U.S.House of Rep., *Calculation of Reactor Accident Consequences for U.S. Nuclear Power Plants (Health Effects & Costs),* Nov. 1st, 1982.]

Nuclear Power Threatens Our Security.

"Nuclear power entails potential security risks, notably the possible misuse of commercial or associated nuclear facilities and operations to acquire technology or materials as a precursor to the acquisition of a nuclear weapons capability." (Future of Nuclear Power, MIT,2003) Nuclear power reactors create plutonium during their operating cycle—plutonium from which nuclear bombs can be manufactured. Plutonium is one of the most toxic man-made substances known, remaining radioactive for more than 240,000 years.

Nuclear Power Pollutes.

➢ ***Radioactive spent fuel (nuclear waste) is dangerous*** and remains radioactive for millions of years and we have yet to find a solution for effective nuclear waste management. More reactors means more nuclear waste in Georgia.

➢ ***There is no safe level of radiation, no 'safe' dose.*** Radiation exposures damage reproductive cells and can lead to mutations from generation to generation in humans and animals. Each new exposure to radiation adds to the risk of: genetic mutations and cancer, damage to the immune system, spontaneous abortion, mental retardation, spina bifida, heart disease, leukemia and more. [Nat'l Academy of Sciences, *BEIR V & VII; World Health Organization, & more.*]

➢ ***Nuclear power threatens our water supply.*** All reactors must be located next to large bodies of water to create steam to power the turbines and to continuously cool the fuel rods in the reactor core to prevent meltdown. Plant Vogtle, along the Savannah River, currently withdraws over 60 million gallons of water per day, returning only 1/3 of that amount. More reactors will result in much more water needed--competing with other important needs here in Georgia. Hot water is also discharged to the river and this "thermal pollution" can stress organisms living within the area and impact the surrounding environment. More reactors will only make this worse.

What can you do to help?

Contact the U.S. Nuclear Regulatory Commission. They are responsible for licensing new nuclear power plants. Comment on the draft Environmental Impact Statement for two proposed new reactors at Plant Vogtle by 11/28/07. You can send written comments by email to VOGTLE_EIS@nrc.gov.

Tell your local utilities that you have concerns about nuclear power. Urge them to redirect their investments towards affordable, clean, & safe energy solutions such as bioenergy, wind, solar and energy efficiency that can help farmers, forest interests, and rural communities throughout Georgia.

Urge your elected officials to support legislative initiatives that give incentives to energy efficiency and renewable energy and that discourage the continued use of nuclear power.

Join Southern Alliance for Clean Energy at www.cleanenergy.org and build a strong coalition that will advance clean, safe, energy solutions in Georgia!

For more information contact Southern Alliance for Clean Energy
912.201.0354 or www.cleanenergy.org

Call - No Nukes or fax Sincere! to Nuke loan Guarantees - [illegible] Asking us to subsidize our own demise!

JUST SAY NO! Vote for People not dead Corps.

No Nukes - Martinez - Nay to Renewables
Go Solar also Mack (Nelson - full)

Subj: **Vote Imminent, please call/fax Congress this weekend and Monday!**
Date: 12/14/2007 9:39:21 P.M. Pacific Standard Time
From: info@nukefree.org
Reply-to: confirmation@nukefree.org
To: diamondteldeb@aol.com

Fellow Green Energy Advocates:

We have won a great victory, but now face a critical last-ditch fight.

Thanks in part to your efforts, the Congressional leadership has removed proposed loan guarantees from the Energy Bill. Spearheaded by House Speaker Nancy Pelosi and Senate Majority Leader Harry Reid, we took a great step forward for a green-powered future. need for solar + renewables

But now $25 billion in loan guarantees for new reactors, plus $2 billion for uranium enrichment, have been introduced into the Omnibus Appropriations Bill. It will take all our renewed energies to get them removed, as we did from the Energy Bill.

Nukefree.org is committed to this effort, and we are calling on you to continue your support for a safe-energy future. Please take a moment to call your Senators and Representatives, and to also call the offices of Senate Minority Leader Mitch McConnell, House Minority Leader John Boehner, Senate Appropriations Committee Chair Robert Byrd, House Appropriations Committee Chair David Obey, as well as Majority Leader Reid and Speaker Pelosi and tell them to remove the $25 billion in nuclear loan guarantees from the Omnibus Appropriations Bill.

To contact Senators, phone the Senate switchboard and they will connect you: (202) 224-3121.
To contact Representatives, contact the House switchboard at (202) 225-3121.

We know it's the weekend, but MESSAGES ON VOICE MAIL at Congressional offices do get counted, as do FAXES. And if you can call or FAX again Monday morning, that would be great. The final vote may not come until Tuesday. Here's the basic message:

Dear Representative/Senator _________,

I'm writing to urge you to remove the $25 billion in nuclear loan guarantees from the Omnibus Appropriations Bill currently under consideration.

Nuclear reactors have 50 years of proven failure behind them, and we see no reason to build more. They are expensive, dangerous and environmentally destructive. They cannot get their own private liability insurance, cannot solve their nuclear waste problem, and cannot attract private investment without federal guarantees. They offer no solution to the climate crisis, and have been surpassed in every way by the revolution in renewables and efficiency.

Thank you for your consideration.

Sincerely,

F - Dole ✓
Burr ✓
Hayes ✓

See Rest of articles
Bring to create These are

Robin Mark.

Bey Sen Martinez ✓

33920

202 2285171 fax

martinez.senate.gov.

Sen Nelson - full!

✓ Connie Mack -

NUKEWATCH PATHFINDER

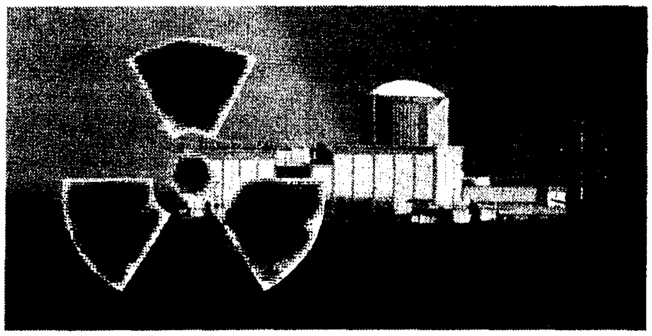
A publication of the Progressive Foundation — Fall 2006

News & Information on Nuclear Weapons, Power, Waste & Nonviolent Resistance

No Nuclear Waste in Utah! Story on page 1

Wisconsin's Kewaunee Reactor Contaminates Groundwater

By Paul Vos Benkowski and Bonnie Urfer



A tritium leak at Wisconsin's Kewaunee nuclear reactor on the shore of Lake Michigan has contaminated the groundwater beneath the site. A Nukewatch press release alerted the media which resulted in limited coverage state wide.

A tritium leak at the Kewaunee nuclear site on the shore of Lake Michigan has contaminated the groundwater beneath the reactor in eastern Wisconsin. A Nuclear Regulatory Commission report, issued on August 9, said the radioactive groundwater had infiltrated into narrow shafts beneath two buildings. The alarming notice and subsequent sketchy reports reveal that tritium contaminated water is leaking at the rate of one gallon every five minutes. No one knows when the leak began. Kewaunee is not the only leaking reactor in the country. To date close to one quarter of U.S. reactors have leaked tritium into the ground and in the case of Braidwood in Illinois, into drinking water.

The situation at Kewaunee was discovered when Dominion, owner and operator of the reactor, voluntarily investigated the site for signs of leakage. They found elevated levels of radioactive contamination onsite. Detected tritium levels were between 6,000 and 103,000 Pico curies per liter. The U.S. Environmental Protection Agency's safety limit for tritium is 20,000 Pico curies per liter. The source of the leak is unknown, but the cooling pool for irradiated fuel rods has been ruled out and investigators are looking at piping beneath the reactor.

Dominion contacted the State of Wisconsin's Department of Emergency Management and Department of Natural Resources Regional Office, the Kewaunee and Manitowoc County Emergency Directors and the NRC Resident Inspector.

An unacceptable number of tritium leaks have occurred within the past six months, shattering the notion that nuclear reactors are a safe and reliable source of energy. Reactors with tritium leaks include: Callaway, Missouri; St. Lucie, Florida; Diablo Canyon and San Onofre, California; Prairie Island, Minnesota; Braidwood, Dresden and Byron in Illinois; Pickering (site of eight reactors), Ontario, Canada; Indian Point and Brook Haven Research reactor, New York; Palo Verde, Arizona; Connecticut Yankee, Connecticut; Sequoyah and Watts Bar, Tennessee and the Kewaunee reactor in Wisconsin. The groundwater beneath the Braidwood, Dresden, Brook Haven, Palo Verde, Indian Point, Diablo Canyon, San Onofre and Kewaunee sites are all at contamination levels above EPA and NRC standards.

The NRC investigates these reactor leaks, but always a little too late. These leaks have been steadily occurring for years. A case in point is the San Onofre nuclear reactor near San Clemente, California which has been shut down for 15 years but is still leaking tritium into the groundwater below the site. It is unknown how much has seeped out, where it came from or when the leak started, although the closest guess is 1968.

Tritium is a radioactive isotope of hydrogen which is produced in the reactor core. It has a half life of 12.5 years. It remains radioactive for 120 years. Even in low levels it has been linked to developmental problems, cancer, genetic defects, miscarriages and damage to fetuses as it crosses the placenta. A poison any way you look at it, yet the NRC and the nuclear industry have been slow to confront this growing problem and the agency assures the public that there is no danger.

It's Nukewatch's opinion that it's best to shut the nuclear industry down — before we drink the radioactive water.

Subj: **SOLAR NATION --- U.S. SENATE VOTES FOR THE PAST**
Date: 12/14/2007 12:53:00 P.M. Pacific Standard Time
From: chris@solar-nation.org
To: diamondteldeb@aol.com

U.S. SENATE, REVERING HISTORY, VOTES FOR THE PAST 202-224-3121 More Info

Yesterday, the U.S. Senate dealt a losing hand to all those who believe in solar power as a vital component of our energy future.

By a vote of 59-40, just one vote short of the number needed to cut off debate, the Senate failed to include a tax title in the 2007 energy bill that would have provided investment and production tax credits for renewable energies.

Many people have worked long and hard this year to secure a government commitment of support for solar and other nascent renewable industries, including solar citizens like yourself, Congressional Democratic leadership, environmental and conservation groups, industry associations, and scientific bodies. And although representatives and senators were left in no doubt about the importance of the legislation to America's future, the peculiarities of the American way of politics trumped common sense and hope. Senators from states where the oil and gas industry lobby is strongest voted to continue support for the industry, even though the proposed tightening of tax breaks would have amounted to only 1%-2% of its net profits. To see which senators voted against the tax title measure, check the list at the end of this message. (Look closely and you'll find one Democrat who voted 'nay', and one presidential candidate who failed to vote at all).

Late yesterday evening, the Senate finally voted on what was left of the bill. Absent investment tax credits, production tax credits and a national renewable electricity standard (RES), the bill sailed through by a vote of 85-12. It will now go back to the House, then on for signature by President Bush. And what the President signs will contain CAFE standards for automobile mileage standards, a renewable fuels mandate, and provisions for energy efficiency in federal government departments. For renewables, there is practically nothing.

The timing of the vote may strike historians as curious in years to come; half a world away in Bali, attendees at the UN global warming conference were working toward final agreement on long-term measures to mitigate climate change while the U.S. Senate was rewarding the oil and gas industry for its long-term support.

That renewable energy development in America has suffered a setback is not in question. But reports of its death have been greatly exaggerated. Congressional Democrats have stated that they intend to resurrect the RES and tax credit issues in their next session, perhaps in a separate, dedicated bill. And lobbyists for renewable industries have vowed to keep up pressure on legislators from now until the November elections.

For all those solar citizens who took the time this year to call, fax or e-mail their legislators over this issue, we say a loud and heartfelt "THANK YOU!" And yes, you were heard. In the week before Thanksgiving, the House of Representatives took the tax title off the table; the uprush of public outrage caused by this maneuver forced the lower chamber to restore the funding in short order. Did this matter, given the final result? It certainly did, because now no-one on Capitol Hill can be in any doubt that renewables have a high level of support among their constituents. This should impact Congress' decision-making as an election year unfolds.

For news on the Senate vote from RenewableEnergyAccess.com, click here

For Solar Nation commentary, click here.

And the joy of the season, and all seasons, to you. info@1sky.org

Solar Nation

FLORIDA PUBLIC SERVICE COMMISSION
DOCKET NO. 070650-EI **EXHIBIT** 5
COMPANY Witness on behalf of the of FL
WITNESS Debbie Arnason
DATE 01/09/08

Public Citizen News

July/Aug 2007

Nuclear Experts Warn Against Repeating Errors

Public Citizen Brings Delegation to United States to Educate Lawmakers, Citizens

By Robert Yule

On a recent visit to the United States, international nuclear experts warned Americans not to repeat the costly and dangerous mistakes other countries have made by creating a program to "reprocess" nuclear waste.

Public Citizen brought the experts here to educate lawmakers and the American public about the problems with reprocessing programs, which separate plutonium and uranium from nuclear waste.

The three experts – who spoke about the debacles of the reprocessing programs in France, the United Kingdom and Japan – all commended the United States for its decision 30 years ago to abandon such efforts.

However, things are poised to change in the U.S. The Bush administration has created a new program, the Global Nuclear Energy Partnership (GNEP), which will revive reprocessing in the U.S. as a way to deal with the nation's radioactive waste. In theory, the plutonium would be used to make fuel for so-called "fast reactors" – a kind of reactor that has not been successfully commercialized anywhere in the world.

The Department of Energy is looking at 11 sites to build not only a reprocessing plant, but also a spent fuel storage facility and what is known as a fast reactor. The sites are in Portsmouth, Ohio; Oak Ridge, Tenn.; Paducah, Ky.; Barnwell, S.C.; Morris, Ill.; Hobbs, N.M.; Roswell, N.M.; Atomic City, Idaho; the Hanford Site in south central Washington; the Savannah River Site in southwestern South Carolina; and the Idaho National Laboratory, located west of Idaho Falls, Idaho.

The agency also is proposing to build a research facility for developing the reprocessing technology and fuel for the fast reactor.

The fast reactor is a key component of the GNEP program. However, the reactors remain unsafe, uneconomical and unable to address the problems of nuclear power, even after decades of research and experimentation.

> "The U.S. government should heed the lessons of reprocessing failures from around the globe. The technology is costly, highly polluting and will only add to our nuclear waste problem, not reduce it."
>
> – Michele Boyd, legislative director, Public Citizen's Energy Program

In addition to meeting with Washington-based journalists and lobbying lawmakers on Capitol Hill, two of the experts – Shaun Burnie, an independent consultant from the United Kingdom, and Aileen Mioko Smith, founder of a Kyoto, Japan-based citizen group – traveled to South Carolina, Georgia and Illinois.

The two met with local journalists and lobbied state lawmakers, governors and federal legislators to reject reprocessing. They also educated local citizens and activists about the costs and dangers of reprocessing programs and nuclear waste.

According to Burnie, who specializes in reprocessing and waste disposal and transportation consulting, other countries with reprocessing programs for spent nuclear fuel have found that the technology is too costly and does not solve the problem of radioactive waste.

For example, a July 2000 report commissioned by the French government concluded that reprocessing is uneconomical – costing about $25 billion more than a normal fuel cycle – and does little to reduce the amount of long-lived radioactivity in the waste.

The Rokkasho reprocessing plant in Japan was also uneconomical, costing $20 billion and taking 12 years to build, Smith said. Smith pointed out that Japan's reprocessing plant would contribute tens of tons more plutonium to the nation's waste stockpile within just five years.

Reprocessing plants are not without their dangers, according to William Walker, a professor of international relations at the University of St. Andrews in Scotland who attended the Washington, D.C., portion of the tour.

In England, a recent leak of 20 tons of uranium and plutonium fuel from the government-owned reprocessing plant in Sellafield led to the plant's operator calling on the government to permanently close the facility, which had been losing money even when it was operational. Walker warned that once governments begin reprocessing programs, they tend to have trouble stopping them – even when they are not successful.

Although the Ford and Carter administrations both took steps to end commercial reprocessing in the U.S., we have not cleaned up the high-level radioactive waste and other pollutants more than 30 years later from a reprocessing site at West Valley, N.Y. – estimated to cost $5.2 billion. The U.S. also reprocessed to get plutonium for nuclear weapons, which resulted in highly radioactive liquid waste in tanks at Hanford and the Savannah River Site that continues to threaten important water resources, including the Columbia and Savannah rivers.

As an alternative, storing radioactive materials in hardened facilities at individual reactor sites is the safest means to deal with nuclear waste in the near-term, said Michele Boyd, legislative director of Public Citizen's Energy Program.

"The U.S. government should heed the lessons of reprocessing failures from around the globe," said Boyd. "The technology is costly, highly polluting and will only add to our nuclear waste problem, not reduce it."

Also see:
AOL/Microsoft-Hotmail Preventing Delivery of Truthout Communications

Waiting for the Energy
By Kelpie Wilson
t r u t h o u t | Environment Editor

"Addicted to Oil" Nuclear is a fossil-fuel, Like switching drinks or deck chairs on Titanic. Subsidize our own Demise - Lawmakers asking/telling US to pay for it. NO

Thursday 11 October 2007

Conventional wisdom among environmentalists today says it would be unwise to pass a major climate change bill too soon. As long as the Bush veto looms and Republicans retain the filibuster club in the Senate, any climate change bill that passes through that birth canal is likely to be a stunted, shriveled thing. Better to wait until a strong bill can be passed than to establish a weak policy now.

But energy is supposed to be different. President Bush has admitted that America is "addicted to oil," and he is a big booster of technology as the solution to global warming. At his major-economies meeting on climate change in September, Bush called for an international fund to help developing nations finance clean-energy projects to stem climate change. But when he refused to offer a funding commitment or any other mechanism to implement the plan, international delegates turned up their noses and said they would wait till 2009 to engage the US on climate.

You might expect that Bush would be more willing to put his money where his mouth is where the US is concerned, but that does not seem to be the case.

Both houses of Congress passed energy bills last summer. The Senate, in particular, made a big effort to produce a bipartisan consensus. Environmentalists are calling the new energy bill "a down payment on efforts to combat global warming." But President Bush has not come out in support of either the House or Senate version of the bill.

Meanwhile, getting both houses of Congress to sit down and reconcile two very different bills has been difficult. In early September, Democrats sent discouraging signals about any bill passing this session. Perhaps they heard from their constituents, because by the end of the month, Harry Reid, the Senate majority leader, was promising to appoint conferees soon. It was to have been last week and has now been postponed until after the Senate gets back from its Columbus Day recess. On Wednesday, House Speaker Nancy Pelosi met with other Democrats to discuss bringing an energy bill directly to the floor.

There is no question that public support for clean, renewable energy is at an all-time high. This is showing up at the state level, where 31 states have passed some sort of mandate to produce energy from solar, wind and other renewable sources. The National Governors Association is proceeding to coordinate programs as best it can in the vacuum of federal energy policy. At an NGA forum on renewable energy, Minnesota Governor Tim Pawlenty (a Republican) said, "Energy is the defining issue of our time. The public is way ahead of the politicians ... there is enormous running room for policy makers to make significant advances ... there's an urgency to this issue, and none of us - Democrats, Republicans, politicians and the public - have acted as urgently as we need to."

With such strong public support, why have the Democrats found it so difficult to produce an energy bill?

Cars, Coal and Nukes

One problem has been Michigan Representative John Dingell, who chairs the House Energy Committee. Backing the position of Detroit automakers, Dingell refused to allow any increase in Corporate Average Fuel Economy (CAFE) fuel mileage standards.

And while the House bill has no CAFE increase, the Senate bill lacks a Renewable Energy Standard (RES). The House passed a RES requiring utilities to generate 15 percent of their power from renewable sources (mostly solar, wind and biomass) by 2020. The US is one of the few nations left that has not adopted such a standard, but Bill Wicker, on the staff of Senate Energy Committee Chair Jeff Bingaman, said the Republicans "blocked every effort" to include a national RES in the Senate energy bill.

Matt Letourneau, energy policy aide to Senator Pete Domenici, ranking member of the Senate energy committee, said a national RES would be unfair to some regions of the country that don't have abundant renewable resources, particularly the Southeast. He said the standard is too high and it is "not possible" to get 15 percent of the region's power from renewable energy.

But Scott Sklar, a solar energy lobbyist, said that there is plenty of renewable energy in the Southeast. "The Southeast is biomass rich and solar rich. Solar could provide 5-6 percent of the region's power, wind 1-2 percent and biomass 10-15 percent. The waste biomass from Hurricane Katrina alone could provide power for 30 years." Utilities can also substitute up to 4 percent of the target with increases in efficiency.

Lynn Hargis, a former attorney with the Federal Energy Regulatory Commission (FERC), who now works for Public Citizen monitoring energy regulation, said that the real problem is giant utility companies in the South, such as Duke, Entergy and Southern Company, which want to make huge profits selling cheap, coal-generated power in unregulated markets.

leave out

The Senate bill also includes loan guarantees of up to $50 billion for nuclear power. Tyson Slocum of Public Citizen calls that "an unprecedented financial obligation" and says that inclusion of those loan guarantees in a final bill would "overwhelm any benefits" from the other provisions.

Analysts say that loans to build nuclear plants are distinctively "sub-prime" with the risk of utilities defaulting running well over 50 percent, according to the Congressional Budget Office. Taxpayer billions wasted on boondoggle nuke plants are taxpayer billions that can't be spent putting solar panels on roofs or developing better batteries for electric cars.

Scott Sklar is less concerned about the loan guarantees. He says that any energy bill able to get past a Republican filibuster and a Bush veto will include loan guarantees for nuclear power, so there's no point in fighting it. He predicts that the Democrats will pass an energy bill by January or they "won't survive" the pressure from constituents, and that the bill will include lighter versions of the RES and CAFE standards, along with renewed production tax credits for solar and wind power.

But if the RES and CAFE provisions are watered down even more than the current versions, what will that do to our climate policy down payment?

A new analysis released by Environmental Defense shows that if we do nothing, US greenhouse gas emissions will rise 35 percent by 2030. If all of the best provisions from both House and Senate versions pass and are vigorously implemented, emissions would climb only 4 percent above today's levels by 2030. But because many of the provisions allow flexibility, if they are not implemented aggressively, they will allow emissions to grow 22 percent by 2030.

Combine this flimsy "down payment" with the sub-prime nuke loans, and you don't end up with much value. We need to do a lot better than this if we are going to prevent the worst ravages of global warming and hang on to our planetary home.

Scott Sklar says it is possible that Democrats could produce a final energy bill that is stronger than both current versions, but they would have to "ram" it through.

Democratic leaders could bypass a formal conference committee and strike a bicameral deal to put an energy bill directly on the floor in both houses at once. Nancy Pelosi indicated on Wednesday that she would pursue that option. A strongly progressive energy bill might not survive a Bush veto, but at least it would energize the progressive constituency that is ready for a real energy revolution.

Struggle Behind the Scenes

Meanwhile, a series of skirmishes is taking place over coal among utilities, politicians, agencies and environmental groups.

Two weeks ago, Representative Henry Waxman sent a letter to the US Environmental Protection Agency, objecting to its permitting of a coal-fired power plant in Deseret, Utah. Waxman said the recent Massachusetts v. EPA Supreme Court decision requires EPA to address the coal plant's greenhouse gas emissions under the Clean Air Act. The Sierra Club is following up with a lawsuit.

On September 14, New York Attorney General Andrew Cuomo subpoenaed five of the country's largest energy companies, demanding that they disclose the financial risks of their greenhouse gas emissions to shareholders.

Some environmental groups are targeting banks that invest in coal power-plant construction. Rainforest Action Network is planning protests at Citigroup and Bank of America branch offices around the country on November 16. "We're going upstream," a RAN spokesperson said. "Without bank financing, utilities can't actually build any of those plants."

Peter Montague of Environmental Research Foundation reports that since the beginning of 2006 at least two dozen new coal-fired plants have been canceled. Montague says, "A small but effective citizens' movement has managed to box in Big Coal."

Politicians are starting to declare themselves against coal. Presidential candidate Barack Obama released his energy and global warming plan this week, saying he would oppose all new coal-fired generation that did not include carbon capture and storage technology.

Just last week, Tampa Electric Co., a Florida utility, announced it was canceling plans to build a coal plant with carbon capture and storage because of uncertainties around the technical feasibility. Florida is one state that has been very clear that it won't allow any new coal-fired generation without carbon capture and storage. The Massachusetts Institute of Technology estimates that it will take ten years of testing for the technology to mature, if we start today. But today there is not even one demonstration plant anywhere in the world that incorporates the complete cycle of carbon capture and storage.

Senate majority leader Harry Reid also opposes new coal plants and has introduced a far-reaching bill (S. 2076 - the Clean Renewable Energy and Economic Development Act) that limits the federal financing of power transmission lines to those that carry at least 75 percent renewable energy. It applies the same standard to new power lines crossing federal land. This would keep Big Coal out of some of the new energy corridors that may be established under the Energy Policy Act (EPACT) of 2005.

But King Coal is hardly down for the count.

In early September, FERC designated a set of new national power corridors in the Northeast under the EPACT. State regulators and environmentalists are suspicious about the locations of the corridors, which seem designed to funnel cheap coal power from the Ohio Valley to the Northeast - where states have already committed to reducing greenhouse gasses, but power demand is high. Under the EPACT, federal regulators can override state concerns. Environmental Defense is considering a lawsuit.

Power to the People

Michael Peevey, president of the California Public Utilities Commission, said in a recent opinion piece for the San Francisco Chronicle that the old energy paradigm - where large centralized generators convert fossil fuels to electricity which is sent over transmission lines to homes and businesses - is over. Solar, he says, is a "disruptive technology" that is changing everything. He says the California Solar Initiative passed last year is on track to power one million homes by 2017.

And in California, it is not just homes getting powered; it is also people who are getting empowered.

Van Jones, an environmental and social activist and cofounder of the Ella Baker Center for Human Rights in Oakland, California, was interviewed on the radio program Living on Earth last week about the impact of solar jobs on the American workforce:

"There's a wonderful program, which I just can't stop bragging on, called 'Solar Richmond,' where they got a modest amount of money, got 20 guys - you know low-income African-American, Latino, Filipino, one African-American woman. For nine weeks these guys got up, this young woman got up, every morning. They had to be there at nine o'clock. They had to learn these skills. Nine weeks later they did their first installation. There were local TV cameras there, solar employers were there saying, 'hey, we need workers.' And you know, the look on these young people's faces. Often these are the young men who are always seen as the villains and yet here they are, nine weeks later, African-American, Latino, with the baggy pants, the hair or whatever, but they've got their work boots on, they've got their orange jerseys on, and they're doing this work. And they are the ecological heroes."

One of the stupidest news stories on energy I've seen was a piece on CNN Money last week that said economists were "split" on whether renewable energy would create millions of new jobs. The article quoted experts at the Energy and Resources Group at the University of California, Berkeley, affirming that installing solar arrays, building wind farms and producing biomass would create at least a million new jobs, not vulnerable to offshore outsourcing. To counter them, the article quoted the chief economist at a Manhattan consultancy, who said it would be unrealistic to count on job gains in the solar sector since the technology hasn't taken off yet and there is no way of knowing if it ever will. "You certainly don't want to move all sorts of money into an area that's not going to be viable," he said.

Sadly, there are still too many people like this brain-dead economist running things in this country. And there are still too many unfortunates living in the past, such as the auto workers who have given up almost everything to hang on to production lines making Detroit Dinosaurs - those gas guzzlers no one will want in a few years' time when oil supply peaks and gas prices shoot up to the moon.

The future belongs to "Solar Richmond," and all we are waiting for now is for those who think they are in charge to catch up with rest of us so we can build this beautiful new future together.

The Boston Globe

Dr James Hansen
of NASA on
fossil-fuel addiction

The wrong choice for Massachusetts

By James Hansen
January 2, 2008

THE EARTH is close to passing climate change "tipping points." Greenhouse gases released in burning fossil fuels are nearing a level that will set in motion dangerous effects, many irreversible, including extermination of countless species, ice sheet disintegration and sea-level rise, and intensified regional climate extremes.

As a society we face a stark choice. Move on to the next phase of the industrial revolution, preserving and restoring wonders of the natural world, while maintaining and expanding benefits of advanced technology. Or ignore the problem, sentencing humanity and other creatures to struggle on an increasingly desolate planet. Massachusetts is on the cusp of making this choice, and, barring citizen objections, is in danger of making the wrong choice on two counts.

Energy legislation in the state Senate would reshape rules designed to encourage renewable energies, modifying them to encourage energy generation from coal. A proposed amendment to the "Green Communities Act" - in most respects a good piece of legislation - provides incentives for coal gasification technologies without requiring carbon capture and sequestration. If passed, Massachusetts would be promoting projects that increase greenhouse gas emissions, just when we need to reduce emissions!

Meanwhile, the Department of Environmental Protection granted draft approval and is poised to grant final approval to a project extending the life of an 80-year-old coal plant with coal gasification that would not capture and sequester carbon dioxide emissions. Prolonging the life of NRG Energy's coal-fired power plant in Somerset would be a tragic mistake. This plant was scheduled to shut down in January of 2010 or to "repower" as a new cleaner plant. NRG now proposes to do neither. Instead, it wants to retain its dependence on dirty fuel, converting the plant's boiler to "plasma gasification" of coal.

NRG and state officials have resisted a comprehensive environmental review, demanded by environmental groups like the Conservation Law Foundation, which would compare the greenhouse gases that NRG's proposal is expected to emit over its extended lifetime with other scenarios, including a complete shutdown. The Somerset project should not be rushed through without full environmental review.

If the wonders of nature, our coastlines, and our social and economic well being are to be preserved, our society must begin phasing out coal use until and unless the carbon dioxide emissions are captured and stored. Continuing to build coal-fired power plants without carbon capture will lock in future climate disasters for our children and grandchildren.

The people of Massachusetts took great risk, for the sake of themselves and their progeny, when they drew a line with the British at Lexington and Concord. It is time for a line to be drawn with the powerful special interests, who reap profits from our fossil-fuel addiction.

Changing the course dictated by fossil-fuel interests will not be easy. It requires leadership to define a path with increased support for energy efficiency and clean-energy sources. But this is what citizens must demand, as they tell their government to say no to coal.

The alternative is to shrink from personal responsibility and allow the pleadings and misinformation of special interests, driven by motives of short-term profit, to determine government actions.

But is that a picture of our generation we dare leave for our children, a picture of timidity in the face of special-interest greed?

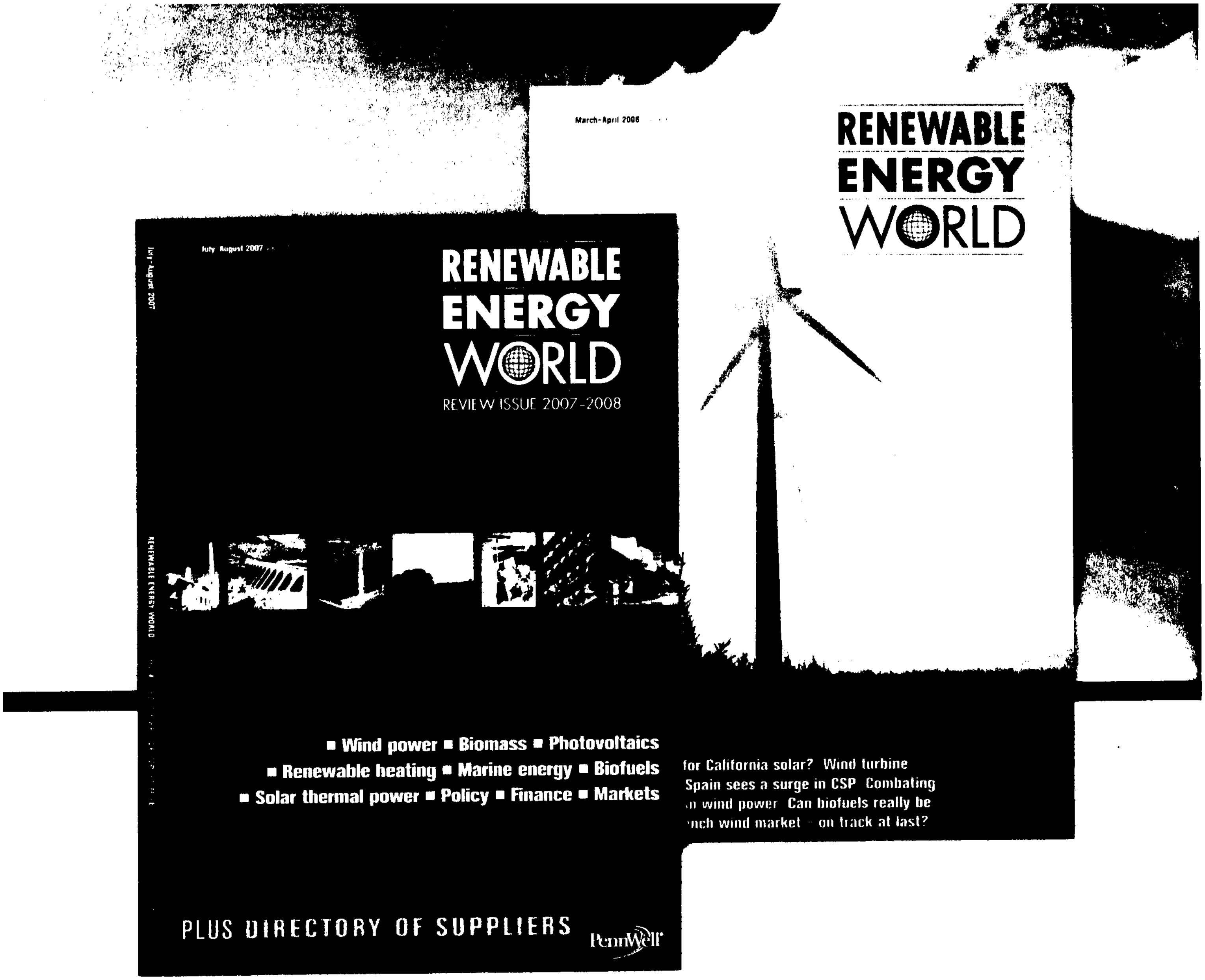
We live in a democracy. Policies represent our collective will. We cannot blame others. If we allow the planet to pass tipping points, to set in motion irreversible changes to the detriment of nature and humanity, it will be hard to explain our role to future generations.

Today, the citizens of Massachusetts have two opportunities to change this course: first, by contacting legislators and demanding rejection of attempts to subsidize coal through legislation that mistakenly treats coal gasification as a "clean energy" technology; second, by demanding that NRG Energy be held to its original commitment to shut down or repower as a truly new and clean plant.

This is an opportunity for citizens of Massachusetts to exercise leadership again, taking bold actions to oppose entrenched special interests and helping initiate change that is essential if we are to retain a hospitable climate and a prosperous future for our children.

James Hansen *is director of the NASA Goddard Institute for Space Studies. This column is his personal opinion.*

http://www.boston.com/bostonglobe/editorial_opinion/oped/articles/2008/01/02/the_wrong_choice_for_massachusetts/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for California solar? Wind turbine
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Subj: **[saveitnowglades] Small wind systems**
Date: 10/25/2007 6:39:26 P.M. Pacific Daylight Time
From: ljacobs50@comcast.net
Reply-to: saveitnowglades@yahoogroups.com
To: no_coal@yahoogroups.com

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OCTOBER 2007 VOLUME 2 ISSUE 15

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Distributed Architectural Renewable Energy Generation

Electric Cos! Stay in business by hybridizing local solar generators into the existing grid!

Brian Braginton-Smith
Executive Director
Sustainable Resources Group

blog about this

In today's energy marketplace professionals and planners are lamenting the looming potential of wholesale energy supply shortages. Issues concerning the growing energy supply demands include every sector from the long term availability of non-renewable fossil fuel resources to issues relating to transmission and distribution constraints and limitations. In many areas of the world it is not the availability of generation but the availability of transmission capacity to wheel the power around from where it is generated to where it is needed that is the issue.

The potential costs associated with increasing the efficiency of and expanding the capacity of transmission and distribution infrastructure, are staggering and difficult to get financed. Another potential facet of the energy supply scenario is the concept of distributed generation, on the village or consumer level. A facet of this venue has become known as architectural or building integrated energy, this article will discuss renewable energy specifically.

The Return of Distributed Generation

This distributed generation model existed prior to the establishment of the national electrical grid network, before power companies and transmission and distribution were initiated in the early 20th Century by federal programs such as the Rural Electrification Administration and regional entities like the Tennessee Valley Authority. Distributed generation as a resource lost the debate, as fossil fuel costs were low and the promise of nuclear generation with rates too low to meter, were promised.

Distributed generation has long been the domain of the solar industry where small scale solar thermal arrays and photovoltaics (commonly known as PV) are installed at consumer locations where direct retail offset of the retail energy supply is accomplished. This distributed generation provides a venue for the mitigation of centralized plant supply shortages and transmission and distribution infrastructure constraints. The world of consumer based supply

STOP DINGELL + BOUCHER FROM CRIPPLING EPA for Auto + Coal Industry

instead of Nukes

Solar power in space, why not on Earth?

STOP GLOBAL WARMING - ONLY HOME WE HAVE!

Also Cloudy Germany + Oil Rich Abu Dhabai use Solar Concentrators - We can too

Author: Karl Grossman

People's Weekly World Newspaper, 09/21/06 18:02

For years NASA insisted it couldn't be done. Beyond the orbit of Mars, NASA said, solar energy could not be used to generate electricity for onboard power on space devices.

So the agency used the extremely dangerous nuclear substance plutonium — and people on Earth were put at great risk in the event of an accident.

For instance, in 1997 NASA launched its Cassini plutonium-fueled space probe, and in 1999 it had Cassini hurtle back at Earth in a "slingshot maneuver" to increase its velocity so it could get to Saturn. If there was an "inadvertent reentry" of Cassini into the Earth's atmosphere during this maneuver, it would disintegrate and "5 billion … of the world population … could receive 99 percent or more of the radiation exposure," NASA admitted in its Final Environmental Impact Statement for the Cassini Mission.

The potential death toll from a Cassini accident was put by Ernest Sternglass, professor emeritus of radiological physics at the University of Pittsburgh School of Medicine, at 20-40 million.

This is not a sky-is-falling story. Of 28 U.S. space missions using plutonium, there have been three accidents, the worst in 1964 in which a plutonium-powered satellite fell back to Earth, breaking up and spreading the toxic radioactive substance widely.

That caused NASA to develop solar power for satellites — and today all satellites (and the International Space Station) are energized by solar panels. But, insisted NASA, in deep space sunlight is too weak, and solar energy could not work, only plutonium would.

Now the leading space industry trade magazine, Aviation Week & Space Technology, reveals that solar energy is to be used by NASA to substitute for nuclear power in deep space: "Budget and technical realities have led NASA to put its once-ambitious space nuclear power plans on a slow track, but development in solar power generation should allow new scientific probes beyond Mars to operate without nuclear energy. The U.S. space agency is already planning a solar-powered mission to study the atmosphere of Jupiter, and has looked at sending probes as deep into space as Neptune using only the Sun's energy for spacecraft and instrument power … It is all but certain the next U.S. deep-space missions will be solar-powered."

The piece described the new giant solar energy systems that will be used to harvest solar energy at record efficiencies vast distances from the Sun.

Bruce Gagnon, coordinator of the Global Network Against Weapons & Nuclear Power in Space, comments, *"For years NASA said that we didn't know what we were talking about. Now NASA is planning to do what we've been saying all along they could do. It just goes to show that if you are willing to stay on top of an issue for a long time, something good can come from your hard work."

Jeremy Maxand, executive director of the Snake River Alliance, an Idaho group that's been challenging the use of Idaho National Laboratory to produce plutonium for space power systems, says, "We've said since day one that plutonium is unnecessary and dangerous, and that we can do the same job a better way, and now we're seeing what that better way is — solar."

What's to happen in space is what should also happen on Earth. The Bush administration and nuclear industry are pushing for a "revival" of nuclear power.

We don't need to take the enormous risk of building new nuclear plants — or having nuclear poisons over our heads. Safe energy technologies are here.

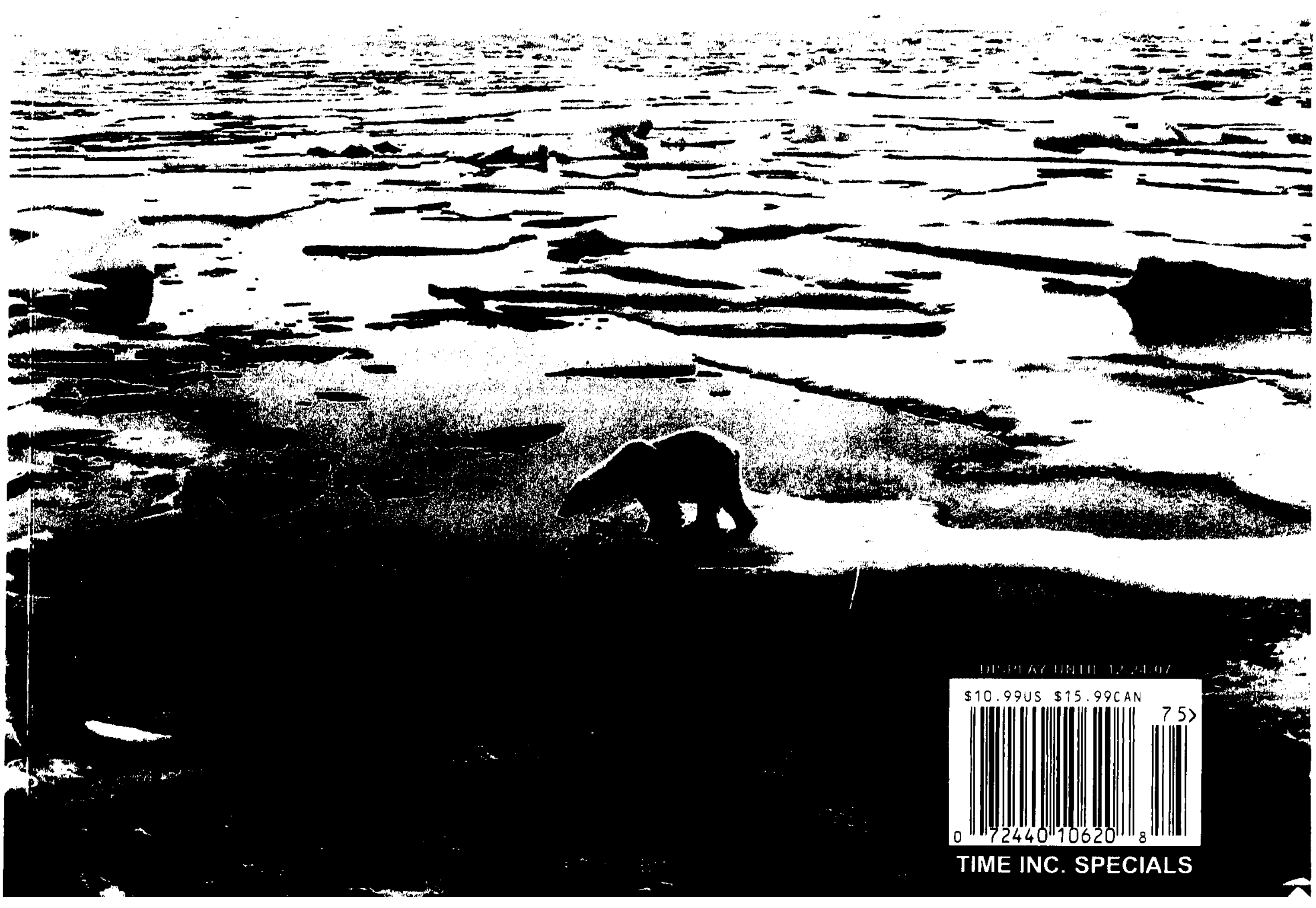
Karl Grossman, professor of journalism at the State University of New York/College at Old Westbury, is the author of "The Wrong Stuff" and narrator of the documentary "Nukes In Space" (www.envirovideo.com).

*Duke Power would say the same + be WRONG ... its just cheaper + easier for them to ask ratepayers to pay for their own pollution
Subsidize our own demise?

TIME

GLOBAL WARMING

The Causes • The Perils • The Solutions
The Actions: What You Can Do



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TIME INC. SPECIALS

Benchwarmer *A windmill atop this British bus station heats its seats. In the future, more power will be generated onsite rather than created centrally and transmitted via power lines*

MARTINE HAMILTON KNIGHT—ARCAID—CORBIS

was only in the mid-1800s, after the forests had largely been felled and whales hunted to the brink of extinction, that people began listening to energy prophets like Edwin Drake, who believed that the black slime bubbling out of the ground in places like Oil Creek, Pa., could be used for fuel.

The revolution unleashed by Drake and other petroleum pioneers, like John D. Rockefeller, remade the world. We now find ourselves at a similar threshold, not because the world is quickly running out of hydrocarbons (although some experts argue persuasively that it is) but because we can't live much longer with the consequences of their continued use.

The earth is, quite simply, choking on greenhouse gases. Global carbon dioxide output in 2006 approached a staggering 32 billion tons, with about 25% of that amount coming from the U.S. Turning off the carbon spigot is essential, and many of the proposed alternatives are familiar: windmills, solar panels and nuclear plants. All these technologies are already part of today's energy mix, though each has serious drawbacks.

But there is reason to be encouraged. A May 2007 report produced by the United Nations Intergovernmental Panel on Climate Change concluded that many of the worst consequences predicted for global warming can still be averted by making the switch to renewable, nonpolluting sources of energy. The report found that government incentives designed to encourage more widespread adoption of technology that already exists—combined with legal mandates to make cars, homes and factories more energy efficient, as well as aggressive investment in renewable energy—could hold global temperature increases to around 3.6° Fahrenheit above preindustrial-era levels, which is low enough to avoid potentially disastrous droughts, severe storms and sea-level rise.

One of the frustrating myths about alternate energy is that we're still waiting to find a single energy source to replace hydrocarbons. The truth is, we may never do so, because no one source is likely to fit the bill. While oil and its cousins, coal and natural gas, are now king, they will most likely be succeeded not by another absolute monarch but instead by a parliament of many energy sources.

If the task of replacement seems daunting, it is helpful to recall that the people who built our hydrocarbon economy faced similar obstacles and in conquering them not only made the world a better place for everyone, but also enriched themselves in doing so.

In the years to come, fortunes will have to be invested on drilling wells into the ground (looking for heat instead of oil), laying vast networks of pipelines (to transport hydrogen rather than fossil fuels), building new power plants (that collect energy from the sun and wind) and manufacturing cars that run on electricity or on fuel derived from corn, sugarcane or hydrogen instead of hydrocarbons. The pioneers who succeed in doing so will be the Rockefellers of a new age, remaking and improving the world.

* In the meantime, the phases by which we have come to acknowledge global warming and begun to relinquish our embrace of hydrocarbons closely track the five stages of grief experienced by terminally ill patients, as formulated by Elisabeth Kubler-Ross in the 1960s. First came Denial ("This isn't happening"), then Anger ("How can this be happening?"), followed by Bargaining ("Just let us use dirty energy for one more generation, then our children will switch to alternate sources of power"). The fourth step is Depression ("There's nothing we can do about this"). Finally, there is Acceptance ("The world that we're moving toward is a better one"). In the first decade of the 21st century, we appear to have just about finished Bargaining, and we're now facing the question of whether we can skip Depression and go straight to Acceptance. ■

TIME GLOBAL WARMING INC SPECIALTIES 800-327-6388 Editor Kelly Knauer

SOLAR CAN SOLVE ENERGY PROBLEM... without Nuclear hazards

Need an "American Idol" show for Solar

The good news is that solar power has never been hotter. More than 1 million rural homes in developing countries get electricity from the sun, and fully 80% of China's hot water comes from solar cells. The not so good news is that while solar power has enormous potential, it is decades away from supplying a significant slice of the world's overall energy consumption. As of 2006, according to the International Energy Agency, that share was 0.4%.

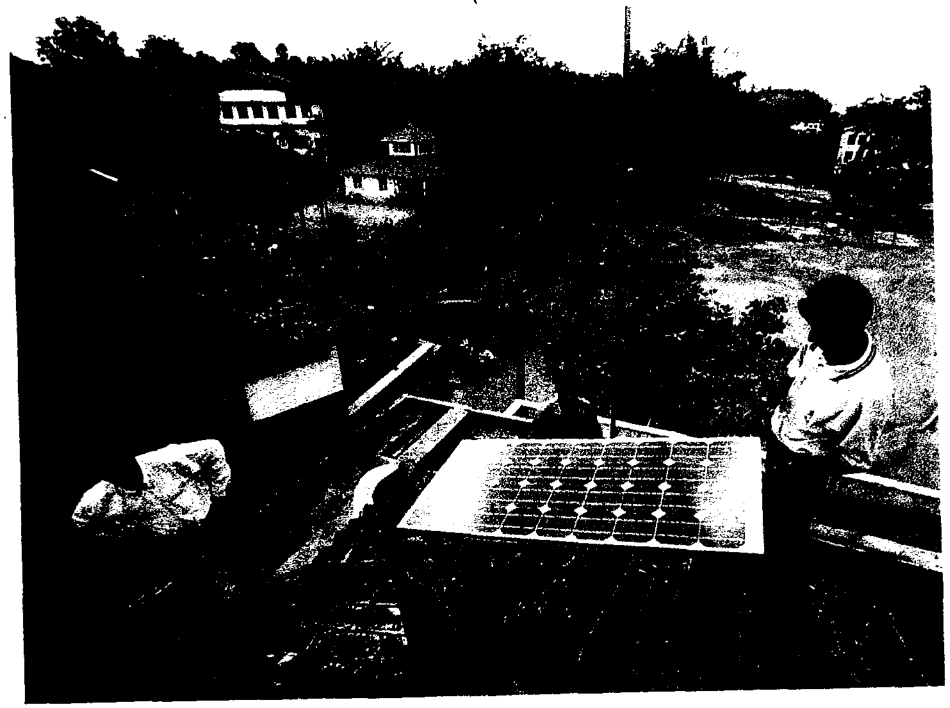
Why? To begin with, the technology is still in its infancy. The first practical photovoltaic cell, which uses silicon to convert sunlight into electricity, was developed in 1954, making solar power younger than the transistor. Yet solar has lagged, while the latter technology has already transformed the world.

Perhaps more important, solar power has an image problem. Since their invention, solar cells have proved far more useful in generating publicity than electricity. Decades of inflated hopes have been followed by deflating results. The last time many Americans paid attention to solar power was in the 1970s, when a series of oil shocks prompted President Jimmy Carter to install solar panels on the roof of the White House. (They were removed by the Reagan Administration a few years later.) In Carter's day, solar equipment was bulky, ugly, anemic in output and very expensive, a recipe for public resistance.

Most people remain in the dark about solar power's capabilities. One persistent myth: solar cells don't work on cloudy days. In fact, photovoltaics will generate electricity in any kind of daylight, although their output is greatest when the sun is brightest. Few people realize that solar-power technology has evolved several generations since the 1970s. Solar cells now convert as much as 17% of the energy they gather from the sun into electricity, up from 6% when they were developed. At the same time, the price of cells has plummeted: solar cells cost more than $200 per watt of generating capacity in the 1950s; the figure was $2.70 per watt in 2004. Since then, a silicon shortage has pushed the price back up, to approximately $4 per watt.

Despite the silicon shortfall, the technology is steadily improving. One vision of the future of solar power can be found in the desert outside Las Vegas, where the $250 million Nevada Solar One power plant is scheduled to come online in the summer of 2007. This state-of-the-art facility will use acres of mirrors to focus solar radiation onto a turbine, producing 64 megawatts of current—enough to power more than 40,000 homes—more cheaply than almost any other solar plant in the world.

The U.S. Department of Energy has set a goal of making solar power cost-competitive with more traditional forms of power, like coal and oil, by 2015. Department scientists calculate that if solar panels covered just 0.5% of America's landmass, they could generate all the electricity the nation currently requires. At least for now, however, the maddening conundrum remains: a clean source of power that falls from the sky, cuts out the middleman and for which the fuel is free still costs more than the dirty old combustibles we have to pull out of the ground.



SCOTT SELLS—REDUX

Sign of the times *Workers install a solar panel on a home in rural India, outside the town of Hanuman Nagar*

Total Recall

The Recent Plague of Tainted Toys

Repeated recalls of children's toys and accessories from shelves and toy boxes has families wondering what's next. Which manufacturers can we trust? Now help is here in databases sponsored by the BabyCenter and the Consumer Product Safety Commission.

"Not only are the 3 billion toys sold in America each year cheaply made and environmentally insensitive, they also, as recent recalls of Chinese toys demonstrate, can pose a real threat to our little ones," writes journalist Lou Bendrick.

Grist.org reports that one recall alone accounted for a half million children's toys and accessories that exceeded allowable lead levels. The Consumer Product Safety Commission warns that more can be expected. In addition to lead paint woes, other causes for recalls include detachable magnets and buttons small enough for tykes to swallow.

Thank goodness for the resurgence of quality toys, signaling that it's time to rethink the whole arena. As an editorial in *The New York Times* suggests, perhaps our daughters don't need a talking dump truck or Malibu Barbie beach house. Instead, "Let her flail on a saucepan with a wooden spoon. Give her paper and crayons."

To stay up with recalls check CPSC.gov/cpscpub/prerel/category/toy.html and BabyCenter.com/product-recall-finder.

Energy High

Solar Power Plant to Orbit Earth

Capturing sunlight via an orbiting platform and beaming electrical power to Earth has the potential to supply endless energy, help stave off climate change and avoid future conflicts over oil, according to a new study led by the National Security Space Office, Department of Defense.

"This is a solution for all mankind," observed former astronaut Buzz Aldrin at the Washington announcement. Aldrin chairs the spaceflight advocacy group ShareSpace Foundation.

The consensus of 170 collaborating experts worldwide estimates that in a single year, satellites in a continuously sunlit orbit could generate an amount of energy nearly equivalent to the total energy available in global oil reserves. Mark Hopkins, senior vice president of the National Space Society, maintains that making this one move could transform the United States into an energy-exporting nation. "It is the largest energy option available to us today…more power potentially than all of the other power sources combined," says Hopkins.

Since the dawn of the Space Age 50 years ago, scientists have dreamed of this day. But technology and cost hurdles stood in the way. Now Charles Miller, director of Space Frontier Foundation, believes that with the proper public and private support, the space-based solar power industry could take off within 10 years.

For more information see NSS.org/settlement/ssp/index.htm.

SOLAR BREAKTHROUGH · Duplicate - extra

Subj: **Bob-This it?"The energy that reaches Earth from sunlight in one hour is mo...**
Date: 4/9/2007 1:08:58 P.M. Pacific Daylight Time
From: DiamondtelDeb
To: Minimushomines

Is this what we discussed today? Hope you can make it to CHEJ, but if not, see you in Tallahassee. Please e-mail me by Wednesday any form to have signed. thanks, love, Deb. 704-851-3925 or fax on request at 704-851-3367 or cell 386-288-4454.

Forwarded Message:
Subj: **[No_Coal] "The energy that reaches Earth from sunlight in one hour is more than that used by all human activities in one year."**
Date: 4/9/2007 6:17:52 A.M. Pacific Daylight Time
From: marshmaid@hughes.net
Reply-to: No_Coal@yahoogroups.com
To: saveitnowglades@yahoogroups.com, blouda@fau.edu, No_Coal@yahoogroups.com, coalition@lists.riseup.net, Terryporter@semtribe.com, amber@webfl.com, barrynh@browardaudubon.org, business7007@adelphia.net, Alliance4Cleanfl@aol.com, seadogdoc@earthlink.net, Carahendu@yahoo.com, dmountn@aol.com, dgreene@dishmail.net, misqueetoo@aol.com, ecrone1@gmail.com, gcavros@att.net, harrisfriedman@floraglades.org, hdixon33917@earthlink.net, msjylstar@hotmail.com, jankartist@aol.com, crittergraphics@peoplepc.com, JFraser@semtribe.com, pegasus@strato.net, mlelighthouse@EARTHLINK.NET, spainy@comcast.net, nancydale@yahoo.com, yatkitischee@earthlink.net, cyda_33440@yahoo.com, sahein@earthlink.net, stevenb@conservancy.org, azaroa40@earthlink.net, susanglickman@verizon.net, boo2ms@yahoo.com, big_lake_bubba2000@yahoo.com, afarago@bellsouth.net, Djumper-Frye@semtribe.com, stephenbuc@earthlink.net, Donlocomm@aol.com, MartiSD@comcast.net, Audubon@Okeechobee.com

Sent from the Internet (Details)

Solar power breakthrough at Massey

By MERVYN DYKES - Manawatu Standard | Thursday, 5 April 2007

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MURRAY WILSON/Manawatu Standard

COLOUR THEIR FUTURE GREEN: Wayne Campbell, left, and Ashton Partridge with a tiny demonstration solar panel filled with synthetic dye. Not only is it environmentally friendly and capable of being made in New Zealand, but it costs a

STATE

Where is SAFE Affordable SOLAR as Primary Focus ?

oard to refile d by judge

luctant to approve and that has left h one of the low- rates in the nation. fficials say that has budgets that have quality and limited

, though, the Leg- l board agreed on tuition increase, arlie Crist vetoed islature passed it pecial session and r approved the in- tive for the spring

nd the private plain- luding former U.S. Rep. Lou Frey and former Florida State University President Talbot "Sandy" D'Alemberte, failed to show what kind of "special injury" they have suffered, challenge a specific appropriation or identify an unlawful expenditure of public money.

Former Florida Supreme Court Justice Stephen Grimes, a lawyer for the private plaintiffs, said he was confident they could meet those requirements, but he declined to discuss details.

"We have the opportunity to refile this complaint and we'll seek to do that," Grimes said. "Ultimately we believe we can prevail."

lant equal to ton of TNT

d. Other parts were as a mile away. of the explosion has mined and Hall said n to determine if it y human error, me- or a combination. rs have not been able to enter the debris field of the failed reactor because it is still too hazardous, Hall said.

So far, the investigation has been confined to surveying the nearby businesses, documenting blast damage, identifying injuries, interviewing injured workers and collecting security camera videos.

Energy proposals include more nuclear power, conservation

Associated Press

TALLAHASSEE — More nuclear power, energy conservation and letting customers who generate their own electricity sell excess amounts to power companies are among a wide range of climate-change recommendations that went to the Legislature on Thursday.

The nine-member Florida Energy Commission, appointed by legislative leaders, also proposed that its own role and membership be expanded including appointments by the governor.

The commission then would be able to centralize the state's approach to energy policy. The panel's additional duties would include recommending grant awards, authorizing incentive programs, advocating public awareness and conducting educational and academic summits.

"Florida's energy policy governance structure must provide a more unified, strategic and streamlined approach to providing energy from generation to end-use," said Sen. Lee Constantine, the only legislator on the commission. "That's what this particular recommendation is all about."

Constantine, R-Altamonte Springs, has been a strong advocate of the centralized approach.

The commission's report includes a timetable for slashing greenhouse gases emissions by 2050 that it approved in November over objections from utility and business interests. It is a slightly watered down version of a plan Gov. Charlie Crist announced in July.

The commission's recommendation would require polluters to reduce emissions to 2000 levels by 2020, to 1990 levels by 2030 and to 80 percent of 1990 levels by 2050. Crist's plan would have allowed three fewer years to meet the first goal and five fewer years to achieve 1990 levels. waste

The commission wanted to give time utilities more time to add nuclear + power and increase the use of $ biomass and solar energy. why ?

What you *ARE NOT* supposed to know:

1. **It doesn't take an accident** for a nuclear power plant to release radioactivity into our air, water and soil. All it takes is the plant's everyday routine operation, and federal regulations permit these radioactive releases.

2. Radioactivity is measured in "curies." A large medical center, with as many as 1000 laboratories in which radioactive materials are used, may have a combined inventory of only about two curies. In contrast, an average operating nuclear power reactor will have approximately 16 billion curies in its reactor core. This is the equivalent long-lived radioactivity of at least 1,000 Hiroshima bombs.

3. A reactor's fuel rods, pipes, tanks and valves can leak. Mechanical failure and human error can also cause leaks. As a nuclear plant ages, so does its equipment – and leaks generally increase.

4. Some contaminated water is intentionally removed from the reactor vessel to reduce the amount of the radioactive and corrosive chemicals that damage valves and pipes. This water is filtered and then either recycled back into the cooling system or released into the environment.

5. A typical 1000-megawatt pressurized-water reactor (with a cooling tower) takes in 20,000 gallons of river, lake or ocean water per minute for cooling, circulates it through a 50-mile maze of pipes, returns 5,000 gallons per minute to the same body of water, and releases the remainder to the atmosphere as vapor. A 1000-megawatt reactor without a cooling tower takes in even more water – as much as one-half million gallons per minute. The discharge water is contaminated with radioactive elements in amounts that are not precisely tracked, but are potentially biologically damaging.

6. Some radioactive fission gases, stripped from the reactor cooling water, are contained in decay tanks for days before being released into the atmosphere through filtered rooftop vents. Some gases leak into the power plant buildings' interiors and are released during periodic "purges" or "ventings." These airborne gases contaminate not only the air, but also soil and water.

7. Radioactive releases from a nuclear power reactor's routine operation often are not fully detected or reported. Accidental releases may not be completely verified or documented.

NUCLEAR POWER PLANTS OF THE SOUTHEASTERN U.S.

1. **North Anna 1 & 2**
   intake & discharge to Lake Anna, VA &, ultimately, to the Chesapeake Bay.
2. **Surry 1 & 2**
   to the James River in VA, then to the Chesapeake Bay.
3. **Shearon Harris**
   to Buckhorn Creek, & the Cape Fear River, NC.
4. **McGuire 1 & 2**
   to Lake Norman on the Catawba River, NC.
5. **Brunswick 1 & 2**
   to the Cape Fear River at Southport, NC.
6. **Catawba 1 & 2**
   to Lake Wylie on the Catawba River, SC.
7. **Oconee 1, 2 & 3**
   to Lake Keowee, near Seneca, SC.
8. **H. B. Robinson 2**
   to Lake Robinson, near Hartsville, SC.
9. **Summer**
   to Monticello Reservoir, near Jenkinsville, 26 mi. northwest of Columbia, SC.
10. **Vogtle 1 & 2**
    to the Savannah River, near Waynesboro, GA.
11. **Hatch 1 & 2**
    to the Altamaha River, near Baxley, GA.
12. **Crystal River 3**
    Crystal River in FL to the Gulf of Mexico.
13. **St. Lucie 1 & 2**
    to the Atlantic Ocean, 8 mi. south of Fort Pierce, FL.
14. **Turkey Point 3 & 4**
    to Biscayne Bay of the Atlantic Ocean, 10 mi. east of Florida City, FL.
15. **Farley 1 & 2**
    to the Chattahoochee River, east of Dothan, AL.
16. **Grand Gulf**
    to Mississippi River, near Port Gibson, MS.
17. **Browns Ferry 2 & 3**
    to the Tennessee River, near Athens, AL.
18. **Sequoyah 1 & 2**
    to Chickamauga Lake, near Soddy Daisy, TN
19. **Watts Bar**
    to Chickamauga Lake, near Spring City, TN

TOTAL REACTORS: 33

8. Accurate, economically-feasible filtering and monitoring technologies do not exist for some of the major reactor by-products, such as radioactive hydrogen (tritium) and noble gases, such as krypton and xenon. Some liquids and gases are retained in tanks so that the shorter-lived radioactive materials can break down before the batch is released to the environment.

9. Government regulations allow radioactive water to be released to the environment containing "permissible" levels of contamination. **Permissible does not mean safe.** Detectors at reactors are set to allow contaminated water to be released, unfiltered, if below the "permissible" legal levels.

10. The Nuclear Regulatory Commission relies upon self-reporting and computer modeling from reactor operators to track radioactive releases and their projected dispersion. A significant portion of the environmental monitoring data is extrapolated – virtual, not real.

11. Accurate accounting of all radioactive wastes released to the air, water and soil from the entire reactor fuel production system is simply not available. The system includes uranium mines and mills, chemical conversion, enrichment and fuel fabrication plants, nuclear power reactors, and radioactive waste storage pools, casks, and trenches.

12. Increasing economic pressures to reduce costs, due to the deregulation of the electric power industry, could further reduce the already unreliable monitoring and reporting of radioactive releases. Deferred maintenance can increase the radioactivity released – and the risks.

13. Many of the reactor's radioactive by-products continue giving off radioactive particles and rays for enormously long periods – described in terms of "half-lives." A radioactive material gives off hazardous radiation for at least ten half-lives. One of the radioactive isotopes of iodine (iodine-129) has a half-life of 16 million years; technetium-99 = 211,000 years; and plutonium-239 = 24,000 years. Xenon-135, a noble gas, decays into cesium-135, an isotope with a 2.3-million-year half-life.

14. It is scientifically established that every exposure to radiation increases the risk of damage to tissues, cells, DNA and other vital molecules. Each exposure potentially can cause programmed cell death (apoptosis), genetic mutations, cancers, leukemia, birth defects, and reproductive, immune and endocrine system disorders.

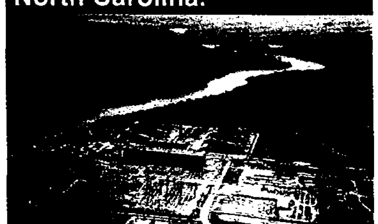
This pamphlet is intended for reprint and, therefore, is not copyrighted.

Nuclear Plant Releases to Air, Water and Soil

A Reactor Building vent at a typical 1000-megawatt pressurized-water reactor.

It does not take an accident . . .

Brunswick Reactors 1 & 2 water intake and discharge area on the Cape Fear River, North Carolina.



Hatch Reactors 1 & 2 water intake and discharge area on the Altamaha River in Georgia.

Typical discharge points for gaseous and liquid releases to air, water and soil

from nuclear power plants including:

planned releases from the reactor's routine operation

and

unplanned releases from leaks and accidents.

RADIOACTIVE RELEASES FROM THE NUCLEAR POWER PLANTS OF THE SOUTHEASTERN UNITED STATES

WHAT ARE THE DANGERS?

Best one for Beth re: Water

Nuclear Information and Resource Service
World Information Service on Energy - Amsterdam

1424 16th St., N.W., Suite 404, Washington, D.C. 20036
202-328-0002, FAX 202-462-2183 • nirsnet@nirs.org
• www.nirs.org • www.antenna.nl/wise •

February 2002

Dear Ones:

2007 we have worked especially hard to leave the planet a better place for our children and grandchildren!

Near our winter home in Alva, FL, we learned of plans by Florida Power & Light to put an enormous no-such-thing-as-clean coal plant in the heart of our endangered Everglades. Joining with local as well as national groups and individuals, and under the auspices of a new, more environmentally-friendly Governor, we defeated the proposed coal-burner as well as several others in progress. Once denied coal, FPL "suddenly" discovered it was possible to use solar power after all!

Then in the spring and summer here in NC, we read of Duke Energy's two-faced efforts to claim they were "green" while trying to build a dirty coal-plant outside Charlotte. Once again, concerned citizens were able to call a temporary halt to such an insane plan at a time of drought and global warming. We even had Dr. James Hansen of NASA come and speak for us.

Coal and nuclear plants waste 21 million gallons of water a day per plant, add thousands of tons of CO2 either directly or in their construction and other pollutants like mercury, acid rain, particulate and radiation to our air and water. Solar, green building, algae, wind, wave energy are more than enough to power our planet in a healthy way. Getting our sick, fossil-fuel addicted politicians off corporate welfare requires tough love on our part. It works if we work it.

Throughout the year, Deb and occasionally, Arne, have been busy on street corners and at special events all over FL, NC and Washington DC, working for peace, environmental and social justice, especially the impeachment of the corporate obstructionists in office who have repeatedly violated our Constitution. If they were CEO's they'd have been fired long ago. Call 202-224-3121 to voice your opinion to your "elected" representatives in Congress. We do. Often. The people, united, cannot be ignored!

The news media is also corporate controlled. Follow the money - CNN advertiser "Americans for Balanced Energy" is actually a front organization for big Coal and Nuclear, Fox of course is the Corporate Propaganda Channel seeking to pit Americans against each other

Peace

and too worked up to bother with the truth, ABC is Big Pharma and Disney, so don't expect their news to be anything but Fantasyland and so on.

We find real news from Public and British Broadcasting, Free Speech TV, Democracy Now and on the internet from Truthout.org, Information Clearing House, and a multitude of climate and governmental interest groups not tainted by corporate spin.

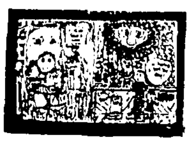
You might try Friends of Earth, (FOE.org), NCWARN.org and Clean-Air-Coalition.org, Public Citizen, Common Cause or Hightower Lowdown for laughs. Don't overlook www.thepatriots.us, Military Families Speak Out, Sojourners, Grassroots Impeachment Movement, GRIM.org, and an umbrella organization to help pull all our separate movements together called 1 Sky www.1skycampaign.org

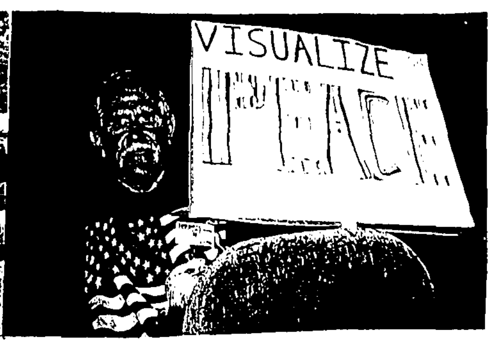
I know this is a Holiday letter, supposed to be full of cheer and good wishes. And it is! We have had a wonderful year. Grandchildren helped us with letters and posters. We gained a sense of community and purpose with others in Florida and the Carolinas, visited with family and friends from New Jersey, Pennsylvania and in Iceland where we met more of Arne's wonderful family during 2 weeks in September.

Local, sustainable living in community is our answer. Grow a tomato in a pot or join a food coop. Change a light bulb. Call your Representatives and ask them to "Go Solar." Buy a hybrid if possible. (I love my Prius - 50 MPG, quiet, clean and dependable.) All that is needed is for concerned citizens to say "NO" to business-as-usual. When you consider that our oxygen cover is just 6 miles high, we must act now to clear the air. We can do it for ourselves and the future.

Happy Holidays with much love and gratitude for all God's creation,

Deb and Arne Arnason Deb and Arne
Diamondteldeb@aol.com
360 Webb Rd, Wadesboro, NC 28170 til 12/22/07
12 Dill Street, Alva, FL 33920 - 239-728-3147 or cells 386-288-4454 Deb, 4450 Arne





On the Horizon

Algae: The Alternative-Energy Dream Fuel

What needs only sunlight, water and carbon dioxide to grow, can quadruple in a day, helps remove pollutants from the air and water and has the potential to fuel every vehicle in the U.S.? Algae. In fact, using algae as a feedstock for biofuels has so many advantages over other biomass sources that some experts believe it will eventually eclipse all others, though large-scale commercial production is still about five years off.

Algae are highly efficient converters of solar energy into chemical energy—fuel for cars, homes, power generators and so on. Some strains are over 50% oil, and their yield per acre is tremendous. Average per-year, per-acre oil yield for firms that grow algae for use in the food and pharmaceutical industries today is sufficient to make about 5,000 gallons of biodiesel. An acre of soybeans typically yields enough oil to make about 70 gallons of biodiesel, while an acre of corn converts into about 420 gallons of ethanol.

"Your bang for your buck is just bigger because you can really do this on a much smaller amount of land and yet yield much, much higher biomass," says Michael S. Atkins, CEO of **Ocean Technology & Environmental Consulting** (OTEC), a San Francisco bay-area firm that is developing photobioreactors—enclosed systems that produce algae in layer upon layer of tubes or shallow ponds.

Algae have another powerful appeal as a biomass source. The aquatic organisms thrive on harmful emissions such as nitrogen from wastewater and carbon dioxide from power plants. So growing them can help solve other environmental problems and provide an additional income stream.

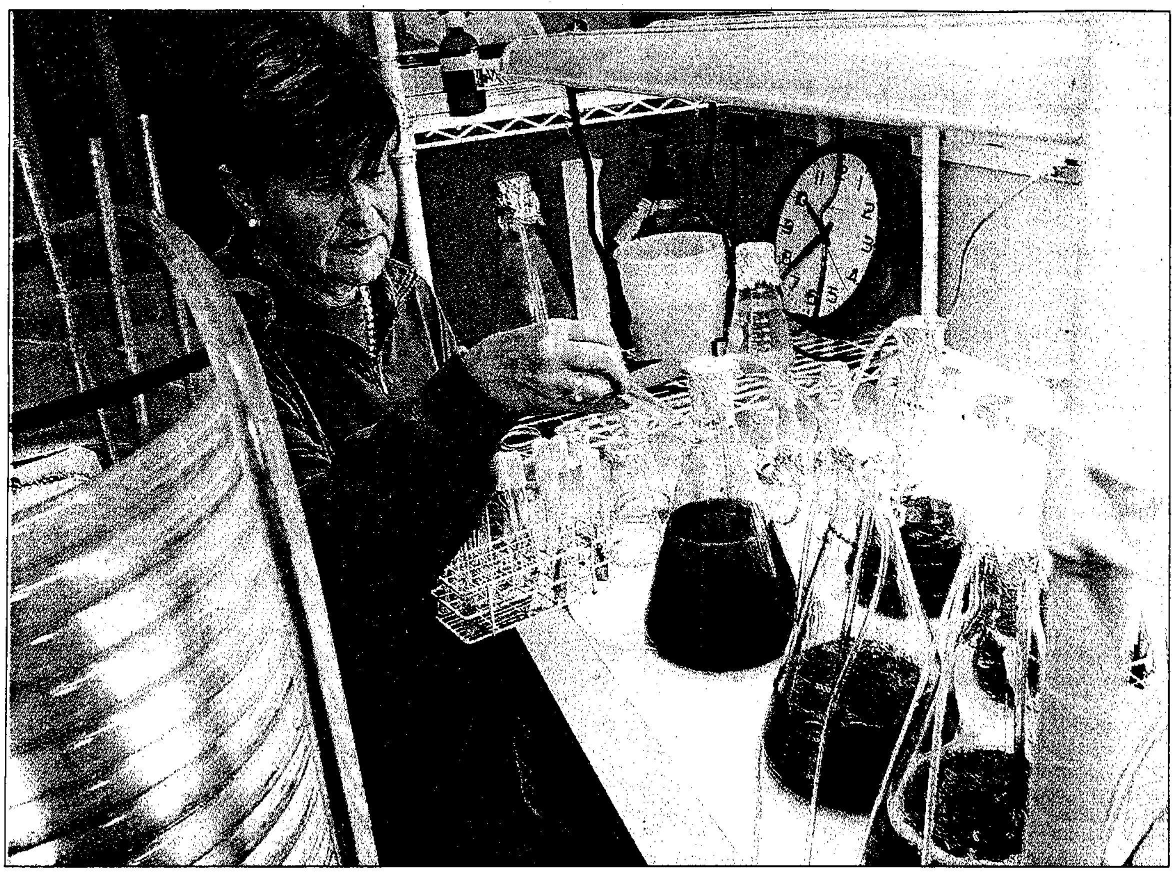
OTEC, for example, is working with the **Mohave Generating Station** in Laughlin, Nev., to get the plant, which is majority-owned by a Calif. company, in compliance with Calif. clean air standards and back on-line. OTEC will install about 10 photobioreactors to capture the carbon emissions from the plant. The CO_2 will then help feed algae production at a nearby site.

Similarly, **GreenFuel Technology Corp.** of Cambridge, Mass., is working with power plants in Arizona, Louisiana and Germany to build algae producing photobioreactors. Recent tests by GreenFuel show its system captured about 80% of the CO_2 emitted during the day when sunlight is available.

Between that and the tremendous potential yields algae production offers—according to the Department of Energy's National Renewable Energy Laboratory, up to 15,000 gallons of biodiesel a year from a saltwater pond—the financial outlook for algae-based biodiesel is rosy. ■

China's Fading Ethanol Future

China's rapid growth in ethanol output will slow to a crawl under a new government rule, effective immediately, that restricts production to nonfood feedstocks.



THOMAS WHISENAND - ASSOCIATED PRESS PHOTO

Scientist Blanca Martinez works with varieties of algae at the Center for Biorefining at the University of Minnesota in St. Paul. Driven by renewed investment as oil prices push $100 a barrel, scientists are racing to turn algae into a commercially viable energy source.

Algae research blooms

High oil prices renew interest in their promise as renewable energy

BY STEVE KARNOWSKI
Associated Press

ST. PAUL, Minn. — The 16 big flasks of bubbling bright green liquids in Roger Ruan's lab at the University of Minnesota are part of a new boom in renewable energy research.

Driven by renewed investment as oil prices push $100 a barrel, Ruan and scores of scientists around the world are racing to turn algae into a commercially viable energy source.

Some varieties of algae are as much as 50 percent oil, and that oil can be converted into biodiesel or jet fuel. The biggest challenge is slashing the cost of production, which by one Defense Department estimate is running more than $20 a gallon.

"If you can get algae oils down below $2 a gallon, then you'll be where you need to be. And there's a lot of people who think you can," said Jennifer Holmgren, director of the renewable fuels unit of UOP LLC, an energy subsidiary of Honeywell International Inc.

Researchers are trying to figure out how to grow enough of the right strains of algae and how to extract the oil most efficiently. Over the past two years they've enjoyed an upsurge in funding from governments, the Pentagon, big oil companies, utilities and venture capital firms.

The federal government halted its main algae research program nearly a decade ago, but technology has advanced and oil prices have climbed since then, and an Energy Department lab announced in late October that it was partnering with Chevron Corp., the second-largest U.S. oil company, in the hunt for better strains of algae.

"It's not backyard inventors at this point at all," said George Douglas, a spokesman for the Energy Department's National Renewable Energy Laboratory. A New Zealand company demonstrated a Range Rover powered by an algae biodiesel blend last year, but experts say it will be many years before algae is commercially viable. Ruan expects some demonstration plants to be built within a few years.

Converting algae oil into biodiesel uses the same process that turns vegetable oils into biodiesel. But the cost of producing algae oil is hard to pin down because nobody's running the process start to finish other than in a laboratory, Douglas said. One Pentagon estimate puts it at more than $20 per gallon, but other experts say it's not clear cut.

If it can be brought down, algae's advantages include growing much faster and in less space than conventional energy crops.

An algae farm could be located almost anywhere. It wouldn't require converting cropland from food production to energy production. It could use sea water. And algae can gobble up pollutants from sewage and power plants.

The Pentagon's research arm, the Defense Advanced Research Projects Agency, is funding research into producing jet fuel from plants, including algae.

The Charlotte Observer
Friday, November 30, 2007

How SOLAR POWER can SAVE THE WORLD

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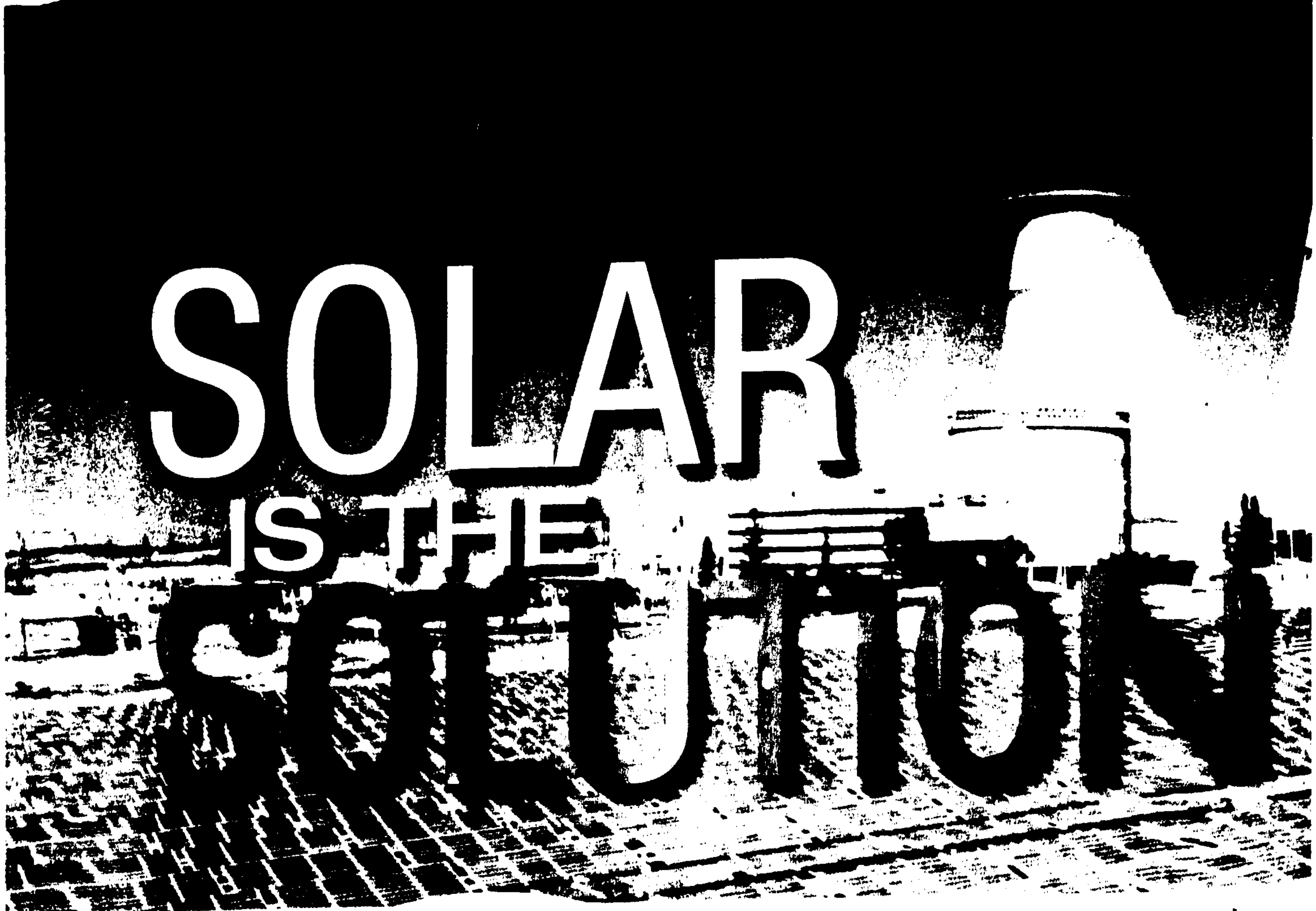
SOLAR IS THE SOLUTION



Annual Global RENEWABLE Energy Resources
(in Terawatt hours*)

Direct Solar Radiation
350,000,000

Wind	200,000
Ocean/Thermal	100,000
Biofuels	50,000
Geothermal	10,000
Tidal/Wave	5,000

The amount of solar energy available ***each year*** (yellow circle) dwarfs supplies of any other source of power, including ***total*** reserves of all the fossil fuels on Earth (small circle, right).

Total Global NON RENEWABLE Energy Resources
(Terawatt hours*)

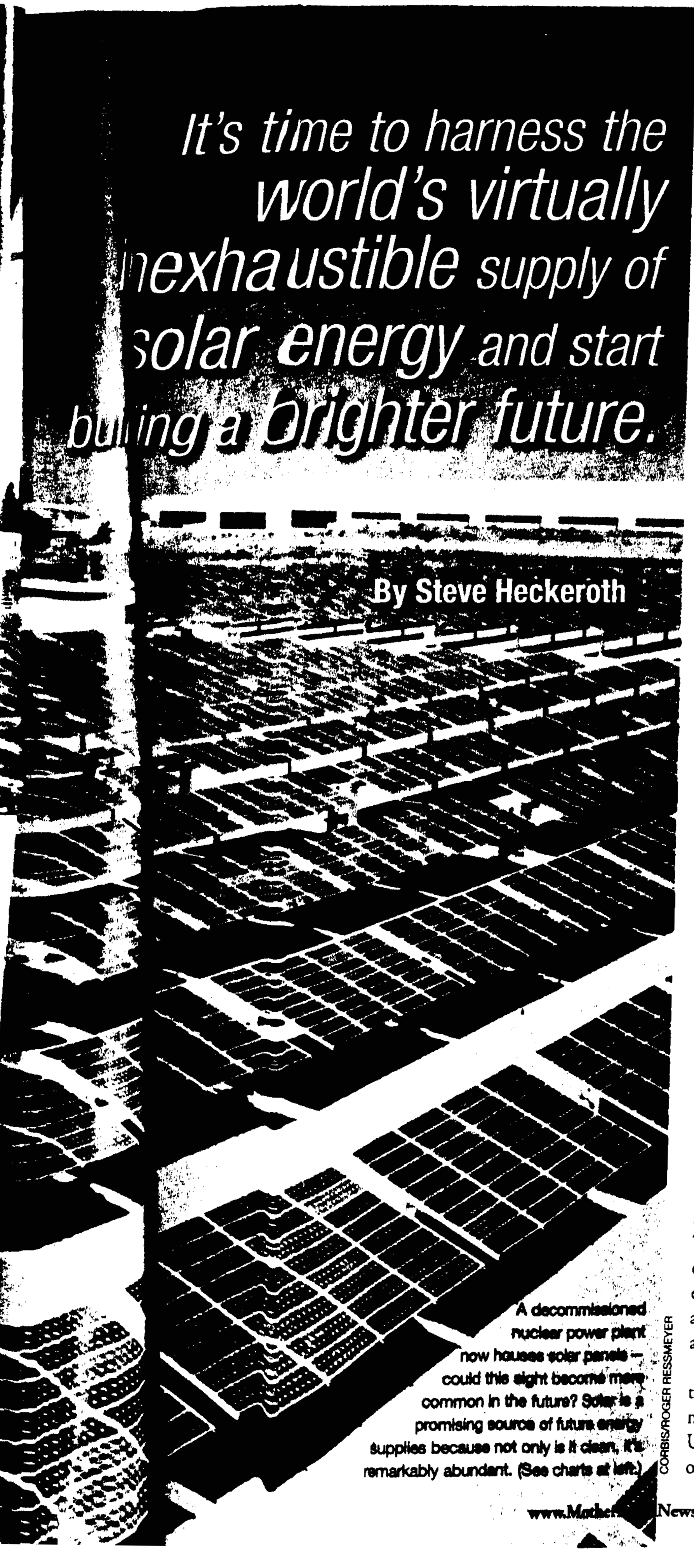
Coal	6,000,000
Natural Gas	1,500,000
Uranium 235	1,500,000
Oil	1,000,000
Tar Sands	800,000
Total:	**10,800,000**

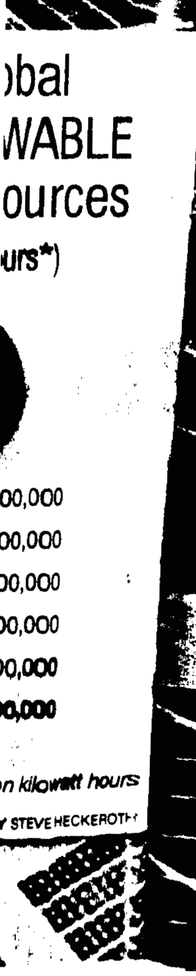
**1 terawatt hour is equal to 1 billion kilowatt h*

SOURCE: *SUNCELL* BY CHRISTOPHER C. SWAN. UPDATED BY S[illegible]EVE HECKE[illegible]

It's time to harness the world's virtually inexhaustible supply of solar energy and start building a brighter future.

By Steve Heckeroth





A decommissioned nuclear power plant now houses solar panels — could this sight become more common in the future? Solar is a promising source of future energy supplies because not only is it clean, it's remarkably abundant. (See charts at left.)

CORBIS/ROGER RESSMEYER

We know that relying on coal, oil and natural gas threatens our future with toxic pollution, global climate change and social unrest caused by diminishing fuel supplies. Instead of relying on unsustainable fossil fuels, we must transform our economy and learn to thrive on the planet's abundant supply of renewable energy.

I have been studying our energy options for more than 30 years, and I am absolutely convinced that our best and easiest option is solar energy, which is virtually inexhaustible. Most importantly, if we choose solar, we don't have to wait for a new technology to save us. We *already have* the technology and energy resources we need to build a sustainable, solar-electric economy that can cure our addiction to oil, stabilize the climate and maintain our standard of living all at the same time. It is well past time to start seriously harnessing solar energy.

FOSSIL-FUELED PROBLEMS

Before you read on, take a moment to study the two pie charts at left, which compare the Earth's estimated *total reserves* of *non-renewable* energy resources with the *annual renewable* energy options. You'll see that the potential of solar energy dwarfs all other options, renewable or otherwise. To understand why a solar-electric economy is our best option, let's look at the energy resources we currently depend on and compare them with the solar energy available to us.

Coal is burned mainly to produce electricity, and coal-fired power plants produce more than half the electricity used in the United States. But burning coal has serious drawbacks. One is that it releases ca newsfrommother

Why Solar Power is Our Best Solution

The more we study America's energy options, the more convinced we are that the fastest and best way to shift our energy economy from fossil fuels to clean renewable sources is to support solar power in all its forms (including wind). As MOTHER's contributing editor Steve Heckeroth explains on Page 50, several powerful solar options are already up and running:

Electric vehicles charged by photovoltaics or wind power are about to hit the mainstream as new and existing automakers finally begin to produce more plug-in hybrids and all-electric cars and trucks.

Photovoltaics, together with super-insulation and energy-efficient windows, are making it possible to build homes that generate all the energy they need from the solar panels on their roofs.

Concentrating solar power (CSP, which uses parabolic mirrors to focus solar heat and generate steam to drive electric generators) is already producing utility-scale power. The U.S. Department of Energy estimates that installing CSP plants on 9 percent of the Southwestern deserts could produce enough electricity to meet the needs of the entire United States!

Electricity from **large-scale wind farms** is already cost-competitive, and in some cases cheaper than electricity from natural-gas-fired power plants.

Do-it-yourselfers can easily tap the huge potential of solar energy with projects such as Gary Reysa's innovative "Solar Heating Plan for Any Home," Page 36.

What makes Reysa's new design so flexible is that the solar collector is built into a small outbuilding, and you can locate that building anywhere on your property to get the best solar exposure. Solar heat captured by the collector is stored in a water tank and then piped into the house and circulated in radiant floor tubing or baseboard radiators. And even existing homes can be converted to use radiant floor heating.

Some solar technologies already cost less than some of the fossil fuels we're burning. Others are poised to drop in cost as manufacturing capacity increases, and as batteries and other technologies undergo improvements. For example, Heckeroth is testing new lithium iron phosphate (LFP) batteries that he thinks can provide electric vehicles with twice the range and twice the speed for one-quarter the weight, compared to lead batteries. (We're planning a report about LFP batteries soon.)

ENERGY CAPTURED
(kilowatts per acre)

Ethanol *(from corn, etc.)*	3 to 4
Wind turbines	12 to 16
Photovoltaics	240 to 730
Concentrating solar	1,600

MOTHER EARTH NEWS readers have been using and improving solar technologies ever since the magazine began reporting about them back in 1970. (Our first article about a hybrid car was published nearly 30 years ago!) Today's declining fossil fuel supplies and growing concerns about climate change are making our national energy policy a critical issue. Right now, solar is looking like a far better option than trying to resurrect nuclear power or use land to grow crops for biofuels—see the charts on Page 50. We already have super-abundant solar resources and the technologies we need to shift from fossil fuels to a bright solar-powered future. Now all we need is the collective wisdom to make the right choices.

—*MOTHER*

MOTHER EARTH NEWS
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(800) 234-3368
www.MotherEarthNews.com

Homes Powered by the Sun

Most of us depend on fossil fuels to keep our homes comfortable by providing heating, cooling and electricity. But surprisingly, it isn't all that difficult to turn our homes from energy consumers into energy producers. New homes can easily be designed to take advantage of natural heat, light and ventilation; run more efficiently on less electricity; and be fitted with solar panels to produce electricity. Here are a few specific steps that make a big difference:

1. Orient buildings to maximize solar exposure and protect them from prevailing winds. Use wind breaks and berms to channel cold weather around or over buildings.
2. Add insulation to hold heat in winter and exclude heat in summer.
3. Use sunrooms to capture solar energy when needed and vent it when it is not.
4. Take advantage of natural light by using daylighting techniques.
5. Use earth-sheltered building techniques to take advantage of natural heating and cooling provided by stable underground temperatures.
6. Cool homes naturally using convection loops and cooling towers to circulate air.
7. Add thermal mass to buildings by using dense materials, such as brick and stone on interior walls, to maintain more constant temperatures.
8. Design overhangs and plant deciduous vegetation to shade living spaces in the summer but not in the winter.
9. Plant food gardens and edible landscaping to produce more food at your doorstep.
10. Install Energy Star appliances and water saving fixtures to conserve water and energy.

Annual World Energy Consumption

1980: 82,919 terawatt hours

2004: 130,971 terawatt hours

Projected for 2030: 205,686 terawatt hours

SOURCE: U.S. ENERGY INFORMATION ADMINISTRATION

ISTOCKPHOTO

bon dioxide, which contributes to g
warming. It also releases heavy metals,
as mercury and sulfur. These toxins
were locked in the Earth's crust ove
lions of years are suddenly spewed int
atmosphere and thus degrade our air,
and soil. The exhaust from burning
contains more pollutants and global w
ing emissions per unit of energy proc
than *any other fossil fuel*. In additior
methods used to mine coal are destru
to the land and dangerous for the mi

Now consider that coal is enorm
inefficient from a total energy perspe
It took billions of years of solar ener
form the coal we have today. And
coal is the most abundant fossil reso
the total amount of energy produce
burning all the coal on the planet w
only be equivalent to the solar energy
strikes the Earth every *six days*.

Natural gas supplies more thar
the fuel used to heat buildings and a
15 percent of the electricity in the U
States. Natural-gas-fired power p
only emit about half the pollutants
duced by coal plants, as long as the
is extracted close to where it is bu
However, U.S. natural gas extrac
can no longer keep up with deman
expensive and hazardous methods t
uefy and ship foreign natural gas ar
ing devised. In the future, natural ga
the United States would have to be
ported from countries such as Ru
Kazakhstan, Qatar and Iran, w
together have 60 percent o
world's reserves. When al
externalities, such as the
and pollution caused by
uefying and transporting
fuel, are included, liqu
natural gas (LNG) is r
more expensive than
and almost as dirty.

Natural gas is the se
most abundant fossil fuel
its total potential energy is eq
lent to only about 1? days of
shine striking the Earth.

Nuclear power plants fueled b
dioactive isotopes of uranium pro

stored in metal hydrates or at 10,000 psi in heavy containers.

Even after more than 20 years of development, fuel cell vehicles still cost more than a million dollars each and don't last very long or go very far. Finally, it takes about four times more renewable energy to drive a fuel cell vehicle than it does to charge the batteries in an electric vehicle to go the same distance. *This is like the difference in fuel economy between a Hummer and a Prius.* If you are wondering why hydrogen fuel cell vehicles continue to receive billions of dollars in funding given all these barriers, the fact that 96 percent of all hydrogen is currently extracted from fossil fuels may have something to do with it. There are powerful vested interests controlling our energy policy. Only informed citizens acting together can steer the best course.

A BRIGHT SOLAR-ELECTRIC FUTURE

A solar-electric economy is well within our reach. We're already generating solar electricity at the utility scale using powerful concentrating solar power technology. We're also generating electricity through wind energy, which many experts consider an indirect form of solar energy because it's driven by temperature differences.

But also consider that simply incorporating passive solar design strategies (see "Homes Powered by the Sun," Page 52), energy efficiency, conservation and other active solar heating strategies in the construction of buildings can save up to 95 percent of the energy used in conventional buildings. With the addition of building-integrated photovoltaics, buildings can be turned into net energy producers. Energy from the sun can be used to power our vehicles, and that includes not only our cars, but also heavy vehicles such as tractors.

Electric Vehicles & Plug-in Hybrids. Electric vehicle drivetrains are inherently five to 10 times more efficient than internal combustion engines and they produce no greenhouse gases at the tailpipe. Even if powered by fossil-fuel electricity, emissions at the power plant are much lower per mile traveled than with internal combustion engines. In addition, electric vehicles can be charged directly from renewable sources, thereby eliminating emissions altogether.

One of the main excuses the auto industry offers for the lack of electric vehicles is that "the batteries are not developed yet." But consider how quickly cell phone batteries developed, transforming mobile phones from heavy, bulky, short-lived nuisances to amazingly light, small and long-lasting necessities. The oil companies are doing a good job of protecting the American consumer from "dangerous" batteries, but in parts of the world where oil companies have less control, large format battery development is progressing at rapid speeds.

BETTER Living Through *SOLAR* Electricity

Not only is the potential of solar power enormous, we already have the technology to take advantage of it. We can design our homes for solar heating and wind-powered cooling. Solar electricity can power our homes, our cars and even our tractors. All we have to do is start using it on a wider scale. So what are we waiting for?

Electric Tractors and Agriculture. Experts have estimated that it takes eight to 10 units of fossil energy to put one unit of food energy on American tables, and that it takes the equivalent of 10 barrels of oil to feed each person in the country. Hearing those figures, it's frightening to imagine what will happen as oil prices rise. To begin with, how would we fuel our farm machinery?

The good news is that not only can tractors run on electricity, they run even better on electricity than passenger vehicles do because of their greater weight and slower speeds. An electric tractor can quietly accomplish all the tasks necessary to maintain productivity on a small farm.

Dealing with the rising cost of mobility and energy are huge challenges, and the biggest challenge facing humanity may be maintaining an affordable and nourishing food supply. But we can have fresher and more nourishing food without fossil fuels. What it will take is public support for a switch to local food production on small organic farms using solar irrigation pumps and solar-charged electric tractors.

WE HAVE THE POWER

It's easy to feel confused cynical and even hopeles about the state of the plane these days. But I am excite and optimistic because *know* we have the technol ogy *now* that will allow u to wean ourselves from foss fuels and move to a renewab solar-electric energy system.

Yes, I know—solar panels a still too expensive for many of u But 10 years ago, nobody gave hybri cars a chance of succeeding. Today, th Toyota Prius is the hottest thing going. Plu in hybrids and all-electric options should b available soon. If we all work together an demand that our government set a wi energy policy and use taxes to support t right renewable energy options, I predict can put the brakes on climate change a enjoy clean, true-green energy.

Contributing editor Steve Heckero has built more than two dozen elect vehicles. He's chair of the American So Energy Society's Renewable Fuels a Transportation Division, and spent the seven years as director of building-integr ed photovoltaic products for the largest fl ible thin-film PV manufacturer in the wo His Web site is *www.renewables.com*.

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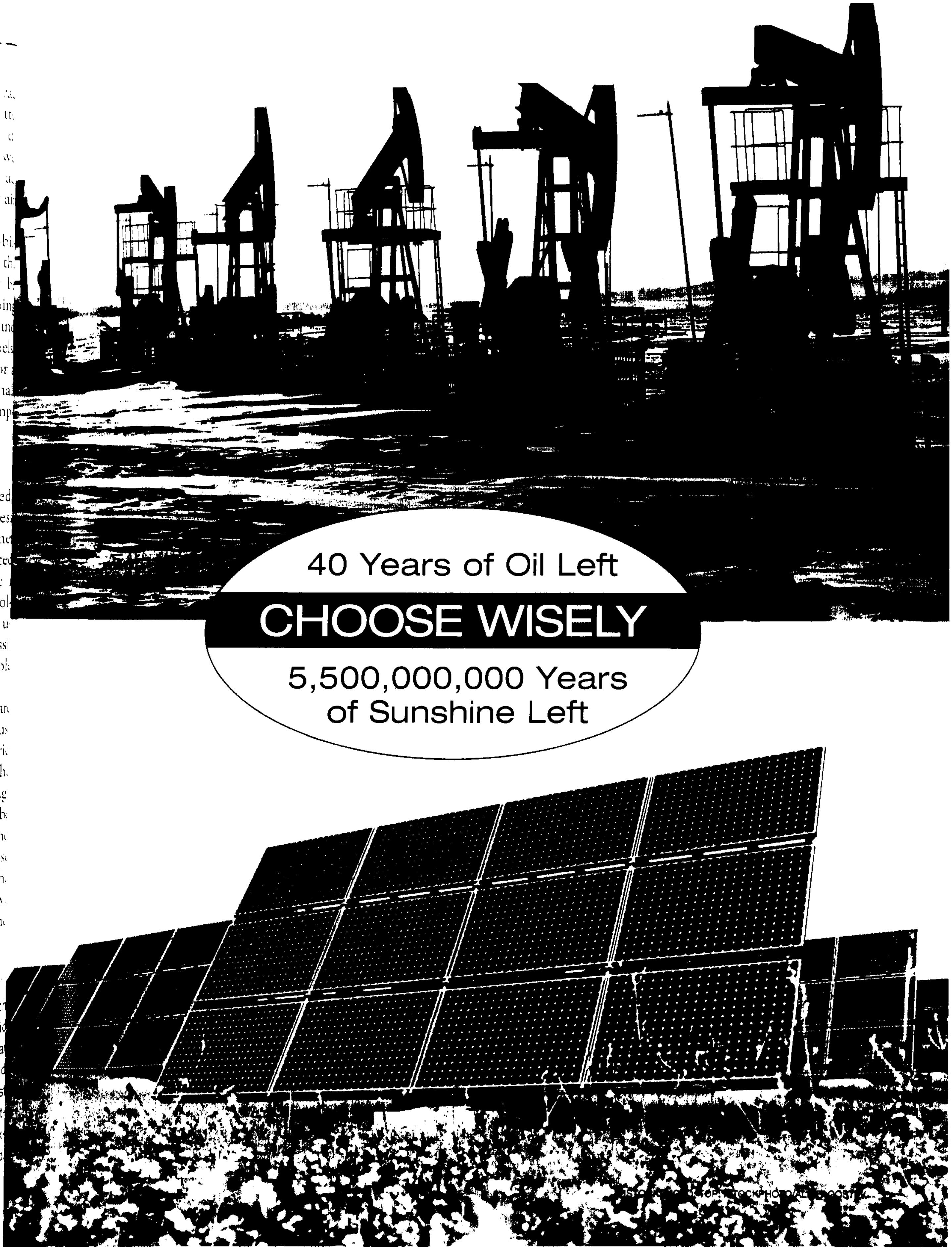

ELECTRIC RATEPAYERS RESOLUTION:

WE, THE UNDERSIGNED RECOMMEND:

1) **That no new coal-fired energy plants should be permitted to further pollute our air** contributing to asthma and other lung disorders, to endanger our planet and our children from mercury, nitrous and sulphur dioxides, ozone and global-warming carbon dioxide at the rate of thousands of tons per year per plant.

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5) **That a new triple bottom line of People, Planet as well as Profit be worked out to benefit** all concerned, instead of this broken system where energy companies profit only at the detriment of citizens by building outmoded, costly and dangerous facilities.

SUMMARY: That Solar, Wind, Ocean, Renewables and Conservation will be instituted first on a large scale before any of the coal or nuclear proposed projects go forward at Rate Payers expense without Rate Payers consent.

Name	Address	Phone & E-mail
Ann [illegible]	9 Kelp, Alva FL 33920	[illegible]
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Helmut May	"	"
Lou Raynow	6639 Trident Way Naples 34108	591-3961 lraynow 314@[illegible] com
Jan Daley	22291 Fountain Lakes Blvd Estero FL 33928	
[illegible]	[illegible]	[illegible]
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[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
Patrick J Marson	[illegible] FL 33922	239-728-391[illegible]
Dorothy J Trowbridge	Alva FL 33930	239-337-1403

Send completed resolution to **NC WARN** POB 61051, Durham, NC 27715-1051 Attn Pete www.ncwarn.org
Co-sponsor **Carolinas Clean Air Coalition**, POB 30204, Charlotte, NC 28230 704-342-9161
www.clean-air-coalition.org

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Jim Palmer	5 CORK ST ALVA, FL 33920	
[illegible]	4 KELP, ALVA, FLA. 33920	

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Michael Hettich	561 NE 95 St	MHETTICH@MDC.edu 305-237-3187
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
Lucia Goyen	290 174th St Apt 1105	Lucia.Goyen@gmail.com
Rhonda Koff	Box 1953 Clewiston FL 33440	[illegible]@hughes.net

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Name	**Address** Charlotte	**Phone & E-mail - (2 lines if needed)**
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✓ Denise Caudle	15314 Catawba Cir. Matthews	704-684-0523
✓ Randy Fox	166 Bexley Court WAXHAW, NC 28173	
Collin Worth	10901 SW 102nd Ct. Miami, FL 33176	
Adam Schachner	1188 SW 22 Terr Miami, Fl 33129	adam.schachner@gmail.com
Marie M FRANÇOIS	2029 Adams ST Apt 108 Holly FL 33020	954 604 8453
Toby Lopez		9544341838 tobyklopez@bellsouth
Harry Hanauer	10325 SW 99th St Miami, FL 33176	HARBHAN@BELLSOUTH.NET
Xavier Vazquez	800 N. Miami Ave E 510 Miami FL 33136	[illegible]

Wants Email

Ya-send Stevenson Old King Coal II also to Teacher Lady [illegible] teacher in my [illegible]

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* Summary No Coal No NUKES 3D SOLAR

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Name	Address	Phone & E-mail - (2 lines if needed)
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MICHELSON FLEURANT	328 NW 108 ST MIAMI FL 33168	
Michael O'Brien	809 NE 16 Ct Ft. Laud FL 33305	954-865-4548 SlamrockMRT721@gmail.com
ANNA MACHEK	4911 NE 8 Ave MIAMI 33138	305-756-4561
Johanna Parker	1166 Garfield St, Hollywood 33019	
[illegible]	1521 Alton Rd, Box #740 M.Beach Fl 33139	
[illegible]	[illegible] ST MIAMI FL 331[illegible]	[illegible]@HOTMAIL.COM
KELLI MURPHY	940 NE 85th ST. MIAMI, FL 33138	MKCDM3@AOL.COM

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Please return to Deb Anderson - 385-283-4454 11/29/07 (Bloomington [illegible])

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Name	**Address**	**Phone & E-mail - (2 lines if needed)**
Jeena Thomas	1146 NW 144th terrace Pembroke Pines FL 33028	(954) 849-[illegible] Jeena[illegible]@yahoo
Audrey Castro	11780 SW 18st #319 Miami FL 33175	305 4909054 massi[illegible]2@Hotmail.com
Bryan Gintoft	125 NE 108 Street Miami Shores, FL 33161	(305) 904-8874
FERNANDA MEDICI	5785 SW 60th, MIAMI, FL 33143	954 609-1969
Christopher [illegible]	15830 NW 83 PL MIAMI LAKES FL 33016	786-[illegible]
Katherine [illegible]	[illegible] St, Miami FL 33[illegible]7	305 237 4291 [illegible]
Kimberly [illegible]	Miami, FL	[illegible]@hotmail.com [illegible]
Michael Brown	2[illegible] NE 104 St. Miami Shores, FL 33138	305 778-1770 [illegible]
PATRICIA [illegible]	238 NE [illegible] St [illegible] FL 33138	(305) [illegible] [illegible]@hotmail.com
STEPHANIE GAUTIER	238 NE 87 St, Miami, FL 33138	305-757-6546 s_gautier@[illegible]
Glenda Phipps	95 South Shore Drive, [illegible] FL 33141	(305) 868 3037 gphipps@[illegible]

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Please return to PCS 20060007707 11/29/07 Little Blonde in Pink Shirt

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Sum-
No Coal
No Nukes
Yes Solar

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Name	Address	Phone & E-mail
Anouchka Rachelson	8175 SW 185th St, MIA, FL 33157	
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LARRY THURSON	8550 BYRON AVE. MIAMI BEACH 33141	
Rebecca Castle	3801 South Ocean Dr. #10 Hollywood FL 33019	Rebecca.Castle@fiu.edu
Monica Wilson		954-462-8300 cymrywilson@yahoo.com
Ross Williams	1217 White St Key West 33040	drrossw@yahoo.com
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Erika Biddle	824 Olivia St. Key West 33040	erikaB@earthlink.net
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Name	Address	Phone & E-mail
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[illegible]	[illegible]	[illegible]
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Sarah Ridley	4414 Prairie Ave MB [illegible]	[illegible]
Steve Jens-Rochow	1420 SW 13 St FT.L 33312	SJENSROCHOW@comcast.net

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ELECTRIC RATEPAYERS RESOLUTION and sign-on to Letter to Gov. Easley

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OK?

Name	Address	Phone & E-mail
Chris Martin	Knoxville, TN ~~[illegible] Grainger Ave.~~	431-216-5011 CM@UTK.EDU ✓
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Mike Cherin	2631 Rock Rd Union Mills NC	mikecherin@yahoo
Maureen Hollan	28210 6409-13 Cameron Forest Ln	mph@lwon.com 704-980-428-3107 ✓Charlotte

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Aloysius B. Simpson	6327 Spring Garden Ln	704-779-585
Denise Caudle	15314 Catawba Cir. Mathews	704-684-0523
Randy Fox	100 Berkley Court	Waxhaw, NC 28173
Caitlen Nellis	704 763 1310	caitlen.nellis@gmail.com
Katie McFarlane	katie.mcfarlane@mecklenburgcountync.gov	
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Christopher Pierce	chrisp@popstar.com	
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greenpower.org

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Name	Address	Phone & E-mail
Matt Wallace	31 Chestnut St Asheville NC	
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Jacqui Murray	330 Grandview Hts Boone, NC 28607	828-355-9151
Harold J. Outcalt	PO Box 1485 Asheville NC 28802	
Jacob Stockwell	5 Sunnyridge Burnsville, NC 28714	

Submit completed resolution to NCWarn.org, POB 61051, Durham, NC 27715 Attn Pete

ELECTRIC RATEPAYERS RESOLUTION

WE, THE UNDERSIGNED RECOMMEND:

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May Stentucci	" " "	
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Jennifer Keech	6701 Ronda Ave, Charlotte, NC 28211	
ANNE JACKSON	430 QUEENS RD #532 CHARLOTTE NC 28207	
Tina Pope	3210 Brixton Charlotte NC 28205	
Sandra Clemmons	3210 Eastburn Rd Clt NC 28210	
Muriel (Mimi) Wadum	3109 Selwyn Farms Ln. Charlotte, NC 28209	
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David Zeeso	5312 McAlpine Farm Rd Chlt 28226	704 563 8912 zeeso@bellsouth.net
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Meg Houlihan	1718 Chestnut Ave Cha NC 28205	
John Dainotto	2119 Kinmore Ave 28204	
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Name	Address	Phone & E-mail
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Laurie Keel	2017 E 5th Char 28204	
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PERRIN MORSE	2812 PARK RD CHARLOTTE NC 28209	704 719 4777
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Send completed resolution to NC WARN POB 61051, Durham, NC 27715-1051 Attn Pete www.ncwarn.org

also participating - Carolinas Clean Air Coalition, Charlotte NC
kelly@clean-air-coalition.org

Charlotte Eastside Spring 1/16/07 ages First

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SUMMARY: That Solar, Wind, Ocean, Renewables and Conservation will be instituted first *on a large scale before any of the coal or nuclear proposed projects go forward at Rate* Payers expense without Rate Payers consent.

Name | **Address** | **Phone & E-mail - (2 lines if needed)**

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Nancy Duncan 2408 Westfield Rd Charlotte NC 28207
KAREN MERRITT 2407 CARSON DR. MARVIN NC 28173
Mark Elam 447 Elam Rd, Lowndesville NC 28090 elammt@hotmail.com

Submit completed resolution to NCWarn.org, POB 61051, Durham, NC 27715 Attn Pete

— NCWARN@NCWARN.ORG —

ELECTRIC RATEPAYERS RESOLUTION and sign-on to Letter to Gov. Easley

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Submit completed resolution to NCWarn.org, POB 61051, Durham, NC 27715 Attn P[illegible]

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Name **Address** **Phone & E-mail**

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Aandra Champion 3210 Eastburn Rd clt NC 28210
Ernie McLaney 6216 Rocky Falls Road, Clt. 28211 704-443-9623
Margaret Wimberley 2101 Sycamore Rd 28209
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Jimmy Pettit
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Sandra Carlson

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Mr. Steven Gerald Fowler 121 Bartlett Arms APT 224 Asheville N.C. 28801 (828) 318-5247
Mr Howard P. Buckner 76 old Leicester Hwy Asheville 828-255-4622
Mrs Michelle Fox 37 McDade St. Asheville NC 828 253-1013
Miss Tegan Temple 31 McDade St " " (843) 670-316
Chris O'Neill - 46 McClain St " 828-776-0578 (Green Building
Fallon Mitchell 1949 Fisher Creek RD Sylva NC
Cheryl Harvin 2814 Coatesdale Ln, Matthews NC 704-889-218
Amanda Kadlec 225 Noblitt Rd Marion NC 828-652-407,

Submit completed resolution to NCWARN.org, POB 61051, Durham, NC 27715 Attn Pete

NCWARN

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Name **Address** **Phone & E-mail**

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Carol Reid 4508 Eshenwood Ln Ch. 28270
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DD 2316 Laburnum Ave CLT NC 28205
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Natalie Slack 15328 Legend Oaks Ct, Indian Land SC 29707
John L Flack 15328 Legend Oak Ct. Indian Land, SC. 29707
Gary Hudson 4114 Larkspur Lane Charlotte, NC 28205
Erik Lensch 3115 Lakeside Cir Belmont NC 28201 elensch710

TEPAYERS RESOLUTION:

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e Miller	149 Saron Ch Rd Ellerbe NC 28338	
a Greese	946 Bennette Rd. Ellerbe NC 28338	
: Toole	118 Kellywille Dr Rkm	997-5952
ıd Johnson	840 Cheek Cr Rd Rkham NC	
ıy Rowe	29 Reece Milloy Rd Marion, N.C.	
ıle Ingram Jr	156 Birchwood Dr. Wadesboro NC 28170	
ıy Coward	124 Hreenacswil Rd Rkham 2837	
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	Address	
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yn Rivers	2620 Hampton Av	(704) 334-7063
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? Mahaffy	511 W. King St. Apt 3 Boone NC 28608	LM71338 @appstate.edu
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Ed Hughes	275 Woodland Boone 28607	828-262-6381 harvard@boone.net

eted resolution to NC WARN POB 61051, Durham, NC 27715-1051 Attn Pete www.ncwarn.org
rticipating - Carolina Clean Air Coalition, Charlotte NC

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Travis Bryson	225 Patton Ave 28801	
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w/help near * Matthew Norman	36 [illegible] AVE #4	[illegible] NCIMAN.MAT@GMAIL.COM
Mona [illegible] Fowler	121 Bartlett St Asheville NC 28801 Bartlett Arms Apt 204	(828) 258-0366 828 423 9106 828 316 5247

Submit completed resolution to NCWarn.org, POB 61051, Durham, NC 27715 Attn Pete

TOTAL 256

Aug - Nov 10, 2007

FLORIDA PUBLIC SERVICE COMMISSION
DOCKET NO. 070650-EI **EXHIBIT** 6
COMPANY Citizens of the State of Fl
WITNESS George Cavros
DATE 01/09/08

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St. Pete Times
Page 1 of 3 6

NUCLEAR POWER COSTS SURGE

[2 TAMPA Edition]

St. Petersburg Times - St. Petersburg, Fla.
Author: ASJYLYN LODER
Date: Dec 12, 2007
Start Page: 1.A
Section: NATIONAL
Text Word Count: 1103

Document Text

Customers may face higher bills as estimates for new plants swell.

Nuclear energy - billed as the cheap, carbon-free energy source of the future - isn't sounding so cheap anymore.

In fact, the price for a new nuclear plant has soared as the rush to construct nearly 30 facilities across the country over the next 15 years has pushed up the cost of labor, raw materials and possibly even the plants themselves.

New industry estimates double and even triple prices quoted a year ago by utilities throughout the Southeast, including those for Progress Energy Florida's planned nuclear plant in Levy County. Based on cost estimates for other nuke plants and analyst reports, Progress Energy's costs could balloon to more than $10-billion, far more than early estimates of $4-billion to $6-billion.

Jeff Lyash, president and CEO of Progress Energy, said that material prices have escalated and that the utility's early estimates didn't include costs like the land purchase, financing or transmission. But he refused to offer a new estimate.

"We're in the middle of negotiations and don't have a number to give you," Lyash said.

The upshot for Florida customers of Progress Energy? Be prepared to pay billions of dollars more than you bargained for. Under Florida law, customers could start seeing that cost tacked on to their monthly bills years before the plant is complete.

That scenario has raised concerns in the industry that optimistic early estimates may leave customers with sticker shock.

"We were very concerned early on that there were some improper expectations being set by not telling the whole story," said Steven Scroggs, who is in charge of new nuclear plants for the state's biggest utility, Florida Power & Light.

Its two-reactor project planned in South Florida could cost $12- billion to $18-billion, Scroggs said.

That's far higher than prices quoted elsewhere in the industry, and double Progress Energy's early estimate in Levy County. Florida Power & Light's unusual candor raises questions about the low estimates offered by utilities throughout the Southeast. What did their estimates include? Are those estimates reliable? Just how much will this nuclear renaissance cost us?

No one knows what a new nuclear plant will cost. No one has built one here in more than 30 years, and no U.S. utility has signed a contract yet for a new plant.

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St. Pete Times
Page 2 of 3

The utility industry quotes costs in its own jargon of cost per kilowatt. Progress Energy's early estimates ranged from $1,800 to nearly $3,200. Florida Power & Light recently offered a much higher range of $3,108 per kilowatt to $4,540.

Moody's Investor Services offered an October estimate of $6,000 per kilowatt.

A year ago, Progress Energy quoted costs of $2-billion to $3- billion for a one-reactor project in Levy County, and later said that it might build two reactors. The St. Petersburg utility selected a new reactor called the Westinghouse AP1000 - the same technology Florida Power & Light is considering.

So why the enormous difference in their costs?

Lyash said that the early estimates were "generic overnight costs." It didn't include interest costs, price escalation, the $47- million the utility spent buying land, or the cost of more than 200 miles of transmission lines the utility will need to run through 10 counties.

By contrast, Scroggs' estimate of $12-billion to $18-billion for FP&L's plant is "all in," and includes costs like transmission, site preparation, financing and price escalation.

"To understand how it really impacts customers, you have to talk about the all-in costs," Scroggs said.

The confusion over what estimates include is only part of the problem. Prices for materials like cement and steel have risen dramatically, driving up the cost of coal and natural gas plants as well as nuclear.

Lyash said he didn't want to give an estimate while negotiations are ongoing with Westinghouse. He also declined to say whether Florida Power & Light's estimates seemed in line with Progress Energy's expectations.

"I'm not trying to be evasive," Lyash said. "I'd prefer to wait until we have a specific number."

- - -

Utilities throughout the Southeast face the same quandary as Progress Energy.

Five utilities chose the Westinghouse AP1000, for a total of 12 reactors. Progress Energy plans to build four of those, two in Levy County and two in North Carolina. Georgia Power and Duke Energy have also selected the AP1000.

Georgia Power hasn't offered a public estimate, but Duke Energy offered early estimates of $4-billion to $6-billion for two reactors, similar to Progress Energy's early estimate.

Rita Sipe, spokeswoman for Duke Energy, said those estimates are now being revised, but declined to offer a new number.

Westinghouse spokesman Vaughn Gilbert said the company will not discuss costs while it is still negotiating with utilities.

The nuclear industry already has a credibility hangover from the multibillion-dollar cost overruns that plagued the industry in the 1970s and 1980s. If the public senses that its numbers aren't reliable, it could face a backlash.

Hoping to avoid a repeat, the Nuclear Energy Institute, an industry trade group, pulled back from early estimates last year, said Adrian Heymer, senior director for new plant deployment for the Nuclear Energy Institute, a Washington, D.C., nuclear trade group.

Many utilities weren't very clear about what their early estimates included, he said.

"We sensed about a year ago now that we were a little out of synch with each other, and we've been drilling down trying to figure out what is the number, and we're getting varying stories out there," Heymer said.

But his group couldn't offer a number, either. Heymer said a real number won't be known until utilities sign their agreements with Westinghouse, which he predicted will happen in the next six to 18 months.

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St. Pete Times
Page 3 of 3

Progress Energy has not decided that it will build the Levy County plant, which is about 10 miles north of its Crystal River nuclear plant. But Lyash said he doesn't see high up-front costs as a death knell for the nuclear renaissance. "I still view nuclear as a cost-competitive alternative," he said.

Nuclear still has some clear advantages over fossil fuels and solar, he explained. Natural gas prices fluctuate wildly, unlike nuclear fuel. If new regulations add a cost for greenhouse gases like carbon dioxide, carbon-heavy coal could prove more expensive in the long run. Nuclear plants generate power day and night, unlike intermittent solar.

Yes, nuclear costs far more up front, said Lyash. "But it still may be the right policy thing to do."

Times researchers Angie Holan and John Martin contributed to this report. Asjylyn Loder can be reached at aloder@sptimes.com or (813) 225-3117.

Credit: Times Staff Writer

Abstract (Document Summary)

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CAVROS · 2
EPA Matrix
Page 1 of 2

[illegible] Policy Trends
A[illegible]

Katrina [illegible]
[illegible] Program Manager
[illegible] Partnerships Division
[illegible] Protection Agency
[illegible] Initiatives Workshop
[illegible]

Agenda

- Today's energy challenges and EE
- Issues Garnering Increased Interest
  - "Quick start" EE programs
  - Aligning utility incentives with EE
  - Incorporating EE as a resource in utility planning processes
  - Cost-effectiveness tests
- State examples
- Resources and Summary

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EPA Matrix
Page 2 of 2

Snapshot of states use of cost tests

No specific test/s required:

- KY, PA, ME, IL, ND, OK, ID, WY, NC, SC

All 5 tests required:

- VA, IN, MN, CA, HI, GA

Doesn't include info. from: MD, WV, MI, NE, OH, SD, AK, NV, TX, UT, WA, AL, LA, MS, TN

Only specific tests required	Ratepayer Impact (RIM)	Total Resource Cost	Partic. Cost Test	Utility Cost Test / Prog. Admin	Societal Cost Text	Other
DC						X
DE		X				
NJ						X
NY		X				
CT		X		X*		
MA		X				
NH	X	X				
RI						X
VT					X	
IA	X		X	X	X	
KS	X	X				
MO		X*		X		
WI					X	
AZ		X				
CO		X				
MT		X			X	
NM		X				
OR				X	X	
AR	X	X	X	X		
FL	X					

Cost Test	Questions Addressed
Participant Cost Test	-Is it worth it to the customer to install EE? -Is the customer likely to want to participate in a utility program that promotes EE?
Ratepayer Impact Measure	-What is the impact of the EE project on the utility's operating margin? -Would the project require an increase in rates to reach the same operating margin?
Utility Cost Test	-Do total utility costs increase or decrease? -What is the change in total customer bills required to keep the utility whole (the change in revenue requirement)?
Total Resource Cost Test	-What is the regional benefit of the EE project including the net costs and benefits to the utility and its customers? -Are all of the benefits greater than all of the costs (regardless of who pays the costs and who receives the benefits)? -Is more or less money required by the region to pay for energy needs?
Societal Cost Test	-What is the overall benefit to the community of the EE project, including indirect benefits? -Are all of the benefits, including indirect benefits, greater than all of the costs (regardless of who pays the costs and who receives the benefits)?

Source: Guide to Resource Planning with Energy Efficiency - a Product of the National Action Plan for Energy Efficiency. 2007.

CAVROS - 3
PSC RIM Analysis
Page 1 of 3

Conservation Program Cost-Effectiveness Tests

Presentation to the:

Florida Public Service Commission
Workshop on Energy Efficiency Initiatives

November 29, 2007

Mark Futrell
Division of Economic Regulation
Florida Public Service Commission

Background

- A utility may serve customer load with:
  - Supply-Side Resources:
    - Generation
    - Purchased Power
  - Demand-Side Resources:
    - Energy Efficiency Programs
    - Load Management Programs
- Each·option has associated costs that must be borne by ratepayers
- How to analyze the benefits and costs of Demand-Side Management (DSM) Programs?

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PSC RIM Analysis
Page 2 of 3

Rate Impact Measure Test

Benefits	Costs
Avoided Supply Costs (Capital and O&M) - Generation - Transmission - Distribution Net Fuel Impact	Program Costs - Equipment, Administration Program Incentives Decreased Revenues

Rate Impact Measure Test

- What is the impact of the program on utility revenues (rates) and what is the effect on the non-participating customer?
- A program passing the RIM test will cause rates to go up, but not as high as they otherwise would.
- Eliminates DSM cross subsidies as participants and non-participants benefit.
- Programs with relatively higher kWh reductions will result in higher revenue losses and reduce the potential to be cost-effective under RIM.

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PSC RIM Analysis
Page 3 of 3

Total Resource Cost Test

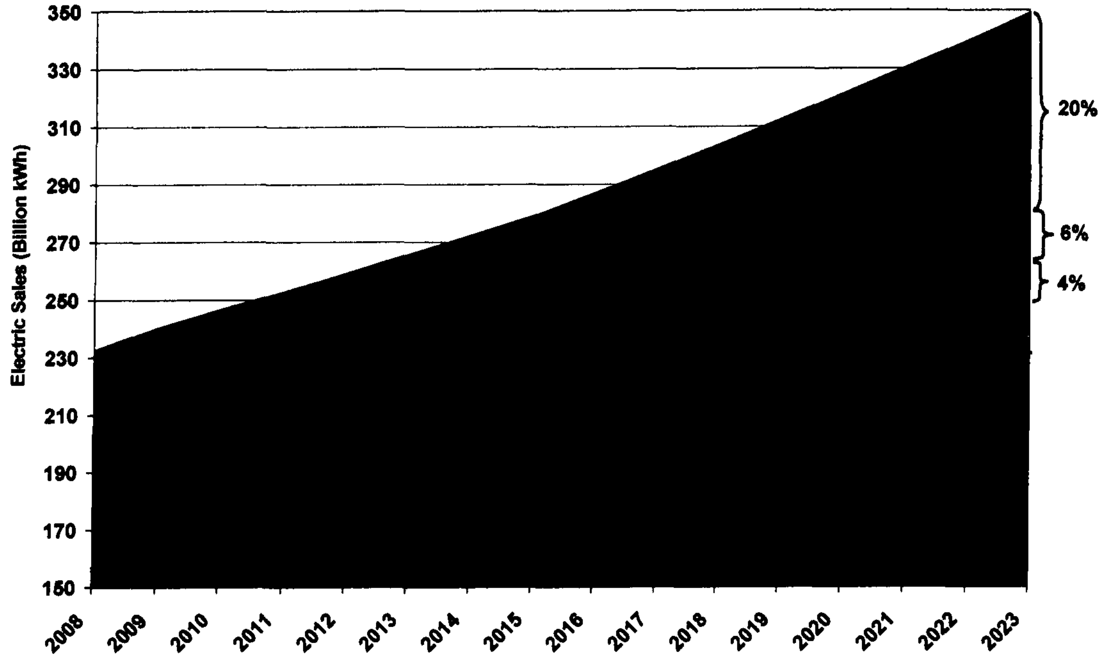
Benefits	Costs
Avoided Supply Costs (Capital and O&M) - Generation - Transmission - Distribution Net Fuel Impact	Program costs - Equipment, Administration Participant's Out of Pocket Expenses - Equipment Costs - Maintenance Costs

Total Resource Cost Test

- Measures the overall economic efficiency of a DSM program from the perspective of society.
- Measures the net costs of a DSM program based on total program costs, including both the participants and utility's costs.
- Incentives and revenue losses are <u>not</u> included as costs, and are treated as transfer payments among ratepayers (no net cost).
- Because revenue losses are not included, programs with relatively higher kWh reductions are more likely to be cost-effective under TRC.

Figure 1. Share of Future Electricity Consumption that Can Be Met with Energy Efficiency and Renewable Energy Resources

2023 Savings = 102,513 Million kWh



Policy Recommendations

To make these energy efficiency and renewable energy resources a reality, we recommend eleven specific policies that the state should consider adopting:

1. Utility-Sector Energy Efficiency Policies and Programs (EERS)
2. Appliance and Equipment Standards
3. Building Energy Codes
4. Advanced Building Program
5. Improved Combined Heat and Power (CHP) Policies
6. Industrial Competitiveness Initiative
7. State and Municipal Buildings Program
8. Short-Term Public Education and Rate Incentives
9. Expanded Research, Development, and Demonstration Efforts
10. Renewable Portfolio Standard (RPS)
11. Onsite Renewables Program

We believe these policies would establish a foundation upon which the state could build a sustainable energy future, while improving the state's economic health. The most significant energy efficiency recommendation is for a Utility-Sector Energy Efficiency Program, specifically an Energy Efficiency Resource Standard (a utility savings target similar to the RPS concept), which accounts for over 30% of the total savings in 2023 (see Table 1). As would be anticipated because of the importance of buildings-related electric loads, buildings policies (including an improved building energy code and advanced-buildings policies) would contribute another 12% toward the total electricity savings in 2023.

American Council for an Energy-Efficient Economy

WASHINGTON, DC

CAVROS - 4
ACEEE Report - Efficiency

Potential for Energy Efficiency and Renewable Energy to Meet Florida's Growing Energy Demands[1]

June 2007

Florida is among the fastest growing states in the country, and the state's electricity demand is growing even faster than the state's population. To sustain this rapid economic and population growth, Florida needs to take action to meet the resulting increases in energy needs. A particular challenge is peak demand – those times when extreme heat or extreme cold crank up air conditioners and heaters – which is growing slightly faster in recent years than regular day-to-day electricity demand, and is the most expensive type of electricity.

Florida's unique energy vulnerabilities have also become apparent during the past several years. Florida is one of the most natural-gas-dependent states in the country, with more than a third of its electricity generated by natural gas. In December 2005, the natural gas "crisis" drove utility prices from less than \$3 per thousand cubic foot to over \$14, a price that hurt Floridians' pocketbooks. The pain intensified when Hurricane Katrina disrupted natural gas supplies and jeopardized electricity generation. While the price of natural gas has fallen over the past year, it still costs more than two and a half times more than it did when many of the state's new natural gas power plants were planned. It is not the bargain we once thought.

To meet the growing electricity needs, Florida is planning for major investments in new power plants. The state's utilities project the need for both more natural-gas- and coal-powered plants.

Opportunities for Energy Efficiency and Renewable Energy

Fortunately, another suite of energy resource options is available – slowing energy demand growth with energy efficiency resources and demand response, and diversifying the supply resources with renewables. This report explores the magnitude of the efficiency and renewable resources that are available to the state, and suggests some specific policies that could be implemented to reduce future energy demands. If all the policies we recommend were implemented, the state could reduce its projected future use of electricity from conventional sources (i.e., natural gas, coal, oil, and nuclear fuels) by about 29% in the next 15 years (see Figure 1). Energy efficiency accounts for about two-thirds of the 2023 total 102,513 million kWh electricity reductions, with the renewable energy provisions accounting for the balance.

[1] This report was prepared by R. Neal Elliott, Maggie Eldridge, Anna M. Shipley, John "Skip" Laitner, and Steven Nadel with ACEEE; Philip Fairey, Robin Vieira, and Jeff Sonne with FSEC; Alison Silverstein; and Bruce Hedman and Ken Darrow with EEA, Inc.

1001 Connecticut Avenue N.W. • Suite 801 • Washington, D.C. 20036 • (202) 429-8873 / FAX (202) 429-2248

Note:
Exh. 7
is a poster — Tom B. has custody
Ballinger

FLORIDA PUBLIC SERVICE COMMISSION
DOCKET NO. 070650-EI **EXHIBIT** 7
COMPANY Witness on behalf of Citizens of FL
WITNESS Jennifer Rock's Poster
DATE 01/09/08

Table 1. Summary Results from Analysis of Recommended Policies

	Annual Savings in 2013 and 2023	2013		2023	
	Energy Efficiency (EE) Policies	**Electricity Savings (million kWh)**	**Demand Savings (MW)**	**Electricity Savings (million kWh)**	**Demand Savings (MW)**
1	Utility savings target	7,183	1,375	30,962	5,828
2	More stringent building codes	1,760	336	12,286	2,302
3	Public buildings program	1,536	293	4,608	847
4	Improved CHP policies	1,097	172	3,291	517
5	Short-term public ed. & rate incentives	4,582	873	3,549	653
6	Appliance & equipment standards	776	233	3,680	990
7	Advanced buildings program	458	336	7,503	2,302
8	Industrial competitiveness initiative	232	44	676	124
9	Expanded RD&D efforts	23	6	2,800	756
	Subtotal	*17,647*	*3,668*	*69,354*	*14,319*
	Renewable Energy (RE) Policies				
10	Onsite renewables policy package	2,542	486	20,183	3,775
11	Renewable portfolio standard	4,090	779	12,976	2,386
	Subtotal	*6,631*	*1,265*	*33,159*	*6,161*
	Total	**24,278**	**4,933**	**102,513**	**20,480**

Our calculations show that these energy efficiency and renewable energy policies can also reduce peak demand for electricity by over 20,000 MW in 2023, or 32% of projected peak demand. In addition, we also recommend that the state consider implementing a robust demand response effort, which could reduce peak demand by an additional 4,353 MW in 2013 and 9,637 MW in 2023, or 9% and 15% of projected peak demand, respectively (see Figure 2). While the utilities in the state have had various curtailable tariffs for many years, there is much more that could be done to reduce peak electrical loads. Demand response programs combined with energy efficiency and renewable energy policies could slow the rapid growth in peak demand projected by the state's utilities.

Our study asserts that energy efficiency, coupled with renewable energy, can slow future electricity demand. It would also diversify the state's energy resources, making Florida less vulnerable to global markets and volatile energy prices. The study shows that implementing energy efficiency policies alone, such as efficient windows, compact fluorescent light bulbs, and ENERGY STAR new homes and appliances, can almost offset the future growth in electric demand.

Economic and Jobs Impacts

Increased investments in energy efficiency rather than construction of new conventional power generation would result in significant reduction in consumer energy expenditures over the next 15 years, while promoting robust job growth in the state (Table 2). The energy efficiency policies would reduce consumer energy costs by over $28 billion relative to constructing new power plants, and would result in the creation of more than 14 thousand new jobs – many trade jobs related to the implementation of the energy efficiency measures. The direct and indirect total jobs mean that the efficiency strategy would be equivalent to nearly 100 new manufacturing plants relocating to Florida, but without the demand for infrastructure and other energy needs. And, in light of recent volatility in energy prices, the efficiency strategy has an added benefit of balancing the fuel supply and therefore stabilizing energy prices.

Figure 2. Impact on Summer Peak Demand of Expanded Demand Response, Energy Efficiency and Renewable Energy

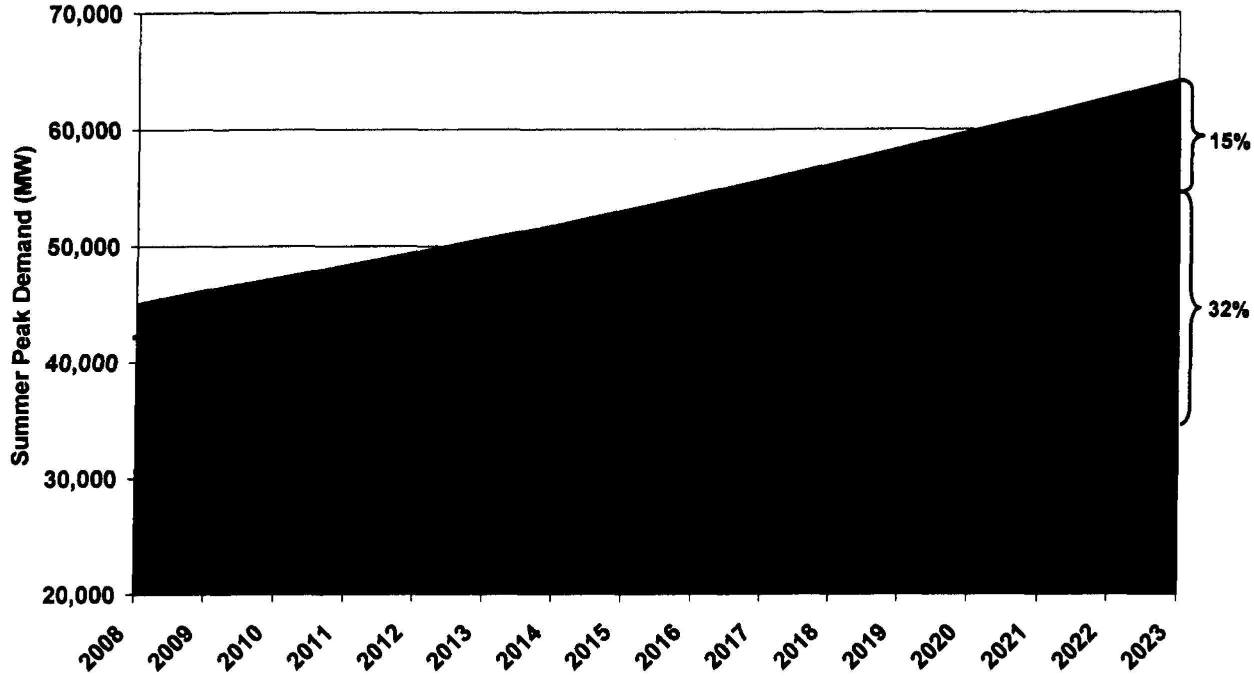


Table 2. Economic Impact on the State of Florida of Expanded Energy Efficiency

Financial Impacts (Millions of $2004)	2008	2013	2018	2023
Annual Consumer Outlays	1	1,585	2,172	2,584
Annual Electricity Savings	3	1,174	2,679	4,674
Electricity Supply Cost Adjustment	(1)	(894)	(1,867)	(2,975)
Net Consumer Savings	3	484	2,375	5,065
Net Cumulative Energy Savings	2	840	8,652	28,250

Macroeconomic Impacts	2008	2013	2018	2023
Jobs (Actual)	(33)	366	7,557	14,264
Wages (Million $2004)	(2)	(168)	(62)	64
GSP (Million $2004)	(4)	(1,134)	(1,857)	(2,745)

Estimate of Avoided Emissions *	2008	2013	2018	2023
SO_2 (thousand short tons)	0.0	5.9	10.8	16.3
NO_x (thousand short tons)	0.0	3.7	6.7	10.9
CO_2 (million metric tons)	0.0	11.1	21.8	37.1

* Note: Emissions are based on average emission rates.

The state's environment would benefit as well, with reductions in conventional power plant operations reducing SO_2 by more than 16 thousand tons and NO_X by almost 11 thousand tons. With concern growing about global warming, these efficiency measures would reduce CO_2 by over 37 million metric tons in 2023, making a down payment of reducing the state's carbon signature.

Conclusions

Based on this analysis, we are confident that energy efficiency and renewable energy can change Florida's energy future for the better. Energy efficiency resource policies can offset the majority of projected load growth in the state over the next 15 years. Expanded development of renewable energy resources in the state would further reduce future needs for conventional generation. Combined, these policies can meet nearly 30% of projected needs for electricity in 2023, deferring the need for many new electric power generation projects in the state.

The economic savings from the recommended energy efficiency policies alone in this report can cut Florida consumers' electricity bills by about $840 million in 2013 and $28 billion in 2023. While these savings will require substantial investments, they cost less than the projected cost of electricity from conventional sources. In addition, the investments would save consumers money while creating new jobs for the state.

Reducing demand for electricity with efficiency and renewables will also reduce emissions from the combustion of fossil fuels at utility power plants, offering the state a more sustainable environmental future at an affordable cost and allowing the state to start on a path to reducing its global warming emissions.

Florida faces important decisions on its energy future. The current course calls for investments in new coal, gas, and potentially nuclear generation to make sure that the state has enough electricity to sustain its economic prosperity. Energy efficiency and renewable energy resources offset some of that growth in demand, offering a lower cost, cleaner, and more stable energy path, without sacrificing Florida's quality of life or its economic growth.

ABOUT THE AMERICAN COUNCIL FOR AN ENERGY-EFFICIENT ECONOMY (ACEEE)

The report, *Potential for Energy Efficiency and Renewable Energy to Meet Florida's Growing Energy Demands* is available for free download at http://aceee.org/pubs/e071.htm or a hard copy can be purchased for $35 plus $5 postage and handling from ACEEE Publications, 1001 Connecticut Avenue, N.W., Suite 801, Washington, D.C. 20036-5525, phone: 202-429-0063, fax: 202-429-0193, e-mail: aceee_publications@aceee.org.

ACEEE is a nonprofit organization dedicated to advancing energy efficiency as a means of promoting both economic prosperity and environmental protection. For more information, see http://www.aceee.org. ACEEE fulfills its mission by:

- *Conducting in-depth technical and policy assessments*
- *Advising policymakers and program managers*
- *Working collaboratively with businesses, public interest groups, and other organizations*
- *Organizing conferences and workshops*
- *Publishing books, conference proceedings, and reports*
- *Educating consumers and businesses*

Projects are carried out by staff and selected energy efficiency experts from universities, national laboratories, and the private sector. Collaboration is key to ACEEE's success. We collaborate on projects and initiatives with dozens of organizations including federal and state agencies, utilities, research institutions, businesses, and public interest groups.

ACEEE is not a membership organization. Support for our work comes from a broad range of foundations, governmental organizations, research institutes, utilities, and corporations.

8

UNITED STATES
NUCLEAR REGULATORY COMMISSION
REGION II
SAM NUNN ATLANTA FEDERAL CENTER
61 FORSYTH STREET, SW, SUITE 23T85
ATLANTA, GEORGIA 30303-8931

October 30, 2007

EA-07-256

Wackenhut Nuclear Services
ATTN: Mr. Eric Wilson, President
4200 Wackenhut Drive
Palm Beach Gardens, FL 33410

SUBJECT: NRC OFFICE OF INVESTIGATIONS REPORT NO. 2-2006-013 - TURKEY POINT NUCLEAR PLANT

Dear Mr. Wilson:

This refers to an investigation completed by the NRC's Office of Investigations (OI) initiated on December 13, 2006. The purpose of the investigation was to determine if security officers employed with The Wackenhut Corporation (Wackenhut) at the Turkey Point Nuclear Plant (Turkey Point) were willfully inattentive to duty (sleeping) during 2004 – 2006. Enclosure 1 contains a factual summary of the OI investigation.

Based on the results of the OI investigation, apparent violations of NRC requirements were identified, including an apparent violation of 10 CFR 50.5, Deliberate Misconduct, and are being considered for escalated enforcement action in accordance with the NRC Enforcement Policy. The apparent violations involved the actions of multiple security officers employed by Wackenhut Corporation at Florida Power and Light Company's Turkey Point Nuclear Plant in 2004-2006. In this case, security officers were willfully inattentive to duty or served as lookouts such that other security officers could be inattentive while on duty. These actions caused Wackenhut to be in violation of 10 CFR 50.5, and caused the facility (Turkey Point) to be in violation of 10 CFR 73.55(f)(1), because these officers were unable to maintain continuous communication with an individual in each continuously manned alarm station.

Before the NRC makes its enforcement decision, we are providing you an opportunity to either: (1) respond to the apparent violations within 30 days of the date of this letter or (2) request a predecisional enforcement conference. If a conference is held, it will be closed to public observation in accordance with the NRC Enforcement Policy because the findings are based on an NRC Office of Investigations report that has not been publicly disclosed. Please contact Mr. Joel T. Munday, Chief, Plant Support Branch 2, Division of Reactor Safety, at (404) 562-4560, within 10 days of the date of this letter to notify the NRC of your intended response.

FLORIDA PUBLIC SERVICE COMMISSION
DOCKET NO. 070650-EI **EXHIBIT** 8
COMPANY Witness on behalf of the Citizens of FL
WITNESS Steve McGonigle
DATE 01/09/08

If you choose to request a predecisional enforcement conference, please be prepared to discuss the corrective actions you have taken to correct these inattentiveness issues and prevent recurrence.

If you choose to provide a written response, it should clearly be marked as a "Response to Apparent Violation EA-07-256" and should include: (1) the reason for the apparent violations, or, if contested, the basis for disputing the apparent violations; (2) the corrective steps that have been taken and the results achieved; (3) the corrective steps that will be taken to avoid further violations; and (4) the date when full compliance will be achieved. In presenting your corrective actions, you should be aware that the promptness and comprehensiveness of your corrective actions will be considered in assessing any civil penalty for the apparent violation. Your response should be submitted under oath or affirmation and it may reference or include previously docketed correspondence, if the correspondence adequately addresses the required response. If an adequate response is not received within the time specified or an extension of time has not been granted by the NRC, the NRC will proceed with its enforcement decision.

In lieu of a predecisional enforcement conference, you may also request Alternative Dispute Resolution (ADR) with the NRC in an attempt to resolve this issue. Alternative Dispute Resolution is a general term encompassing various techniques for resolving conflicts outside of court using a neutral third party. The technique that the NRC has decided to employ is mediation. Additional information concerning the NRC's program is described in the enclosed brochure (NUREG/BR-0317) and can be obtained at http://www.nrc.gov/about-nrc/regulatory/enforcement/adr.html. The Institute on Conflict Resolution (ICR) at Cornell University has agreed to facilitate the NRC's program as a neutral third party. Please contact ICR at 877-733-9415 within 10 days of the date of this letter if you are interested in pursuing resolution of this issue through ADR.

Since the NRC has not made a final determination in this matter, no Notice of Violation is being issued for the investigative findings at this time. In accordance with 10 CFR 2.390 of the NRC's "Rules of Practice," a copy of this letter and enclosures, and your response, will be made available electronically for public inspection in the NRC Public Document Room or from the NRC's document system (ADAMS), accessible from the NRC Web site at www.nrc.gov/reading-rm/pdr.html www.nrc.gov/reading-rm/adams.html. To the extent possible, your response should not include any personal privacy, proprietary, or safeguards information so that it can be made available to the Public without redaction.

In addition, please be advised that the number and characterization of the apparent violations described in this letter may change as a result of further NRC review.

If Safeguards Information is necessary to provide an acceptable response, please provide the level of protection described in 10 CFR 73.21.

Should you have any questions concerning this letter, please contact me at (404)-562-4600 or Mr. Joel T. Munday at (404) 562-4560.

Sincerely,

/RA/

Joseph W. Shea, Director
Division of Reactor Safety

Enclosures: 1. Factual Summary to OI Report No. 2-2006-013
2. NUREG/BR-0317

FACTUAL SUMMARY
Office of Investigations Report No. 2-2006-013

On March 8, 2006, the U.S. Nuclear Regulatory Commission (NRC), Office of Investigations (OI), initiated an investigation to determine if security officers employed with The Wackenhut Corporation (Wackenhut) at the Turkey Point Nuclear Plant (Turkey Point) were willfully inattentive to duty (sleeping) at times during 2004 through 2006.

Five security officers admitted that, at times during 2004 through 2006, they were inattentive to duty on separate occasions. Although specific dates of inattentiveness could not be established, one of these five security officers was observed by other security officers to be inattentive to duty on several occasions.

One security officer admitted that, on at least one occasion during 2004-2006, he stood lookout for two other security officers such that they could be inattentive to duties without risk of being caught.

One security officer stated that, on at least one occasion during 2004-2006, two security guards stood as lookouts for him such that he was able to be inattentive to duties without risk of being caught.

One security officer was observed by an NRC inspector to be inattentive to duties on April 6, 2006, while standing duty on a vital area compensatory post.

The Nuclear Regulatory Commission's

POST-INVESTIGATION ADR PROGRAM

Alternative Dispute Resolution

Administered by
Cornell University's

Institute on Conflict Resolution

What is ADR?

- The U.S. Nuclear Regulatory Commission is using alternative dispute resolution (ADR) to promote improved effectiveness of the enforcement program through efficient, timely, and amicable resolution of investigation findings.

- ADR includes a variety of processes that emphasize creative, cooperative approaches to handling conflicts in lieu of adversarial procedures.
- Parties in ADR remain in control of the decision on whether to participate in the process and whether to agree to any resolution. In other words, **the process is completely voluntary and any party may withdraw from the negotiation at any time.**

The Post-Investigation ADR Program

- Post-Investigation ADR occurs after the NRC Office of Investigations (OI) has completed its investigation of the case and an enforcement panel concludes that pursuit of an enforcement action appears warranted.
- Post-Investigation ADR may be used to resolve both discrimination and other wrongdoing cases apparently in violation of the NRC's regulations at three distinct points:
  - prior to the predecisional enforcement conference,
  - after the initial enforcement action is taken, and
  - after imposition of a civil penalty and prior to a hearing request.
- Post-Investigation ADR *may* resolve: whether a violation occurred, the appropriate enforcement action, and the appropriate corrective actions for the violation(s).
- Terms of the ADR settlement agreement will be confirmed by order.

Who can use Post-Investigation ADR?

- After OI has completed its investigation of the case and an enforcement panel concludes that pursuit of an enforcement action appears warranted; the licensee (or contractor) will typically be offered a chance to participate in ADR with the NRC.

- The NRC's program administrator can advise and assist the licensee in determining ADR potential for their case.
- After the licensee and the NRC agree to participate, the program administrator will help them appoint a neutral mediator and get started.

Why use Post-Investigation ADR?

- It allows people to develop solutions quickly to assist in resolving the case.
- Post-Investigation ADR will benefit both parties by bringing about more effective, efficient, and timely resolution of enforcement concerns.

What is mediation?

- Mediation is the ADR process normally used in the Post-Investigation ADR Program.
- It is an informal process in which a trained neutral (the "mediator") works with the parties to help them reach resolution.

- The mediator, who has no stake in the outcome and no power to make decisions, uses consensus-building skills and knowledge of negotiation to help parties find creative solutions.

How does mediation work in the Post-Investigation ADR Program?

- The mediator guides the parties through an informal process to develop solutions to resolve the case.
- The mediator helps the parties work together to reach an agreement that meets their needs without conforming strictly to their original positions.
- The mediator will usually give each party an opportunity to explain the issues. Often, the mediator will meet privately with each party (where they are more likely to speak freely)

to understand the parties' situations better and explore and assess options.

- The mediator may ask questions that will aid parties in assessing the merits of their positions, identify potential settlement options, and probe participants' realistic alternatives.

- A settlement agreement in Post-Investigation ADR will not become binding until both parties agree to it and a confirmatory order is issued.

Who serves as neutrals in ADR?

- To ensure a source of skilled, unbiased neutrals, the NRC uses Cornell University's Institute on Conflict Resolution (ICR) to select and oversee a roster of experienced mediators and administer the Post-Investigation ADR program's operations.
- Parties may jointly select the mediator for their case from among a panel of three furnished by ICR.
- Parties preferring to locate their own mediator may do so by mutual consent.

What does ADR cost me?

- The licensee requesting Post-Investigation ADR pays half the mediator's fees and the NRC, subject to availability of funds, will pay half.

Where do Post-Investigation ADR sessions take place?

- The session will typically occur at or near the licensed facility, or at NRC's Headquarters or Regional Office depending on site availability and party desires.

How long do sessions take?

- Many Post-Investigation ADR cases will be completed in one meeting that lasts several hours. Some could require a few additional sessions.

Is ADR confidential?

- Yes. With limited exception, the proceedings are private and the ADR neutral is generally prohibited from discussing the mediation with outsiders.
- To obtain additional details on confidentiality in Post-Investigation ADR, see the NRC's web site at **http://www.nrc.gov/what-we-do/regulatory/enforcement/adr.html.**

Who administers the ADR Program?

- Cornell University's Institute on Conflict Resolution (ICR) is the neutral program administrator for the Post-Investigation ADR program's day-to-day operation, including working with parties to identify appropriate mediators.
- ICR embraces a network of independent dispute resolution practitioners who work on a regional, national, and international basis.

- ICR works in partnership with companies, unions, and government to help resolve conflicts and evaluate the efficacy of conflict resolution methods.

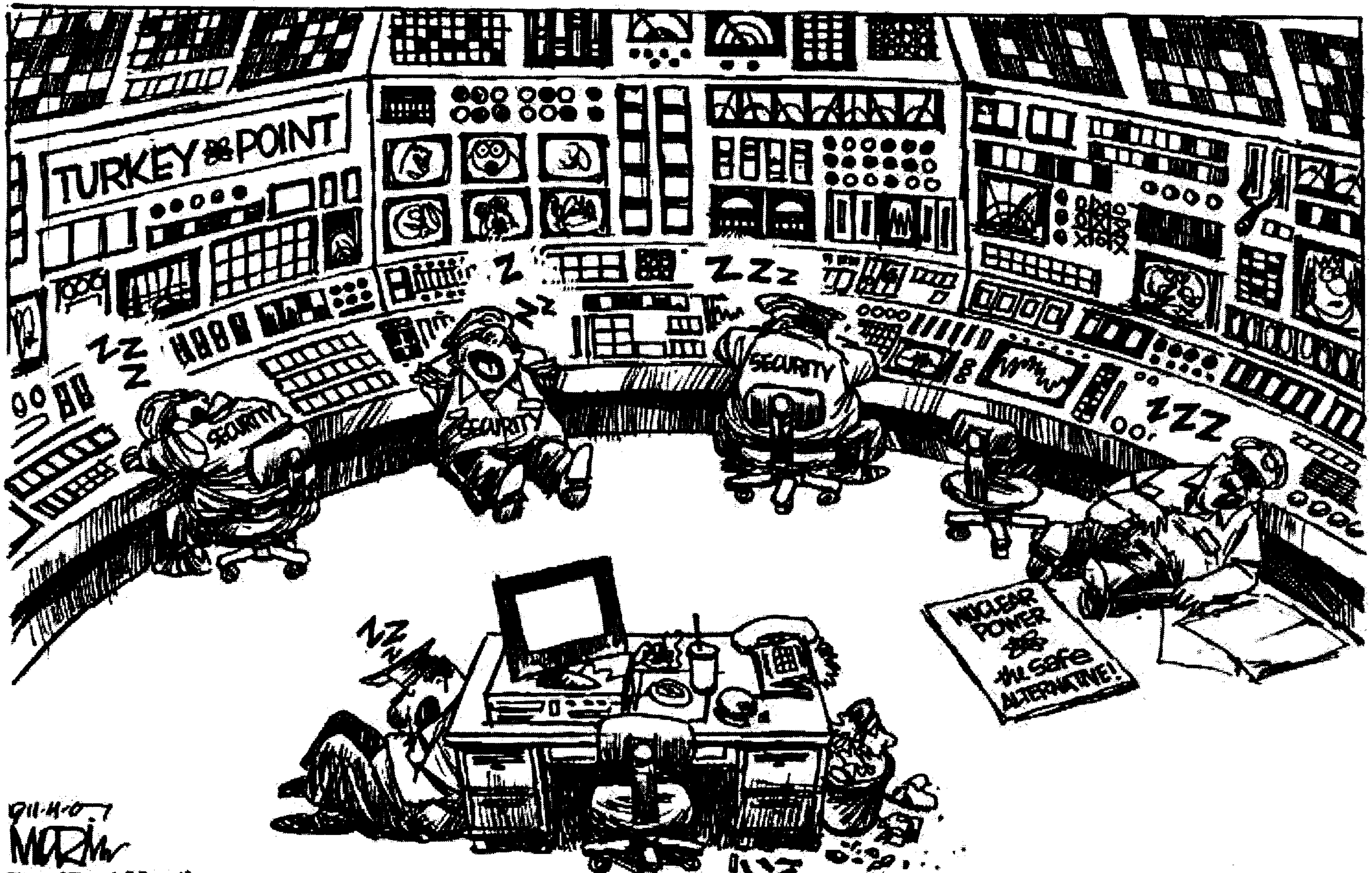
How do I obtain additional information?

Further information on participating in the Post-Investigation ADR program (besides this brochure's overview of the Post-Investigation ADR program) is available from:

- The NRC ADR Program Administrator (ICR: Catherwood Library Tower, Ives Hall, Cornell University, Ithaca, NY 14853; Phone: (877) 733-9415)
- The NRC's Enforcement ADR Pilot Program on its web site: **http://www.nrc.gov/what-we-do/regulatory/enforcement/adr.html.**

NUREG/BR-0317
January 2005

Enclosure 2



The Miami Herald

washingtonpost.com

Video of Sleeping Guards Shakes Nuclear Industry

Sight of Guards Asleep Shakes Industry

By Steven Mufson
Washington Post Staff Writer
Friday, January 4, 2008; A01

Kerry Beal was taken aback when he discovered last March that many of his fellow security guards at the Peach Bottom nuclear power plant in Pennsylvania were taking regular naps in what they called "the ready room."

When he spoke to supervisors at his company, Wackenhut Corp., they told Beal to be a team player. When he alerted the regional office of the Nuclear Regulatory Commission, regulators let the matter drop after the plant's owner, Exelon, said it found no evidence of guards asleep on the job.

So Beal videotaped the sleeping guards. The tape, eventually given to WCBS, a CBS television affiliate in New York City, showed the armed workers snoozing against walls, slumped on tabletops or with eyes closed and heads bobbing.

The fallout of the broadcast is still being felt. Last month, Exelon, the country's largest provider of nuclear power, fired Wackenhut, which had guarded each of its 10 nuclear plants. The NRC is reviewing its own oversight procedures, having failed to heed Beal's warning. And Wackenhut says that the entire nuclear industry needs to rethink security if it hopes to meet the tougher standards the NRC has tried to impose since the Sept. 11, 2001, terrorist attacks on the United States.

The most immediate impact has been felt at Wackenhut, which protected half of the nation's 62 commercial nuclear power plants. Exelon's decision to terminate Wackenhut's contract reduces the number of commercial sites protected by the company to 21.

"In the past, the standards were not our standards," said Craig Nesbit, vice president of communications at Exelon. "They were Wackenhut standards, and that's not what we want, and we're going to fix that." Exelon chief executive John W. Rowe added: "We had had some difficulties with them from time to time. We felt the incident with the guards was the last straw."

While Wackenhut has a long history of alleged flaws in its nuclear security operations and labor discontent, there is plenty of blame to go around.

The NRC, which in the past has referred 40 percent of wrongdoing allegations to nuclear plant licensees, is looking at its own procedures as well as Wackenhut's. David Lochbaum, a nuclear safety expert at the Union of Concerned Scientists, faults the NRC for "failing to 'connect the dots' " between Peach Bottom and other complaints about Wackenhut.

"More than anything else, we have to change the way the NRC responds to these allegations," said commission member Gregory B. Jaczko.

Exelon has come under scrutiny, too, from congressional and NRC investigators. Eric Wilson, the head of Wackenhut's nuclear security operations, was not available for comment for this article, but he has pointed a finger at the nuclear plant owners like Exelon.

In a slide presentation he made to watchdog groups last year, he said nuclear plant owners have pressed so hard for lower costs that "we are now 'down to the bone' " and that "the current business model does not yield consistently acceptable performance levels."

"The contractor worked for us," Exelon chief Rowe conceded in an interview. "Their performance is ultimately our responsibility. There's no way to paint that wagon any brighter."

For Wackenhut, controversy is nothing new.

Former FBI agent George Wackenhut founded the company in Miami in 1954 as a four-man detective agency and built it into a huge private security firm with 35,000 employees. Wackenhut, who died almost three years ago, wooed prominent people to his board, including former heads of the FBI, Secret Service and the Pentagon. Today the company is owned by a British firm, Group 4 Securicor, and does work ranging from guarding libraries to transporting immigration detainees for the Department of Homeland Security to guarding the government's Y-12 complex at Oak Ridge, Tenn., where nuclear weapons and materials are stored and maintained.

The company has a history of bad relations with its workers, which some experts say could undermine security procedures. The Union of Concerned Scientists said it has received complaints dating to 2001 from Wackenhut nuclear site workers, including one who was disciplined for declining to work a sixth 12-hour shift in one week while taking medication for a back injury.

In 2006, the NRC dispatched inspection teams to the Turkey Point nuclear plant in Florida to follow up on complaints of security problems. The Union of Concerned Scientists said that unhappy Wackenhut security guards at the plant had sabotaged their own equipment.

"Wackenhut's track record shows no regard for the welfare of their workforce or for public safety," said Andy Stern, president of the Service Employees International Union, which represents more than 25,000 security workers and has been organizing workers at Wackenhut sites.

"Wackenhut, along with the entire contract security industry, is the target of a massive effort by the SEIU to increase its membership and thereby its financial coffers," said Marc Shapiro, senior vice president of Group 4 Securicor.

It isn't only workers and the SEIU highlighting problems, though. Energy Department Inspector General Gregory Friedman has cited Wackenhut for a series of problems at the nation's most sensitive nuclear weapons sites.

In 2003, a Wackenhut employee took two government-owned handguns and one of his own in a briefcase to the National Nuclear Security Administration's Nevada test site, according to an IG report.

In 2005, the inspector general said that at the NNSA's Oak Ridge site, Wackenhut had routinely worked security personnel more than the 60-hour-a-week maximum permitted there. In addition, Wackenhut had misled the government about worker training. It reported planned training as actual training time, and protective-force personnel had signed attendance rosters for on-the-job refresher training they had not attended, the IG report said.

Friedman's office also found that one Wackenhut unit, hired by the NRC to simulate an attack on nuclear facilities, had tipped off another Wackenhut unit charged with guarding the facilities at Y-12 about the attack strategy. Danielle Brian, executive director of the Project on Government Oversight, said in a 2004 letter to the NRC that "this is more than a case of the proverbial fox guarding the henhouse. It is not an apparent conflict of interest -- but a blatant conflict of interest."

Regulators and some Wackenhut employees say, however, that some notice is always given to plants about to undergo a test and that the attackers in such "force-on-force" exercises often succeed in penetrating defenses. Officials from the NNSA said the inspector general exaggerated.

Last summer, in testimony before a subcommittee of the House Oversight and Government Reform Committee, Friedman said, "We did not use the word 'cheating' in the report, but it was. The test was compromised."

Despite the problems, in June Wackenhut was awarded contracts worth $549 million to protect the Y-12 National Security Complex and the Energy Department's Oak Ridge facility for another five years. But a spokeswoman for the IG said the Energy Department "is considering doing a feasibility study of federalizing the guard force at Y-12."

The heightened crisis for Wackenhut's nuclear operations comes just as the head of that unit, Wilson, has been trying to change the industry's approach to security and improve Wackenhut operations. A former member of the Army's 75th Ranger Regiment, he joined the company in 2004 and took over the nuclear security unit about a year ago. He has made the rounds of company critics and watchdog groups in Washington.

Wilson said the nuclear industry improved operating safety procedures after the accident at the Three Mile Island nuclear plant in Pennsylvania in 1979, but that the industry has not taken similar steps on security procedures since the 2001 terrorist attacks. The size of security staff at nuclear power plants has more than doubled as a portion of total staffing, yet low pay makes it "difficult to attract the right staff and leadership talent." He said corporate investment in the area was "inadequate."

Exelon's Rowe said, however, that "it's hard to say you're overusing people when the reason they went to sleep is that they had nothing to do."

"All companies, from time to time, have employees who do not perform up to standards. When this occurs, we address the problem," Wilson said in a Nov. 15 letter protesting an editorial cartoon in the Miami Herald about the sleeping guards. "While others mock and belittle our employees for the actions of a few, I applaud them for their hard work."

Wilson proposed expanded training and re-training programs and college-level offerings for guards. He also favored the introduction of devices similar to those carried by firefighters; if the device detects no movement for a given period of time, it would page itself, and if a worker does not answer promptly, other security guards would be dispatched to investigate.

"Eric has good ideas and comes across as sincere in wanting to implement them," said the Union of Concerned Scientists' Lochbaum, who has met Wilson twice. "I'm not sure he will have the time he needs to make it happen. Because Wackenhut treated its guards so badly for so long, many have lost trust in the company and view Eric's talk as just that."

9

UWMD Statement for FSPC Hearing:

- Acknowledge members of the Commission and thank them for the opportunity to speak today.

- Self-Introduction {Sharon Griemsman, Senior Director for United Way of Miami-Dade. One of primary responsibilities is managing the annual development partnership between Florida Power and Light and our organization}

- CEO/Organization Introduction {I am speaking on behalf of our CEO, Harve Mogul, who asked me to share our organization's statement}

- Longstanding relationship of almost half a century between Florida Power and Light (FPL) and United Way of Miami-Dade (UWMD) and the United Way system

- FPL's corporate commitment, leadership and compassion to help others through their partnership with UWMD

- FPL's community-centric mission is a culture that lives within the organization; in that it is shared and acted upon by its leaders, management and labor, its employees, contractors and vendors.

- Through the years they have fostered an impressive track record that reads as a 'top rated report card' for the most philanthropic minded entities in the country.

- FPL provides its annual UWMD investment to our local communities, through:

  - Volunteer Service, as Board/Committee members, community service days/hours, ancillary committees/program (Women's Leadership (focusing on our children) and Loaned Executive program)

  - Advocacy, sharing information and supporting our ability to provide citizens with opportunities for health/human service benefits. As well as providing low-income families with options for better meeting their energy service needs.

  - Community Planning/Development, serving as an information resource and providing professionals' time and expertise for the development of solutions to meet the most urgent needs of the communities

  - Resource Provider, by annually directing in excess of $2M in South Florida, ($1 million plus locally here in Miami-Dade); and since 2000 have topped well over $10 million statewide towards investments that improve the quality of life for Floridians, thus allowing UWMD to implement and deliver results.

- We are proud and honored to be here today to say that FPL has proven it is a responsible, community conscience partner.

FLORIDA PUBLIC SERVICE COMMISSION
DOCKET NO. 070650-EI **EXHIBIT** 9
COMPANY Witness on behalf of the Citizens of FL
WITNESS Sharon Griemsman
DATE 01/09/08

For more information, please visit

The Silver Nightingale Nuclear Free Zone

www.SilverNightingale.com/nuclearfree.html

FLORIDA PUBLIC SERVICE COMMISSION

DOCKET NO. 070650-EI EXHIBIT 10

COMPANY Witness on behalf of the Citizens of FL

WITNESS Laura Sue Wilansky

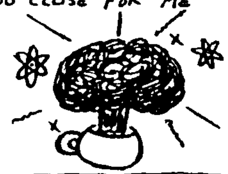
DATE 01/09/08

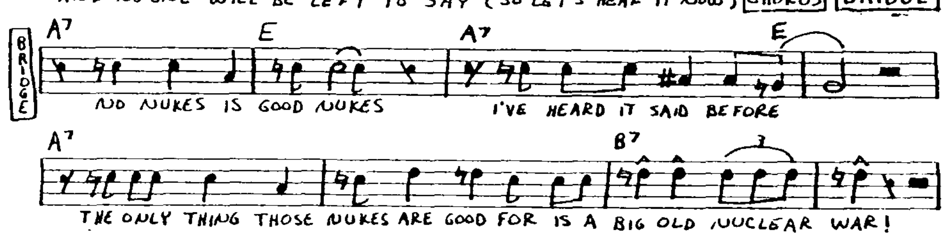
REPRINTED FROM PEOPLE'S ENERGY 1979 CALENDAR

NO NUKES SWING

from the SOLAR POWER SUITE

2. WELL I HEARD THEY BUILT A NUCLEAR REACTOR
SOMEWHERE OUT WEST AROUND CHICAGO WAY
THE DAMN THING NEARLY KILLED A COUPLE MILLION FOLKS
"WELL ACCIDENTS WILL HAPPEN" SO THEY SAY
SOME DAY SOME BIG OLD ACCIDENT WILL HAPPEN
AND NO ONE WILL BE LEFT TO SAY (SO LET'S HEAR IT NOW) CHORUS BRIDGE





3. THEY WANT TO BUILD THOSE NUCLEAR REACTORS
IT'S UP TO US TO STOP THEM 'FORE THEY CAN
THERE'S PEOPLE ALL AROUND THE WORLD UNITING
TO SAVE THEIR HOMES AND COUNTRIES FROM THAT PLAN
WE ALL OF US HAVE GOT TO WORK TOGETHER
AND GET A LITTLE NUCLEAR BAN (SO WE'LL HAVE) CHORUS

The Solar Power Suite is a two-part composition. In addition to the "No Nukes Swing" in contains "Salute to the Sun," a flute or English horn solo that uses music to describe the sun.

Movement organizations may reproduce "No Nukes Swing" for non-profit use in anti-nuclear work. Be sure to include the copyright notice.

Laura Sue Wilansky is determined to use her music to change the world and to assert her power as a woman. She is currently a member of Felicidad, a Syracuse women's band.

WHICH SIDE ARE YOU ON?

CHORUS:

Which side are you on?
(repeated 4 times)

NEW VERSES by JACKMANNO

They tell us that our future's
in nuclear power plants;
We say that for our children
we're not gonna take that chance.

They measure all their power
in the kilowatt and gun;
Our strength is in our numbers
and the warmth of the sun.

They think we're like their money,
our strength will soon run dry;
But our power, it won't weaken
and our energy won't die.

The only kind of trust they know
is the trust funds that they own;
We have come together
and we are not alone.

In Sterling, NY,
we're gonna draw the line;
There's going to be no more nukes;
we're running out of time.

We say that nuclear power plants
are guaranteed to kill;
If plutonium don't get to you
nuke warfare surely will.

"Cultural Worker"

The term "cultural worker" may be new to some people. We use it to suggest several things. First, that the task of creating culture in a society is not the work of an elite, highly-paid few--which has become the case in our mass-market society; for example, if a restaurant needs a painting for its wall or a musician to entertain its customers, why not seek out the talents of local people rather than the highly-paid

"notables that have made it." Second, that people who create culture are legitimate workers who deserve to be recognized and valued for their work, not "patronized." Third, that the process of creation is based in a desire to improve the lives of people not turn a profit. Fourth, that all of us in some way are capable of being cultural workers if we can only free ourselves from the "I'm not talented" paralysis that elitism and competition produce in our capitalist society.

Most of the wonderful cultural workers in People's Energy are struggling. They need and deserve all of our support. If you're interested in them doing some work for you, please contact SPC for their address and phone.

No Nukes Swing

VERSE They want to build a nuclear reactor
They picked a spot that's just across the street
They say we won't have any trouble parking
They say they'll keep the lawn so nice and neat
Well I don't want no nuclear reactor
A-staring through my window at me (so I told them)

CHORUS No nukes in my coffee
No nukes in my tea
No nukes in my backyard
That's just a little too close for me

VERSE It started with that first atomic weapon
The peaceful atom is your friend they'd say
Just let us have another billion dollars
And we'll be building new bombs every day
As if they didn't have enough already
To blow the whole world away

CHORUS No nukes in my coffee
No nukes in my tea
No nukes in my backyard
That's just a little too close for me

BRIDGE No nukes is good nukes, I've heard it said before
The only thing those nukes are good for is a big old nuclear war!

WAR!

VERSE Kazoo solo

BRIDGE No nukes is good nukes, at least that's what I hear
The only thing those nukes are good for is a profit for those profiteers!

VERSE They want to build those nuclear devices
It's up to us to stop them while we can
There's people all around the world uniting
To save their homes and countries from that plan
All of us have got to work together
And get a little nuclear ban (so we'll have)

CHORUS No nukes in our coffee
No nukes in our tea
No nukes in our backyard
That's just a little too close for me

No nukes in my coffee
No nukes in my tea
No nukes in my backyard
That's just a little too close for me :| 3x

FLORIDA PUBLIC SERVICE COMMISSION
DOCKET NO. 070650-EI EXHIBIT 11
COMPANY Witness on behalf of the Citizens of FL
WITNESS Cathy Gilbert
DATE 01/09/08

Green Party Statement on Nuclear Power in Florida

The Green Party of Florida and the Miami-Dade Green Party strongly oppose the construction of new nuclear power plants in Florida, and we call upon the Public Service Commission of Florida to reject proposals for new reactors at Turkey Point and other Florida sites.

In the context of the escalating global climate crisis, it is imperative that all public funds invested in the production of electrical power be focused exclusively on clean, renewable energy production and sustainable solutions.

Our commitment to the security and survival of not only our own society, but the global human community, obligates us to reject false solutions such as the nuclear power option, and instead to work together to end dependence on the polluting energy industries that endanger the health and wellbeing of all life on the planet.

The nuclear power industry owes its very existence to massive government subsidies, and the current attempt to revive this industry under the guise of combating global climate change is little more than a scheme by corporate profiteers to enrich themselves once again at the public's expense, and at the expense of our future quality of life.

Increased nuclear energy production will not and cannot solve the climate crisis. The construction of new nuclear power plants would be prohibitively expensive when all costs are factored in, and in any case they could not be brought on line in time to meet the CO_2 reduction goals that must be met to avert catastrophe.

Among the hidden costs of nuclear power:

- the poisoning of indigenous people and ecosystems in the mining and extraction of uranium
- the consumption of massive amounts of fossil fuels in the production process, including the mining, refining, and transportation of uranium
- the use of massive amounts of water for the cooling of the plants, placing unnecessary demands on the supply of ever more precious water
- the long term health risks associated with ongoing radioactive emissions from nuclear plants
- the negative environmental impacts on marine life in the plant's discharge zone
- the everpresent potential for catastrophic failure
- the permanent need for security to prevent attacks on nuclear facilities
- the long term handling and storage of highly radioactive nuclear waste, which remains a threat to public health and safety for millenia

Given the improved efficiency of clean, renewable energy technologies that are at our disposal now, and in development around the world, it would be foolhardy and irresponsible to implement an energy policy for the 21st century energy that diverts public funds into subsidizing a dangerous and obsolete industry.

The development of a safe and sustainable energy policy requires that public funds be invested in clean, affordable and renewable energy technologies. The expansion and perpetuation of the nuclear power industry can only be accomplished by means of huge government subsidies. The public interest is not served by such a policy, and subsidies for nuclear power should be firmly opposed by all citizens and public officials who are truly concerned about the health and safety of future generations, and the future of the planet itself.

FLORIDA PUBLIC SERVICE COMMISSION
DOCKET NO. 070650-EI EXHIBIT 12
COMPANY Witness on behalf of the Citizens of FL
WITNESS Suzette Rice
DATE 01/09/08

12

News code:SPH - 01_SLEEPING.txt News date: Saturday, January 5, 2008

www.tehrantimes.com

Print Documents

Video of nuclear plant guards snoozing shocks U.S.

By Steven Mufson

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In 2003, a Wackenhut employee took two government-owned handguns and one of his own in a briefcase to the National Nuclear Security Administration's Nevada test site, according to an IG report.

In 2005, the inspector general said that at the NNSA's Oak Ridge site, Wackenhut had routinely worked security personnel more than the 60-hour-a-week maximum permitted there. In addition, Wackenhut had misled the government about worker training. It reported planned training as actual training time, and protective-force personnel had signed attendance rosters for on-the-job refresher training they had not attended, the IG report said.

Friedman's office also found that one Wackenhut unit, hired by the NRC to simulate an attack on nuclear facilities, had tipped off another Wackenhut unit charged with guarding the facilities at Y-12 about the attack strategy. Danielle Brian, executive director of the Project on Government Oversight, said in a 2004 letter to the NRC that "this is more than a case of the proverbial fox guarding the henhouse. It is not an apparent conflict of interest -- but a blatant conflict of interest."

Regulators and some Wackenhut employees say, however, that some notice is always given to plants about to undergo a test and that the attackers in such "force-on-force" exercises often succeed in penetrating defenses. Officials from the NNSA said the inspector general exaggerated.

Last summer, in testimony before a subcommittee of the House Oversight and Government Reform Committee, Friedman said, "We did not use the word 'cheating' in the report, but it was. The test was compromised."

Despite the problems, in June Wackenhut was awarded contracts worth $549 million to protect the Y-12 National Security Complex and the Energy Department's Oak Ridge facility for another five years. But a spokeswoman for the IG said the Energy Department "is considering doing a feasibility study of federalizing the guard force at Y-12."

The heightened crisis for Wackenhut's nuclear operations comes just as the head of that unit, Wilson, has been trying to change the industry's approach to security and improve Wackenhut operations. A former member of the Army's 75th Ranger Regiment, he joined the company in 2004 and took over the nuclear security unit about a year ago. He has made the rounds of company critics and watchdog groups in Washington.

Wilson said the nuclear industry improved operating safety procedures after the accident at the Three Mile Island nuclear plant in Pennsylvania in 1979, but that the industry has not taken similar steps on security procedures since the 2001 terrorist attacks. The size of security staff at nuclear power plants has more than doubled as a portion of total staffing, yet low pay makes it "difficult to attract the right staff and leadership talent." He said corporate investment in the area was "inadequate."

Exelon's Rowe said, however, that "it's hard to say you're overusing people when the reason they went to sleep is that they had nothing to do."

"All companies, from time to time, have employees who do not perform up to standards. When this occurs, we address the problem," Wilson said in a Nov. 15 letter protesting an editorial cartoon in the Miami Herald about the sleeping guards. "While others mock and belittle our employees for the actions of a few, I applaud them for their hard work."

Wilson proposed expanded training and re-training programs and college-level offerings for guards. He also favored the introduction of devices similar to those carried by firefighters; if the device detects no movement for a given period of time, it would page itself, and if a worker does not answer promptly, other security guards would be dispatched to investigate.

"Eric has good ideas and comes across as sincere in wanting to implement them," said the Union of Concerned Scientists' Lochbaum, who has met Wilson twice. "I'm not sure he will have the time he needs to make it happen. Because Wackenhut treated its guards so badly for so long, many have lost trust in the company and view Eric's talk as just that."

Print Documents

FLORIDA PUBLIC SERVICE COMMISSION
DOCKET NO. 070650-EI **EXHIBIT** 13
COMPANY Witness on behalf of the Citizens of FL
WITNESS Steve Showen
DATE 01/09/08

Green Party Statement on Nuclear Power in Florida

The Green Party of Florida and the Miami-Dade Green Party strongly oppose the construction of new nuclear power plants in Florida, and we call upon the Public Service Commission of Florida to reject proposals for new reactors at Turkey Point and other Florida sites.

In the context of the escalating global climate crisis, it is imperative that all public funds invested in the production of electrical power be focused exclusively on clean, renewable energy production and sustainable solutions.

Our commitment to the security and survival of not only our own society, but the global human community, obligates us to reject false solutions such as the nuclear power option, and instead to work together to end dependence on the polluting energy industries that endanger the health and wellbeing of all life on the planet.

The nuclear power industry owes its very existence to massive government subsidies, and the current attempt to revive this industry under the guise of combating global climate change is little more than a scheme by corporate profiteers to enrich themselves once again at the public's expense, and at the expense of our future quality of life.

Increased nuclear energy production will not and cannot solve the climate crisis. The construction of new nuclear power plants would be prohibitively expensive when all costs are factored in, and in any case they could not be brought on line in time to meet the CO2 reduction goals that must be met to avert catastrophe.

Among the hidden costs of nuclear power:

- the poisoning of indigenous people and ecosystems in the mining and extraction of uranium
- the consumption of massive amounts of fossil fuels in the production process, including the mining, refining, and transportation of uranium
- the use of massive amounts of water for the cooling of the plants, placing unnecessary demands on the supply of ever more precious water
- the long term health risks associated with ongoing radioactive emissions from nuclear plants
- the negative environmental impacts on marine life in the plant's discharge zone
- the everpresent potential for catastrophic failure
- the permanent need for security to prevent attacks on nuclear facilities
- the long term handling and storage of highly radioactive nuclear waste, which remains a threat to public health and safety for millenia

Given the improved efficiency of clean, renewable energy technologies that are at our disposal now, and in development around the world, it would be foolhardy and irresponsible to implement an energy policy for the 21st century energy that diverts public funds into subsidizing a dangerous and obsolete industry.

The development of a safe and sustainable energy policy requires that public funds be invested in clean, affordable and renewable energy technologies. The expansion and perpetuation of the nuclear power industry can only be accomplished by means of huge government subsidies. The public interest is not served by such a policy, and subsidies for nuclear power should be firmly opposed by all citizens and public officials who are truly concerned about the health and safety of future generations, and the future of the planet itself.