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COMMISSION CLERK

November 2, 2006

Hand Delivery
Blanca Bayo
Director, Office of the Commission Clerk
Florida Public Service Commission
2540 Shumard Oak Blvd
Tallahassee, Florida 32399-0850

RE: Docket No. 060635-EU, Petition for determination of need for Electrical power plant in Taylor County by Florida Municipal Power Agency, JEA, Reedy Creek Improvement District, and City of Tallahassee.

Dear Ms. Bayo:

Enclosed for filing in the above captioned docket are fifteen copies of the testimony of Daniel Lashof and Dale Bryk on behalf of Intervenor, Natural Resources Defense Council and Intervenor, Rebecca J. Armstrong. Copies of this testimony have been provided by regular mail to the parties.

Please acknowledge the receipt of this filing by date stamping the enclosed copy of this letter and returning it to the person who has hand delivered it.

Thank you very much for your assistance.

Sincerely,

for < Patrice Simms

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Lashof
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Bryk
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SCANNED

Docket No. 060635EU
Lashof Direct Testimony
Intervenors NRDC and Anderson

BEFORE THE PUBLIC SERVICE COMMISSION

In re: Petition for determination of need for Electrical power plant in Taylor County by Florida Municipal Power Agency, JEA, Reedy Creek Improvement District, and City of Tallahassee.	)))))	Docket No. 060635EU

Direct Testimony of Daniel Lashof

on behalf of

Intervenor, Natural Resources Defense Council
and
Intervenor, Rebecca J. Armstrong

November 2, 2006

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Q: Please state your name, occupation, and business address.

A: My name is Daniel Lashof, I am the Science Director for the Natural Resources Defense Council's Climate Center, and my business address is 1200 New York Avenue, NW, Suite 400, Washington, D.C., zip code 20012.

Q: Please summarize your education and experience.

A: I hold a PhD in Energy and Resources from the University of California, Berkeley, and an undergraduate degree in physics and mathematics from Harvard. I am now the Science Director and Deputy Director for the Natural Resources Defense Council's Climate Center, and I have worked for NRDC for over 8 years. Prior to joining NRDC, among other things, I worked at the U.S. EPA as an environmental scientist, with the Bruce Company as a senior analyst in the climate change center, and with Lawrence Berkeley Laboratory as a research assistant. I have authored or co-authored more than 25 major publications, many directly relating to climate change, and have given testimony in dozens of instances in a variety of settings. I also have been the recipient of numerous honors and have held several climate-related appointments. My CV is attached as Exhibit A.

Q: What is the purpose of your testimony today?

A: This testimony is submitted in support of NRDC's intervention to advocate for the best and least cost option for meeting Florida's power needs, and in particular to explain why it is absolutely necessary to consider the likely costs associated with carbon dioxide emission in the context of decisions about the development of new capacity – especially for proposals involving coal-fired electricity generation. The regulation of carbon dioxide (CO_2) will have a significant impact on the relative economics of coal-based electricity generation, and should be taken into account when determining whether a particular project is the most cost-effective and least risky alternative available, whether other cost-effective alternatives exist, and whether efficiency and other demand-side management ("DSM") measures are reasonably available to mitigate the need for the proposed plant.

Q: Why are Carbon Dioxide emissions so important?

A: Carbon dioxide is a potent heat-trapping (also known as "greenhouse") gas. As we burn fossil fuels, we release more and more CO_2 into the atmosphere – CO_2 that otherwise would have remained trapped in the coal, oil, or other fossil fuel source. By dramatically increasing the rate of such emissions over the past 200 years, we have significantly changed the concentration of CO_2 in the atmosphere, leading to changes in climate, including a pronounced increase in global temperatures, increased melting of sea ice, ice sheets, and glaciers, and alterations in weather patterns (and according to some scientists the generation of larger, more powerful hurricanes).

There is virtual unanimity within the scientific community that human activities have contributed significantly to global climate change and that if left unchecked the continued release of global warming pollutants (primarily CO_2) will result is dramatic climate disruption by the end of this century. The science tells us that each year emissions from burning fossil fuels and destroying forests puts about twice as much carbon dioxide (CO_2) into the atmosphere as natural sources can remove. As a result, the amount of carbon dioxide in the atmosphere is rising worldwide and the rate of growth is increasing. The average CO_2 concentration in Earth's atmosphere is now over 380 parts per million by volume (ppm), which is higher than it has been for at least 650,000 years.[1] In 2005 the concentration of carbon dioxide in the atmosphere increased by 2.5 ppm, the third largest annual increase ever recorded.[2] Although there is considerable variation from year to year in the rate of increase in atmospheric carbon dioxide, the rise has been

[1] Siegenthaler, U., T.F. Stocker, E. Monnin, D. Luthi, J. Schwander, B. Stauffer, D. Raynaud, J. Barnola, H. Fischer, V. Masson-Delmotte, and J. Jouse (2005) Stable Carbon Cycle-Climate During the Late Pleistocent, *Science*, 310, p. 1313-1317.
[2] Tans, P. (2006) Trends in Atmospheric Carbon Dioxide, NOAA ESRL, available at: http://www.cmdl.noaa.gov/ccgg/trends/

more than 2 ppm in 3 of the last 4 years and preliminary 2006 data indicate that this trend is continuing.

The unprecedented buildup of carbon dioxide in our atmosphere endangers our environment, our health, and our economy. Carbon dioxide traps heat in the earth's atmosphere, preventing it from escaping into space. So the imbalance in the carbon cycle has also thrown the earth's energy balance out of whack, which means that each year the earth absorbs more energy from the sun than it radiates back into space. Global warming is the inevitable result and the human fingerprint on Earth's climate is now clearly visible.

As a result, the control of carbon emissions (especially CO_2) is being widely recognized as vital to protect against catastrophic public health, environmental, and economic consequence of global warming. Indeed, a study release just this week, produced by Sir Nicholas Stern, former chief economist of the World Bank and currently the Head of the UK Government Economic Service, concludes, among other things, that the levelized costs of global warming could range from 5 to 20% of global GDP.[3] The report also concludes that many or most of the worst consequence of global warming can still be avoided at much lower cost, but doing so will require immediate and dramatic action.

In particular, because energy production is the single largest anthropogenic contributor of CO_2 emissions, and because coal-fired electricity generation is the largest single source of these energy-related emissions, controlling CO_2 from coal-fired power plants will necessarily become a major component of any program to reduce CO_2 emission.

Q: Why is regulation of CO_2 a virtual certainty during the life of this proposed power plant?

[3] The Summary of Conclusions from this report is included as an attachment to this testimony, and the full report is available at: www.sternreview.org.uk.

A: It has become abundantly clear that CO_2 emissions, from sources such as coal-fired power generation, are creating a serious threat of dramatic climate disruption. The international community has already begun to take action to curb such emissions – 190 countries have joined the United Nation's Framework Convention on Climate Change, and most have ratified the Kyoto Protocol (the U.S. and Australia alone among the industrialized countries have not). More recently certain States have also taken concrete steps to reduce their carbon footprint – for example, several Northeast States have formed the Region Greenhouse Gas Initiative (RGGI) to reduce carbon emission in that part of the country.[4] The state of California also has passed legislation to limit the state's greenhouse gas emissions, and to require that new long-term investments in baseload generation meet a minimum standard for greenhouse gas emissions, and several Western and Midwest States are now contemplating action to limit greenhouse gases. Moreover, members of Congress have introduced numerous bills, amendments, and resolutions specifically addressing global warming, and the Senate last year passed a resolution calling for a "comprehensive and effective national program of mandatory, market-based limits and incentives on emissions of greenhouse gases that slow, stop, and reverse the growth of such emissions"[5,6] Studies continue to show that such regulation is the only responsible and economically sensible course of action; for example the Stern Report referenced above concluded that while the cost of inaction could range from 5-20% of GDP, the cost of stabilizing ambient concentrations at 450 to 550 ppm CO_2-equivalent can be accomplished for about 1% of GDP. According to the report, the key policies

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[4] See www.rggi.org.

[5] Senate Amendment 866 a Sense of the Senate climate change resolution proposed by Senators Bingaman, Specter, Domenici, Alexander, Cantwell, Lieberman, Lautenberg, McCain, Jeffords, Kerry, Snowe, Collins and Boxer adopted by a vote of 53 to 44 on June 22, 2005. Congressional Record, Vol. 151, June 22 2005, S7033 – S7037, S7089.

[6] See www.aip.org/fyi/2005/114.html. In May of this year the House Appropriations Committee approved similar language. See www.pewclimate.org/what_s_being_done/in_the_congress/index.cfm for more information on Congressional action on global warming.

require to meet the goal are the implementation of carbon emission regulation (such as cap and trade measures), the deployment of low carbon-technologies and further low-carbon innovation, and the removal of barriers to energy efficiency.

As the momentum to regulate greenhouse gas emissions continues to grow around the country and internationally, businesses are increasingly recognizing the risk associated with carbon emissions. For example:

- PacifiCorp and Idaho Power Company have explicitly addressed the financial risk associated with carbon emissions in their recent IRPs. Idaho Power's draft IRP, for example, explains that the utility analyzed the financial risk of carbon emissions because "it is likely that carbon dioxide emissions will be regulated within the thirty year timeframe addressed in the 2004 IRP."[7]
- PG&E's long-term plan recognizes the risk of increasing costs for carbon emissions.
- Last year, the Coalition for Environmentally Responsible Economies (CERES) convened a Dialogue among experts from the power sector, environmental groups, and the investment community focusing on climate change. The Dialogue participants found that greenhouse gas emissions will be regulated in the U.S., and that the "issue is not whether the U.S. government will regulate these emissions, but when and how."[8]
- Utility shareholders are recognizing that the likelihood of regulation of carbon emissions represents a real financial risk, and are asking utilities to disclose those risks. Thirteen major public pension funds, which manage $800 billion in assets, recently asked the Securities and Exchange Commission to require companies to

[7] See PacifiCorp, "2003 Integrated Resource Plan," www.pacificorp.com. Idaho Power Company, "Draft 2004 Integrated Resource Plan," www.idahopower.com/energycenter/2004irpdraft.htm.
[8] Coalition for Environmentally Responsible Economies, "Electric Power, Investors, and Climate Change," June 2003, p. 4 (www.ceres.org/reports/main.htm).

disclose the financial risks they face from climate change.[9] Meanwhile, in 2004 alone institutional shareholder groups filed 29 proposals asking individual companies to outline their response to global warming.

There is overwhelming evidence that carbon emissions will likely be regulated in the near future, and accordingly, businesses in the U.S. are taking this financial risk quite seriously. We urge the Commission and Florida's utilities to recognize formally that carbon dioxide emissions pose a real and substantial financial risk to customers and shareholders.

The general consensus in the U.S. is that federal CO_2 emission controls are inevitable. Notably, the utility industry as well has begun to recognize that national carbon emission limits are both necessary and desirable – for example, executives from Duke Energy and NRG have recently made statements strongly supporting the idea of national carbon limits, and emphasizing the responsibility of the electric power sector to take action to address global warming.[10] Because power generation is the single most significant source of CO_2 in the United States (accounting for nearly 40% of U.S. emission), this industry – and coal-fired power generation in particular – is certain to be among the first industry sectors affected by carbon-related regulation.

Based on the growing consensus and concern about global warming, it is my view that national regulation of CO_2 is imminent, and is virtually certain to occur within the operational life of this proposed facility.

Q: Why would regulation of CO_2 have such a significant impact on the cost of coal-fired power generation?

A: Unlike other pollutant emissions, it is not economically feasible to capture CO_2 from conventional coal fired power plants. As a result, when a facility like the proposed TEC

[9] Margaret Kriz, "Measuring The Climate For Change," Congress Daily, April 22 2004.
[10] *See, e.g.*, http://www.cleartheair.org/proactive/newsroom/release.vtml?id=25835.

is built, its carbon emissions are effectively "locked in" for the plant's operational life, making an overall reduction of aggregated CO_2 emissions that much more difficult.

However, because coal-fired power plants are the largest single contributors to CO_2 emissions, they represent the low-hanging fruit when it comes to CO_2 regulation. As a result, any strategy aimed at reducing CO_2 in order to address the impending global warming crisis will need to achieve significant reductions in emissions from such facilities. Because it is considered the most cost-effective way to ensure these reductions, a carbon trading scheme is likely to be established (much like the one now operating in Europe), which will assign a cost for CO_2 emission credits that large emitters of CO_2 (like power plants) will need to purchase. One result of this kind of regulatory scheme is a significant increase in the cost of generating electricity using carbon intensive-technology.

When carbon reduction requirements emerge they will make the operation of carbon intensive power generation units – like the one proposed here – much more expensive (requiring either the purchase of CO_2 credits to offset emissions, or the direct control of CO_2 output). To minimize costs of meeting Florida's power needs, the PSC should require exploration of other options (including conservation, efficiency, and other demand-side strategies, renewable energy sources, and alternative technologies such as IGCC).

Q: Why do you believe that the proposed Taylor Energy Center is not the least cost option and is a risky proposition for Florida's electricity customers?

A: *As indicated in other testimony it appears that there are real opportunities to address* future capacity needs through conservation, efficiency and other demand-side management options, and there are other potentially more cost-effective alternatives to the proposed project, such as renewable energy resources (such as biomass-fired power plants), and more advanced and more efficient coal technologies such as integrated gasification combined cycle (IGCC), which can allow for the capture and permanent disposal of CO_2.[11] Indeed, an analysis of energy options available to the City of Tallahase found that a resource plan based on increased investment in demand side management (DSM) and a biomass-fired power plant would be lower cost than a plan in which the City invests in its proposed share of the Taylor Energy Facility. In addition, however, because the applicants here have not evaluated the true cost of a pulverized coal-fire power plant, including costs associated with future carbon regulation, their analysis is incomplete.

The Taylor Energy Center project has chosen a coal-based technology for generating electricity that will create huge volumes of CO_2 emissions that will be effectively uncontrollable for the foreseeable future. We estimate that the proposed 800 MW facility will emit about 5.8 million tons of CO_2 pollution annually. The facility will likely operate for at least 50 years – adding over 290 million tons of CO_2 to the atmosphere during its operational life. (Assuming the generating unit has an approximate heat rate of 9000 BTUs per kWh, that means about 1,850 pounds of CO_2 per MWH. An 800 MW plant running at approximately 90% capacity factor would produce 6.3 million MWH per year (800 * 8760 * 0.9). That equates to (1850*6,300,000/2000) or 5,827,500 million annual tons of CO2.). Because CO_2 emission will likely be regulated over most of this plant's operating life, these carbon emissions will add significantly to the cost of operating this facility.

There are various cost estimates related to future carbon dioxide emissions control that span a range from $8 per ton to $40 per ton. For example, there is currently a carbon dioxide trading program in Europe that serves as one component of European efforts to

[11] For a description of IGCC see: http://www.gasification.org/gasproc.htm. More information is also available at: http://www.netl.doe.gov/technologies/coalpower/gasification/index.html. Presentations from vendors and others from the recent gasification technologies conference in Washington D.C. are available on-line at: http://www.gasification.org/Presentations/2006.htm.

address global warming. In that trading program, carbon dioxide emissions have reached a high of about $42 per ton.[12] Several states in the U.S. have specifically required consideration of future carbon costs as a part of their energy planning processes. In particular, the California Public Utilities Commission requires that the utilities use a "greenhouse gas adder" of $8 per ton CO_2, beginning in 2004 and escalated at 5% per year, in long-term planning and procurement for purposes of evaluating new long-term resource investments.[13] The Montana Public Service Commission has a similar requirement.[14] Idaho Power is using a carbon cost of $14/ton starting in 2012.[15] As a result, reasonable estimates for CO_2 costs under expected U.S. regulations range from about $8 to about $40 per ton.

Even assuming a relatively low carbon cost, of say $12 per ton, it is clear that emission from a facility like the one proposed here could create a significant financial burden. At this rate to fully account for the facility's emission, for example, it would cost TEC almost 70 million dollar per year. Given the growing consensus regarding the need for quick and decisive action to control global warming, and the clear indication that carbon emission restriction of some kind are a virtual certainty, there is simply no good reason not to include consideration of such costs in the planning process. Failing to do so, in fact, does a material disservice to Florida's electricity consumers.

The fact that there is uncertainty about the timing and the specific cost impact of carbon dioxide regulation is no excuse to ignore the issue entirely. Assuming no cost for carbon emissions over the life-time of the plant is equivalent to assuming there is 100%

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[12] *See* http://pubs.acs.org/subscribe/journals/esthag-w/2006/jul/business/mb_carbonprices.html.
[13] California Public Utilities Commission. Decision No. 04-12-048, and Decision 05-04-024.
[14] Montana Public Service Commission. "Written Comments Identifying Concerns Regarding Northwestern Energy's Compliance with A.R.M. 38.5.8201-8229." Docket No. N2004.1.15. *In the Matter of the Submission of Northwestern Energy's Default Electricity Supply Resource Procurement Plan.* August 17, 2004.
[15] See http://www.idahopower.com/energycenter/irp/2006/2006IRPFinal.htm.

certainty that carbon will not be regulated, clearly an imprudent assumption. Indeed, there is an entire industry – the insurance industry – whose business it is to quantify uncertain risks, and despite profound uncertainty about whether and when we might experience significant costs, most of us make monthly payments to insure ourselves and our families against risks related to sickness, auto accidents, fire, disability and death. We do so because it is the responsible thing to do. The PSC owes no lesser responsibility to the people of Florida.

In addition to the purely energy cost-related issues described above, Florida sits on the front-lines of the battle against global warming and its potentially devastating effects, and therefore should have a particular interest in recognizing the importance of addressing global warming and leading the charge to reduce carbon emissions. The overwhelming consensus among climate scientists is that global warming, if it remains unchecked, will cause serious climate disruption including more intense hurricanes, more frequent and more severe floods, and potentially catastrophic sea level rise – effects that the citizens of Florida are likely to feel acutely. Certainly a strong policy that recognizes the likelihood and importance of controlling CO_2 emissions would be consistent with the PSC's mission to serve the public welfare, especially in a state with 2,276 miles of tidal coastline and a mean elevation of only 100 feet above sea level.

Q: Are you sponsoring any exhibits?

A: Yes. There are 7 exhibits attached to my testimony.

Daniel A. Lashof

EDUCATION

9/81 - 6/87	**University of California, Berkeley** Ph.D. in Energy and Resources, 1987. Dissertation: *The Role of the Biosphere in the Global Carbon Cycle--Alternative Methods of Evaluation.* M.S. in Energy and Resources, 1983.
9/77 - 6/80	**Harvard University** A.B. Magna Cum Laude in Physics and Mathematics, 1980.

EMPLOYMENT

7/01 – present	**Natural Resources Defense Council** Science Director and Deputy Director, Climate Center
4/89 – 6/01	**Natural Resources Defense Council** Senior Scientist, Air and Energy Program.
9/92 - 12/92	**University of Maryland** Adjunct Professor, School of Public Affairs
4/88 - 4/89	**United States Environmental Protection Agency** Environmental Scientist, Strategic Analysis Branch.
5/87 - 4/88	**The Bruce Company** Senior Analyst, Climate Change Program.
7/82 - 6/85	**Lawrence Berkeley Laboratory** Research Assistant, Atmospheric Oxygen Project.
7/80 - 5/81	**Solar Energy Research Institute**, Golden CO Consultant, Strategic Planning Branch.

HONORS AND APPOINTMENTS

1997	Member, Panel on Energy Research and Development President's Council of Advisors on Science and Technology
1997	Member, Subcommittee on Energy, Clean Air, and Climate Change Federal Advisory Committee on Clean Air Act Implementation
1995	Member, Presidentially-appointed Federal Advisory Committee on Options for Reducing Greenhouse Gas Emissions from Personal Motor Vehicles
1982	Chancellor's Fellowship, University of California, Berkeley.
1982	Chancellor's Fellowship, University of California, Berkeley.
1981	Alfred F. Moore and Chella D. Moore Scholarship, University of California, Berkeley.
1980	A.B. Magna Cum Laude in Physics and Mathematics, Harvard University.
1979	Harvard College Scholarship.

MAJOR PUBLICATIONS

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Gambling with Coal
How Future Climate Laws Will Make New Coal Power Plants More Expensive

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Abstract
New conventional coal plants are an imprudent financial investment. The world scientific community warns that carbon dioxide (CO_2) emissions from our use of fossil fuels, especially coal, is leading to dangerous global warming. Policies to reduce CO_2 emissions are emerging at every level of government, including in the US Congress, which is actively considering several mandatory, market-based CO_2 proposals with increasing support from the private sector. Laws requiring coal plants to pay to emit CO_2 will be adopted in the next few years, substantially raising the costs of coal power.

Nevertheless, many utilities have proposed investing in new conventional coal plants that will operate for decades, ignoring the economic impact of these virtually inevitable CO_2 reduction laws, perhaps because they believe they will be able to pass these costs on to ratepayers. Utility managers and shareholders should reconsider the financial risks to their companies and customers. Regulators should prevent utilities from making these major investment mistakes by refusing to approve the construction of new conventional coal plants and by requiring them to invest in cleaner alternatives, or at the very least, by warning utilities that CO_2 costs must be borne by their shareholders, not by ratepayers.

Executive summary

It is now virtually inevitable that America will adopt a federal law limiting global warming pollution from power plants. Indeed, given the momentum of emerging policy responses to global warming on the local, state, and regional levels in the United States (as well as internationally), federal legislation will probably be adopted within the next five years. This document discusses why such a law is so likely, what kind of new costs coal plants will face as a result, and how these future costs make building new, conventional coal plants a reckless financial gamble.

[1] We would like to thank the Garfield Foundation for providing funding for this work.

The need for legal limits to America's global warming pollution is undeniable. Scientists have long known that the burning of fossil fuels releases heat-trapping carbon dioxide (CO_2) into the air, where it is building up. Scientific concern that this buildup could disrupt our climate has been growing steadily since the late 1980s. Every year, the science has become even more compelling: Earth continues to experience record-breaking warmth, humans' dominant role in this warming becomes clearer, and we see the planet reacting to the warming in troubling ways.

Most developed nations have responded to this evidence by ratifying the Kyoto Protocol, which requires them to reduce their CO_2 emissions. The United States has not ratified Kyoto, but as the world's largest emitter of heat-trapping gases by far, it is under increasing international pressure to act. Along with almost every other nation in the world, the United States did ratify the 1992 Framework Convention on Climate Change, a treaty with the objective of preventing dangerous global warming. And in 2005 the U.S. Senate passed a landmark resolution stating that mandatory federal CO_2 limits should be enacted. Several proposals establishing CO_2 limits are being considered by Congress, and a series of hearings have been held in the Senate to discuss the design of such limits.

The congressional response is being spurred in part by a growing policy response on the state and regional level, including the regional CO_2 limits and trading system being established by eight northeastern states. Within the last year or two, a substantial number of major companies—including half of America's 10 largest power companies—have called for such regulation, and most utility executives believe that such regulation is coming.

There is no doubt that the burden of future CO_2 regulations will fall heavily on coal plants. Power plants are the largest source of U.S. CO_2 emissions, accounting for 39 percent of the nation's energy-related emissions, and most of these emissions come from coal plants. In fact, coal plants produce one-third of America's CO_2 emissions—about the same amount as all our cars, SUVs, trucks, buses, planes, ships, and trains combined.[2]

Each new coal plant represents an enormous long-term increase in global warming emissions. A 500-megawatt (MW) plant, for example, produces the annual global warming emission equivalent of roughly 600,000 cars,[3] but unlike a car, a coal plant is designed to operate for 40 to 50 years (and they often operate even longer). Global warming cannot be effectively addressed without limiting coal plant emissions, so the congressional proposals under consideration all target coal plants.

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[2] U.S. Environmental Protection Agency (EPA), "Inventory of US Greenhouse Gas Emissions and Sinks: 1990-2004," April 2006. Online at http://yosemite.epa.gov/oar/globalwarming.nsf/content/ResourceCenterPublicationsGHGEmissionsUSEmissionsInventory2006.html. Also see U.S. Energy Information Administration (EIA). *Emissions of Greenhouse Gases in the United States 2004*, December 2005, 20–22. Online at ftp://ftp.eia.doe.gov/pub/oiaf/1605/cdrom/pdf/ggrpt/057304.pdf.

[3] Based on average annual emissions of 13,500 lbs/vehicle as estimated by the EPA (http://yosemite.epa.gov/oar/globalwarming.nsf/content/ResourceCenterToolsGHGCalculator.html) and annual emissions of 4.1 million tons from a 500 MW plant as estimated by the Public Service Commission of Wisconsin (http://psc.wi.gov/utilityinfo/electric/cases/weston/document/Volume1/W4_FEIS.pdf).

It is widely expected that future CO_2 regulations will take the form of a "cap-and-trade" system, similar to the national law for controlling the sulfur dioxide (SO_2) emissions that cause acid rain. Such a system would establish a national cap on CO_2 emissions, and power plant operators would have to own an "allowance" for each ton of CO_2 they emit. Operators could buy and sell these allowances for a price established by market forces. Economists believe such a cap-and-trade system would provide the flexibility and incentives to meet a given CO_2 cap at the lowest cost.

Utilities are increasingly quantifying the risk they face from future CO_2 allowance costs in their planning documents. In some cases, they do so because state regulators demand it, and in other cases they do it at their own initiative. Studies forecasting the price of future CO_2 allowances range widely, but useful estimates are emerging from the literature. These estimates indicate that coal plants face CO_2 costs that will increase the cost of coal power substantially and perhaps severely. Mid-range projections of CO_2 allowance prices could increase the cost of electricity from the average new coal plant by roughly half.[4] Because coal plants are designed to last for decades, these added financial costs—along with the environmental costs created by coal plants—will be borne by both the present and future generations.

These allowance price forecasts generally assume the adoption of federal policies that aim for modest CO_2 emission reductions at best. However, the science now indicates that if we hope to avoid dangerous global warming, developed nations will need to reduce their CO_2 emissions dramatically—as much as 60 to 80 percent or more—by 2050.[5]

This evidence has prompted governments including California, New Mexico, the New England states, the eastern Canadian provinces, the United Kingdom, and the European Union to adopt long-term CO_2 emission reduction targets in the 60 to 80 percent range. It is therefore reasonable to expect that even if the emission cap initially enacted establishes only modest, short-term targets, it will be followed with increasingly strict national caps in the decades ahead—that is, throughout the operating lifetime of coal plants proposed today.

Meanwhile, climate policies are likely to accelerate the development of energy resources that significantly reduce heat-trapping emissions (reducing the cost of these resources relative to coal) and the development of energy efficiency technologies (reducing electricity demand below currently projected levels). In all likelihood, these changes will improve the economics of coal alternatives just as ever-tightening emission caps are worsening the economics of coal plants.

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[4] For CO_2 price projections see Synapse Energy Economics, "Climate Change and Power: Carbon Dioxide Emissions Costs and Electricity Resource Planning," May 18, 2006. Online at *http://www.synapse-energy.com*.

[5] European Environment Agency, "Climate Change and a European Low-Carbon Energy System," Copenhagen, 2005. Online at *http://reports.eea.eu.int/eea_report_2005_1/en/Climate_change-FINAL-web.pdf*.

Given these highly foreseeable trends, why are so many utilities still proposing to lock themselves into capital-intensive coal plants rather than investing in options that do not expose them to such financial risk? These utilities may be betting on their ability to pass the risk on to ratepayers in the form of higher electric rates—the same way they routinely pass through environmental compliance costs today. Utilities holding this belief have little incentive to assess and avoid the risks of future CO_2 regulation. That places on state utilities regulators an enhanced responsibility to assess for themselves the risks associated with gambling huge amounts of money on a large, multi-decade source of CO_2 emissions just as the nation is about to launch a large, multi-decade effort to reduce CO_2 emissions that will surely target coal power.

Utilities may also be ignoring these political developments under the reckless assumption that any plant built before a federal CO_2 cap is adopted will be allocated allowances for free. This gamble ignores the growing opposition to granting such a windfall to utilities (particularly those that could avoid new allowance costs by simply investing in alternatives to coal). The Northeast Regional Greenhouse Gas Initiative (RGGI) model rule, for example, requires that at least 25 percent of allowances be auctioned rather than allocated,[6] and Vermont, the first Northeast state to pass enabling legislation, requires *all* allowances to be auctioned.[7] In fact, 28 different stakeholders in the RGGI model rule draft—including businesses, consumer groups, environmental organizations, state agencies, and an electricity distribution company—supported auctioning 50 to 100 percent of allowances.[8]

At the federal level, Senators Pete Domenici (R-NM) and Jeff Bingaman (D-NM) issued a white paper describing the design elements of a mandatory system to reduce emissions. The paper notes that auctioning off all allowances would minimize the costs to the U.S. economy as a whole, streamline the administrative process, and avoid unintended competitive advantages and windfall profits for certain market participants.[9] A recent Wall Street study also predicts that the United States will have an auction-based rather than allocation-based cap-and-trade system.[10]

If regulators do authorize the construction of a new coal plant, they should notify the utility up front that it will not be allowed to pass future CO_2 compliance costs on to ratepayers. The last time the nation's utilities embarked on a large-scale campaign to build new baseload plants (plants that operate most of the time) was the 1960s and 1970s; the result was scores of abandoned nuclear projects and a great deal of excess generating capacity. Disputes over whether ratepayers or utility shareholders should pay for these

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[6] Regional Greenhouse Gas Initiative (RGGI) Model Rule, subpart XX-5.3. Online at http://www.rggi.org/docs/model_rule_8_15_06.pdf.

[7] The Vermont law (H. 860) is online at http://massclimateaction.org/RGGI/VTRGGISignedMay06.pdf.

[8] Environment Northeast, Natural Resources Defense Council, and Pace Law School Energy Project, "Summary of Comments on the RGGI Model Rule Draft," 2006.

[9] Sen. Pete V. Domenici and Sen. Jeff Bingaman, "Design Elements of a Mandatory Market-Based Greenhouse Gas Regulatory System," February 2006.Online at http://www.nam.org/s_nam/bin.asp?CID=43&DID=236483&DOC=FILE.PDF.

[10] Hugh Wynne, "U.S. Utilities: The Prospects for CO_2 Emissions Limits in the United States and Their Implications for the Power Industry," Bernstein Research, April 19.

investment mistakes led to a series of decisions requiring shareholders to pay for at least a portion of the losses. Those decisions stressed the importance of forcing utilities to assume financial risk in order to give them an incentive to track events that could increase the cost of construction projects and to reassess the viability of those projects as conditions warrant.

Given the momentum now driving the nation toward CO_2 limits—and the substantial impact such limits will have on the cost of coal power—it has never been more critical to ensure that utility managers are staying abreast of current developments. Placing the financial risk of future CO_2 costs on shareholders, clearly and up front, will create that incentive. This regulatory approach is not only fully consistent with rate-making principles, but also builds on the lessons learned from the expensive investment mistakes of the past.

I. Scientific evidence clearly establishes the need for policies limiting CO_2 emissions now and reducing them dramatically over a period of decades.

A. The scientific consensus about the reality of global warming is strong and growing stronger.

The world scientific community spoke with one voice recently to deliver an unprecedented and remarkably pointed message to world leaders. Eleven of the world's most respected national science academies, including the U.S. National Academy of Sciences (NAS), issued this joint statement in anticipation of the 2005 G8 Summit:

> *"Climate change is real. There will always be uncertainty in understanding a system as complex as the world's climate. However, there is now strong evidence that significant global warming is occurring."*[11]

The statement called on world leaders to acknowledge that "the threat of climate change is clear and increasing," and urged all nations "to take prompt action to reduce the causes of climate change."[12]

The NAS is generally considered America's preeminent scientific association. It was chartered by Congress in 1863 and tasked with the role of advising the nation on scientific matters. Its 2,000 members—all elected to the academy in recognition of their distinguished achievements in original research—include the nation's most respected scientists; roughly 10 percent have won a Nobel Prize.[13] When the Bush administration

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[11] The "Joint Science Academies' Statement: Global Response to Climate Change" was issued by the NAS and its counterpart academies in Brazil, Canada, China, France, Germany, India, Italy, Japan, Russia, and the United Kingdom. Online at http://nationalacademies.org/onpi/06072005.pdf.
[12] Ibid.
[13] See the NAS website: http://www.nasonline.org/site/PageServer?pagename=ABOUT_main_page.

took office in 2001, it asked the NAS for confirmation that our heat-trapping emissions are causing global warming, and it received that confirmation.[14]

This joint statement follows a growing number of statements and reports reflecting concern about global warming from the NAS, the American Geophysical Union, the American Association for the Advancement of Science, the American Meteorological Society—indeed every scientific association in the nation whose membership has expertise directly relevant to the issue.[15] The consensus on the reality of climate change is so strong that a review of 928 papers published in peer-reviewed scientific journals between 1993 and 2003 did not find a single paper that disagreed with the consensus view.[16]

The scientific consensus has been gaining strength at the international level as well. Since 1988, thousands of scientists have been part of a formal process—under the auspices of the Intergovernmental Panel on Climate Change (IPCC)—for methodically and collectively looking at the climate science and publishing reports to help the world's policy makers determine the scope of the global warming threat. The IPCC has published three major assessments to date (1990, 1995, and 2001), each time expressing greater concern about the certainty and potential danger of global warming.[17] Given the record-breaking warmth the planet has continued to experience since the 2001 IPCC report and subsequently published scientific assessments,[18] it is widely expected that the IPCC's upcoming 2007 report will continue that trend.[19]

Evidence that we are changing the climate and that the planet is responding in worrisome ways is now so strong that many who have dismissed global warming in the past have recently changed positions. Prominent members of the media who formerly declared themselves skeptical of the threat have quite publicly "switched sides."[20] Even

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[14] NAS, "Climate Change Science: An Analysis of Some Key Questions," 2001. Online at *http://fermat.nap.edu/books/0309075742/html*.

[15] Ibid. Also see NAS, "Understanding and Responding to Climate Change: Highlights of National Academies Reports," 2006 (online at *http://dels.nas.edu/basc/Climate-HIGH.pdf*); American Geophysical Union, "Human Impacts on Climate," December 2003 (online at *http://www.agu.org/sci_soc/policy/climate_change_position.html*); Atlas of Population and Environment by the American Association for the Advancement of Science, "Climate Change" (online at *http://www.ourplanet.com/aaas/pages/atmos02.html*); American Meteorological Society Council, "Climate Change Research: Issues for the Atmospheric and Related Sciences," February 9, 2003, *Bulletin of the American Meteorological Society* 84, 508–515 (online at *http://www.ametsoc.org/POLICY/climatechangeresearch_2003.html*).

[16] Naomi Oreskes, "Beyond the Ivory Tower: The Scientific Consensus on Climate Change," *Science*, December 3, 2004, 1686. Online at *http://www.sciencemag.org/cgi/content/full/306/5702/1686*.

[17] Intergovernmental Panel on Climate Change (IPCC), "16 Years of Scientific Assessment in Support of the Climate Convention," December 2004. Online at *http://www.ipcc.ch/about/anniversarybrochure.pdf*.

[18] For example, see Scientific Symposium on Stabilisation of Greenhouse Gases, "Avoiding Dangerous Climate Change," Executive Summary of the Conference Report, February 1-3, 2005, 2. Online at *http://www.defra.gov.uk/environment/climatechange/internat/dangerous-cc.htm*.

[19] Roger Harrabin, "Consensus Grows on Climate Change," BBC News, March 1, 2006. Online at *http://news.bbc.co.uk/1/low/sci/tech/4761804.stm*.

[20] Gregg Easterbrook recently wrote in the *New York Times*, "[a]s an environmental commentator, I have a long record of opposing alarmism. But based on the data I'm now switching sides regarding global

ExxonMobil, which has for years disputed the mainstream climate science more aggressively than any corporation in America, now admits "that the accumulation of greenhouse gases in the Earth's atmosphere poses risks that may prove significant for society and ecosystems. We believe that these risks justify actions now, but the selection of actions must consider the uncertainties that remain."[21] The company continues to exaggerate the uncertainties, to fund groups that cast doubt on the science (to the growing dismay of investors[22]), and to resist government regulation, but the science is now so strong that it can no longer deny that the risks justify an immediate response.[23]

B. The evidence establishes that global warming is already harming the planet, and that we face much greater levels of damage in the century ahead.

The basics of global warming science have been understood for a long time. Heat-trapping or "greenhouse" gases, of which CO_2 is the most important, allow the sun's light to penetrate to Earth's surface, where some of it is absorbed and converted into heat. These gases then prevent that heat from radiating back out to space, thereby keeping the planet warm enough to support life.

When we burn fossil fuels, the carbon in those fuels is converted into CO_2; since coal contains the most carbon, it creates the most CO_2 for every unit of energy released.[24] Humans have emitted enough CO_2 to raise background concentrations of this critical heat-trapping gas by about one-third above pre-industrial levels, and concentrations continue to rise.[25] Once concentrations rise, it takes centuries for natural processes to bring them back down again.[26]

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warming, from skeptic to convert." ("Finally Feeling the Heat," May 24, 2006. Online at *http://select.nytimes.com/gst/abstract.html?res=F40B1EF63B5A0C778EDDAC0894DE404482*; subscription required). A few days earlier, Michael Shermer wrote in *Scientific American*, "environmental skepticism [on climate change] was once tenable. No longer. It is time to flip from skepticism to activism." ("The Flipping Point: How the Evidence for Anthropogenic Global Warming Has Converged to Cause this Environmental Skeptic to Make a Cognitive Flip," June 2006, 28. Online at *http://www.sciam.com/article.cfm?articleID=000B557A-71ED-146C-ADB783414B7F0000&sc=I100322*.)

[21] ExxonMobil, 2005 Corporate Citizenship Report, May 2006, 22. Online at *http://www.exxonmobil.com/Corporate/Citizenship/citizenship.asp*.

[22] Andrew Logan and David Grossman, "ExxonMobil's Corporate Governance on Climate Change," CERES and Investor Network on Climate Risk, May 2006, 2. Online at *http://www.ceres.org/pub/docs/Ceres_XOM_corp_gov_climate_change_052506.pdf*.

[23] Other major oil companies publicly accepted the reality of climate change years ago, and are more direct in their recognition of the risks it poses. The head of BP Amoco said to the British House of Lords in 2002, "Very few people now deny that climate change is a serious risk to the whole of the world" (online at *http://www.bp.com/genericarticle.do?categoryId=98&contentId=2000291*). Also see the climate statements on the websites of Royal Dutch Shell (*www.shell.com*) and Chevron (*www.chevron.com*).

[24] Coal contains nearly 90 percent more carbon per unit of energy than natural gas. However, a new conventional (supercritical) coal power plant produces nearly 150 percent more CO_2 than a new natural gas combined-cycle power plant, which is much more efficient. Based on data from EIA, *Assumptions to Annual Energy Outlook 2006*, Table 38, March 2006, 73. Online at *http://www.eia.doe.gov/oiaf/aeo/assumption/pdf/0554(2006).pdf*.

[25] IPCC Third Assessment Report (TAR), Climate Change 2001: Report of Working Group 1, Summary for Policymakers, 7. Online at *http://www.ipcc.ch*.

[26] Ibid, 17.

In recent years, scientific concern over global warming has grown both because our understanding of Earth's climate has improved and because the warming trend has continued. The National Aeronautics and Space Administration (NASA) reports that 2005 was the warmest year on record.[27] The five warmest years have all occurred since 1997 (including each of the last four years).[28] In 2001 the IPCC concluded that global average temperatures rose 0.6 degree Celsius (1.1 degrees Fahrenheit) in the twentieth century.[29] However, due to steady warming in this century, total warming over the last 100 years is now up to 0.8 degree Celsius (1.4 degrees Fahrenheit), with most of that increase (0.6 degree Celsius or 1.1 degree Fahrenheit) occurring in just the last 30 years.[30] Scientists have a high level of confidence that the present time is warmer than any period in at least 400 years.[31]

Scientists have been looking for natural causes that would explain the steep warming trend of recent years and have been unable to find them; indeed, it appears that natural causes alone (e.g., solar variation and volcanic activity) should have led to stable or slightly cooler average global temperatures in recent decades.[32] Computer models can only duplicate the recent warming by including today's phenomenally high concentrations of heat-trapping gases, especially CO_2.[33] Figure 1 compares today's CO_2 levels with those occurring over the last 400,000 years. New ice core data go back even further, and show that global CO_2 levels are 27 percent higher than they have been at any time in the past 650,000 years.[34]

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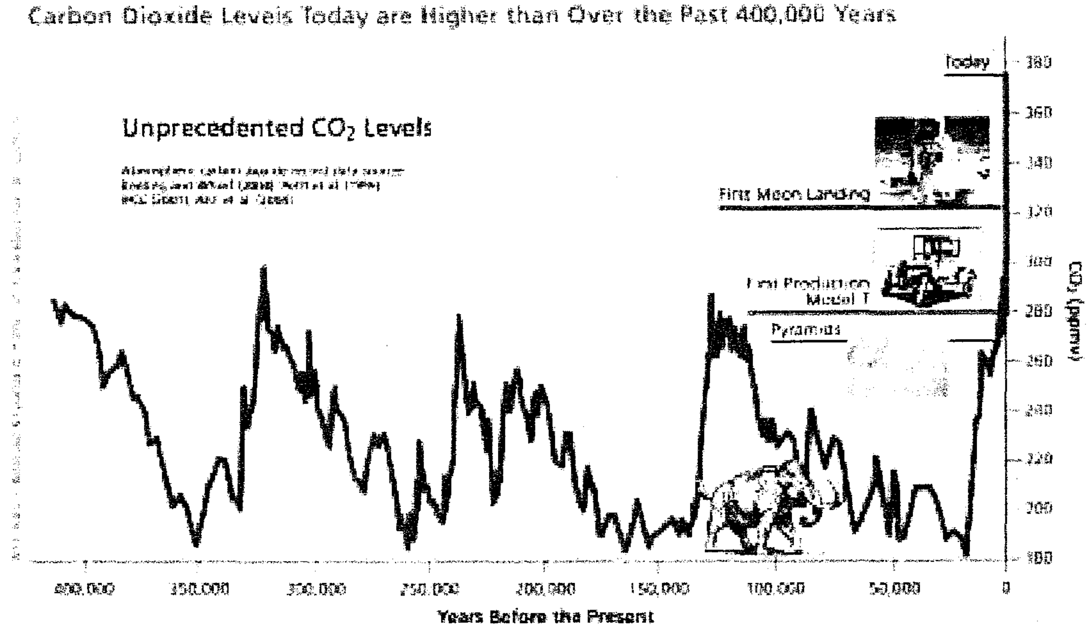
[27] National Aeronautics and Space Administration (NASA), "2005 Warmest Year in Over a Century," January 24, 2006. Online at http://www.nasa.gov/vision/earth/environment/2005_warmest.html.
[28] Ibid.
[29] IPCC TAR, Summary for Policymakers, 2.
[30] NASA, 2006.
[31] National Research Council, *Surface Temperature Reconstructions for the Last 2000 Years*. National Academies Press, 2006, 3. Online at http://www.nap.edu/catalog/11676.html#toc.
[32] IPCC TAR, Summary for Policymakers, 10–11.
[33] Ibid.
[34] Urs Siegenthaler, et al., "Stable Carbon Cycle-Climate Relationship during the Late Pleistocene," 2005. *Science* 310:1313–1317.

Figure 1



Sources: UCS, "Past, Present and Future Temperatures: the Hockeystick FAQ," online at http://www.ucsusa.org/global_warming/science/hockeystickFAQ.html.

Other geologic evidence indicates that current CO_2 levels are probably higher than at any time in the last 20 million years.[35] Projections show that in the years ahead, unless actions are taken to reduce emissions, CO_2 levels could rise to 750 parts per million by volume (ppmv) or higher[36]—well beyond the scale used in Figure 1. In other words, we have already dramatically increased the atmospheric concentrations of a gas that plays a critical role in determining Earth's climate, and much more dramatic changes lie ahead if current trends continue.

The consequences of global warming are now evident around the world, and in many respects Earth is responding to the warming at a faster rate than scientists predicted just a few years ago. The effects of climate change are now visible in most ecosystems and appearing more rapidly than predicted.[37] Recent studies have suggested a link between global warming, higher sea surface temperatures, and an unexpected increase in hurricane strength.[38] Mountain glaciers are in widespread retreat, enormous ice shelves in

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[35] IPCC TAR, Summary for Policymakers, 7.
[36] Ibid., 14.
[37] Hans Joachim Schellnhuber, ed., *Avoiding Dangerous Climate Change*, Chapter 12, Cambridge University Press. 2006. Online at http://www.defra.gov.uk/environment/climatechange/internat/dangerous-cc.htm.
[38] Kerry Emanuel. "Increasing Destructiveness of Tropical Cyclones Over the Past 30 Years," August 4, 2005, *Nature* 436:686 (online at http://www.nature.com/nature/journal/vaop/ncurrent/abs/nature03906.html); Georgia Institute of Technology, "Hurricanes are Getting Stronger, Study Says," press release, September 15, 2005 (online at

Antarctica have collapsed with surprising suddenness, and Arctic permafrost and northern polar sea ice are melting dramatically.[39] Satellites show that perennial sea ice in the Arctic shrunk at a rate of nine percent per decade between 1979 and 2003 (Figure 2).

Figure 2: Arctic Sea Ice Is Retreating

Arctic sea ice in 1979 **Arctic sea ice in 2003**

Source: NASA Goddard Space Flight Center, online at
http: earthobservatory.nasa.gov Newsroom NewImages images.php3?img id=16340.

Earth's response to the warming we have experienced thus far increases concerns about how the planet will respond to the much greater warming expected in the century ahead. The IPCC's 2001 assessment predicts warming of another 1.5 to 5.8 degrees Celsius (2.7 to 10.4 degrees Fahrenheit) by 2100.[40] Figure 3 compares this warming with observed temperatures during the previous century and with estimated temperatures of the last 1,000 years.

The range of warming estimates for the next century reflects uncertainties about Earth's climate system as well as uncertainty about the future rate at which heat-trapping gases will be emitted. Recent studies of how natural systems release more heat-trapping gases in response to warming, amplifying the effect of human-made emissions, suggest the 2001 predictions may be conservative.[41]

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http: www.gatech.edu news-room release.php?id=654); National Center for Atmospheric Research, "Global Warming Surpassed Natural Cycles in Fueling 2005 Hurricane Season, NCAR Scientists Conclude," press release, June 22, 2006.

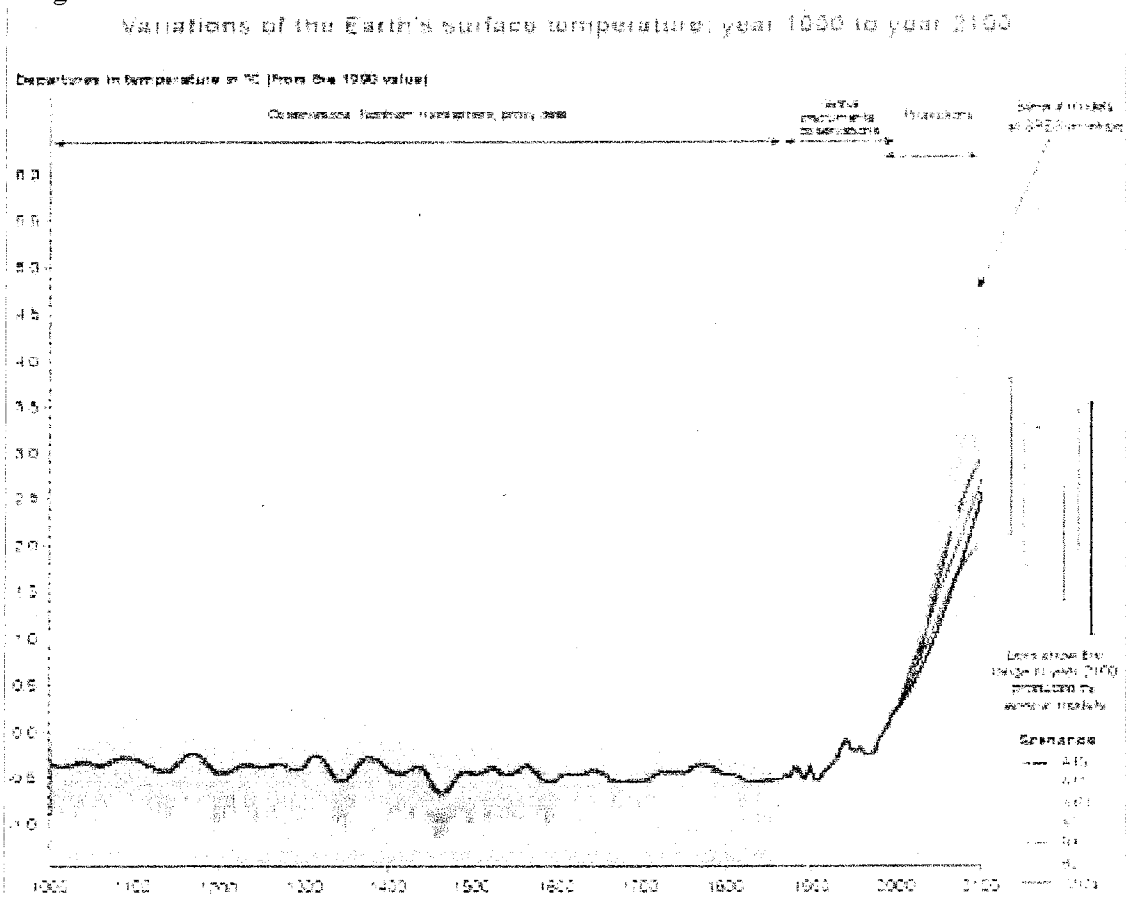
[39]IPCC TAR, Summary for Policymakers, 4; Arctic Climate Impact Assessment: Impacts of a Warming Arctic. Cambridge University Press. 2004 (online at *http: amap.no acia*); Ice shelf collapses described by the National Snow and Ice Data Center (online at *http: nsidc.org sotc iceshelves.html*).

[40] IPCC TAR. Summary for Policymakers. 13.

[41]Margaret S. Torn and John Harte. "Missing Feedbacks. Asymmetric Uncertainties. and the Underestimate of Future Warming," 2006, *Geophysical Research Letters* 33:L10703; Lawrence Berkeley National Laboratory, "Feedback Loops in Global Climate Change Point to a Very Hot 21st Century," press release, May 22. 2006 (online at *http: www.lbl.gov Science-Articles Archive ESD-feedback-loops.html*); American Geophysical Union, "Greenhouse Gas/Temperature Feedback Mechanism May Raise Warming Beyond Previous Estimates," press release, May 22, 2006 (online at *http: www.agu.org sci soc prrl prrl0617.html*).

Moreover, the NAS and others warn that future warming could occur in abrupt and unpredictable ways. Evidence of past climate changes show the planet has a history of quickly lurching from one climate pattern to another in a way that would make it far harder for nature and society to adapt.[42]

Figure 3



Source: IPCC, "Climate Change 2001:Synthesis Report," Summary for Policymakers, 34.

C. Evidence indicates that dramatic reductions in CO_2 levels will be required in the decades ahead.

Currently, much of the scientific and policy discussion occurring globally focuses on how deeply and quickly CO_2 emissions need to be cut in order to avoid triggering dangerous global warming.[43] The international community has been treaty-bound to work

[42] National Research Council, *Abrupt Climate Change: Inevitable Surprises*, National Academies Press, 2002. Online at http://www.nap.edu/catalog/10136.html?onpi_newsdoc121101.

[43] Scientific Symposium on Stabilisation of Greenhouse Gases, 2005.

toward this goal since the Framework Convention on Climate Change was adopted in 1992 and ratified by 188 nations (including the United States).[44]

Evidence of the dangers associated with warming greater than two degrees Celsius above pre-industrial levels has been compelling enough to persuade the European Union (EU) to adopt the goal of limiting planetary warming to this level.[45] Studies show that to have a reasonable chance of achieving this goal, net heat-trapping emissions for both developed and developing countries must be reduced at least 15 to 50 percent below 1990 levels by 2050.[46] The European Parliament has adopted a resolution pushing for developed nations to reduce emissions 30 percent by 2020 and 60 to 80 percent by 2050.[47] The United Kingdom adopted a similar target in 2003: 20 percent reductions by 2010 and 60 percent by 2050.

In this country, two states have already adopted similarly ambitious goals. California has adopted a target of reducing heat-trapping emissions by 80 percent (below 1990 levels) by 2050,[48] and New Mexico seeks a 75 percent reduction (below 2000 levels) by 2050.[49] A regional goal was set in 2001 when the Conference of New England Governors and Eastern Canadian Premiers adopted a long-term target of reducing global warming emissions 75 to 85 percent below 2001 levels.[50]

In the discussion that follows it is important to keep this science in mind. Most of the policies currently in place or being debated, internationally and domestically, aim to achieve relatively modest targets that will have to be followed with more aggressive reductions in the years ahead if we are to avoid dangerous warming over the long term. Today's policy proposals must therefore be seen as the first steps in a much longer global process.

Ultimately, emission reductions of the magnitude needed will require a historic, worldwide transition away from the energy technologies that we rely on today, and particularly away from conventional coal plants, during the next four and a half decades—roughly during the operating lifetime of a new coal plant.

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44 Framework Convention on Climate Change," Article 2. Online at http://unfccc.int/resource/docs/convkp/conveng.pdf.

45 European Environment Agency. 2005. 10.

46 European Environment Agency. 2005, 7 and Chapter 3.

47 European Parliament Resolution on Climate Change, January 18, 2006. Online at http://www.europarl.europa.eu/omk/sipade3?PUBREF=-//EP//TEXT+TA+P6-TA-2006-0019+0+DOC+XML+V0//EN&L=EN&LEVEL=1&NAV=S&LSTDOC=Y&LSTDOC=N.

48 Executive Order S-3-05, June 1, 2005. Online at http://www.climatechange.ca.gov/index.html.

49 Office of Governor, State of New Mexico, "Governor Bill Richardson Announces Historic Effort to Combat Climate Change," press release, June 9, 2005. Online at http://www.governor.state.nm.us/press/2005/june/060905_3.pdf.

50 New England Governors/Eastern Canadian Premiers. "Climate Change Action Plan 2001," August 2001. Online at http://www.neg-ecp-environment.org/page.asp?pg=46.

II. The global warming policy response is mounting at every level.

A. Other developed nations are deepening their commitments to emission cuts.

The global policy response to climate change has increased along with scientific concern. As noted above, in 1992 the United States and most other nations entered into the Framework Convention on Climate Change. That treaty commits developed nations to adopt policies limiting global warming emissions, but its emission reduction target is not binding.[51] The world community then negotiated the Kyoto Protocol, under which developed nations must reduce their emissions an average of five percent below 1990 levels by the period 2008 to 2012. The protocol went into effect in February 2005 despite the United States' refusal to ratify it.

Almost every other developed nation did ratify Kyoto, so that currently nearly half of the global economy is committed to emission reductions under its provisions.[52] Many nations, particularly within the EU, have already adopted mandatory emission limits. The EU itself is limiting CO_2 emissions with a multinational cap-and-trade system, a market-based regulatory approach pioneered in the United States (see part II, section C), and the European Parliament has also endorsed steep, long-term emission reductions.

The United States' refusal to ratify Kyoto or otherwise limit its global warming emissions leaves it nearly isolated within the developed world—a conspicuous position for a country that is the world's richest and also emits roughly one-quarter of the world's heat-trapping emissions, far more than any other nation.[53] The only other developed country that has refused to be bound by Kyoto is Australia.[54]

Over the years, pressure has mounted on the United States to reduce its emissions. At the 2005 G8 Summit, climate change was at the top of the agenda, and the United States was persuaded to sign a statement pledging to "act with resolve and urgency" in reducing emissions.[55] In November 2005, the European Parliament passed a resolution stating that it "[d]eplores the non-implementation by the current U.S. administration" of the Framework Convention and America's failure to ratify Kyoto.[56]

Industrial nations currently subject to the Kyoto limits helped sustain the protocol's momentum by agreeing in December 2005 to negotiate deeper cuts in global

[51] Framework Convention on Climate Change, article 4, section 2(a).

[52] Innovest Strategic Value Advisors, "Carbon Disclosure Project 2005," 19. Online at http://www.cdproject.net/aboutus.asp.

[53] EPA, Global Warming Emissions: Inventory. Online at http://yosemite.epa.gov/OAR/globalwarming.nsf/content/EmissionsInternationalInventory.html.

[54] The status of each nation's ratification of the Kyoto Protocol is available on the United Nations Framework Convention on Climate Change website (http://unfccc.int/essential_background/kyoto_protocol/status_of_ratification/items/2613.php).

[55] Gleneagles Communiqué, "Climate Change, Energy, and Sustainable Development," July 2005. Online at http://www.fco.gov.uk/Files/kfile/PostG8_Gleneagles_Communique.pdf.

[56] European Parliament, "Winning the Battle Against Global Climate Change," (2005/2049(INI)). November 16, 2005. Online at http://www.europarl.eu.int/news/expert/infopress_page/064-2439-320-11-46-911-20051117IPR02438-16-11-2005-2005-false/default_en.htm.

warming emissions for the years after Kyoto compliance ends in 2012.[57] As these and other nations deepen and extend their commitments to mandatory emission cuts, pressure will continue to increase on the United States to do likewise.

B. U.S. states, regions, and cities are enacting their own climate policies.

In the absence of federal limits on heat-trapping emissions, many states have moved forward with their own climate-related policies, including cap-and-trade systems now emerging on both coasts. The most developed of these is the Regional Greenhouse Gas Initiative (RGGI) being undertaken by several northeastern and mid-Atlantic states. In December 2005, Connecticut, Delaware, Maine, New Hampshire, New Jersey, New York, and Vermont formally agreed to launch the nation's first regional program imposing a mandatory cap on heat-trapping emissions from power plants.[58] In April 2006, Maryland joined RGGI as well.[59] Under the agreement, beginning in 2009, the states will stabilize power plants' CO_2 emissions and then cut them 10 percent by 2019.[60] The RGGI model rule was adopted in August 2006 to implement the agreement.[61]

On the West Coast, the California legislature passed a bill on August 31, 2006 that sets in place the nation's most comprehensive, economy-wide global warming emissions reduction program. The bill requires the state's global warming emissions to be reduced to 1990 levels by 2020. This reduction will be accomplished through an enforceable statewide cap on global warming emissions that will be phased in starting in 2012. The bill would also coordinate the efforts of various state agencies, including a pending proceeding at the Public Utilities Commission to establish a load-based cap on the three large investor-owned utilities as well as other jurisdictional utilities in the state. Governor Schwarzenegger has indicated that he will sign the bill into law.[62]

California has also taken the lead in fighting climate change by requiring utilities to make aggressive investments in energy efficiency as well as factor future CO_2 regulatory costs into their resource choices (see part V, section A) and by pursuing a performance standard for global warming emissions that would prevent the procurement of power from conventional coal plants.[63] Other efforts California has taken to reduce global warming emissions include the adoption of motor vehicle standards requiring a 30

[57] Union of Concerned Scientists, "World Moves Forward on Global Warming, Bush Administration Stays Behind," press release, December 10, 2005. Online at *http://www.ucsusa.org/news/press_release/world-moves-forward-on-global-warming-MONTREAL.html*.

[58] See the RGGI website (*www.rggi.org*).

[59] *New York Times*, "Pollution Pact Gets Maryland as 8th Member," April 7, 2006. Online at *http://select.nytimes.com/search/restricted/article?res=FA0E15FD3A540C748CDDAD0894DE404482*.

[60] RGGI Memorandum of Understanding.

[61] Regional Greenhouse Gas Initiative (RGGI) Model Rule. Online at *http://www.rggi.org/docs/model_rule_8_15_06.pdf*.

[62] *Sacramento Bee*, "Schwarzenegger, lawmakers strike deal on greenhouse gases," August 31, 2006. Online at http://www.sacbee.com/content/politics/story/14312261p-15214839c.html.

[63] California PUC, "Policy Statement on Greenhouse Gas Performance Standards," April 12, 2006. Online at *http://www.cpuc.ca.gov/word_pdf/REPORT/50432.doc*.

percent reduction in CO_2 emissions from vehicles by the period 2013 to 2016.[64] As of June 2006, 10 other states plus Canada—representing approximately one-third of automobile sales in North America—had adopted California's standards.[65]

These efforts are part of a wider trend among states to respond to global warming. Twenty states and the District of Columbia, for example, have already adopted renewable energy standards covering approximately 40 percent of the electricity used in the United States,[66] partly in response to global warming. Massachusetts, New Hampshire, Oregon, and Washington have already passed laws limiting power plant CO_2 emissions or requiring plant owners to purchase offsets.[67] California, Oregon, and Washington have also joined forces on the West Coast Governors' Global Warming Initiative, which involves a variety of steps for reducing global warming emissions.[68]

The policy response to climate change is also accelerating at the local level. Mayors of more than 270 cities, representing more than 48 million Americans, have endorsed the US Mayors Climate Protection Agreement. Under this agreement they commit to working within their own communities to achieve the emission reduction targets of the Kyoto Protocol, and to urge the federal government to adopt a global warming emission trading system.[69] More than 150 local governments participate in another initiative to inventory their heat-trapping emissions, develop emission reduction targets, and implement policies to meet them.[70]

All of these state and local efforts increase the calls for and the likelihood of a climate response at the federal level, which would avoid a patchwork of different standards around the nation.

C. Congress is moving toward mandatory cap-and-trade CO_2 limits.

Momentum behind mandatory federal limits on CO_2 emissions continues to grow in Congress. In 2005, the Senate (with bipartisan support) passed a resolution finding that accumulating global warming emissions are causing temperatures to rise beyond natural variability and posing a "substantial risk" of rising sea levels and more frequent and severe droughts and floods. It states that "mandatory steps will be required to slow or stop the growth" of global warming emissions and that "Congress should enact a

64 California Air Resources Board, "Climate Change Emission Control Regulations." Online at http://www.arb.ca.gov/cc/factsheets/cc_newfs.pdf.
65 See the California Clean Cars Campaign website (http://www.calcleancars.org/news.html#senators).
66 Minnesota also has a renewable energy requirement for one utility, Xcel Energy (see http://www.ucsusa.org/clean_energy/renewable_energy/page.cfm?pageID=47). Also see Ryan H. Wiser. "Meeting Expectations: A Review of State Experience with RPS Policies," Lawrence Berkeley National Laboratory. March 2006. Online at http://eetd.lbl.gov/ea/ems/reports/awea-rps.pdf.
67 Massachusetts Department of Environmental Protection. "Emissions Standards for Power Plants." 310 CMR 7.29; New Hampshire Revised Statutes Annotated. "Multiple Pollutant Reduction Program," Chapter 125-O; Washington Revised Code, "Carbon Dioxide Mitigation," Chapter 80.70; Oregon Revised Statutes, Carbon Dioxide Emissions Standard. § 469.503.
68 West Coast Governors' Global Warming Initiative. Online at http://www.ef.org/westcoastclimate.
69 US Mayors Climate Protection Agreement. Online at http://www.seattle.gov/mayor/climate/.
70 Cities for Climate Protection. Online at http://www.iclei.org/index.php?id=1118.

comprehensive and effective national program of mandatory, market-based limits and incentives on emissions of greenhouse gases." The program goal would be to eventually reverse the growth of such emissions in a way that would not harm the U.S. economy and would encourage comparable action by major trading partners.[71] In May 2006, an identically phrased resolution was adopted with bipartisan support by the powerful House Appropriations Committee.[72]

It is widely understood that by using the phrase "mandatory, market-based limits," the Senate was referring to a particular kind of regulatory approach known as cap-and-trade. Under such a program, a cap would be established limiting how many tons of CO_2 could be emitted nationwide, and the same number of "allowances" would be issued, each one granting its owner the right to emit one ton of CO_2.

A market price for CO_2 allowances would emerge as operators begin buying and selling them. In practice, power plants that could reduce CO_2 emissions at a lower cost than the market price of an allowance would do so; those that could not would purchase additional allowances to cover their emissions. This system of regulation was pioneered in 1990 to reduce power plants' emissions of sulfur dioxide and other pollutants that cause acid rain, and it proved so successful and efficient that virtually every proposal to regulate CO_2—whether international, regional, or federal—has included some form of cap-and-trade.[73]

As of July 2006, there are at least seven proposals[74] under consideration that would establish a cap-and-trade system for CO_2, including the Climate Stewardship and Innovation Act (S. 1151) introduced by Senators John McCain (R-AZ) and Joseph Lieberman (D-CT) and a proposal sponsored by Senator Jeff Bingaman (D-NM) modeled after a proposal of the National Commission on Energy Policy (NCEP).[75] The Senate Energy and Natural Resources Committee also conducted extensive hearings on the design features of a cap-and-trade system based on the NCEP model in April 2006, accepting comments from many different stakeholders. Many members of the power industry participated in these hearings, including companies that support mandatory regulations and those that, while still opposed to mandatory limits, now consider them inevitable and want to have a say in shaping them (see part III). Two of the most

[71] Sense of the Senate on Climate Change, H.R.6 §1612, Energy Policy Act of 2005. This resolution passed by a vote of 54-43.
[72] See Senate Committee on Energy and Natural Resources, "Chairman Domenici and Senator Bingaman React to House Committee Vote on Climate Change," press release, May 10, 2006. Online at *http://energy.senate.gov/public/index.cfm?FuseAction=AboutSubcommittee&Subcommittee_ID=7*.
[73] Another regulatory option, though one with much less political momentum, is enactment of a carbon tax. By setting a price on CO_2 emissions, the effect on coal plant risks would be the same as a cap-and-trade system that results in equivalent allowance prices, and the arguments in this paper would still apply.
[74] In addition to those mentioned in the text, these proposals include the Clean Air Planning Act of 2006 (S. 2724) introduced by Senator Thomas Carper (D-DE); the Keep America Competitive Global Warming Policy Act of 2006 (H.R. 5049), introduced by Representatives Tom Udall (D-NM) and Tom Petri (R-WI); and the Strong Economy and Climate Protection Act, announced and circulated for discussion by Senator Dianne Feinstein (D-CA) but not yet introduced.
[75] The NCEP proposal is set forth in "Ending the Energy Stalemate" (online at *http://www.energycommission.org/site/page.php?report=13*).

ambitious bills -- the Global Warming Pollution Reduction Act (S. 3698) introduced by Senator Jim Jeffords (I-VT) and the Safe Climate Act (H.R. 5642) introduced by Representatives Henry Waxman (D-CA) and Maurice Hinchey (D-NY)-- would aim to reduce heat-trapping emissions 80 percent below 1990 levels (in line with scientific estimates of what is needed to avoid dangerous global warming).[76]

Political support for a cap-and-trade system is extremely broad, encompassing major U.S. environmental advocacy groups and those in industry that support CO_2 regulation in general. This method of regulation has even been explicitly endorsed by a substantial segment of the U.S. evangelical Christian movement. Several dozen evangelical leaders recently issued a statement declaring that the need for action on global warming is urgent and calling for national legislation requiring CO_2 reductions through "cost-effective, market-based mechanisms such as a cap-and-trade program." They stress that we need urgent action because we are making long-term decisions today that will determine CO_2 emissions in the future, including "whether to build more coal-burning power plants that last for 50 years rather than investing more in energy efficiency and renewable energy."[77]

Utilities may be ignoring these political developments under the reckless assumption that any plant built before a cap-and-trade system is adopted will be allocated allowances for free. This gamble ignores the growing opposition to granting such a windfall to utilities (and particularly those who could avoid new allowance costs by simply investing in alternatives to coal).

The RGGI model rule, for example, requires that at least 25 percent of allowances be auctioned rather than allocated, and Vermont, the first Northeast state to pass enabling legislation, requires auctioning 100 percent of allowances.[78] In fact, 28 different stakeholders in the RGGI model rule draft, including businesses, consumer groups, environmental organizations, state agencies, and an electricity distribution company, supported auctioning 50 to 100 percent of allowances.[79] The proceeds from such an auction would be used to fund investments in energy efficiency, renewable energy, and other low-carbon energy technologies, as well as direct rebates to consumers.

On the federal level, Senators Bingaman and Pete Domenici (R-NM) issued a white paper describing the design elements of a mandatory system to reduce CO_2 emissions. The paper notes that auctioning off all allowances would minimize the costs to the U.S. economy as a whole, streamline the administrative process, and avoid unintended competitive advantages and windfall profits for certain market participants.[80]

[76] See Senator Jeffords' website (*http://jeffords.senate.gov/~jeffords/press/06/07/072006climatebill.html*) and Representative Waxman's website (*http://www.house.gov/waxman/safeclimate/index.htm*).

[77] Evangelical Climate Initiative. "Climate Change: An Evangelical Call to Action." Online at *http://www.christiansandclimate.org/statement*.

[78] RGGI Model Rule. A bill pending in Massachusetts would begin with 50 percent auctioning and increase 10 percent a year (reaching 100 percent auctioning in year six). New York Attorney General Eliot Spitzer is calling for 100 percent auctioning. For more information, see *http://massclimateaction.org/RGGI.htm*.

[79] Environment Northeast, Natural Resources Defense Council, and Pace Law School Energy Project, 2006.

[80] Domenici and Bingaman, 2006.

A recent Wall Street study further predicts that the United States will have an auction-based rather than allocation-based cap-and-trade system.[81]

In short, not only is it now virtually inevitable that a federal program limiting CO_2 emissions will be approved in the next few years, but it is also fairly certain that this program will take the form of a cap-and-trade system under which every ton of CO_2 emitted will come with a cost, determined by the forces of supply and demand for CO_2 allowances.

D. Coal plants will certainly be covered by future climate regulations.

While the scope of a federal program limiting global warming emissions is under active discussion, every climate bill that has been proposed would cover CO_2 emissions from coal plants—for good reason. Coal plants are by far the largest individual sources of CO_2 emissions, representing nearly one-third of U.S. energy-related CO_2 emissions (the entire power sector accounts for 39 percent of such emissions). Coal plants emit about the same amount of CO_2 as all petroleum-based emissions from cars, trucks, trains, and planes combined, which represent another third of U.S. energy-related CO_2 emissions. The remaining third comes from a variety of technologies and sources including, most notably: industrial use of petroleum, natural gas, and coal; residential use of natural gas; and the electricity sector's use of natural gas.[82]

Not only are coal plants a dominant source of CO_2, but they are also relatively few in number compared with the millions of sources in other sectors, making them far easier for any federal program to regulate. A single new 500 MW conventional coal plant, for example, can emit the annual CO_2 equivalent of more than 600,000 cars.[83] All of the federal regulatory proposals described above would limit CO_2 emissions from coal plants; the only question is whether they would also attempt to regulate other sectors of the economy as well.

Additionally, analysis by the U.S. Energy Information Administration (EIA) shows that the electricity sector accounts for many of the most cost-effective reduction options.[84] While power plants account for 39 percent of U.S. energy-related CO_2 emissions, they have the potential to account for somewhere between 66 and 85 percent

[81] Wynne, 2006.

[82] EPA, 2006; EIA, 2005. Energy-related emissions of CO_2 represent 97 percent of total U.S. emissions of CO_2.

[83] According to the EPA, annual vehicle emissions are about 13,500 lbs/vehicle; see the EPA Personal Greenhouse Gas Calculator (http://yosemite.epa.gov/oar/globalwarming.nsf/content/ResourceCenterToolsGHGCalculator.html). Power plant CO_2 emissions of 4.1 million tons for a new 500 MW plant are based on the Public Service Commission of Wisconsin's Final Environmental Impact Statement for Weston Unit 4 Power Plant, Volume 1, July 2004, 145 (online at http://psc.wi.gov/utilityinfo/electric/cases/weston/document/Volume1/W4_FEIS.pdf).

[84] EIA. "Energy Market Impacts of Alternative Greenhouse Gas Intensity Reduction Goals." March 2006. Online at http://www.eia.doe.gov/oiaf/servicerpt/agg/pdf/sroiaf(2006)01.pdf.

of energy-related CO_2 emission reductions according to computer models designed to show the least expensive options for complying with various CO_2 regulations.[85]

The most significant change from the EIA's "business-as-usual" scenario to its carbon reduction scenarios is the resulting impact on coal generation. In the business-as-usual scenario, approximately 174 gigawatts (GW) of new coal capacity (the equivalent of 290 new 600 MW coal plants) are added by 2030. By contrast, in the two deepest carbon reduction scenarios EIA analyzed, *not a single new conventional coal plant is added beyond those already under construction.*[86] In other words, the construction of any additional conventional coal plants would make it more expensive to achieve the carbon reduction targets.[87]

III. The power industry increasingly supports federal CO_2 limits.

Over the years, most of the power industry has been strongly opposed to federal CO_2 limits from power plants, but that attitude has been changing rapidly, especially in 2006. Many prominent power companies now openly support the federal regulation of CO_2 from coal plants. The chief executive of Duke Energy, one of the nation's largest coal-burning utilities, has said of global climate change, "From a personal perspective I can think of no more pressing global issue." He went on to say:

> *"From a business perspective, the need for mandatory federal policy in the United States to manage greenhouse gases is both urgent and real. In my view, voluntary actions will not get us where we need to be. Until business leaders know what the rules will be—which actions will be penalized and which will be rewarded—we will be unable to take the significant actions the issue requires."*[88]

Duke's website states, "Congress needs to establish a national, economy-wide greenhouse gas mandatory program as soon as possible."[89]

The head of Exelon has stated, "We accept that the science on global warming is overwhelming. There should be mandatory carbon constraints."[90] And the head of PNM

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[85] Ibid., 18.

[86] Ibid., 22. In the deepest carbon reduction scenario, approximately 103 GW of existing coal capacity (171 plants) is retired, and 17 GW of new integrated-gasification combined-cycle (IGCC) capacity with carbon capture and sequestration equipment is added.

[87] UCS does not consider all of EIA's assumptions and methods realistic, nor do we believe its scenarios achieve the lowest possible cost. EIA has typically underestimated the potential of energy efficiency, combined heat and power, and renewable energy to reduce emissions at lower costs (see UCS, *Clean Energy Blueprint*, 2001). However, EIA's modeling is still useful for demonstrating how changes in one variable (e.g., imposition of carbon reduction targets) affect the economics of another (e.g., building new conventional coal plants) under a consistent set of assumptions.

[88] Paul Anderson, "Being (and Staying in Business): Sustainability from a Corporate Leadership Perspective," speech to CERES Annual Conference, April 6, 2006. Online at *http://www.duke-energy.com/news/mediainfo/viewpoint/PAnderson_CERES.pdf*.

[89] "Climate Change: Duke Energy Position on U.S. Climate Change Policy." Online at *http://www.duke-energy.com/environment/policies/climate_change*.

Resources said at Senate hearings, "We believe now is the time for a healthy debate at the federal level on climate change, and we support the move to a mandatory program."[91]

Many other power companies have expressed their support for federal CO_2 limits through coalition statements. In 2003, for example, Calpine, Con Edison, Keyspan, Northeast Utilities, PG&E Corporation, PPL Corporation, Public Service Enterprise Group, and Wisconsin Energy signed onto the CERES Consensus Statement, which called on the federal government to "develop a national, mandatory, market-based program" limiting global warming emissions.[92] In April 2006, the Clean Energy Group's Clean Air Policy Initiative submitted comments to the Senate Committee on Energy and Natural Resources supporting the adoption of a cap-and-trade program for the electricity sector.[93] Entergy, Exelon, and Florida Power & Light thereby added their names to those publicly calling for such a law.[94]

In sum, five of the nation's 10 largest private power producers (Calpine, Duke, Entergy, Exelon, and Florida Power & Light), accounting for more than 15 percent of U.S. electricity generation,[95] now support mandatory limits on CO_2 from power plants. Another (Progress) acknowledged in a 2006 special report to shareholders that the evidence for climate change is sufficient to warrant "action" by the "public sector," which the company believes should cover all sectors of the economy.[96] Executives from three of the remaining companies in the top 10 (American Electric Power, Southern Company, and Xcel), accounting for another 12 percent of U.S. power generation, have acknowledged that federal limits on CO_2 are coming, even if they do not support them.[97]

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[90] John W. Rowe, August 16, 2004, quoted in *Business Week*. Online at http://www.businessweek.com/print/magazine/content/04_33/b3896001_mz001.htm?gl.

[91] Jeff Sterba, April 4, 2006, quoted in the *Albuquerque Tribune*. Online at http://www.abqtrib.com/albq/nw_national_government/article/0,2564,ALBQ_19861_4594645,00.html.

[92] CERES, "Electric Power, Investors and Climate Change: A Call to Action," September 2003. Online at http://www.ceres.org/pub/docs/Ceres_electric_power_calltoaction_0603.pdf.

[93] Michael J. Bradley, April 4, 2006. Online at http://energy.senate.gov/public/_files/ExecutiveSummariesforwebsite.pdf.

[94] In addition, three signatories of the CERES Consensus Statement (Calpine, PG&E, and Public Service Enterprise Group) are part of the Clean Energy Group Clean Air Policy Initiative.

[95] The nation's 10 largest private power producers in 2004, in order of megawatt hours produced, were American Electric Power, Southern Company, Exelon, FPL Group, Entergy, Dominion, Duke Energy, Progress Energy, Calpine, and Xcel Energy. (Duke Energy has since moved up in the rankings by merging with Cinergy). See CERES, NRDC, and PSEG, "Benchmarking Air Emissions of the 100 Largest Electric Power Producers in the United States—2004," April 2006. Online at http://www.nrdc.org/air/pollution/benchmarking/default.asp.

[96] Progress's vague statement on the need for action on global warming has been interpreted by the trade press as a call for carbon regulation. See "Progress Energy calls for US carbon regulation," March 31, 2006, *Carbon Finance Online* (online at www.carbonfinanceonline.com; subscription required); also see "2006: Progress Energy's Report to Shareholders: An Assessment of Global Climate Change and Air Quality Risks and Actions" (online at http://www.progress-energy.com/environment/climatechange.asp).

[97] See Dale E. Heydlauff (American Electric Power), quoted in "Global Warming," August 16, 2004, *Business Week* (online at http://www.businessweek.com/print/magazine/content/04_33/b3896001_mz001.htm?gl); David Ratcliffe (Southern Company), quoted in "U.S. Utilities Urge Congress to Establish CO_2 Limits," Bloomberg.com (online at http://www.bloomberg.com/apps/news?pid=10000103&sid=a75A1IDJvSes&refer=us); and

This expectation is widely shared in the industry: a 2004 national survey of electricity generating companies found that 60 percent of respondents expected mandatory limits on CO_2 within 10 years, and about half expected such limits within five years.[98]

The industry leaders quoted above echo the rising call for CO_2 limits by companies in other industries, including some of the nation's largest corporations. Wal-Mart calls climate change "an urgent threat not only to our business but also to our customers, communities, and the life support systems that sustain our world."[99] Both Wal-Mart and GE expressed support for CO_2 limits in April 2006 Senate hearings,[100] and Ford Motor Company and Hewlett-Packard joined 22 other multinational corporations in a 2005 statement urging leaders of the G8 nations to adopt cap-and-trade or other market-based mechanisms to limit global warming emissions.[101]

When a significant share of industry speaks out in favor of environmental regulations, including several major companies in the industry sector likely to be most heavily regulated, it is a strong sign that such regulations are near at hand. It is quite possible that CO_2 limits will be in place and operational before the same could be said for a proposed coal plant currently in the regulatory approval process.

IV. The private financial community is pushing companies to disclose and reduce their exposure to future climate regulation.

Concern is undeniably growing among investors and lenders over the financial risks of future CO_2 constraints. For example, the Investor Network on Climate Risk (INCR) was launched in 2003 as a coalition of institutional investors managing $600 billion in assets; by early 2006, it included a much wider array of investors managing more than three trillion dollars in assets.[102] The Carbon Disclosure Project, an investor coalition undertaken on the international level to obtain global warming emission data from 1,900 multinational corporations, now represents investors managing $31 trillion in assets—three times more than in 2003.[103]

The INCR stresses the regulatory risk faced by U.S. companies with high global warming emissions, calling federal carbon constraints "only a matter of time."[104] It has

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Wayne Brunetti (Xcel), quoted in "Xcel Energy expects US carbon regulations," September 9, 2004, PointCarbon (online at *http://www.pointcarbon.com/article.php?articleID=4459&categoryID=147*).

[98] PA Consulting Group. "PA survey finds that US generating companies expect mandatory carbon dioxide regulations within 10 years," press release, October 22, 2004. Online at *http://www.paconsulting.com/news/press_release/2004/pr_carbon_dioxide_regulations.htm*.

[99] Wal-Mart website (*http://walmartstores.com/GlobalWMStoresWeb/navigate.do?catg=347*).

[100] Raymond Bracy (Wal-Mart) and David Slump (GE Energy), comments to Senate Energy and Natural Resources Committee, April 4, 2006. Online at *http://energy.senate.gov/public/_files/ExecutiveSummariesforwebsite.pdf*.

[101] "Statement of the G8 Climate Change Roundtable." World Economic Forum. June 9, 2005. Online at *http://www.weforum.org/pdf/g8_climatechange.pdf*.

[102] Investor Network on Climate Risk (INCR) website (*http://www.incr.com/index.php?page=2*).

[103] Carbon Disclosure Project website (*http://www.cdproject.net/aboutus.asp*).

[104] INCR website. "INCR Overview." Online at *http://www.incr.com/index.php?page=9*.

called on companies in the electricity sector to estimate how future heat-trapping emission limits will affect their businesses and to identify steps they are taking to reduce those effects.[105] In doing so, a board member of the nation's largest public pension fund said, "Ignoring the impact of carbon on the environment and on corporate bottom lines would be fiscally irresponsible and a disservice to investors, taxpayers and the environment."[106]

Investors are particularly concerned with the financial wisdom of building new coal plants in the United States given the growing momentum here for federal CO_2 limits. Several of the nation's largest institutional investors recently warned TXU that the "future cost of carbon could alter the prudence" of the utility's plan to invest in new coal plants, and that TXU was "potentially exposing itself to unprecedented compliance costs" given the long lifespan of coal plants. It urged TXU to disclose to shareholders "how it has accounted for the 'future cost of carbon' in its resource planning for these plants."[107]

Many of the nation's largest banks and investment firms have recently announced more aggressive climate policies. Bank of America, for example, has launched a formal effort to assess and limit its risk from financing emission-intensive industries, including a commitment to reduce emissions from its public energy and utility portfolio seven percent by 2008.[108] JP Morgan Chase sees climate change as a "critical issue" with "potentially very serious consequences for both ourselves as well as our clients." In a recent speech, its director of environmental affairs said, "for the new power projects we are beginning to quantify the financial costs of those greenhouse gas emissions and incorporating that into our financial analysis of the transaction," and went on to note that looking at those costs is "going to have a big impact."[109] The head of global projects for Lehman Brothers has also addressed a cap on global warming emissions by saying, "There's a consensus that something's coming," adding that, "people are very much focused on how that's going to affect economics."[110]

Wall Street is also beginning to assess the impact new laws would have on particular power companies. Bernstein Research recently released a report describing the growing momentum toward CO_2 regulation, concluding that, "Regardless of which party wins the 2008 presidential elections . . . it is probable that the next administration will favor mandatory national limits on CO_2 emissions."[111] The report went on to identify the

[105] INCR website. "Ten Point Investor Action Plan." Online at http://www.incr.com/index.php?page=2C.

[106] Phil Angelides, quoted in "Investors Call on Power Sector and Wall Street to Focus Attention on Financial Risks From Climate Change," CERES website, April 13, 2005. Online at http://www.ceres.org/news/news_item.php?nid=108.

[107] INCR website. "Investors Concerned About TXU's Aggressive Coal Strategy." May 16, 2006. Online at http://www.incr.com/index.php?page=ia&nid=178.

[108] Bank of America website. "Bank of America Climate Change Position." Online at http://www.bankofamerica.com/newsroom/presskits/view.cfm?page=climateandforests.

[109] Amy Davidson, "Financial Institutions: Challenges and Opportunities," speech to the Earth Institute, Columbia University, March 29, 2006. Online at http://www.earthinstitute.columbia.edu/sop2006/transcripts/tr_davidsen.html.

[110] John Veech, quoted in "Analysts View Energy Policy Act through Climate Change Lens," August 30, 2005, *SNL Generation Markets Week*.

[111] Wynne, 2006.

utilities facing the greatest financial risk: "unregulated coal-fired generators supplying markets where gas is the predominant price setting fuel,"[112] which cannot pass the added costs of an emission cap on to consumers. The assumption, of course, is that regulated utilities *will* be able to pass future compliance costs on to ratepayers—an assumption we challenge below (see part VI), but which does reflect current regulatory practice.

This attitude reveals why, at least for the moment, some sectors of the financial community are still willing to help regulated utilities build new coal plants even when they know that such plants will be substantially more expensive in the carbon-constrained world ahead. Wall Street is not concerned with protecting ratepayers—that will be a job for state regulators.

V. Future costs of CO_2 regulation must be part of any realistic estimate of a new coal plant's operating costs.

A. CO_2 costs are increasingly factored into risk planning by utilities, regulators, and regional planners.

Representatives of three utilities explained in a 2005 trade journal article the importance of assessing and managing CO_2 risk:

> *"The financial risk associated with likely future regulation of carbon dioxide emissions is becoming a focus of utilities' and regulators' risk management efforts, as they recognize the imprudence of assuming that carbon dioxide emissions will not cost anything over the 30-year or longer lifetime of new investments. Utilities can help protect their customers and shareholders from this financial risk by integrating an estimated cost of carbon dioxide emissions into their evaluation of resource options, and selecting the overall least-cost portfolio of resources. Utilities can learn from the experience that some utilities have gained at managing this risk to ensure that today's investments do not lock customers or shareholders into much higher costs tomorrow if greenhouse gases are regulated."*[113]

A recent Lawrence Berkeley National Laboratory analysis of western U.S. utilities' resource planning practices found the practice of quantifying CO_2 risk to be widespread: "Given the potential for future carbon regulations to dominate environmental compliance costs, seven of the twelve utilities in our sample . . . specifically analyzed the risk of future carbon regulations on portfolio selection."[114] State regulators have since ordered three additional utilities to include CO_2 costs in their planning, leaving only two

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[112] Ibid, 2.

[113] Karl Bokenkamp (Idaho Power), Hal LaFlash (Pacific Gas & Electric), Virinder Singh (Pacificorp), and Devra Bachrach Wang, "Hedging Carbon Risk: Protecting Customers and Shareholders from the Financial Risk Associated with Carbon Dioxide Emissions," July 2005, *The Electricity Journal* 18(6): 11–24.

[114] Mark Bolinger and Ryan Wiser, "Balancing Cost and Risk: The Treatment of Renewable Energy in Western Utility Resource Plans," Lawrence Berkeley National Laboratory, August 2005. Online at http://eetd.lbl.gov/ea/EMS/reports/58450.pdf.

utilities (out of the 12 sampled) that continue to ignore CO_2 risks.[115] In its most recent resource plan, Northwestern Energy (formerly Montana Power) says it is "the mainstream practice of utility planners to factor a carbon tax into their models."[116]

California, Oregon, and Washington require utilities to factor CO_2 costs into their resource plans, and Montana ordered one utility, Northwestern Energy, to do so in its 2005 plan.[117] The California PUC actually chose a specific CO_2 value and requires the three investor-owned utilities in the state to use that value when evaluating bids (which has a direct, ongoing effect on resource selection outside the planning context).[118]

In 2005, the Northwest Power and Conservation Council (often referred to as the Northwest Council) issued a resource plan that incorporates estimates of future CO_2 values beginning in 2008.[119] This is worth noting not only because the 20-year plans developed by this federally created regional agency cover the entire Northwest, but also because most energy planning is conducted by utilities rather than independent planners who have no financial incentive to select one type of resource over another.

B. *A useful range of CO_2 price forecasts is emerging from the literature.*

Over the last few years, federal cap-and-trade proposals before Congress have spawned numerous analyses using computer models to simulate the market response to these regulations. For example, the EIA, the U.S. Environmental Protection Agency, the Massachusetts Institute of Technology (MIT), and the Tellus Institute have all modeled the effects of proposed legislation resulting in varying CO_2 cost projections.[120] The

[115] Ibid., 62.

[116] Northwestern Energy, "2005 Electric Default Supply Resource Procurement Plan," Volume 2, Chapter 1, 25.

[117] See Bolinger and Wiser, 2005, 57 (note 75) and 60; Washington Administrative Code, section 480-100-238; and California PUC, "Interim Opinion on E3 Avoided Cost Methodology," April 22, 2004 (online at *http://www.cpuc.ca.gov/PUBLISHED/AGENDA_DECISION/45195.htm#TopOfPage*).

[118] California PUC, "Interim Opinion on E3 Avoided Cost Methodology," Decision 05-04-024, Proceeding 04-04-025, 29 and 89. Online at *http://www.cpuc.ca.gov/PUBLISHED/AGENDA_DECISION/45195.htm*. Also see UCS testimony submitted in this proceeding (online at *http://www.ucsusa.org/clean_energy/clean_energy_policies/testimony-on-accounting-for-californias-global-warming-gas-costs.html*).

[119] Northwest Power and Conservation Council, "The Fifth Northwest Electric Power and Conservation Plan," 2005, Volume 1, 19. Online at *http://www.nwcouncil.org/energy/powerplan/plan/Default.htm*.

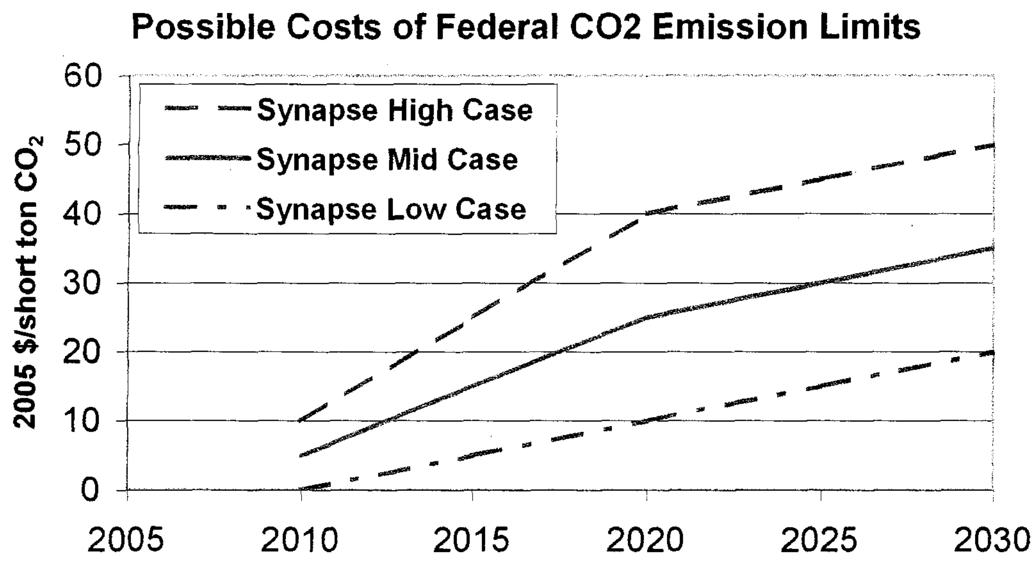
[120] See EIA, "Energy Market Impacts of Alternative Greenhouse Gas Intensity Targets," March 2006; "Impacts of Modeled Recommendations of the National Commission on Energy Policy," April 2005; "Analysis of Senate Amendment 2028, the Climate Stewardship Act of 2003," May 2004; "Analysis of S.139, the Climate Stewardship Act of 2003," June 2003;(online at *http://www.eia.doe.gov/oiaf/service_rpts.htm*); EPA, "Multi-Pollutant Legislative Analysis: The Clean Power Act," October 2005; and "Multi-Pollutant Legislative Analysis: The Clean Air Planning Act," October 2005 (online at *http://www.epa.gov/airmarkets/mp/index.html*); Massachusetts Institute of Technology Joint Program on the Science and Policy of Global Change, "Emissions Trading to Reduce Greenhouse Gas Emissions in the United States: The McCain-Lieberman Proposal," June 2003 (online at *http://web.mit.edu/globalchange/www/MITJPSPGC_Rpt97.pdf*); Tellus Institute, "Analysis of the Climate Stewardship Act Amendment," June 2004 (online at *http://www.tellus.org/energy/publications/McCainLieberman2004.pdf*).

domestic policy option that has been subjected to the most analysis is the Climate Stewardship Act proposed by Senators McCain and Lieberman.

Another more recent policy proposal analyzed by the EIA is one developed by the NCEP. This approach focuses on reducing emission "intensity" (emissions per dollar of gross domestic product) rather than total emissions, but like all cap-and-trade proposals it would still impose a cost on CO_2 emissions.

In May 2006, Synapse Energy Economics conducted a review of the cost projections of 10 such modeled analyses, as well as the emerging policy response to climate change and recent scientific and political developments.[121] This review resulted in the high, mid-range, and low CO_2 cost projections shown in Figure 4.

Figure 4



Source: Johnston et al., 2006.[122]

While Synapse warns that the real cost of CO_2 is unlikely to follow a smooth path, the company believes its projections "represent the most reasonable range to use for planning purposes, given all of the information we have been able to collect and analyze bearing on this important cost component of future electricity generation."[123] When

[121] Lucy Johnston, Ezra Hausman, Anna Sommer, Bruce Biewald, Tim Woolf, David Schlissel, Amy Roschelle, and David White, "Climate Change and Power: Carbon Dioxide Emissions Costs and Electricity Resource Planning." Synapse Energy Economics. May 18, 2006. Online at http://www.synapse-energy.com.
[122] Ibid., p. 40.
[123] Ibid., 39.

Synapse's cost projections are levelized[124] over 30 years to 2005 dollars, the low CO_2 cost projection is $8.50/ton, the mid-range projection is $19.60/ton, and the high projection is $30.80/ton.[125]

Estimates of the price of future CO_2 allowances vary depending on a variety of factors, including the emission reduction target, the availability of offsets, whether international trading is allowed, the implementation timeline, and the existence of complementary policies such as energy efficiency programs and renewable electricity standards.[126] Two assumptions are particularly important and merit additional discussion here: the emission reduction target and the rate of technological progress.

First, all the analyses are based on relatively modest changes in U.S. emissions. The Climate Stewardship Act, for example, aims to return U.S. CO_2 emissions to 2000 levels over the period 2010 to 2015.[127] The NCEP proposal, which has been at the forefront of Senate hearings to design a cap-and-trade system, would slow the rate of emission growth but not reverse it.[128] None of the federal proposals that underlie these CO_2 cost estimates actually claim to deliver emission cuts sufficient to stabilize global CO_2 concentrations at a level that would avoid dangerous climate change.[129] Even the Kyoto Protocol, which would have required the United States to cut emissions seven percent below 1990 levels by the period 2008 to 2012, is only intended to be a first step leading to greater reductions later.[130]

As discussed in part I, section C, the science indicates that in order to prevent dangerous climate change, developed nations will need to reduce CO_2 emissions as much as 60 to 80 percent by 2050. Therefore, whatever federal policy to limit CO_2 emissions is initially adopted will have to be quickly followed with increasingly tighter caps if we are to put ourselves on a path toward climate stabilization in the decades ahead.

Much tighter national caps than those that have been analyzed would—all other things being equal—have the effect of driving CO_2 prices higher than the studies project. However, at some point, rising CO_2 prices would make low- or zero-carbon technologies competitive, leveling out the increase in CO_2 costs. How quickly that point is reached depends on a second important assumption: how quickly these technologies will develop. Most of the studies that provide the basis for the published cost projections (particularly

[124] "Levelized" cost means "The present value of the total cost of building and operating a generating plant over its economic life, converted to equal annual payments. Costs are levelized in real dollars (i.e., adjusted to remove the impact of inflation)." EIA Glossary, http://www.eia.doe.gov/glossary/glossary_l.htm.

[125] Johnston, et al., 2006., 41.

[126] Ibid. 35–39.

[127] See Pew Center on Global Climate Change, "Summary of the 2003 Climate Stewardship Act." Online at http://www.pewclimate.org/policy_center/analyses/s_139_summary.cfm.

[128] Johnston et al., 2006, Figure 5.1.

[129] The newly introduced bills discussed in part II.C aiming for 80 percent reductions below 1990 levels by 2050 have not yet been the subject of analysis and are not reflected in cost projections.

[130] Climate Change Secretariat, "Caring for Climate: A Guide to the Climate Change Convention and the Kyoto Protocol," United Nations Framework Convention on Climate Change, 2003, 25. Online at http://unfccc.int/resource/cfc_guide.pdf.

those by the EIA) make very pessimistic assumptions about the cost and performance of renewables, efficiency, and other alternative technologies, both today and in the years ahead.[131] Moreover, they assume that there will be no new policies requiring or providing incentives for greater use of these technologies, despite growing support for such policies at both the state and federal level.

Using more optimistic assumptions about the costs, performance, and policy support for these clean energy technologies would have the effect of reducing CO_2 prices below projected levels (or keeping them from rising as much as they otherwise would in response to ever-tightening caps).[132] In this way, the rapid development of coal alternatives would have the paradoxical effect of reducing the future costs of coal power. Of course, if utilities and regulators use these more optimistic assumptions about the development of low-carbon energy in forecasting CO_2 prices, they must use the same assumptions when determining whether it would be cheaper in the long run to simply invest in low-carbon alternatives rather than building new coal plants. Optimism about alternative technologies to coal may reduce the estimated cost of coal plants by keeping future CO_2 allowance prices low, but that same optimism undermines the economic logic of building a new coal plant in the first place.

The CO_2 price projections by Synapse are roughly consistent with the range of projections being used by utilities and the Northwest Council in their resource plans, though without encompassing the highest and lowest of those values. Table 1 shows the range of numbers in use.[133] (In some cases, these values are discounted by the utility with a probability weighting when actually used in planning.)

Table 1: CO_2 Emission Trading Assumptions for Various Years (in 2005 dollars)

PG&E*	$0-9/ton (start year 2006)
Avista 2003*	$3/ton (start year 2004)
Avista 2005	$7 and $25/ton (2010) $15 and $62/ton (2026 and 2023)
Portland General Electric*	$0-55/ton (start year 2003)
Xcel-PSCCo	$9/ton (start year 2010) escalating at 2.5%/year
Idaho Power*	$0-61/ton (start year 2008)
Pacificorp 2004	$0-55/ton
Northwest Energy 2005	$15 and $41/ton
Northwest Power and Conservation Council	$0-15/ton between 2008 and 2016 $0-31/ton after 2016

Source: Johnston et al., 2006, Table 6.1.

[131] For example, see Steve Clemmer (Union of Concerned Scientists), "Renewable Energy Modeling Issues in the National Energy Modeling System," presentation at the National Renewable Energy Laboratory Energy Analysis Seminar, Washington, DC, December 9, 2004. Online at http://www.nrel.gov/analysis/seminar/docs/2004/ea_seminar_december_9.ppt.

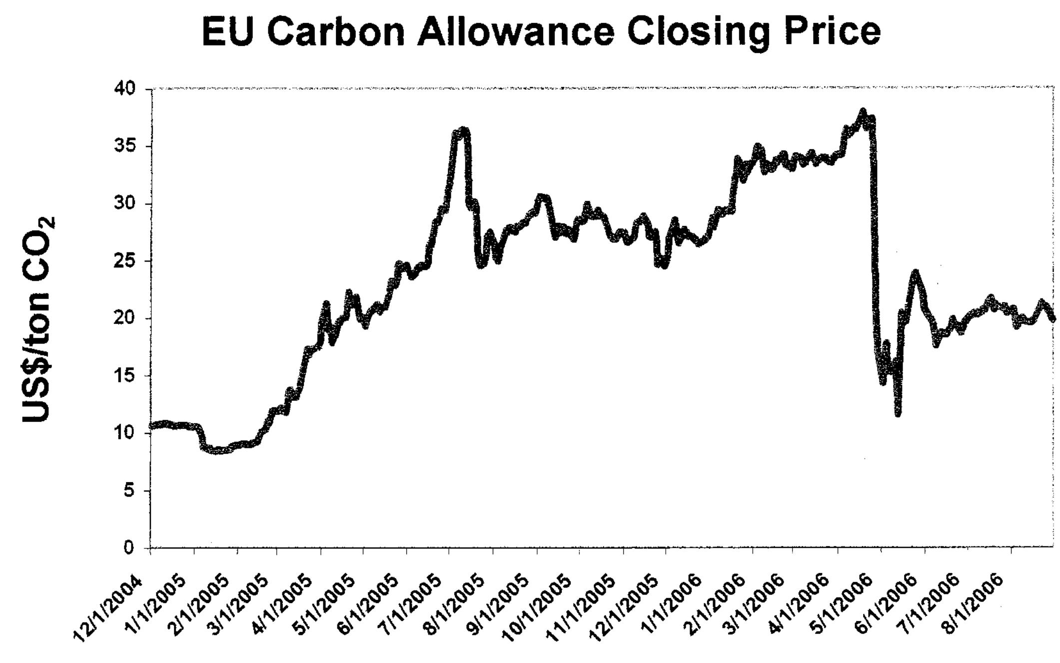
[132] The studies reviewed by the Tellus Institute used more optimistic assumptions and included complementary policies for energy efficiency and renewable energy technologies. The resulting CO_2 cost projections were closer to the Synapse mid-range projections and leveled off more in the later years of the forecast. See Tellus Institute, 2004.

[133] Ibid., 30.

Not included in Table 1 is the estimate of future CO_2 regulatory costs that California requires its utilities to assume in resource selection. At eight dollars per ton in 2004, rising by only five percent annually (less than the rate at which Synapse's projections rise), California's estimate begins near the high end of the Synapse analysis but move toward the low end in later years.[134]

Wall Street analysts Bernstein Research recently modeled the impact of a CO_2 allowance requirement on the earnings of several U.S. coal-fired generators, choosing nine dollars per ton of CO_2 as the price on which to base its analysis. It also considered a $28/ton CO_2 price based on the allowance prices recently prevalent under the European Union's cap-and-trade system, which reached levels as high as $35/ton during the past year.[135] As Figure 5 shows, CO_2 prices dropped sharply in May on news that many companies emitted less CO_2 than expected, suggesting that large emitters had been allocated too many allowances.[136] Prices have since partially rebounded.

Figure 5



Source: EU: PointCarbon.com using an average exchange rate for 2005 of 1.25 U.S. dollars per euro.

There are great uncertainties associated with predicting the future cost of CO_2 allowances, but this holds true for many other aspects of utility planning—especially

[134] See Bolinger and Wiser, 2005, 60.
[135] Wynne, 2006, 11–17.
[136] Reuters, "EU undershoots emissions cap that critics call lax," May 12, 2006. Online at http://today.reuters.com/News/CrisesArticle.aspx?storyId=L12101022.

when considering the wisdom of investing in capital-intensive power plants that typically operate for a half-century or more in a rapidly changing world. The most prudent way to assess and minimize this risk is to consider the impact of a reasonable range of CO_2 cost projections (such as those described above) on a proposed coal plant. The one CO_2 price projection certain to be wrong is zero.

C. Reasonable projections of CO_2 prices would greatly increase the cost of coal power.

CO_2 allowance prices in the ranges discussed above would significantly increase the price of power from new coal plants. How much CO_2 allowance prices raise the cost of generating electricity from coal depends on the efficiency of the plant in question, but generally speaking, new coal plants emit roughly one ton of CO_2 per megawatt hour (MWh) of electricity produced.[137] This means, for example, that a CO_2 price of $10 per ton would increase a plant's costs by $10/MWh (or one cent per kilowatt-hour). Figure 6 shows how the cost of coal-fired electricity would rise in response to different CO_2 prices, starting with the EIA's estimated average base price of $47.50/MWh for new pulverized coal plants placed into service in the upper Midwest in 2015.[138]

Applying the Synapse levelized CO_2 cost projections to a coal plant increases the cost of energy from the EIA's average coal plant by the amounts and percentages shown in Table 2. For example, the cost of energy from an average coal plant would be 40 percent higher over its operating lifetime assuming mid-range CO_2 costs starting at five dollars per ton in 2010 and rising to $35 per ton by 2030.

Table 2: Increase in Energy Cost Based on Projected CO_2 Cost

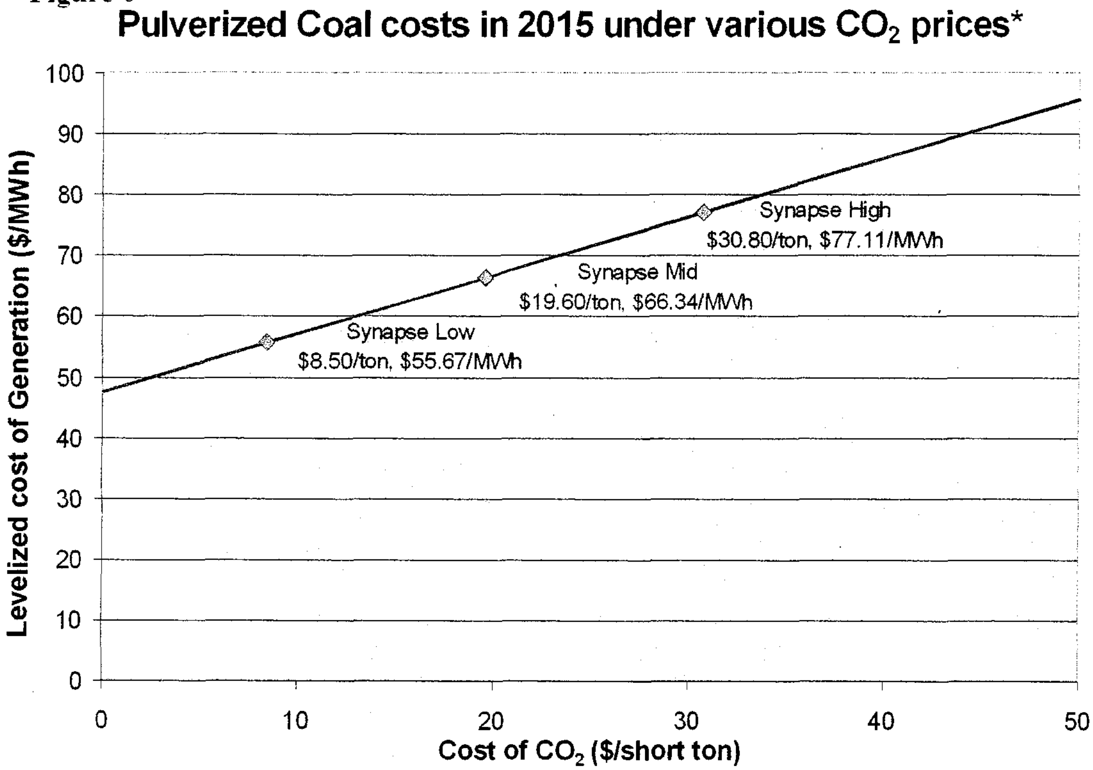
Price of CO_2 Allowance (levelized)	**Cost of energy**	**Percent increase above base price**
Base price (no CO_2 cost)	$47.50/MWh	–
Low projection: $8.50/ton	$55.67/MWh	17%
Mid-range projection: $19.60/ton	$66.34/MWh	40%
High projection: $30.80/ton	$77.11/MWh	62%

[137] Coal has a carbon intensity of 220 pounds per million British thermal units (Btu) and a new supercritical pulverized coal plant has a heat rate of 8,742 Btu per kilowatt-hour in 2005 (220 lbs/million Btu x 8,742 Btu/kWh/2,000 lbs/ton x 1,000 kWh/MWh/1,000,000 = 0.96 ton of CO_2 per MWh). See EIA, *Assumptions for Annual Energy Outlook 2006*, 2006.

[138] EIA, "NEMS EMM Factors for AEO06," spreadsheet, 2006. The costs are representative of a new coal plant built in the Midwest. Recent data indicates that EIA's base price for coal may be low. EIA's figure assumes overnight capital costs of $1,235/kW for a new plant. By comparison, the engineering firm Black and Veatch assumes overnight capital costs of $1,730/kW, based on the average cost of over 60 coal plant projects under construction or with air permits. (Source: Personal Communication with Ric O'Connell, Black and Veatch, August 20, 2006.) Using these capital costs, along with EIA's other assumptions, would raise the base cost of energy to $58/MWh.

Any utility proposing to build a coal plant would be reckless to make such a long-term investment without fully assessing a variable that could easily increase costs by $86 million per year on average, or $4.3 billion over a 50-year period, for a 600 MW coal plant.[139] The risk of future carbon constraints is far too great to ignore.

Figure 6



Source: EIA, "NEMS EMM Factors for AEO06," spreadsheet, 2006, and Johnston et al., 2006. The costs are representative of a new coal plant built in the Midwest.

D. Given the carbon-constrained world ahead, renewables and efficiency will generally be a much better investment than new coal plants.

In many cases, coal plants are already more expensive than cleaner options. This is particularly true with respect to investments in energy efficiency and wind turbines (in locations with favorable winds). With mid-range estimates of future CO_2 costs adding close to $20/MWh (or two cents per kilowatt-hour) to the cost of energy from a coal plant, cleaner options will cost less than coal in an even wider range of cases.

[139] Based on an estimate by Synapse for the Big Stone II coal plant under a mid-range CO_2 cost projection. See David A. Schlissel and Anna Sommer, direct testimony to the South Dakota PUC, case no. EL05-022, May 19, 2006, 24. Online at http://www.state.sd.us/puc/commission/dockets/electric/2005/el05-022/testimonyschlisselsommer.pdf.

While the exact cost comparisons will vary by location, two recent analyses compare coal plants with cleaner options in a carbon-regulated world, and in these analyses new conventional coal plants cannot compete. The first such analysis is a massive exercise in regional resource planning recently conducted by the Northwest Council.[140] With no financial stake in the outcome to skew its planning judgment, the council's fifth 20-year plan (adopted in December 2004) is a useful contribution to resource planning.

Among other things, the plan ranks various supply- and demand-side options on a cents-per-kilowatt-hour scale. The Northwest Council identifies 25 different conservation and renewable options that cost less than the cheapest new coal plant (even in Montana, a coal-producing state).[141] The plan looks at many different scenarios and various price estimates for future CO_2 costs (though these estimates pre-date recent developments such as the Senate resolution calling for carbon regulation).[142]

The plan concludes that much more investment in conservation is warranted even though the Northwest has already made relatively high investments in conservation over the years.[143] Overall, the Northwest Council's approach of identifying options that are both low-cost and low-risk yielded a plan that greatly increases investment in conservation and wind and *does not include any new conventional coal plants* for the region throughout the 20-year planning period.[144] While the council's cost estimates may not directly apply to other regions, they provide a valuable example of how conventional coal plants become uncompetitive compared with energy efficiency and renewable energy when independent resource planners use realistic assumptions about the future and factor in carbon risk.

The second relevant analysis was conducted by Synapse Energy Economics, which in May 2006 submitted testimony critiquing a resource comparison that a coalition of utilities seeking to build a conventional coal plant submitted to South Dakota regulators.[145] The utilities did not compare the proposed 600 MW Big Stone II plant with a comparable investment in energy efficiency, nor did Synapse. However, the utilities did compare Big Stone II with the alternative of building 600 MW of wind power along with a 600 MW natural gas combined-cycle plant. Not surprisingly, the utilities' wind/gas alternative was more expensive than Big Stone II, since it assumed only 600 MW of wind power and unnecessarily assumed that the wind turbines required 100 percent backup from natural gas to compensate for the wind's intermittent nature.

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140 Northwest Power and Conservation Council, 2005.
141 Ibid., Table OV-2, 26–27.
142 Ibid., 19. The Northwest Council assumes CO_2 costs of between zero and $15 per ton beginning in 2008, and between zero and $30 per ton beginning in 2016.
143 Ibid., 4, 29–31.
144 Ibid., 29.
145 David A. Schlissel and Anna Sommer, direct testimony to the South Dakota PUC, case no. EL05-022, May 26, 2006. Online at *http://www.state.sd.us/puc/commission/dockets/electric/2005/el05-022/testimony/schlissel052606.pdf*.

Synapse reworked the comparison by increasing the amount of wind power to 800 and 1200 MW, reducing the amount of natural gas to levels that would be needed to provide an equivalent amount of electric generation and capacity (300 to 480 MW) as the coal plant,[146] and factoring in its low, mid-range, and high CO_2 cost estimates (described in part V, section B). Synapse also completed a sensitivity analysis of a few key variables including the continued existence of the federal production tax credit for wind, a capacity value for wind (which affects the amount of natural gas capacity needed), and whether the utilities were investor-owned or publicly owned.

Under all of the CO_2 price forecasts, the analysis showed that all of the high-wind (1,200 MW) scenarios were approximately the same or less costly than the 600 MW coal plant, even without the federal production tax credit and using a very conservative capacity value for wind. Under the most likely mid-range CO_2 price forecast, Big Stone II cost 27 to 71 percent more than the high-wind scenarios, across the entire range of assumptions.[147]

The analysis also showed that all of the wind/gas alternatives had lower costs than the 600 MW coal plant under both the mid-range and high CO_2 price forecasts. Coal fared remarkably poorly in these comparisons even though Synapse did not correct all of the utilities' assumptions that underestimated the cost of coal and overestimated the cost of wind.[148] In addition, the Big Stone II co-owners recently announced that the capital costs for the project have increased by 50 percent—from $1.2 billion to $1.8 billion.[149] Using these new costs, and incorporating energy efficiency into the alternatives analysis, would make the alternatives even more economically viable than described above.

Both the Northwest Council and Synapse analyses show coal unable to compete financially with other options available today when future carbon constraints are considered. In the future, coal is likely to be even less competitive, because policies designed to combat global warming will not just make coal more expensive but will surely accelerate improvements in cleaner technologies. Unlike conventional coal plants, many energy efficiency and renewable energy technologies are still relatively new. As they break out of niche markets and achieve greater economies of scale, improvements in price and performance will follow. Utilities that invest heavily in coal today are therefore

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[146] Ibid., 14. Synapse explains in its testimony that, by accepting the utilities' assumption that any dedicated backup plants would be built to support wind power, its analysis overstates the cost of the wind options.

[147] Ibid., Tables 1 and 2, 17. (A corrected version of these tables with slight alterations to the originally-filed numbers is online at http://www.state.sd.us/puc/commission/dockets/electric/2005/el05-022/corrected062306.pdf.)

[148] Ibid., 13–16. Synapse explains in its testimony its decision not to correct several of the utilities' original assumptions that bias the analysis against wind. For example, while the tax and financing advantages of public utilities were reflected in the cost of Big Stone II, they were not reflected in the cost of wind. Synapse corrected the utilities' assumption that wind had zero capacity value, but it conservatively assumed that wind resources have a capacity value of only 15 or 25 percent (despite recent utility studies showing that wind in the region has a capacity value between 27 and 34 percent). Synapse also used the utilities' value of $12/MWh for the production tax credit, despite data from the EIA showing a value of $21/MWh.

[149] Associated Press, "Higher cost for SD power plant won't help ND chances, exec says," August 4, 2006. Online at http://www.kxma.com/getARticle.asp?ArticleId=30517.

not only running unnecessary financial risks, but also losing the flexibility to take full advantage of the technological opportunities ahead.

E. Retrofitting a pulverized coal plant to limit CO_2 emissions is feasible, but will be very expensive.

Coal plants emit far more CO_2 than any pollutant that is federally regulated today. By way of example, the Final Environmental Impact Statement for the Weston 4 coal plant in Wisconsin lists potential mercury emissions of 78 pounds per year, sulfur dioxide emissions of about 2,300 tons per year, and nitrogen oxide emissions of about 1,600 tons per year. CO_2 emissions, by comparison, are projected to be 4,100,000 tons per year.[150] Collecting and disposing of CO_2 emissions therefore pose much greater technological challenges than those faced by coal plants to date.

It is considered technologically possible to capture 80 to 90 percent of the CO_2 from a conventional coal plant by scaling up methods currently in use to produce CO_2 for beverage and chemical applications.[151] However, the costs—in terms of energy consumed by the capture process and added capital and operating expenses—would be very high. The energy penalty of adding such technology to the plant would equal 24 to 40 percent of the energy produced by the plant.[152] A recent MIT study estimates that adding CO_2 capture technology to a conventional coal plant and disposing of the CO_2 in geological formations would increase the plant's levelized cost by nearly $30/MWh or 74 percent.[153]

Thus, there is no technological solution that can be reasonably expected to buffer a conventional coal plant from the financial risk associated with CO_2 regulation. Whether the plant operator ultimately pays for emission allowances or installs technology to capture and dispose of the CO_2, it runs a high risk of greatly increased costs.

VI. Regulators should protect ratepayers from future CO_2 costs by refusing to authorize new coal plants; alternatively, they should clearly place the risk of future CO_2 costs on utility shareholders rather than on ratepayers.

Currently, a utility's environmental compliance costs are routinely passed through to ratepayers as a cost of providing electricity. In particular, costs of buying pollution allowances (such as the sulfur dioxide allowances coal operators purchase today) are considered operating expenses recoverable through rates. This regulatory pattern of

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[150] Public Service Commission of Wisconsin, Weston Unit 4 Power Plant Final Environmental Impact Statement, Volume 1, July 2004, 134 and 145. Online at http://psc.wi.gov/utilityinfo/electric/cases/weston/document/Volume1/W4_FEIS.pdf.

[151] IPCC, "Carbon Dioxide Capture and Storage," 121. Current unit capacities would have to be increased by a factor of between 20 and 50 for deployment at a 500 MW coal plant.

[152] Ibid, Summary for Policymakers, 4.

[153] Ram C. Sekar, John E. Parsons, Howard J. Herzog, and Henry D. Jacoby, "Future Carbon Regulations and Current Investments in Alternative Coal-Fired Power Plant Designs," MIT Joint Program on the Science and Policy of Global Change, December 2005, 4.

treating pollution allowance costs as operating expenses means that utilities may feel confident that they can also recover any future CO_2 allowance costs through their rates.

Such confidence, however, means a utility operating in a regulated environment has little incentive to assess CO_2 allowance costs in a serious way, even when contemplating major new long-term investments. From a societal standpoint, this is a financial disaster waiting to happen; the financial risks of building a new coal plant are very high, but the party making the investment is not deterred because it does not feel at risk.

It is, of course, up to state regulators to make sure this financial disaster is avoided and that ratepayers are protected. By far the best way to do that is to deny approval of the proposed coal plant and encourage the utility to pursue less financially risky alternatives.

However, if regulators do approve construction of a proposed plant, they should ensure that the utility has an incentive to minimize this risk as it emerges by warning it that future CO_2 allowance costs will not be recoverable through rates. This is particularly important given how rapidly climate change policy is evolving and how long it takes to build a coal plant. Because utilities would for some time have the ability to cancel or downsize new plants in response to the growing risk of CO_2 costs, regulators should give them the incentive to monitor and respond to that risk. Shifting the risk of future CO_2 regulations onto utilities may be inconsistent with current rate treatment of pollution allowances, but it is fully consistent with underlying ratemaking principles and the case law related to investments in new baseload plants.

In the late 1960s and 1970s, many of the nation's utilities believed two things that turned out to be wrong: that electricity demand would keep growing at a fast rate and that nuclear power would be an inexpensive way to meet that demand. These mistaken beliefs resulted in substantial excess baseload capacity in the early 1980s (largely from unneeded coal plants), many abandoned nuclear plants, and disputes around the nation about whether the costs of these mistakes should be paid by utility shareholders or ratepayers.

The regulatory decisions made during this era typically allocated at least a share of excess costs to shareholders, and articulated standards intended to give utilities a stronger incentive to avoid such unwise investments in the future.[154] Now that utilities are again in the midst of a baseload power plant construction boom based on risky assumptions, these standards are again highly relevant.

Two complementary regulatory approaches emerge in these disputes: the "prudent investment approach" and the "shared costs approach." Both approaches are intended, in part, to create incentives for utilities to continually rethink their investment decisions in

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154 For overviews of these cases see Richard J. Pierce, Jr., "The Regulatory Treatment of Mistakes in Retrospect: Canceled Plants and Excess Capacity," 132 *U. Pa. L. Rev.* 497 (1984); "Abandoned Nuclear Plant Recovery," 83 *ALR*4th 183 (1991); and Roger D. Colton, "Excess Capacity: Who Gets the Charge from the Power Plant?" 34 *Hastings L.J.* 1133 (1983).

light of emerging events (rather than sticking to a chosen path even when subsequent developments clearly make that path unwise).

Under the prudent investment approach all or part of a utility's investment can be excluded from rates if any decision made by the utility in relation to that investment is found to be imprudent. This could include the decision to build a power plant and the subsequent decision not to cancel it after changing circumstances show the project to be unwise.[155]

While this principle has often been invoked by utilities seeking to recover from unsuccessful investments that appeared to be prudent when they were initially made,[156] the principle is also intended to protect ratepayers from unwise utility decisions.[157] Over the years, regulators have denied rate recovery for some enormous investments judged to be imprudent, including costs related to abandoned nuclear power plant construction plans[158] and coal plants that were built but created excess capacity.[159]

To determine whether an investment was prudent, courts consider what a utility knew or should have known when the investment was made, and any alternative generating options that were available at the time. The inquiry not only focuses on the initial decision to build a plant, but also on the subsequent, ongoing decisions to continue pursuing construction even after events such as the adoption of a new regulatory approach greatly increased cost estimates beyond those originally projected. As parts I through V show, building a coal plant without reasonably factoring in the substantial financial risk associated with coming climate laws is clearly imprudent. On these grounds alone, regulators would be justified in disallowing rate recovery of CO_2 costs.

However, an investment need not be deemed imprudent for recovery to be disallowed. The U.S. Supreme Court has explicitly upheld the authority of state regulators to limit a utility's recovery for an investment that appeared prudent at the time it was made but ultimately proved unwise.[160] States have considerable discretion to set rates that appropriately balance the interests of shareholders and ratepayers, and some have adopted approaches that divide financial risks between these parties. State regulators have particularly used this shared costs approach in cases of excess capacity built as a result of inaccurate demand forecasts, because they concluded that placing all the risk on ratepayers is unfair and creates the wrong incentives for utility management. In 1982, for example, Iowa regulators refused to pass on to ratepayers all the costs a utility incurred in building what later proved to be excess generating capacity, even though the decision to build was reasonable when made. The Iowa commission explained its reasoning this way:

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155 See Pierce, supra, p. 7.
156 See Duquesne Light Co. v. Barasch, 488 U.S. 299, 109 S.Ct. 609 (1989).
157 Verizon Communications Inc. v. FCC, 535 U.S. 467, 122 S.Ct. 1646, 1659 (2002).
158 See e.g., Association of Businesses Advocating Tariff Equity v. Public Service Commission, 527 N.W.2d 533 (Mich. App. 1994); In Re Interstate Power Company, 416 NW2d 800 (Minn. App. 1987); Re Boston Edison Co., 46 PUR4th 431 (Mass DPU, 1982), aff'd 455 NE2d 414.
159 Gulf Power Company v. Florida Public Service Commission, 453 So.2d 799 (Fla. 1984);
160 Duquesne Light Co. v. Barasch, 488 U.S. 299, 109 S. Ct. 609 (1989).

"In the real world of competitive enterprise, management officials must continuously rethink prior decisions as new events unfold. Those who fail to stay on top of current events lose out to their competition. Iowa utilities should also maintain surveillance over costs associated with a particular decision, and in the absence of the kind of incentive provided by a competitor, the responsibility falls upon us to provide the requisite incentive."[161]

The Wisconsin Supreme Court agreed with Iowa's shared costs approach and recognized the authority of Wisconsin regulators to apply it in the same context.[162] Pennsylvania regulators applied similar reasoning in an excess capacity case, noting that while the investments were prudent and the excess capacity was no fault of the utility or its investors, "neither was it the fault of ratepayers. Under these circumstances there must be some sharing of the risk associated with bringing these large plants on line."[163]

North Dakota regulators took a similar approach in response to excess capacity created by a coal plant, refusing to allow all the costs to be passed on to ratepayers. Though they did not deem the utility's investment imprudent, regulators felt it was "unreasonable to expect ratepayers to completely absorb the risk" of excess capacity, and that "there must be some risk placed on the utility and there must be some incentive for the pool and the individual utility member to continuously strive for accurate and precise management" of investments in baseload capacity.[164]

Both the prudent investment approach and the shared costs approach recognize the importance of giving utilities a strong incentive to avoid making investment mistakes, especially when building expensive, long-lived baseload plants. And both lines of cases stress how important it is for utility management to keep track of changes that affect the wisdom of the utility's investment during the period after a plant receives regulatory approval but before construction is completed.

These cases grew out of an era (the 1970s) when utilities making large investments in baseload capacity were surprised by events beyond their control—primarily the OPEC embargo, which led to slower growth in energy demand, and the Three Mile Island accident, which resulted in stricter safety standards and higher construction costs. Once again, utilities are making huge investments in baseload power, but this time the global changes that threaten the economic viability of these investments are far more predictable than they were in the past. Indeed, they are looming, and they threaten to substantially increase the cost of energy from new coal plants. It is even more critical today that utilities be given a strong incentive to track regulatory developments and continually re-examine their construction decisions in light of those developments.

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161 Re Iowa Public Service Company, 46 PUR4th 339, 368-69 (IA Commerce Commission, 1982).
162 Madison Gas and Electric Company v. Public Service Commission of Wisconsin, 325 N.W.2d 339 (Wis. 1982).
163 Pennsylvania Public Utility Commission v. Philadelphia Electric Co., 37 PUR4th 381, 387 (Pa. Public Utility Commission, 1980).
164 Re Montana-Dakota Utilities Co., 44 PUR4th 249, 255 (N.D. PSC 1981); see also Re Otter Tail Power Company, 44 PUR4th 219 (N.D. PSC 1981).

Regulators can create such an incentive by determining, as a condition of plant approval, that future CO_2 costs will be borne by utility shareholders rather than ratepayers.

VII. Conclusion

The fight against global warming will unquestionably change the laws, economics, and technology of power production and use. Many different groups have a role to play in helping ensure our society responds sensibly to these changes.

- Utilities should factor future CO_2 costs into their resource planning and procurement, aggressively pursue conservation, efficiency and renewable energy, and at the very least defer making major coal plant construction decisions until they have a clearer picture of the regulatory risks and technological opportunities ahead.

- Regulators should insist that utilities take the above steps. They should also protect ratepayers by refusing to authorize the construction of new conventional coal plants, which are premised on the regulatory conditions of the past, not those of the future. At the least, they should warn utility managers that shareholders will bear the risk that coal investments will result in excess carbon costs.

- Investors and shareholders should recognize the inevitability of CO_2 regulations and understand that utilities that behave imprudently by building coal plants despite these costs would, under existing regulatory principles, be prevented from recovering at least a portion of such costs in their rates. Shareholders should question utility management closely on how they are assessing and managing carbon risks, and require reporting and accountability. Long-term investors should favorably regard companies who are proactively considering and managing these risks effectively.

- Ratepayers and consumer groups should realize that the utilities building new coal plants will seek to recover all their costs, including CO_2 regulatory costs, from ratepayers. While legal principles support denying rate recovery of these costs, history shows that these cases are extremely contentious and expensive. A far better way for ratepayers and consumer groups to protect themselves from such financial risk is by resisting the construction of new conventional coal plants in the first place and by supporting investments in cleaner alternatives such as efficiency and renewable energy.

Building a major energy resource – especially one that costs as much and lasts as long as a coal plant -- is unavoidably an exercise in predicting the future. It cannot be prudently done without objectively analyzing the trends and potential risks that will shape the decades ahead. In the case of new coal plants, the critical trends are undeniable and moving with unstoppable momentum: CO_2 levels are rising to levels unseen on the planet in millions of years, global temperatures are setting new records, scientific evidence showing that our current energy path is leading to dangerous climate changes is mounting, and the policy response at every level of government is accelerating. To assume in the face of these trends that a new coal plant could be put into service and allowed to emit millions of tons of CO_2 for free for the next few decades is reckless, to say the least. New conventional coal plants in the age of global warming are not just bad policy – they are a bad investment, and one we cannot afford to make.

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Coming to Grips with Carbon

Hedging Carbon Risk: Protecting Customers and Shareholders from the Financial Risk Associated with Carbon Dioxide Emissions

Utilities and regulators are recognizing that it is unlikely that greenhouse gas emissions will continue to cost utilities nothing whatever over the long lifetime of new investments. Several utilities have begun to protect their customers and shareholders from this financial risk by integrating an estimated cost of carbon dioxide emissions into their evaluation of resource options, and selecting the overall least-cost portfolio of resources.

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I. Introduction

As regulation of carbon dioxide emissions becomes increasingly likely, utilities are beginning to analyze and actively manage the financial risk associated with their portfolios' emissions. Fossil fuel-based investments made today will continue operating and emitting carbon dioxide for 30 to 40 years or more, and it is highly likely that carbon dioxide emissions will be regulated within that timeframe. As the single largest source of U.S. greenhouse gas (GHG) emissions, the electric sector is likely to figure prominently in any regulatory program to reduce emissions.

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Utilities such as PacifiCorp, Idaho Power, and Pacific Gas and Electric Company are helping to protect their customers and shareholders from the financial risk associated with future regulation by integrating an estimated future cost of emissions into their evaluation of resource options, and selecting the overall least-cost portfolio of resources. The experience gained to date provides a model for other utilities and regulators seeking to reduce exposure to the cost of future regulation of carbon dioxide emissions and to reduce customers' overall long-term cost for energy services.

II. Risk Management Is a Crucial Utility Responsibility

Integrated resource planning rose in prominence within the electric industry in the 1970s and 1980s amid market shocks associated with oil price volatility and unexpectedly high costs for nuclear power, among other factors. Such trends pushed up electricity prices and prompted regulators to require thorough planning exercises by utilities, allowing for public scrutiny of resource investment plans. With the arrival of deregulation in the mid-1990s, integrated resource plans (IRP) became a historical artifact in many states rather than a vital ongoing process.

Recent turmoil within the electric industry has focused attention once again on one of the crucial responsibilities of utilities: electric-resource portfolio management. Effective portfolio management requires a fully integrated approach to identify customer electric service needs and to select demand- and supply-side alternatives to meet those needs through a portfolio that minimizes total cost and environmental impacts, and has an acceptable level of risk.[1]

Evaluating uncertainties and demonstrating risk management is a key imperative in long-term planning.

In states such as Oregon and Idaho that did not fully restructure their electric industries, utilities never stopped working with their regulators on IRPs. Other states, such as California, that did restructure have reconsidered and are now developing new tools to enable utilities to effectively manage costs and risks through portfolio management and long-term plans. Throughout the industry, there is growing recognition that portfolio management and long-term planning processes are essential to enable utilities to provide low-cost, reliable, and environmentally sensitive energy services. IRPs and long-term plans serve as common guidebooks for both the utility and the regulator, so that subsequent resource decisions are founded upon common understandings and assumptions that utilities believe will assist them in making a strong case for cost recovery.

Evaluating uncertainties and demonstrating risk management is a key imperative in long-term planning. Recent volatility in the electric market has heightened awareness among regulators regarding the importance of utility risk management, and many regulators require risk evaluation in long-term planning. For example, the Oregon PUC issued an order that requires consideration of uncertainty in resource planning.[2] The Utah PSC also requires an evaluation of different load forecasts, the risk associated with various resource options, and consideration of how an action plan addresses such risks.[3] More generally, it requires evaluation of any significant risk associated with resource options, and a demonstration of flexibility in the resulting action plan rather than a pre-determined suite of actions that cannot adjust to changing conditions.

A. Evaluating the financial risk of global warming regulation

More and more utilities, including PacifiCorp and Idaho Power, incorporate extensive risk analysis in their IRPs, with differentiation between stochastic

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and scenario risks. Stochastic risks consist of estimated deviations from an average value, and embody factors with which utilities have substantial experience and can subject to standard statistical models. (Of course, while historical experience is extremely useful in assessing risks, this information must always be combined with informed judgment about the future risk.) Natural gas prices, electricity market prices, hydropower generation, and loads all represent stochastic risks. In contrast, scenario risks represent a significant and sustained movement away from an "average" trend; these are risks that can be quantified but which are the subject of substantial uncertainty often dependent on decision points rather than broader "market" trends. By their nature, scenario risks can be more difficult to quantify than stochastic risks, and are therefore subject to more debate, either about their importance or about their potential material value. GHG regulations represent an important scenario risk associated with political decision making that utilities need to consider in their IRPs.

The Oregon PUC was one of the first to look at the financial risk associated with carbon dioxide emissions. The OPUC issued a 1993 order requiring regulated utilities to conduct sensitivity analyses on carbon dioxide emissions. The OPUC order followed a memo from the Oregon Department of Justice, which stated that the OPUC "may require utilities to consider in their least-cost plans the likelihood that external costs may be internalized in the future." Furthermore, the Commission is authorized to allow a utility to recover the costs of a cleaner but more expensive resource.[4] The order went on to say that the OPUC "would also need to find that the resource acquisition was prudent, presumably because it mitigated the risk that external costs would be internalized" in the future due to new regulation.

The pace of policy development suggests that carbon dioxide emissions may be regulated in the relatively near future, and likely within the lifetime of new utility investments.

III. Carbon Dioxide Emissions Are Likely to Be Regulated within the Lifetime of New Investments

The pace of policy development internationally and throughout the U.S. suggests that carbon dioxide emissions may be regulated in the relatively near future, and likely within the lifetime of new utility investments. These new investments will generate electricity for the next 30 to 40 years or even longer, and investments in carbon-emitting resources therefore create a financial risk for utilities and their customers.

A. National and international actions

In February 2005, the Kyoto Protocol entered into force, binding the ratifying countries to specific targets and timetables for GHG emission reductions, with strong reliance on market-based mechanisms. Just the month before, the European Union's Emissions Trading Scheme became the world's first large-scale GHG emissions trading program. And while the United States did not ratify the international treaty, several bills that would regulate carbon dioxide emissions are pending before the U.S. Congress.[5] One of these, the Climate Stewardship Act, introduced by Sens. McCain and Lieberman, received 43 votes in the Senate in 2003. The bill is expected to be brought back for another vote in the Senate, and the House has introduced a companion bill.[6]

B. State and regional actions

More than half the states around the country have developed or are developing strategies to reduce GHG emissions.[7] For example, the Northeast and Mid-Atlantic states are engaged in a cooperative Regional Greenhouse Gas Initiative (RGGI) to develop a regional cap-and-trade program to reduce carbon dioxide emissions. The goal of RGGI is to reach agreement on the design of the cap-and-trade program this year. Similarly, the governors of California, Washington, and Oregon have joined together to call for a regional GHG reduction initiative, concluding that their states "must act individually and regionally to reduce greenhouse gas emissions."[8] And just last month, in June 2005, Governor Schwarzenegger announced aggressive new GHG emission reduction targets for California.[9]

California has adopted regulations requiring reductions of GHG emissions from vehicles.[10] Other states including New York, New Jersey, and Massachusetts, have also adopted these regulations; in total, the states adopting these regulations represent nearly one-third of the U.S. car market. The California Public Utilities Commission (CPUC) is now exploring a cap-and-trade program for carbon dioxide emissions associated with the utilities' portfolios.[11] The Montana Public Service Commission has required Northwestern Energy to account for the financial risk associated with carbon dioxide emissions in its next long-term plan.[12] In addition, Washington recently passed a law regulating carbon dioxide from new power plants, requiring that 20 percent of the carbon dioxide from new plants either be taxed or mitigated through offset projects[13]; this law is similar to the carbon dioxide emission standards for new power plants that Oregon has had since 1997.[14]

C. Businesses recognize the risk

As the momentum to regulate GHG emissions continues to grow around the country and internationally, businesses are increasingly recognizing the risk associated with carbon dioxide emissions. Organizations such as the Carbon Disclosure Project and the Investor Network on Climate Risk have substantially raised the profile of climate-related risks when analyzing the financial health of companies worldwide. Last year, 13 major public pension funds, which manage $800 billion in assets, asked the Securities and Exchange Commission to require companies to disclose the financial risks they face from climate change.[15] Meanwhile, institutional shareholder groups and public pension funds filed 31 resolutions this year asking individual companies to disclose financial risks and their plans to reduce GHG emissions.[16]

As the momentum to regulate GHG emissions grows, businesses are increasingly recognizing the risk associated with carbon dioxide emissions.

In response to this pressure, some of the nation's largest utilities, including Cinergy, American Electric Power, and TXU, have issued reports on the financial risks they face from complying with regulations to address global warming. And Cinergy, one of the largest emitters of carbon dioxide in the electric industry, made global warming the central focus of its 2004 annual report.[17]

IV. Different Resources Create Widely Varying Risk Exposures

The magnitude of the carbon dioxide regulation risk faced by utilities and their customers depends on the total carbon dioxide emissions of the utilities' portfolio. Portfolios that are more dependent on carbon-emitting resources face a greater risk of increased costs. Different electricity resources have widely varying emissions of carbon dioxide, creating varying levels of financial risk. For example, the Northwest Power and Conservation Council (the Northwest's regional planning organization, established by Congress in 1980) reports that a new conventional coal plant will emit almost 1,000 metric tons of carbon dioxide per GWh, while a new combined cycle natural gas plant will emit about 400 metric tons per GWh, or 60 percent less than the coal plant.[18] Integrated gasification combined cycle (IGCC) coal-fired power plants emit nearly 800

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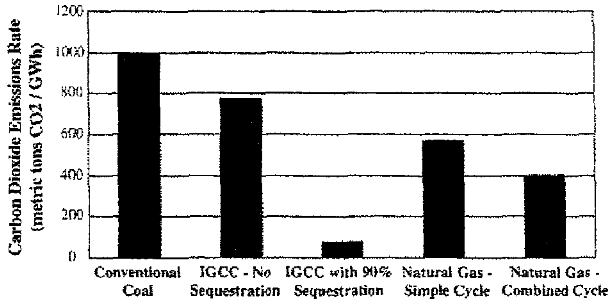
metric tons of carbon dioxide per GWh, 20 percent less than a conventional coal plant but still double a combined-cycle gas plant; with carbon capture and sequestration, these IGCC plants have the potential to decrease carbon dioxide emissions relative to standard coal plants by about 90 percent, emitting only about 80 metric tons of carbon dioxide per GWh.[19] Energy efficiency and renewable resources, such as hydro, wind, solar, geothermal, and biomass have low if any lifecycle carbon dioxide emissions. A number of these resources, particularly IGCC, solar, and many forms of biomass, are typically higher in cost than conventional generation using coal and gas. An important question is whether their lower emissions offer protection against future regulatory costs in a manner that justifies their selection by utilities seeking lowest cost and lowest risk for their customers.

Just as important as the emissions profile of the various technologies is the difficulty in reducing carbon dioxide emissions from existing thermal generation. There is no cost-effective "end-of-stack" technology option currently available to reduce carbon dioxide emissions from existing thermal plants, compared to other pollutants that are more amenable to retrofit approaches to sunk investments. This makes planning in advance of potential regulations even more crucial for carbon dioxide (**Figure 1**).



Source: Northwest Power and Conservation Council, 2005.

Figure 1: Comparison of Carbon Dioxide Emission Rates of Electricity Generation Resources

Conventional coal-fired power plants present the most serious financial risk in the face of potential carbon dioxide regulation, because of their higher GHG emissions. For example, assuming that carbon dioxide emissions will cost about $12 per ton, a 500 MW coal plant's emissions would result in approximately $50 million *per year* in cost exposure for a utility.[20] A 500 MW baseload combined cycle natural gas plant (at a 90 percent capacity factor), by contrast, would result in a cost exposure of about $20 million per year. And a less efficient 500 MW peaker gas plant with a heat rate of 9,300 Btu per kWh (and a 10 percent capacity factor) would have an exposure of about $3 million per year. A 500 MW baseload IGCC coal-fired power plant, with 90 percent carbon sequestration, would have a risk exposure of about $4 million per year. However, this is not the only fuel-related risk that utilities face. The risks associated with carbon dioxide emissions are in addition to the specific risks and costs associated with each fuel. It is the summation of these risks that utilities must consider in future resource decisions.

The magnitude of the carbon dioxide risk is large enough to merit active consideration. To protect customers and shareholders, utilities can and should factor these estimated carbon dioxide costs into their evaluation of different resource options in developing their long-term investment plans and when choosing resources in procurement.

V. A Proxy Value of the Risk Associated with Greenhouse Gas Emissions Is Useful for Planning Purposes

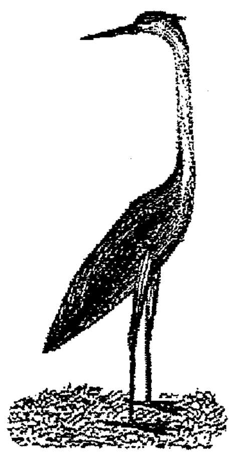
Utilities can help protect their customers and shareholders from the financial risk associated with the likely future regulation of GHG emissions by integrating an estimated cost of emissions into their evaluation of resource options, and selecting the overall least-cost portfolio. Establishing a value of the risk of GHG emission limits requires informed judgments about the likelihood of future regulation, the form such regulation might take (e.g., various options to allocate emission allowances under a cap-and-trade approach), and the likely cost under such regulation.

Utility decisions about resource investments are ideally based upon what is "known and knowable" at the time of the decision. This standard inherently includes the possibility that certain market factors can change after the time of a decision. However, utilities should make an informed judgment about the future. Since it is unlikely that GHG emissions will continue to cost utilities nothing whatever over the long lifetime of new investments, utilities should make an informed judgment about the range of reasonable policy scenarios and associated GHG costs and settle on a best estimate to use as an imputed cost in modeling resources in long-term plans and in evaluating procurement options.

There are several estimates of the potential cost of carbon dioxide emissions that utilities and regulators can look to in order to quantify the risk associated with GHG emissions. Estimates of realistic imputed costs for GHG emissions range up to about $50 per ton of carbon dioxide. These estimates are based on an analysis of current market prices and estimated costs under proposed federal policies. Utilities and regulators can also look to imputed costs now in use in other jurisdictions.

A. Current GHG market prices

The primary market in GHG emission allowances is the European Union's Emissions Trading Scheme (ETS). Since the ETS began full trading in January



2005, the price of emission allowances has ranged from a low of about $9 per ton of carbon dioxide to a high of about $22.[21] In the U.S., the Chicago Climate Exchange provides a forum for entities to voluntarily trade GHG emissions. In recent months, allowances on the Chicago Climate Exchange have been trading at prices between $1.50 and $2 per ton of carbon dioxide[22]; however, since entities participating in the Chicago Climate Exchange voluntarily entered into the exchange, the current prices are very likely lower than would be expected under a regulatory program with enforceable emission limits and comprehensive coverage. The Climate Trust, which invests in carbon dioxide offset projects to mitigate the impact of fossil fuel power plants, estimates the average cost of carbon dioxide based on their investments to range from approximately $3 up to $6 per ton.[23]

B. Estimated GHG costs under proposed federal policies

The Energy Information Administration's analysis of the McCain–Lieberman Climate Stewardship Act found carbon dioxide allowances to be in the range of $15 to $34 per metric ton, over the period 2010–2020 (in 2001 dollars).[24] The Massachusetts Institute of Technology's Joint Program on the Science and Policy of Global Change modeled an earlier and more stringent version of the Climate Stewardship Act and found that the emissions allowance price of carbon dioxide would likely range from $21 per ton in 2010 to $36 per ton in 2020 (in 2001 dollars).[25] In addition, the Energy Information Administration's analysis of another bill before Congress, the Clean Power Act, estimated that carbon dioxide allowance prices in 2010 would range from $15 to $25 per ton of carbon dioxide and in 2020 would range from $14 to $33 dollars per ton (in 1999 dollars).[26] In addition to current proposals in Congress, the National Commission on Energy Policy has proposed a national cap on carbon dioxide intensity that caps market-clearing prices at $7 per ton of carbon dioxide beginning in 2010,

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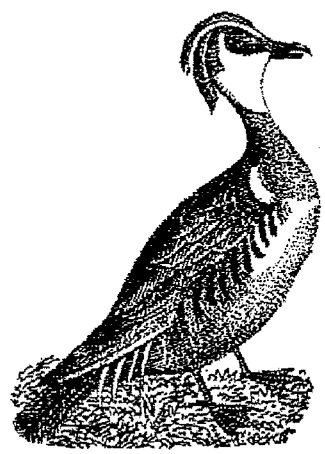
with a 5 percent increase annually thereafter.

C. Estimated carbon dioxide costs currently used by utilities and regulators

Several utilities and regulators have already established estimated costs of GHG emissions to use in planning and procurement. These values are at the conservative end of the spectrum of likely costs, largely due to the continuing uncertainty about when regulations will be enacted and what those costs will be.

The Oregon PUC has required its regulated utilities to use several sensitivities in modeling carbon dioxide costs, including $0, $10, $25, and $40 (in 1990 dollars). While the OPUC did not require utilities to incorporate a carbon dioxide value (above $0 per ton) into the *base case* of their IRP modeling efforts, PacifiCorp decided in 2002 to propose such an approach. PacifiCorp found that the risks of future carbon dioxide regulations were significant enough to warrant "prudently preparing" through appropriate planning. Rather than adopt one of the OPUC-mandated sensitivity values for its IRP base case, PacifiCorp developed its own value for carbon dioxide based upon internal review of a variety of data from domestic and international sources. PacifiCorp staff reviewed several categories of data, including the current carbon dioxide offset market in the U.S.; existing markets for GHG emissions in the United Kingdom and Denmark (which developed an emissions market before the European Union's development of implementation plans for its compliance with the Kyoto Protocol); and macroeconomic analyses of several federal proposals to cap GHG emissions, including analyses by the U.S. Department of Energy.



In its 2002 IRP, PacifiCorp assumed that carbon dioxide limits would begin in 2008. By the time it prepared its 2004 IRP, lack of regulations in the U.S. led PacifiCorp to push back the assumed initiation of limits. Instead of assuming full implementation of carbon dioxide limits in 2008, the company's base case scenario assumes a 50 percent probability of an $8 per ton carbon dioxide cost starting in 2010, increasing to 75 percent in 2011 and a 100 percent probability of occurrence by 2012.[27] The introduction of such probabilities was intended to capture uncertainty more effectively.

As required by the OPUC, PacifiCorp also conducted scenario analysis using costs of $0, $10, $25, and $40 per ton carbon dioxide (in 1990 dollars). The company applied these values to all portfolios that passed an initial evaluation screen based on cost under the base case. The result was an understanding of the possible spread of costs for an individual portfolio based on multiple variations of different risks, including carbon dioxide as well as fuel prices, power market prices, and others. The company could then rank portfolios according to risk and incorporate this information into the final selection of an optimal portfolio.

The base case scenario used in Idaho Power Company's (IPC) 2004 IRP assumes a $12.30 per ton cost for carbon dioxide emissions beginning in 2008; scenario analysis was also conducted at $0 and $49.21 per ton of carbon dioxide. The estimated costs of carbon dioxide emissions used in the risk analysis are based on the Oregon Public Utilities Commission's order, and "IPC also confirmed that these costs represent reasonable estimates of the risk that IPC and its customers face due to potential future regulation of carbon dioxide emissions."[28] In its risk analysis, Idaho Power estimated a 50 percent probability of a cost of $12.30 per ton of carbon dioxide, a 30 percent probability of zero cost, and a 20 percent probability of a cost of $49.21 per ton.[29]

Pacific Gas and Electric Company's 2004 Long-Term Procurement Plan assumed an imputed cost of $8 per ton of carbon

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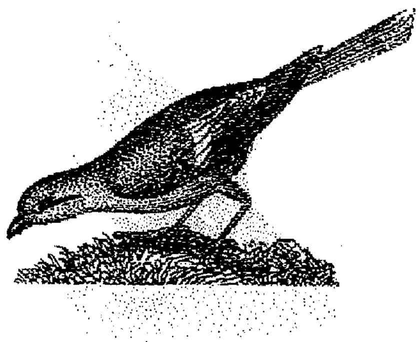
dioxide. In December 2004, the California Public Utilities Commission (CPUC) issued a decision requiring the utilities under its jurisdiction to use an estimated cost for GHG emissions in evaluating new long-term resource commitments and in developing future long-term plans. The Decision adopted a range of costs between $8 and $25 per ton of carbon dioxide, pending a final decision on a single value, and required that the estimated cost of carbon dioxide enter the utilities' analysis of long-term commitments in 2007.[30] In April 2005, the CPUC adopted the final imputed costs for carbon dioxide emissions: a levelized cost of $8 per ton of carbon dioxide, based on a cost stream of $5 per ton in the near term, $12.50 per ton by 2008, and $17.50 per ton of carbon dioxide by 2013.[31] The report upon which the CPUC based its imputed cost assessed the range of likely future scenarios of carbon dioxide regulation, and the associated costs, and concluded that this was a conservative and reasonable estimate.[32]

VI. Utilities Can Reduce Exposure to the Financial Risk Associated with Carbon Dioxide Emissions

Utilities can select a portfolio that reduces exposure to the cost of future regulation of carbon dioxide emissions, while balancing other goals, by including an estimated cost for carbon dioxide emissions in integrated resource planning and in evaluating procurement options. Once a reasonable proxy value of the financial risk associated with carbon dioxide emissions has been assessed, it should be used to inform decision makers about tradeoffs between resource investments in order to properly manage and mitigate the risk.



In general, the ultimate goal of long-term planning processes is to ensure that adequate resources are available to reliably serve the demand for the energy services that utilities provide, while balancing costs, risks, and environmental concerns. Utilities can ensure that resource investments achieve this goal by including all costs and significant risks in modeling portfolio and resource options. Investment decisions should be made with a full understanding of the total costs of each resource alternative, based on the best information available at the time of the investment. Otherwise, customers and utilities could be locked into investments that expose them to higher costs in later years.

As Idaho Power explained in its IRP: "Idaho Power Company believes it is prudent to incorporate reasonable estimates for the cost of carbon dioxide emissions into the IRP resource modeling and analysis, and to thereby actively seek to lessen the Company's and customers' exposure to the financial risk associated with carbon dioxide emissions."[33] Moreover, utilities believe that incorporating carbon dioxide into planning and procurement demonstrates foresight and prudence due to the long lead-times to acquire certain resources, and the long depreciated lives of those resources once they are developed. By comparison, utilities that do not build carbon risk into their long-term planning will be left with few avenues to reduce costs in complying with regulations, due to sunk costs and more limited and costly options to reduce emissions from existing resources.

VII. Incorporating an Estimated Carbon Cost into Planning and Procurement: Examples from Three Leading Utilities

In order to develop a resource portfolio that minimizes overall costs and risks, utilities should incorporate their best estimate of the cost of carbon dioxide emissions as an integral part of their long-term plan and procurement modeling processes, just like

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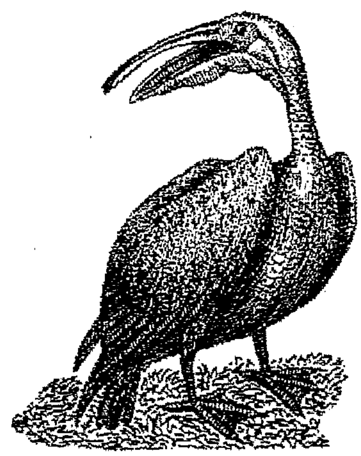
other readily foreseeable and significant costs and risks. The estimated cost should be modeled as an operational cost of each carbon-emitting resource. The outcome of such a modeling process should be a resource portfolio that reduces the utilities' and their customers' exposure to this financial risk to a level that the utility believes is appropriate.

Different utilities have used different methodologies to account for the financial risk of carbon dioxide emissions in their long-term planning and procurement processes. In this section, we discuss the methodology used by three of the leading utilities in this arena, PacifiCorp, Idaho Power, and Pacific Gas and Electric Company, as well as stakeholder reactions to the policy. The three utilities that contributed to this article all agree on the importance of including the future risk of carbon dioxide regulation in their resource planning decisions. However, the examples cited for each utility do not necessarily mean that the other two utilities endorse or would propose similar ways of addressing the issue.

Each of the utilities discussed in this section has integrated an estimated cost for carbon dioxide emissions into their evaluation of resource options. In all cases, the financial risk of carbon dioxide emissions is one of many factors influencing the utilities' decisions about resource investments. The experience gained to date provides insight for other utilities and their regulators seeking to reduce exposure to the cost of future regulation of carbon dioxide emissions and to reduce their customers' overall long-term cost for energy services.

A. Idaho Power Company

In its 2004 Integrated Resource Plan, Idaho Power Company analyzed 12 different portfolios of resources. These portfolios were



developed to explore a variety of different resource alternatives, ranging from portfolios with an emphasis on wind generation to an emphasis on coal generation to diversified portfolios, and the costs and benefits of each. Idaho Power analyzed the total cost of each portfolio over 30 years, including an estimated cost of \$12.30 per ton of carbon dioxide in its base case analysis. (Idaho Power derived the selected value from the \$10 per ton value in 1990 dollars required by the Oregon PUC for risk analysis.) Idaho Power also analyzed and ranked the total cost of the portfolios under four different scenarios, which included variations in the estimated cost of carbon dioxide emissions (from \$0 to \$49.21 per ton of carbon dioxide) as well as other variables. Idaho Power then selected five of the portfolios for further risk analysis, in order to identify a portfolio that was robust under a variety of possible scenarios.

Idaho Power's final portfolio was a balanced and diversified portfolio that faced the second-lowest exposure to the financial risk associated with carbon dioxide emissions of the five "finalist" portfolios. Idaho Power's use of an estimated cost of carbon dioxide emissions materially. influenced the selection of the final portfolio, increasing the procurement of energy efficiency, renewable energy, and other low-emitting resources, but it remained one factor among many used to select the best portfolio.

Idaho Power's IRP lays out a 10-year resource plan as well as a near-term action plan. Because Idaho Power intends to acquire the resources identified in the IRP using separate competitive solicitations or procurement processes for each type of resource, Idaho Power does not intend to incorporate an estimated cost for carbon dioxide emissions into its actual procurement process.

B. PacifiCorp

PacifiCorp incorporated an estimated cost for carbon dioxide emissions into its IRP in two ways. First, it built in an assumption of an \$8 per ton value in its forecasts for natural gas prices and for emissions

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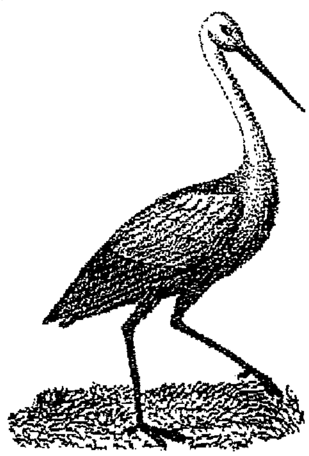
allowances for nitrogen oxide and sulfur dioxide over a 20-year period, which in turn affected the electric market price forecast. (Note that higher carbon dioxide values actually reduce costs associated with nitrogen oxide and sulfur dioxide emissions due to less coal-fired generation and an associated rise in excess allowances.) These market prices then helped the company determine cost-effectiveness for different resource options, and, with variations and multiple model runs, they also helped the company understand the risk associated with carbon dioxide regulation. Second, carbon dioxide costs were attributed to emissions associated with different portfolios, with an assumption that emissions are capped at 2000 levels.[34] Conversely, portfolios with emissions below 2000 levels received credits associated with excess allowances that could be sold to other emitters.[35] This approach adds cost to thermal generation while effectively rewarding renewable energy and demand-side energy efficiency for their emissions-free attributes. Finally, PacifiCorp subjected each portfolio that survived initial cost and risk analysis to carbon dioxide values ranging from $0 to $40 per ton to comply with the OPUC's 1993 order.

When applied to different resource portfolios, the higher carbon dioxide cost scenarios, particularly the $25 and $40 per ton values, had the biggest impact on cost differentials among portfolios. Coal-heavy portfolios looked unattractive due to the cost of emissions above 2000 levels, while "balanced" portfolios that avoided excessive exposure to high gas prices while exhibiting a much lower emissions level than coal-heavy portfolios fared well due to the sale of excess emissions allowances.[36]

PacifiCorp's use of an estimated carbon cost is not limited to



planning; it is also firmly tied into purchasing efforts. PacifiCorp built on its modeling efforts in the IRP by employing a forward price curve for electricity in evaluating procurement options that includes the impact of an $8 per ton estimated cost for carbon dioxide. The curve serves as a market price referent for bids submitted to the utility's 2004 request-for-proposals for renewable resources. Of course, since the vast majority of renewables emit little to no carbon dioxide, the bids themselves do not face carbon dioxide costs, but the market price referent curve includes a market with thermal resources, so the carbon dioxide-free renewables benefit from incorporating carbon dioxide into the price referent.

PacifiCorp also applied the estimated carbon dioxide cost to its 2003 request for proposals (RFP) for thermal resources. In the 2003 RFP, PacifiCorp compared bids to a "next best alternative," which was a combined-cycle natural gas plant proposed by the company to build and own. Because that plant would be an owned resource, the utility assumed that it would have to bear carbon dioxide costs. For bids proposing a power-purchase agreement, the company assumed that the counterparties could pass along carbon dioxide costs to the utility when regulations arrive. Bids were therefore assumed to have the same carbon dioxide costs as the utility-owned plant. However, the utility offered counterparties the ability to explicitly indemnify the utility for any carbon dioxide-related price risks in exchange for a payment of up to $8 per ton in accordance with the IRP assumptions. Effectively, the utility was offering an insurance payment to protect ratepayers from potentially costly regulations.

The resource selected in the 2003 thermal RFP won based on least cost, without indemnifying PacifiCorp for the carbon dioxide risk. However, negotiations between PacifiCorp and potential counterparties prior to final selection included dialogues on contractual language and collateralization to support a supplier's obligation to hold carbon dioxide-related risk. In particular,

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the negotiations raised concerns among PacifiCorp staff that counterparties did not fully appreciate what it meant to hold such risk. For example, a project developer disposed to perceiving little risk of future GHG regulations could claim to bear the risk without a clear plan to cover the commitment in case of regulations and associated imposition of costs. This initial experience should prove instructive for the utility and bidders alike when another thermal RFP is issued.

C. Pacific Gas and Electric Company

The California PUC recently adopted a new policy requiring its regulated utilities to explicitly account for the financial risk associated with carbon dioxide emissions in evaluating long-term resource commitments. The CPUC found that "[i]t is likely that greenhouse gas emissions will be regulated within the timeframe addressed in the utilities' [long-term procurement plans] and the lifetime of the utilities' long-term resource commitments," and concluded that "[g]reenhouse gas emissions pose a real and substantial financial risk to customers and the utilities."[37]

PG&E will be using the CPUC-adopted "greenhouse gas adder" in evaluating offers it receives in response to competitive solicitations, as well as in its next long-term procurement plan. In accordance with CPUC requirements, PG&E's solicitations will be "all-source" solicitations, welcoming both renewable and non-renewable bids, as well as utility-owned and contracted resources. These resource options will be evaluated using a least-cost/best-fit analysis, which uses market value, portfolio fit, credit, location, and other factors to rank all of the offers received and to select the best mix of resources. The "GHG

adder" will be one element of the market value evaluation, and will affect the relative market valuations of resources based on their carbon dioxide emissions.

PG&E is currently in the process of conducting its first competitive solicitation and using the estimated cost for GHG emissions in its evaluation. PG&E's current competitive solicitation is for particular peaking and intermediate products and the resources compared are likely to have similar emission profiles, so the "GHG adder," as just one of many factors used in evaluating bids, is unlikely to have a substantial impact on the outcome of the solicitation. But since PG&E conducts all-source solicitations, at some point it expects to compare resources with significantly different emissions profiles, where the "GHG adder" could have a material effect on the outcome of the solicitation.

D. Stakeholder views

Stakeholder reaction to the introduction of an estimated cost for GHG emissions has been diverse, though typically accepting. Idaho Power's IRP elicited supportive comments on its use of a carbon risk value. PacifiCorp's IRP drew a range of comments reflecting its diverse service territory, which stretches from the Oregon coast to Utah and eastern Wyoming. Utah Commission staff had questions about the mechanics of the estimated carbon dioxide cost and the basis of the valuation, but not about the existence of the estimated cost itself. In California, the issue was the subject of formal regulatory hearings in which numerous issues were debated. As with any kind of scenario risk, this type of debate is to be expected.

The first threshold issue discussed in some areas was whether regulation of carbon dioxide emissions is likely within the lifetime of new investments. An overwhelming majority of stakeholders agree that such regulation is likely. However, other voices expressed concern. For example, the Utah Committee of Consumer Services, while "appreciating PacifiCorp's proactive approach," also felt that the uncertainty surrounding the

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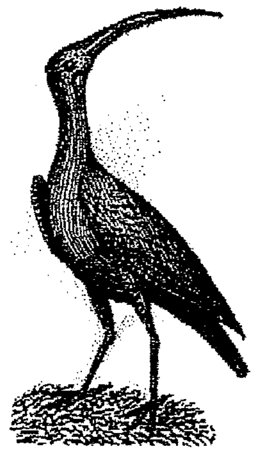
existence and extent of future regulations made them uncomfortable with any value in the base case. In California, some utilities asserted that it would be premature for the Commission to adopt an estimated future cost of carbon dioxide emissions, and that instead the Commission and the utilities should wait to act until carbon dioxide is regulated. By the time carbon dioxide is regulated it may be too late for utilities to protect customers and shareholders from increased costs associated with long-term commitments made earlier. Electric resources are long-term, capital-intensive investments. Once carbon dioxide is regulated, utilities that do not plan now will probably not be able to reshape their portfolios overnight, at least not without incurring massive costs.

Selection of an appropriate estimated cost of carbon dioxide emissions was also the subject of considerable discussion among stakeholders. Some pointed to the lack of federal action to date as a reason to reduce the estimated cost — but not eliminate it entirely. Conversely, other stakeholders asserted that the estimated cost was not high enough, given increasing prices in European markets. Such conflicting comments reflect both different interests, as well as the inherent challenge of quantifying a scenario risk.

Some stakeholders expressed concern that the actual cost of carbon dioxide emissions might ultimately be higher or lower than the estimated cost. However, the most simple and compelling consideration is that the risk of GHG regulations clearly exists, and therefore to value carbon dioxide is prudent utility management; planning and purchasing decisions that are made today must use the best available information. Uncertainty about future costs is simply a fact of life in the electric industry, and utilities must continue to make long-lived investment decisions based on the best information available at the time of the investment.



Stakeholder discussion also centered around the possibility that the use of an estimated carbon cost could increase rates in the near-term before carbon dioxide emissions are regulated. Incurring a small cost in the near-term to hedge against a much larger risk is appropriate. Utilities routinely incur these "insurance premium" type costs to hedge other risks such as natural gas price risk. Moreover, it is often prudent to incur modest, near-term costs in order to protect customers from much larger potential future costs, *even if* those future costs do not end up being as large as anticipated.

Ultimately, both PacifiCorp's and Idaho Power's IRPs received high praise from regulators, environmental stakeholders, and other stakeholders such as customer groups. The praise reflected in part the fact that the utilities examined numerous cost and risk factors that led to diverse resource selections. The financial risk associated with carbon dioxide emissions was one of many factors used to select the optimal portfolio, and no single factor dominated planning decisions. PG&E, for its part, has been a national leader in calling for responsible market-based responses to the risks associated with global climate change, and the company was an early supporter of the California PUC's decision, which attracted widespread support from other key stakeholders.

VIII. Conclusion

Risk management is increasingly recognized as a crucial responsibility of utility portfolio managers. The financial risk associated with likely future regulation of carbon dioxide emissions is becoming a focus of utilities' and regulators' risk management efforts, as they recognize the imprudence of assuming that carbon dioxide emissions will not cost anything over the 30-year or longer lifetime of new investments. Utilities can

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help protect their customers and shareholders from this financial risk by integrating an estimated cost of carbon dioxide emissions into their evaluation of resource options, and selecting the overall least-cost portfolio of resources. Utilities can learn from the experience that some utilities have gained at managing this risk to ensure that today's investments do not lock customers or shareholders into much higher costs tomorrow if greenhouse gases are regulated.■

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30. For example, in analyzing a bid for a 10-year contract that would begin delivery in 2006, the utility would not include the adder in the cost estimate for 2006, but would include the adder beginning in 2007 and continue including it for all the subsequent years of the analysis.

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34. PacifiCorp assumed that emissions costs would apply to new resources identified through the IRP, rather than emissions from existing generation. The assumption was based on a forecast of a cap-and-trade approach to GHG emissions, rather than a tax on all carbon dioxide emissions. The forecast also assumed that the cap-and-trade regime would "grandfather" existing generation and their emissions by issuing emissions allowances equal to their annual total, with cuts to come from subsequent resources. Since the IRP does not make decisions on whether a utility should own generation or acquire the output of generation owned by another entity, it does not address the question of whether there is carbon dioxide risk associated with power purchases.

35. Customers would ultimately receive the credits earned by sales of excess allowances.

36. Modeling results revealed that the $25 per ton and $40 per ton values substantially impacted the price for NO_x and SO_x emissions allowances as well as natural gas prices. Consequently, these carbon dioxide values had the biggest impact on electricity market prices.

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❖ MEETINGS OF INTEREST ❖

Conference	Date	Place	Sponsor	Contact
Renewable Portfolio Standards–Western US	July 27–28	San Diego	Power Marketing Association	(201) 784-5389
Energy 2005: The Solutions Network	Aug. 14–17	Long Beach, CA	U.S. Department of Energy	http://www.energy2005.ee.doe.gov/
2005 Electric Market Forecasting Conference	Sept. 14–16	Coeur d'Alene Resort on Lake Coeur d'Alene, Idaho	EPIS	http://www.epis.com/epis_events/events.htm
Air Quality V: Mercury, Trace Elements, SO_3, and Particulate Matter	Sept. 19–21	Arlington, VA	Energy & Environmental Research Center	(701) 777-5246
Principles of Power and Gas Trading	Oct. 3–7	Oxford, UK	Oxford Princeton Program	http://www.oxfordprinceton.com/
2005 IEEE PES Transmission & Distribution Conference & Exposition	Oct. 9–14	New Orleans	IEEE Power Engineering Society	http://www.ieeet-d.org/
Nuclear Energy in Europe Conference	Oct. 17–18	Brussels	EU Conferences	http://www.euconferences.com/

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models of the global effects – shows that climate change will have serious impacts on world output, on human life and on the environment.

All countries will be affected. The most vulnerable – the poorest countries and populations – will suffer earliest and most, even though they have contributed least to the causes of climate change. The costs of extreme weather, including floods, droughts and storms, are already rising, including for rich countries.

Adaptation to climate change – that is, taking steps to build resilience and minimise costs – is essential. It is no longer possible to prevent the climate change that will take place over the next two to three decades, but it is still possible to protect our societies and economies from its impacts to some extent – for example, by providing better information, improved planning and more climate-resilient crops and infrastructure. Adaptation will cost tens of billions of dollars a year in developing countries alone, and will put still further pressure on already scarce resources. Adaptation efforts, particularly in developing countries, should be accelerated.

The costs of stabilising the climate are significant but manageable; delay would be dangerous and much more costly.

The risks of the worst impacts of climate change can be substantially reduced if greenhouse gas levels in the atmosphere can be stabilised between 450 and 550ppm CO_2 equivalent (CO_2e). The current level is 430ppm CO_2e today, and it is rising at more than 2ppm each year. Stabilisation in this range would require emissions to be at least 25% below current levels by 2050, and perhaps much more.

Ultimately, stabilisation – at whatever level – requires that annual emissions be brought down to more than 80% below current levels.

This is a major challenge, but sustained long-term action can achieve it at costs that are low in comparison to the risks of inaction. Central estimates of the annual costs of achieving stabilisation between 500 and 550ppm CO_2e are around 1% of global GDP, if we start to take strong action now.

Costs could be even lower than that if there are major gains in efficiency, or if the strong co-benefits, for example from reduced air pollution, are measured. Costs will be higher if innovation in low-carbon technologies is slower than expected, or if policy-makers fail to make the most of economic instruments that allow emissions to be reduced whenever, wherever and however it is cheapest to do so.

It would already be very difficult and costly to aim to stabilise at 450ppm CO_2e. If we delay, the opportunity to stabilise at 500-550ppm CO_2e may slip away.

Action on climate change is required across all countries, and it need not cap the aspirations for growth of rich or poor countries.

The costs of taking action are not evenly distributed across sectors or around the world. Even if the rich world takes on responsibility for absolute cuts in emissions of 60-80% by 2050, developing countries must take significant action too. But developing countries should not be required to bear the full costs of this action alone, and they will not have to. Carbon markets in rich countries are already beginning to deliver flows of finance to support low-carbon development, including through the Clean Development Mechanism. A transformation of these flows is now required to support action on the scale required.

Summary of Conclusions

There is still time to avoid the worst impacts of climate change, if we take strong action now.

The scientific evidence is now overwhelming: climate change is a serious global threat, and it demands an urgent global response.

This Review has assessed a wide range of evidence on the impacts of climate change and on the economic costs, and has used a number of different techniques to assess costs and risks. From all of these perspectives, the evidence gathered by the Review leads to a simple conclusion: the benefits of strong and early action far outweigh the economic costs of not acting.

Climate change will affect the basic elements of life for people around the world – access to water, food production, health, and the environment. Hundreds of millions of people could suffer hunger, water shortages and coastal flooding as the world warms.

Using the results from formal economic models, the Review estimates that if we don't act, the overall costs and risks of climate change will be equivalent to losing at least 5% of global GDP each year, now and forever. If a wider range of risks and impacts is taken into account, the estimates of damage could rise to 20% of GDP or more.

In contrast, the costs of action – reducing greenhouse gas emissions to avoid the worst impacts of climate change – can be limited to around 1% of global GDP each year.

The investment that takes place in the next 10-20 years will have a profound effect on the climate in the second half of this century and in the next. Our actions now and over the coming decades could create risks of major disruption to economic and social activity, on a scale similar to those associated with the great wars and the economic depression of the first half of the 20th century. And it will be difficult or impossible to reverse these changes.

So prompt and strong action is clearly warranted. Because climate change is a global problem, the response to it must be international. It must be based on a shared vision of long-term goals and agreement on frameworks that will accelerate action over the next decade, and it must build on mutually reinforcing approaches at national, regional and international level.

Climate change could have very serious impacts on growth and development.

If no action is taken to reduce emissions, the concentration of greenhouse gases in the atmosphere could reach double its pre-industrial level as early as 2035, virtually committing us to a global average temperature rise of over 2°C. In the longer term, there would be more than a 50% chance that the temperature rise would exceed 5°C. This rise would be very dangerous indeed; it is equivalent to the change in average temperatures from the last ice age to today. Such a radical change in the physical geography of the world must lead to major changes in the human geography – where people live and how they live their lives.

Even at more moderate levels of warming, all the evidence – from detailed studies of regional and sectoral impacts of changing weather patterns through to economic

Action on climate change will also create significant business opportunities, as new markets are created in low-carbon energy technologies and other low-carbon goods and services. These markets could grow to be worth hundreds of billions of dollars each year, and employment in these sectors will expand accordingly.

The world does not need to choose between averting climate change and promoting growth and development. Changes in energy technologies and in the structure of economies have created opportunities to decouple growth from greenhouse gas emissions. Indeed, ignoring climate change will eventually damage economic growth.

Tackling climate change is the pro-growth strategy for the longer term, and it can be done in a way that does not cap the aspirations for growth of rich or poor countries.

A range of options exists to cut emissions; strong, deliberate policy action is required to motivate their take-up.

Emissions can be cut through increased energy efficiency, changes in demand, and through adoption of clean power, heat and transport technologies. The power sector around the world would need to be at least 60% decarbonised by 2050 for atmospheric concentrations to stabilise at or below 550ppm CO_2e, and deep emissions cuts will also be required in the transport sector.

Even with very strong expansion of the use of renewable energy and other low-carbon energy sources, fossil fuels could still make up over half of global energy supply in 2050. Coal will continue to be important in the energy mix around the world, including in fast-growing economies. Extensive carbon capture and storage will be necessary to allow the continued use of fossil fuels without damage to the atmosphere.

Cuts in non-energy emissions, such as those resulting from deforestation and from agricultural and industrial processes, are also essential.

With strong, deliberate policy choices, it is possible to reduce emissions in both developed and developing economies on the scale necessary for stabilisation in the required range while continuing to grow.

Climate change is the greatest market failure the world has ever seen, and it interacts with other market imperfections. Three elements of policy are required for an effective global response. The first is the pricing of carbon, implemented through tax, trading or regulation. The second is policy to support innovation and the deployment of low-carbon technologies. And the third is action to remove barriers to energy efficiency, and to inform, educate and persuade individuals about what they can do to respond to climate change.

Climate change demands an international response, based on a shared understanding of long-term goals and agreement on frameworks for action.

Many countries and regions are taking action already: the EU, California and China are among those with the most ambitious policies that will reduce greenhouse gas emissions. The UN Framework Convention on Climate Change and the Kyoto Protocol provide a basis for international co-operation, along with a range of partnerships and other approaches. But more ambitious action is now required around the world.

Countries facing diverse circumstances will use different approaches to make their contribution to tackling climate change. But action by individual countries is not enough. Each country, however large, is just a part of the problem. It is essential to create a shared international vision of long-term goals, and to build the international frameworks that will help each country to play its part in meeting these common goals.

Key elements of future international frameworks should include:

- *Emissions trading:* Expanding and linking the growing number of emissions trading schemes around the world is a powerful way to promote cost-effective reductions in emissions and to bring forward action in developing countries: strong targets in rich countries could drive flows amounting to tens of billions of dollars each year to support the transition to low-carbon development paths.

- *Technology cooperation:* Informal co-ordination as well as formal agreements can boost the effectiveness of investments in innovation around the world. Globally, support for energy R&D should at least double, and support for the deployment of new low-carbon technologies should increase up to five-fold. International co-operation on product standards is a powerful way to boost energy efficiency.

- *Action to reduce deforestation:* The loss of natural forests around the world contributes more to global emissions each year than the transport sector. Curbing deforestation is a highly cost-effective way to reduce emissions; large-scale international pilot programmes to explore the best ways to do this could get underway very quickly.

- *Adaptation:* The poorest countries are most vulnerable to climate change. It is essential that climate change be fully integrated into development policy, and that rich countries honour their pledges to increase support through overseas development assistance. International funding should also support improved regional information on climate change impacts, and research into new crop varieties that will be more resilient to drought and flood.

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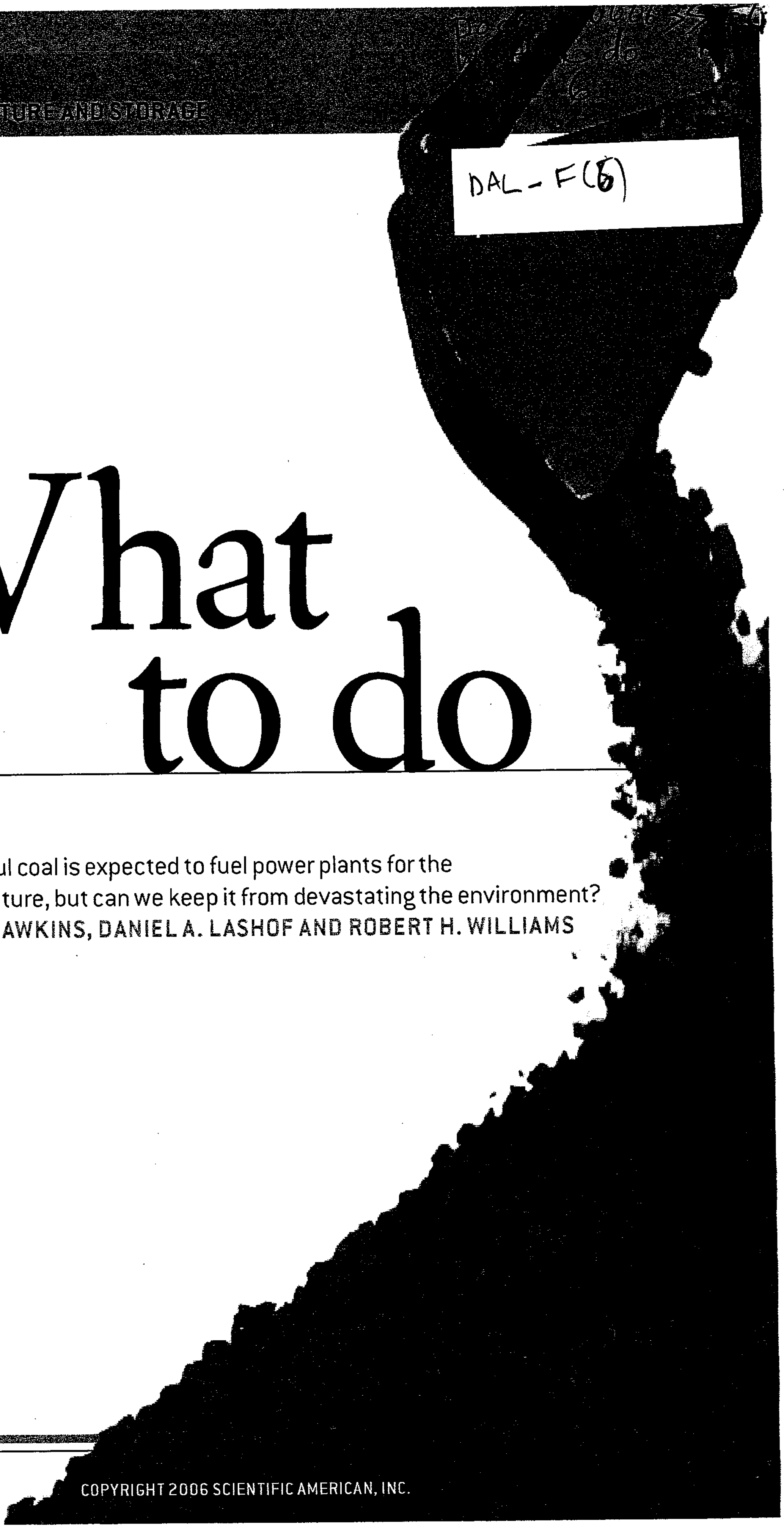

What to do

Cheap, plentiful coal is expected to fuel power plants for the foreseeable future, but can we keep it from devastating the environment?

BY DAVID G. HAWKINS, DANIEL A. LASHOF AND ROBERT H. WILLIAMS

OVERVIEW

* Coal is widely burned for power but produces large quantities of climate-changing carbon dioxide.
* Compared with conventional power plants, new gasification facilities can more effectively and affordably extract CO_2 so it can be safely stored underground.
* The world must begin implementing carbon capture and storage soon to stave off global warming.

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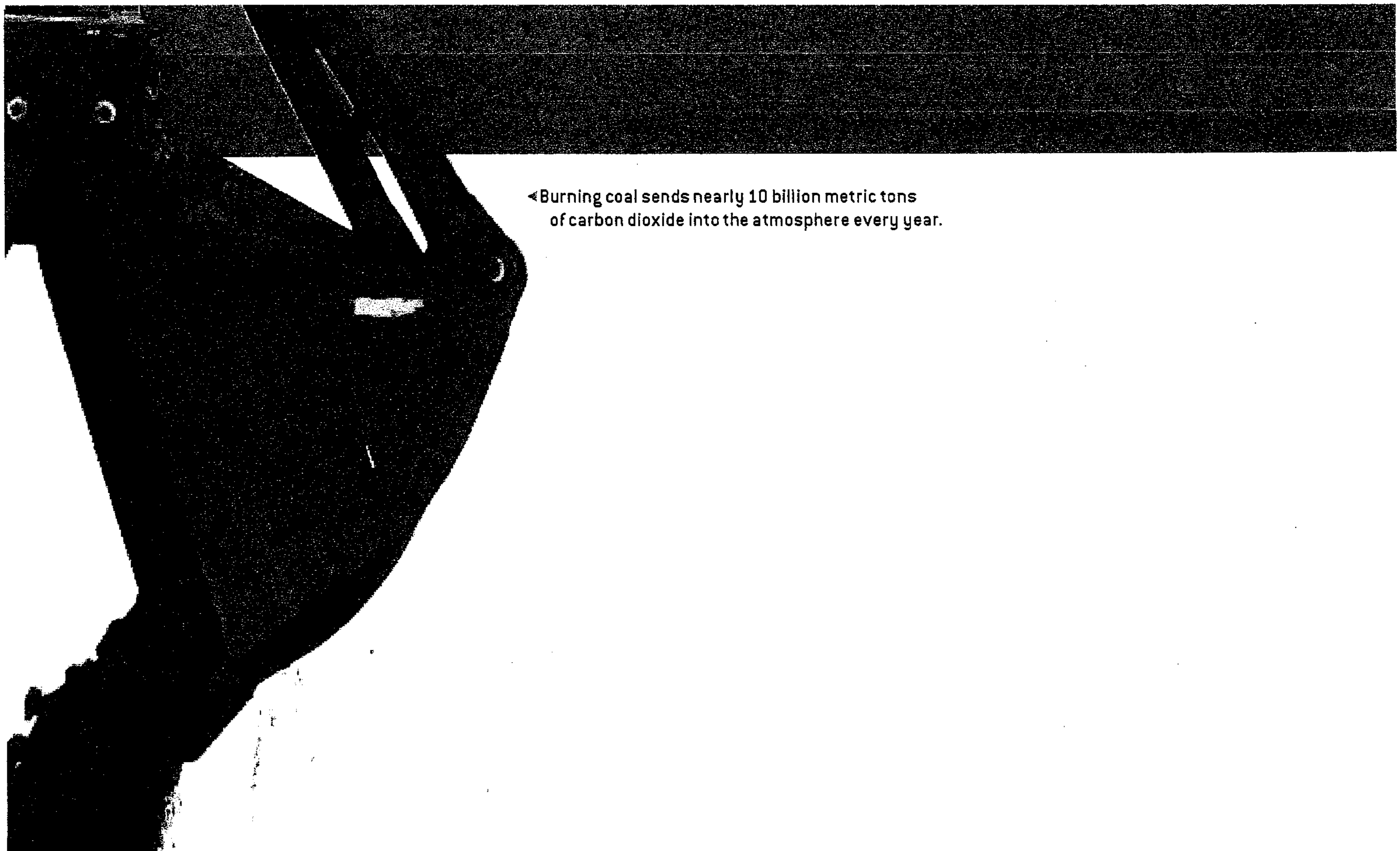

◂Burning coal sends nearly 10 billion metric tons of carbon dioxide into the atmosphere every year.

about Coal

More than most people realize, dealing with climate change means addressing the problems posed by emissions from coal-fired power plants. Unless humanity takes prompt action to strictly limit the amount of carbon dioxide (CO_2) released into the atmosphere when consuming coal to make electricity, we have little chance of gaining control over global warming.

Coal—the fuel that powered the Industrial Revolution—is a particularly worrisome source of energy, in part because burning it produces considerably more carbon dioxide per unit of electricity generated than burning either oil or natural gas does. In addition, coal is cheap and will remain abundant long after oil and natural gas have become very scarce. With coal plentiful and inexpensive, its use is burgeoning in the U.S. and elsewhere and is expected to continue rising in areas with abundant coal resources. Indeed, U.S. power providers are expected to build the equivalent of nearly 280 500-megawatt, coal-fired electricity plants between 2003 and 2030. Meanwhile China is already constructing the equivalent of one large coal-fueled power station a week. Over their roughly 60-year life spans, the new generating facilities in operation by 2030 could collectively introduce into the atmosphere about as much carbon dioxide as was released by all the

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coal burned since the dawn of the Industrial Revolution.

Coal's projected popularity is disturbing not only for those concerned about climate change but also for those worried about other aspects of the environment and about human health and safety. Coal's market price may be low, but the true costs of its extraction, processing and consumption are high. Coal use can lead to a range of harmful consequences, including decapitated mountains, air pollution from acidic and toxic emissions, and water fouled with coal wastes. Extraction also endangers and can kill miners. Together such effects make coal production and conversion to useful energy one of the most destructive activities on the planet [*see box on page 73*].

In keeping with *Scientific American*'s focus on climate concerns in this issue, we will concentrate below on methods that can help prevent CO_2 generated during coal conversion from reaching the atmosphere. It goes without saying that the environmental, safety and health effects of coal production and use must be reduced as well. Fortunately, affordable techniques for addressing CO_2 emissions and these other problems already exist, although the will to implement them quickly still lags significantly.

Geologic Storage Strategy

THE TECHNIQUES that power providers could apply to keep most of the carbon dioxide they produce from entering the air are collectively called CO_2 capture and storage (CCS) or geologic carbon sequestration. These procedures involve separating out much of the CO_2 that is created when coal is converted to useful energy and transporting it to sites where it can be stored deep underground in porous media—mainly in depleted oil or gas fields or in saline formations (permeable geologic strata filled with salty water) [see "Can We Bury Global Warming?" by Robert H. Socolow; Scientific American, July 2005].

All the technological components needed for CCS at coal conversion plants are commercially ready—having been proved in applications unrelated to climate change mitigation, although integrated systems have not yet been constructed at the necessary scales. Capture technologies have been deployed extensively throughout the world both in the manufacture of chemicals (such as fertilizer) and in the purification of natural gas supplies contaminated with carbon dioxide and hydrogen sulfide ("sour gas"). Industry has gained considerable experience with CO_2 storage in operations that purify natural gas (mainly in Canada) as well as with CO_2 injection to boost oil production (primarily in the U.S.). Enhanced oil recovery processes account for most of the CO_2 that has been sent into underground reservoirs. Currently about 35 million metric tons are injected annually to coax more petroleum out of mature fields, accounting for about 4 percent of U.S. crude oil output.

> Affordable methods that prevent CO_2 from reaching the atmosphere exist; the will to implement them quickly lags.

Implementing CCS at coal-consuming plants is imperative if the carbon dioxide concentration in the atmosphere is to be kept at an acceptable level. The 1992 United Nations Framework Convention on Climate Change calls for stabilizing the atmospheric CO_2 concentration at a "safe" level, but it does not specify what the maximum value should be. The current view of many scientists is *that atmospheric CO_2 levels must be kept* below 450 parts per million by volume (ppmv) to avoid unacceptable climate changes. Realization of this aggressive goal requires that the power industry start commercial-scale CCS projects within the next few years and expand them rapidly thereafter. This stabilization benchmark cannot be realized by CCS alone but can plausibly be achieved if it is combined with other eco-friendly measures, such as wide improvements in energy efficiency and much expanded use of renewable energy sources.

The Intergovernmental Panel on Climate Change (IPCC) estimated in 2005 that it is highly probable that geologic media worldwide are capable of sequestering at least two trillion metric tons of CO_2—more than is likely to be produced by fossil-fuel-consuming plants during the 21st century. Society will want to be sure, however, that potential sequestration sites are evaluated carefully for their ability to retain CO_2 before they are allowed to operate. Two classes of risks are of concern: sudden escape and gradual leakage.

Rapid outflow of large amounts of CO_2 could be lethal to those in the vicinity. Dangerous sudden releases—such as that which occurred in 1986 at Lake Nyos in Cameroon, when CO_2 of volcanic origin asphyxiated 1,700 nearby villagers and thousands of cattle—are improbable for engineered CO_2 storage projects in carefully selected, deep porous geologic formations, according to the IPCC.

Gradual seepage of carbon dioxide into the air is also an issue, because over time it could defeat the goal of CCS. The 2005 IPCC report estimated that the fraction retained in appropriately selected and managed geologic reservoirs is very likely to exceed 99 percent over 100 years and likely to exceed 99 percent over 1,000 years. What remains to be demonstrated is whether in practice operators can routinely keep CO_2 leaks to levels that avoid unacceptable environmental and public health risks.

Technology Choices

DESIGN STUDIES indicate that existing power generation technologies could capture from 85 to 95 percent of the carbon in coal as CO_2, with the rest released to the atmosphere.

The coal conversion technologies that come to dominate will be those that

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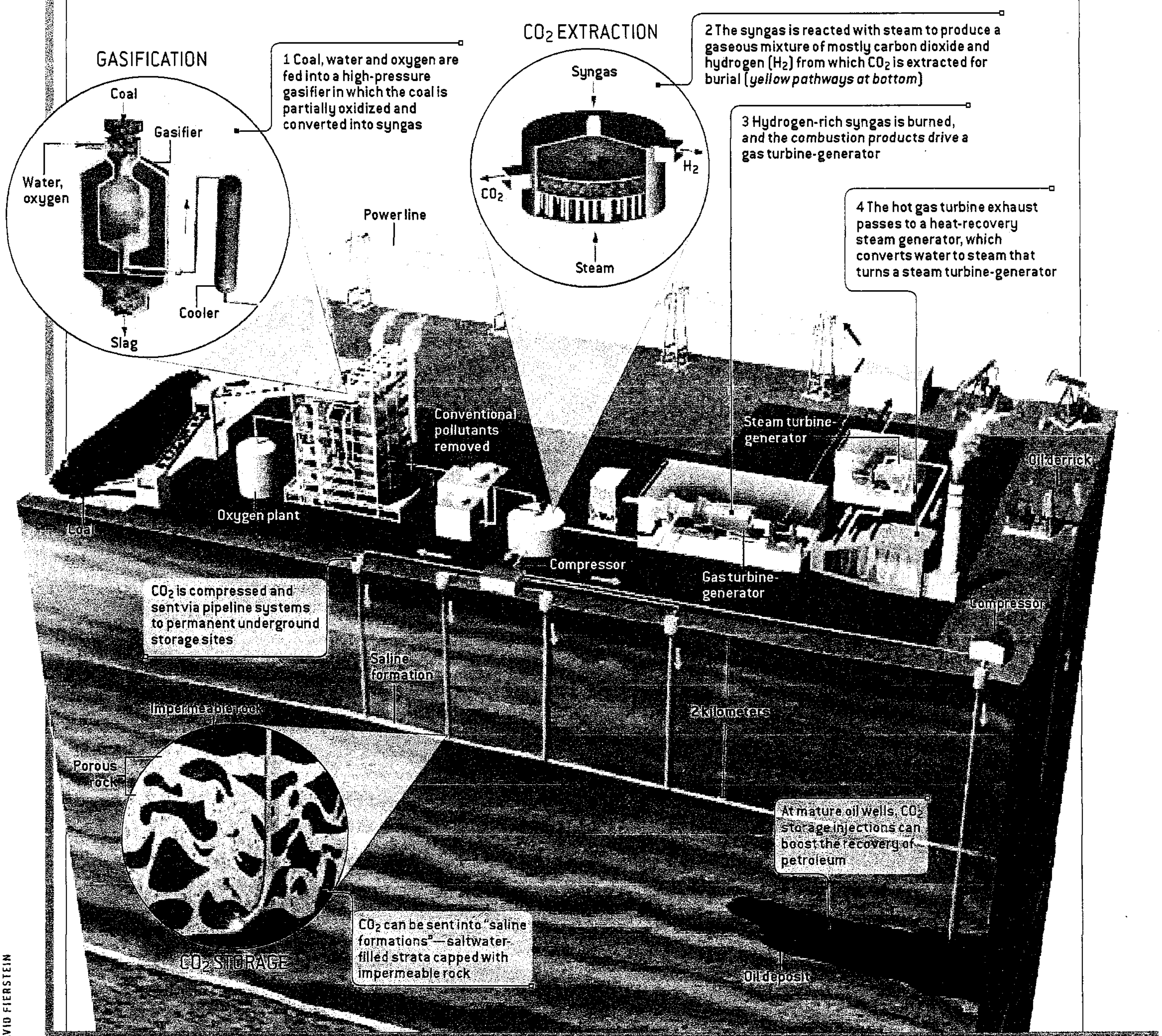
EXTRACTING AND STORING CARBON DIOXIDE

To slow climate change, the authors urge power providers to build integrated gasification combined cycle (IGCC) coal power plants with carbon dioxide capture and storage (CCS) capabilities (*below*) rather than conventional steam-electric facilities. Conventional coal plants burn the fuel to transform water into steam to turn a turbine-generator. If CCS technology were applied to a steam plant, CO_2 would be extracted from the flue exhaust. An IGCC plant, in contrast, employs a partial oxidation reaction using limited oxygen to convert the coal into a so-called synthesis gas, or syngas (mostly hydrogen and carbon monoxide). It is much easier and less costly to remove CO_2 from syngas than from the flue gases of a steam plant. The hydrogen-rich syngas remaining after CO_2 extraction is then burned to run both gas and steam turbine-generators. The world's first commercial IGCC project that will sequester CO_2 underground is being planned near Long Beach, Calif.



DAVID FIERSTEIN

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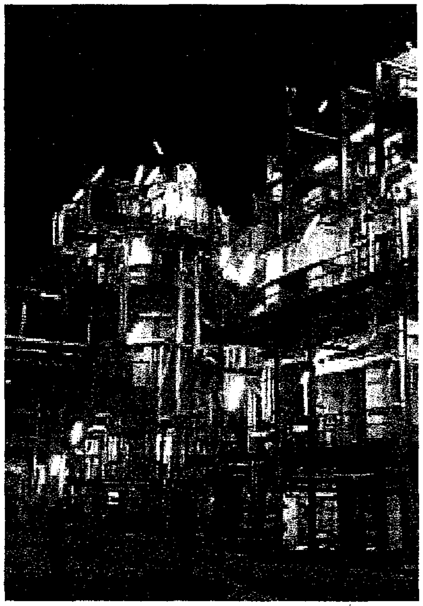
can meet the objectives of climate change mitigation at the least cost. Fundamentally different approaches to CCS would be pursued for power plants using the conventional pulverized-coal steam cycle and the newer integrated gasification combined cycle (IGCC). Although today's coal IGCC power (with CO_2 venting) is slightly more expensive than coal steam-electric power, it looks like IGCC is the most effective and least expensive option for CCS.

Standard plants burn coal in a boiler at atmospheric pressure. The heat generated in coal combustion transforms water into steam, which turns a steam turbine, whose mechanical energy is converted to electricity by a generator. In modern plants the gases produced by combustion (flue gases) then pass through devices that remove particulates and oxides of sulfur and nitrogen before being exhausted via smokestacks into the air.

Carbon dioxide could be extracted from the flue gases of such steam-electric plants after the removal of conventional pollutants. Because the flue gases contain substantial amounts of nitrogen (the result of burning coal in air, which is about 80 percent nitrogen), the carbon dioxide would be recovered at low concentration and pressure—which implies that the CO_2 would have to be removed from large volumes of gas using processes that are both energy-intensive and expensive. The captured CO_2 would then be compressed and piped to an appropriate storage site.

In an IGCC system coal is not burned but rather partially oxidized (reacted with limited quantities of oxygen from an air separation plant, and with steam) at high pressure in a gasifier. The product of gasification is so-called synthesis gas, or syngas, which is composed mostly of carbon monoxide and hydrogen, undiluted with nitrogen. In current practice, IGCC operations remove most conventional pollutants from the syngas and then burn it to turn both gas and steam turbine-generators in what is called a combined cycle.



▲ Commercial power plants using IGCC technology, such as this one in Italy, have been operating since 1994. Together they generate 3,600 megawatts of electricity.

In an IGCC plant designed to capture CO_2, the syngas exiting the gasifier, after being cooled and cleaned of particles, would be reacted with steam to produce a gaseous mixture made up mainly of carbon dioxide and hydrogen. The CO_2 would then be extracted, dried, compressed and transported to a storage site. The remaining hydrogen-rich gas would be burned in a combined cycle plant to generate power [*see box on preceding page*].

Analyses indicate that carbon dioxide capture at IGCC plants consuming high-quality bituminous coals would entail significantly smaller energy and cost penalties and lower total generation costs than what could be achieved in conventional coal plants that captured and stored CO_2. Gasification systems recover CO_2 from a gaseous stream at high concentration and pressure, a feature that makes the process much easier than it would be in conventional steam facilities. (The extent of the benefits is less clear for lower-grade subbituminous coals and lignites, which have received much less study.) Precombustion removal of conventional pollutants, including mercury, makes it feasible to realize very low levels of emissions at much reduced costs and with much smaller energy penalties than with cleanup systems for flue gases in conventional plants.

Captured carbon dioxide can be transported by pipeline up to several hundred kilometers to suitable geologic storage sites and subsequent subterranean storage with the pressure produced during capture. Longer distances may, however, require recompression to compensate for friction losses during pipeline transfer.

Overall, pursuing CCS for coal power facilities requires the consumption of more coal to generate a kilowatt-hour of electricity than when CO_2 is vented—about 30 percent extra in the case of coal steam-electric plants and less than 20 percent more for IGCC plants. But overall coal use would not necessarily increase, because the higher price of coal-based electricity resulting from adding CCS equipment would dampen demand for coal-based electricity, making renewable energy sources and energy-efficient products more desirable to consumers.

The cost of CCS will depend on the type of power plant, the distance to the storage site, the properties of the storage

ERG GROUP

THE AUTHORS

DAVID G. HAWKINS, DANIEL A. LASHOF and ROBERT H. WILLIAMS have endeavored to help stave off climate change problems for decades. Hawkins is director of the Climate Center at the Natural Resources Defense Council (NRDC), where he has worked on air, energy and climate issues for 35 years. Hawkins serves on the boards of many bodies that advise government on environmental and energy subjects. Lashof is science director and deputy director of the NRDC's Climate Center, at which he has focused on national energy policy, climate science and solutions to global warming since 1989. Before arriving at the NRDC, Lashof developed policy options for stabilizing global climate at the U.S. Environmental Protection Agency. Williams is a senior research scientist at Princeton University, which he joined in 1975. At the university's Princeton Environmental Institute, he heads the Energy Systems/Policy Analysis Group and the Carbon Capture Group under the institute's Carbon Mitigation Initiative (which is supported by BP and Ford).

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reservoir and the availability of opportunities (such as enhanced oil recovery) for selling the captured CO_2. A recent study co-authored by one of us (Williams) estimated the incremental electric generation costs of two alternative CCS options for coal IGCC plants under typical production, transport and storage conditions. For CO_2 sequestration in a saline formation 100 kilometers from a power plant, the study calculated that the incremental cost of CCS would be 1.9 cents per kilowatt-hour (beyond the generation cost of 4.7 cents per kilowatt-hour for a coal IGCC plant that vents CO_2—a 40 percent premium). For CCS pursued in conjunction with enhanced oil recovery at a distance of 100 kilometers from the conversion plant, the analysis finds no increase in net generation cost would occur as long as the oil price is at least $35 per barrel, which is much lower than current prices.

CCS Now or Later?

MANY ELECTRICITY producers in the industrial world recognize that environmental concerns will at some point force them to implement CCS if they are to continue to employ coal. But rather than building plants that actually capture and store carbon dioxide, most plan to construct conventional steam facilities they claim will be "CO_2 capture ready"—convertible when CCS is mandated.

Power providers often defend those decisions by noting that the U.S. and most other countries with coal-intensive energy economies have not yet instituted policies for climate change mitigation that would make CCS cost-effective for uses not associated with enhanced oil recovery. Absent revenues from sales to oil field operators, applying CCS to new coal plants using current technology would be the least-cost path only if the cost of emitting CO_2 were at least $25 to $30 per metric ton. Many current policy proposals for climate change mitigation in the U.S. envision significantly lower cost penalties to power providers for releasing CO_2 (or similarly, payments for CO_2 emissions-reduction credits).

Yet delaying CCS at coal power plants until economy-wide carbon dioxide control costs are greater than CCS costs is shortsighted. For several reasons, the coal and power industries and

COAL'S TOLL

Despite the current popularity of the term "clean coal," coal is, in fact, dirty. Although carbon capture and storage could prevent much carbon dioxide from entering the atmosphere, coal production and consumption is still one of the most destructive industrial processes. As long as the world consumes coal, more must be done to mitigate the harm it causes.

MINING DANGERS

Coal mining is among the most dangerous occupations. Official reports for 2005 indicate that roughly 6,000 people died (16 a day) in China from coal mine floods, cave-ins, fires and explosions. Unofficial estimates are closer to 10,000. Some 600,000 Chinese coal miners suffer from black lung disease.

The U.S. has better safety practices than China and achieved an all-time low of 22 domestic fatalities in 2005. U.S. mines are far from perfect, however, as evidenced by a series of fatalities in early 2006.


▲ Acid runoff from a Pennsylvania coal mine stains this creek bed orange.

RICK SMITH AP Photo

ENVIRONMENTAL EFFECTS

Conventional coal mining, processing and transportation practices scar the landscape and pollute the water, which harms people and ecosystems. The most destructive mining techniques clear forests and blast away mountaintops. The "overburden" removed when a coal seam is uncovered is typically dumped into nearby valleys, where it often buries rivers and streams. Strip-mining operations rip apart ecosystems and reshape the landscape. Although regulations require land reclamation in principle, it is often left incomplete. As forests are replaced with nonnative grasslands, soils become compacted and streams contaminated.

Underground mining can cause serious problems on the surface. Mines collapse and cause land subsidence, damaging homes and roads. Acidic mine drainage caused by sulfur compounds leaching from coal waste into surface waters has tainted thousands of streams. The acid leachate releases heavy metals that foul groundwater.

TOXIC EMISSIONS

Coal-fired power plants account for more than two thirds of sulfur dioxide and about one fifth of nitrogen oxide emissions in the U.S. Sulfur dioxide reacts in the atmosphere to form sulfate particles, which in addition to causing acid rain, contribute to fine particulate pollution, a contaminant linked to thousands of premature deaths from lung disease nationwide. Nitrogen oxides combine with hydrocarbons to form smog-causing ground-level ozone.

Coal-burning plants also emit approximately 48 metric tons of mercury a year in America. This highly toxic element persists in the ecosystem. After transforming into methyl mercury, it accumulates in the tissues of fishes. Ingested mercury is particularly detrimental to fetuses and young infants exposed during periods of rapid brain growth, causing developmental and neurological damage.

—D.G.H., D.A.L. and R.H.W.

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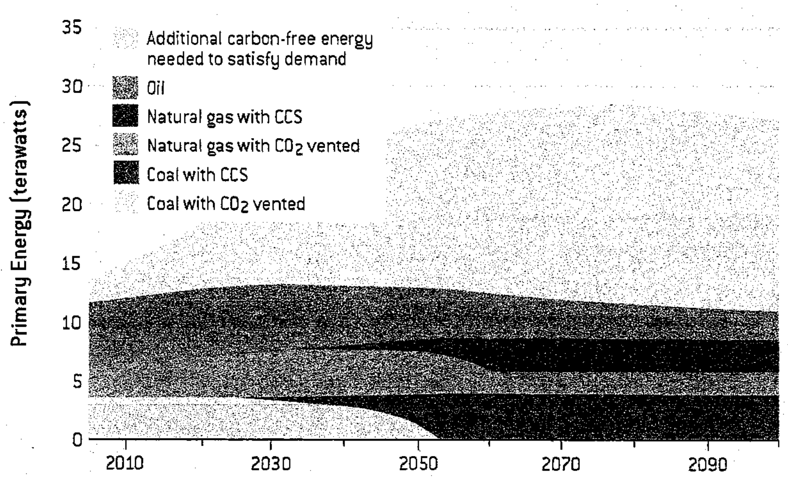
THE PATH TO CO_2 MITIGATION

Our calculations indicate that a prompt commitment to carbon capture and storage (CCS) would make it possible to meet global energy demands while limiting the atmospheric carbon dioxide concentration to 450 parts per million by volume (ppmv). This goal could be attained if, by midcentury, sequestration is applied for all coal use and about a quarter of natural gas use, while energy efficiency increases rapidly and carbon-free energy sources expand sevenfold. Under these conditions, overall fossil-fuel consumption could expand modestly from today: by midcentury, coal use could be somewhat higher than at present, oil use would be down by a fifth and natural gas use would expand by half.

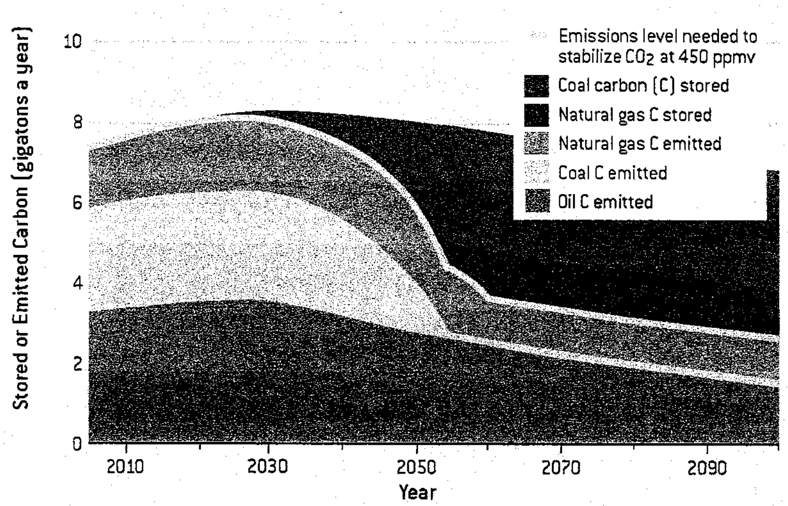
To realize this pathway, growth rates for fossil-fuel use would have to be reduced now, and CCS must begin for coal early in the next decade and for natural gas early in the next quarter of a century. The top graph below depicts the energy provided by the various sources if this mitigation path were followed. The bottom graph shows total quantities of carbon extracted from the earth (emissions plus storage).

—D.G.H., D.A.L. and R.H.W.

FOSSIL AND CARBON-FREE ENERGY MIX FOR CO_2 STABILIZATION



FATE OF CARBON FROM FOSSIL ENERGY SYSTEMS



society would ultimately benefit if deployment of plants fitted with CCS equipment were begun now.

First, the fastest way to reduce CCS costs is via "learning by doing"—the accumulation of experience in building and running such plants. The faster the understanding is accumulated, the quicker the know-how with the new technology will grow, and the more rapidly the costs will drop.

Second, installing CCS equipment as soon as possible should save money in the long run. Most power stations currently under construction will still be operating decades from now, when it is likely that CCS efforts will be obligatory. Retrofitting generating facilities for CCS is inherently more expensive than deploying CCS in new plants. Moreover, in the absence of CO_2 emission limits, familiar conventional coal steam-electric technologies will tend to be favored for most new plant construction over newer gasification technologies, for which CCS is more cost-effective.

Finally, rapid implementation would allow for continued use of fossil fuels in the near term (until more environmentally friendly sources become prevalent) without pushing atmospheric carbon dioxide beyond tolerable levels. Our studies indicate that it is feasible to stabilize atmospheric CO_2 levels at 450 ppmv over the next half a century if coal-based energy is completely decarbonized and other measures described in the box at the left are implemented. This effort would involve decarbonizing 36 gigawatts of new coal generating capacity by 2020 (corresponding to 7 percent of the new coal capacity expected to be built worldwide during the decade beginning in 2011 under business-as-usual conditions). In the 35 years after 2020, CO_2 capture would need to rise at an average rate of about 12 percent a year. Such a sustained pace is high compared with typical market growth rates for energy but is not unprecedented. It is much less than the expansion rate for nuclear generating capacity in its heyday—1956 to 1980—during which global capacity rose at an average rate of 40 percent annually. Further, the

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expansion rates for both wind and solar photovoltaic power capacities worldwide have hovered around 30 percent a year since the early 1990s. In all three cases, such growth would not have been practical without public policy measures to support them.

Our calculations indicate that the costs of CCS deployment would be manageable as well. Using conservative assumptions—such as that technology will not improve over time—we estimate that the present worth of the cost of capturing and storing all CO_2 produced by coal-based electricity generation plants during the next 200 years will be \$1.8 trillion (in 2002 dollars). That might seem like a high price tag, but it is equivalent to just 0.07 percent of the current value of gross world product over the same interval. Thus, it is plausible that a rapid decarbonization path for coal is both physically and economically feasible, although detailed regional analyses are needed to confirm this conclusion.

Policy Push Is Needed

THOSE GOOD REASONS for commencing concerted CCS efforts soon will probably not move the industry unless it is also prodded by new public policies. Such initiatives would be part of a broader drive to control carbon dioxide emissions from all sources.

In the U.S., a national program to limit CO_2 emissions must be enacted soon to introduce the government regulations and market incentives necessary to shift investment to the least-polluting energy technologies promptly and on a wide scale. Leaders in the American business and policy communities increasingly agree that quantifiable and enforceable restrictions on global warming emissions are imperative and inevitable. To ensure that power companies put into practice the reductions in a cost-effective fashion, a market for trading CO_2 emissions credits should be created—one similar to that for the sulfur emissions that cause acid rain. In such a plan, organizations that intend to exceed designated emission limits may buy credits from others that are able to stay below these values.

Enhancing energy efficiency efforts and raising renewable energy production are critical to achieving carbon dioxide limits at the lowest possible cost. A portion of the emission allowances created by a carbon cap-and-trade program should be allocated to the establishment of a fund to help overcome institutional barriers and technical risks that obstruct widespread deployment of otherwise cost-effective CO_2 mitigation technologies.

> Delaying carbon capture and storage at coal power plants is shortsighted.

Even if a carbon dioxide cap-and-trade program were enacted in the next few years the economic value of CO_2 emissions reduction may not be enough initially to convince power providers to invest in power systems with CCS. To avoid the construction of another generation of conventional coal plants, it is essential that the federal government establish incentives that promote CCS.

One approach would be to insist that an increasing share of total coal-based electricity generation comes from facilities that meet a low CO_2 emissions standard—perhaps a maximum of 30 grams of carbon per kilowatt-hour (an achievable goal using today's coal CCS technologies). Such a goal might be achieved by obliging electricity producers that use coal to include a growing fraction of decarbonized coal power in their supply portfolios. Each covered electricity producer could either generate the required amount of decarbonized coal power or purchase decarbonized-generation credits. This system would share the incremental costs of CCS for coal power among all U.S. coal-based electricity producers and consumers.

If the surge of conventional coal-fired power plants currently on drawing boards is built as planned, atmospheric carbon dioxide levels will almost certainly exceed 450 ppmv. We can meet global energy needs while still stabilizing CO_2 at 450 ppmv, however, through a combination of improved efficiency in energy use, greater reliance on renewable energy resources and, for the new coal investments that are made, the installation of CO_2 capture and geologic storage technologies. Even though there is no such thing as "clean coal," more can and must be done to reduce the dangers and environmental degradations associated with coal production and use. An integrated low-carbon energy strategy that incorporates CO_2 capture and storage can reconcile substantial use of coal in the coming decades with the imperative to prevent catastrophic changes to the earth's climate. SA

MORE TO EXPLORE

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Lashof Testimony
DAL-7
13 pages

NRDC
THE EARTH'S BEST DEFENSE

NATURAL RESOURCES DEFENSE COUNCIL

Testimony of Daniel A. Lashof
Science Director, Climate Center
Natural Resources Defense Council

Hearing on

Rebalancing the Carbon Cycle

Committee on Government Reform
Subcommittee on Energy and Resources
House of Representatives

September 27, 2006

Thank you Mr. Chairman for holding this hearing on what I believe should be a critical priority for the federal government: rebalancing the carbon cycle. My name is Daniel A. Lashof, and I am the science director of the Climate Center at the Natural Resources Defense Council (NRDC). NRDC is a national, nonprofit organization of scientists, lawyers and environmental specialists dedicated to protecting public health and the environment. Founded in 1970, NRDC has more than 1.2 million members and online activists nationwide, served from offices in New York, Washington, Los Angeles and San Francisco. I have worked at NRDC since 1989 and have served on committees of the National Research Council, the President's Council of Advisors on Science and Technology, and the Intergovernmental Panel on Climate Change. Prior to joining NRDC I was a scientist at the Environmental Protection Agency, where I was the lead author of a report to Congress on policy options for stabilizing global climate. I am particularly pleased to appear at this hearing because my doctoral dissertation at the University of California addressed the role of the biosphere in the global carbon cycle.

Out of Balance

Mr. Chairman, this hearing is particularly timely because the carbon cycle today is more out of balance than at any time in history. Each year emissions from burning fossil fuels and destroying forests put about twice as much carbon dioxide (CO_2) into the atmosphere as natural sources can remove. As a result, the amount of carbon dioxide in the atmosphere is rising worldwide and the rate of growth is increasing. The average CO_2 concentration in Earth's atmosphere is now over 380 parts per million by volume (ppm), which is higher than it has been for at least 650,000 years[1]. In 2005 the concentration of carbon dioxide in the atmosphere increased by 2.5 ppm, the third largest annual increase ever recorded[2]. Although there is considerable variation from year to year in the rate of increase in atmospheric carbon dioxide, the rise has been more than 2 ppm in 3 of the last 4 years and preliminary 2006 data indicate that this trend is continuing.

The unprecedented buildup of carbon dioxide in our atmosphere endangers our environment, our health, and our economy. Carbon dioxide traps heat in the earth's atmosphere, preventing it from escaping into space. So the imbalance in the carbon cycle has also thrown the earth's energy balance out of whack, which means that each year the earth absorbs more energy from the sun than it radiates back into space. Global warming is the inevitable result and the human fingerprint on Earth's climate is now clearly visible. The consequences have become all too apparent in recent years:

- More severe hurricanes as ocean temperatures rise[3];
- More severe droughts and wildfires, particularly in the western United States, as mountain snowpacks decline and evaporation rates increase[4];
- Coastal flooding and inundation as melting mountain glaciers and polar ice sheets raise sea levels[5];

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- Ecosystem destruction and species extinctions as climate change and ocean acidification destroy polar bear habitat, spread disease among harlequin frogs, and dissolve coral reefs[6].

Time Is Running Out

The good news is that we can avoid the worst effects of global warming if we act decisively now to begin rebalancing the carbon cycle by reducing emissions of carbon dioxide from power plants, automobiles, and other sources. Significant emission reductions are needed, and delay only makes the job harder. As the National Academy of Sciences stated last year:

> Despite remaining unanswered questions, the scientific understanding of climate change is now sufficiently clear to justify taking steps to reduce the amount of greenhouse gases in the atmosphere. Because carbon dioxide and some other greenhouse gases can remain in the atmosphere for many decades, centuries, or longer, the climate change impacts from concentrations today will likely continue well beyond the 21st century and could potentially accelerate. Failure to implement significant reductions in net greenhouse gases will make the job much harder in the future—both in terms of stabilizing their atmospheric abundances and in terms of experiencing more significant impacts.[7]

We are already beginning to see the effects of global warming and scientists are increasingly concerned that we are approaching a tipping point beyond which severe and irreversible impacts will become inevitable. For example, recent observations show that the Greenland ice sheet is melting more rapidly than expected and that global warming of

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[6] Pounds, J.A., M.R. Bustamante, L.A. Coloma, J.A. Consuegra, M.P.L. Fogden, P.N. Foster, E. La Marca, K.L. Masters, A. Merino-Viteri, R. Puschendorf, S.R. Ron, G.A. Sanchez-Azofeifa, C.J. Still and B.E. Young (2006) Widespread amphibian extinctions from epidemic disease driven by global warming. *Nature*, 439, p. 161-167, doi:10.1038/nature04246.

[7] National Academy of Sciences, *Understanding and Responding to Climate Change: Highlights of National Academies Reports*, p.16 (October 2005), http://dels.nas.edu/dels/rpt_briefs/climate-change-final.pdf (emphasis added).

as little as 2 degrees Celsius (3.6 degrees Fahrenheit) from 19th Century levels could cause it to eventually collapse, raising sea levels by as much as 20 feet[8]. A similar amount of warming could put millions of people at risk of water stress, hunger, and malaria and cause the collapse of many vulnerable ecosystems, including most alpine meadows and more than 90% of coral reefs[9].

We have a reasonable chance of staying within this 3.6 degree Fahrenheit envelope if atmospheric concentrations of CO_2 and other global warming gases are kept from exceeding 450 ppm CO_2- equivalent. This implies a budget for cumulative global and U.S. carbon dioxide emissions designed to rebalance the carbon cycle in time to stay within this 450 ppm target. A reasonable allocation of that budget to the United States over the period 2000 to 2050 would limit cumulative U.S. emissions over that period to less than 40 times our emissions level in 2000. To live within this budget we must stop U.S. emissions growth within the next 5-10 years and cut emissions by 60-80 percent over the next 50 years. U.S. action on this scale – together with similar cuts by other developed countries and limited emissions growth followed by reductions from developing countries – would keep the world within that 450 ppm limit.

So here is our choice. If we start cutting U.S. emissions soon, and work with other developed and developing countries for comparable actions, we can stay on the 450 ppm path with an ambitious but achievable annual rate of emission reductions – one that gradually ramps up to about 3.2% reduction per year. (See Figure 1.)

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[8] Overpeck et al, 2006.

[9] Warren, R. (2006) Impacts of Global Climate Change at Different Annual Mean Global Temperature Increase, in H. Schellnhuber, et at., *(eds.) Avoiding Dangerous Climate Change*, Cambridge University Press, New York.

But if we delay a serious start and continue emission growth at or near the business-as-usual trajectory for another 10 years, the job becomes much harder – the annual emission reduction rate required to stay on the 450 ppm path jumps between two- and three-fold, to 8.2% per year. In short, a slow start means a crash finish – the longer emissions growth continues, the steeper and more disruptive the cuts required later.

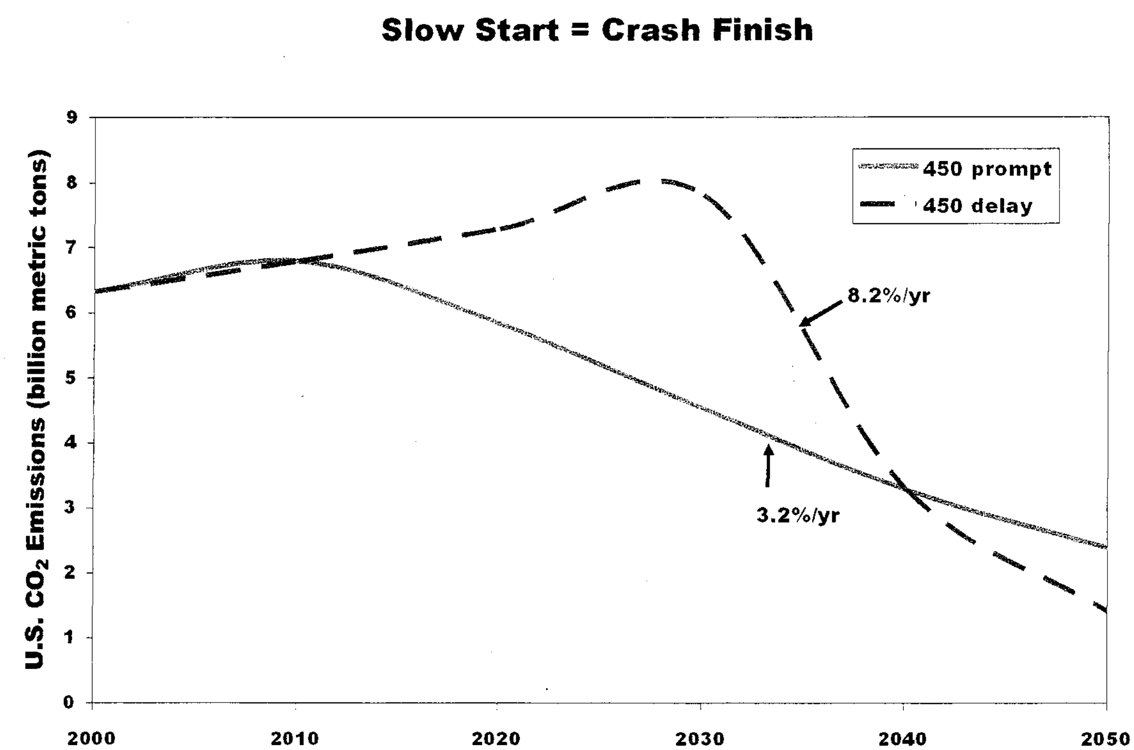

Figure 1. Prompt start and delay pathways consistent with stabilizing heat-trapping gases at 450 ppm CO_2-equivalent. Global emissions 2000-2100 are 1760 Gt CO_2 from Meinshausen's S450Ce scenario.[10] The U.S. share of global emissions is assumed to decline from 25% to 5% linearly between 2000 and 2100. This results in an emissions budget for the U.S. of 308 Gt CO_2 in the 21st Century. In the prompt start case emissions decline by 1.5%/yr from 2010 to 2020, 2.5%/yr from 2020 to 2030 and 3.2%/yr thereafter. The delay case assumes that emissions grow by 0.7%/yr from 2010 to 2030, a reduction of 0.5%/yr compared to the Energy Information Administration forecast;[11] they must decline by 8.2%/yr thereafter to limit cumulative 21st Century emissions to 308 Gt CO_2.

[10] Simple Model for Climate Policy assessment (SiMCaP). available at: http://www.simcap.org/

[11] Reference case from U.S. Department of Energy. Annual Energy Outlook 2006 with Projections to 2030. Report # DOE/EIA-0383(2006)

Here's a common sense illustration of what this means. Imagine driving a car at 50 miles per hour, and you see a stop light ahead of you at a busy intersection. If you apply the brakes early, you can easily stop your car at the light with a gentle deceleration. The longer you wait to start braking, the harder the deceleration. There's some room for choice. Within some limits, you can brake late and still stop in time. But the higher your speed, the earlier you must start braking. If you wait too long, you'll find yourself in the middle of the intersection with your forehead through the windshield.

The captain of the Titanic learned a similar lesson. If he had started turning just a couple of minutes earlier, he would have missed the iceberg. But traveling at full speed, by the time he saw the iceberg, it was too late to miss it. He lost his ship. Will we repeat the same mistake?

Administration officials suggest that, rather than establish enforceable emission limits now that begin to gradually reduce emissions within a few years, it is still cheaper to delay mandatory emission cuts because (somehow) we will develop breakthrough technologies in the interim and these will enable faster reductions later at lower cost. But this argument is implausible for two reasons. First, as already demonstrated, delaying the start of reductions dramatically increases the rate at which emissions must be lowered later. Reducing emissions by more than 8 percent per year would require deploying advanced low-emission technologies at least several times faster than conventional technologies have been deployed over recent decades. Second, delay means that a whole new generation of capital investment will be made in billions of dollars of high-emitting capital stock – conventional power plants, vehicles, etc. that will be built or bought during the next 10-20 years in the absence of meaningful near-term limits. Under the delay scenario, our children and grandchildren would then have to bear the costs of prematurely retiring an even bigger capital stock than exists today. Even taking discounting into account, it is virtually impossible that delaying emission reductions is cheaper than starting them now.

Voluntary Measures Won't Balance the Carbon Cycle

Limited as it is to R&D and voluntary measures, the administration's Climate Change Technology Program has no hope of preventing the "crash finish" scenario. The inadequacy of a voluntary program is plain to see for a growing number of business leaders, state and local elected officials, and a majority of the U.S. Senate, as well as to nearly all other nations.

In 2002, President Bush recommitted the United States to "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system" – the objective of the climate change treaty (the U.N. Framework Convention on Climate Change) adopted and ratified by his father. The president said his goal was to "slow, stop, and reverse" U.S. global warming emissions growth. He set a purely voluntary target of reducing the emissions *intensity* of the U.S. economy – the ratio of emissions to GDP – by 18 percent between 2002 and 2012.

But emissions *intensity* is a deceptive measure, because what counts for global warming is *total* emissions. Even if the president's target were met (and recent reports indicate that it may not be), *total* U.S. emissions will still increase by 14 percent between 2002 and 2012 – exactly the same rate as they grew in the 1990s. (See Figure 4.)

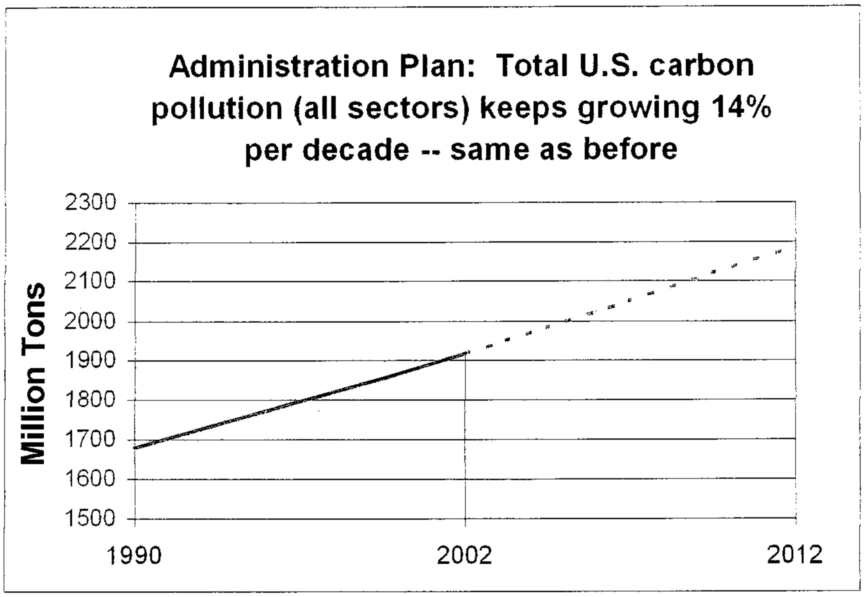

Figure 2

While the administration clings doggedly to the voluntary fiction, most political, civic, and business leaders in the United States are moving on. As Science Committee Chairman Boehlert told this Committee last week:

> As many outside commenters have noted, the plan does not establish clear priorities or a method for doing so. It does not provide clear criteria for determining which programs to fund, when to fund them, or how much funding to provide. It does not clearly connect specific programs with any particular policy goal, such as the Administration's (rather minimal) goal of reducing greenhouse gas intensity. Given that the Plan is about three years late, these failings are particularly unfortunate. The Plan also explicitly fails to deal with what is perhaps the key issue in climate change technology - technology deployment. Creating a market for technologies that could limit climate change - especially, creating a market soon enough that the action can make a real difference - will require government policy, whether that be tax incentives, regulations or some other measures. Simply undertaking research and development (R&D) is not enough, to put it mildly.

A majority of the Senate agrees, having voted last year for a Sense of the Senate resolution endorsing the need for "mandatory, market-based limits" that will "slow, stop, and reverse the growth" of global warming pollution. The resolution affirms that U.S.

mandatory action can be taken without significant harm to the economy and that such action "will encourage comparable action by other nations that are major trading partners and key contributors to global emissions."

State and local governments are leading, with mandatory limits on power plant emissions in the northeast and in California. California and 10 other states have adopted limits on global warming emissions from motor vehicles. Last month, California – the 12th largest emitter in the world – enacted the most far-reaching state plan to reduce the state's global warming pollution to 1990 levels by 2020. The state's new law enjoys wide support from businesses and other constituencies, going well beyond the usual environmental suspects: PG&E; Silicon Valley Leadership Group; Bay Area Council; Sacramento Municipal Utility District; Waste Management; Calpine; California Ski Industry Association; the cities of Los Angeles, San Francisco, Oakland, and Sacramento; the American Academy of Pediatrics; the California Nurses Association; CDF Firefighters; and Republicans for Environmental Protection.

Many other states have adopted standards to increase the percentage of renewable power generation. Stakeholder processes to address global warming are underway or in development in a growing number of states in all regions of the country. More than 200 cities have announced plans to reduce their global warming pollution.

The constituency for real action is broadening and growing. Earlier this year, more than 80 evangelical leaders called for mandatory limits on global warming pollution, citing their duty to care for God's creation.

In April, appearing before the Senate Energy Committee, some of the largest electric utilities, suppliers of generating equipment, and electricity customers called for mandatory limits. Huge companies such as Duke Energy, Exelon, and GE said that voluntary programs won't work and that they need certainty and clear market signals in order to make sensible investments in new power plants that will last 50 years. Big electricity consumers like Wal-Mart endorsed mandatory limits and committed to cut their energy use and emissions through investments in energy efficiency and renewable energy.

They all get it. Voluntary programs and tax incentives are insufficient to get these technologies deployed at a sufficient scale and speed to avoid a climate catastrophe. The market conditions for these new investments will not be created without a limit on CO_2 emissions.

Technologies for Balancing the Carbon Cycle

Scientific American devoted its September issue to "Energy's Future Beyond Carbon." This special issue includes five articles that describe technologies available today to reduce carbon dioxide emissions by improving energy efficiency in transportation, buildings and industry, and by harnessing renewable energy sources and scrubbing carbon dioxide from fossil fuels. With appropriate policy support these technologies can be deployed in a portfolio capable of keeping the United States within the carbon budget described earlier, which is necessary to avoid dangerous global warming. There are many options for assembling such a portfolio. In the scenario illustrated below the largest reductions are obtained from energy efficiency improvements in electrical end uses, non-electric stationary end uses, and motor vehicles.

Additional reductions come from renewable fuels and electricity and carbon capture and disposal at coal-fired power plants and other high-concentration industrial CO2 vents.

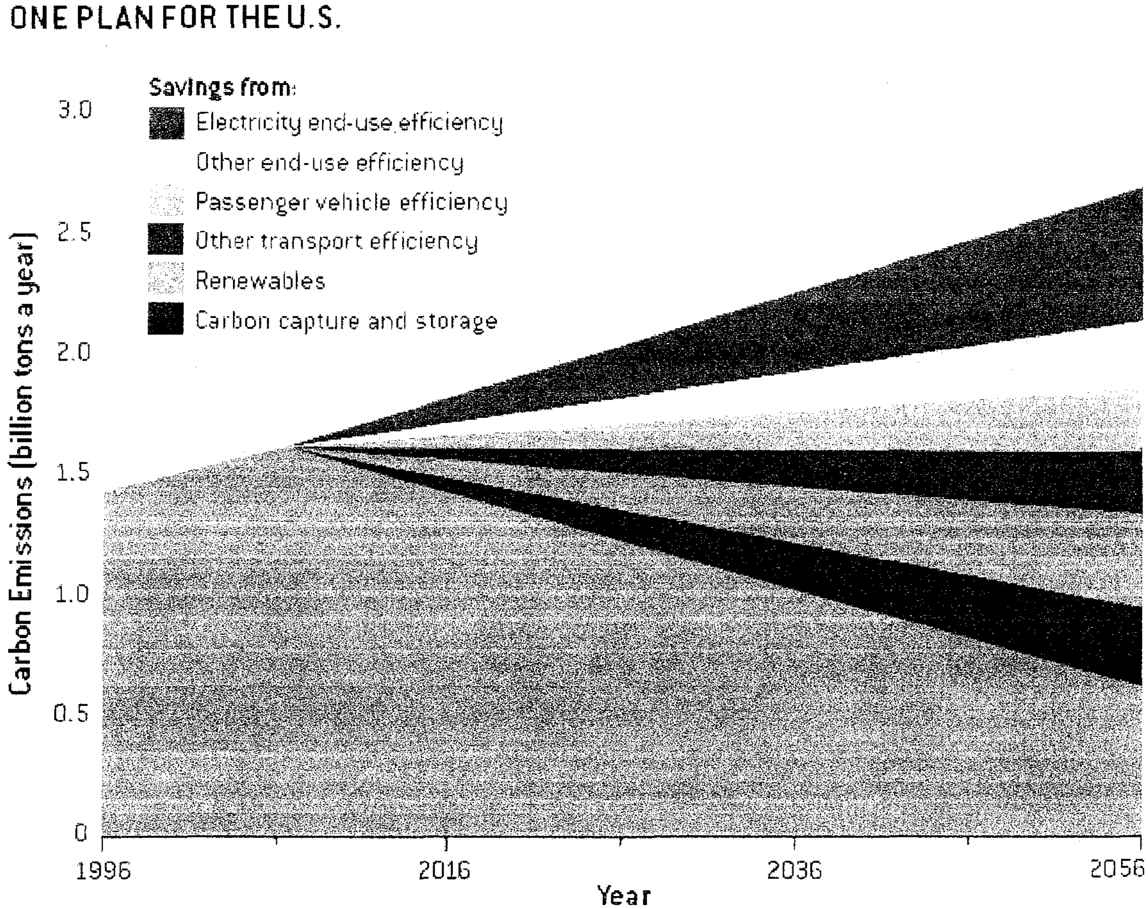

Figure 3. *Source*: Lashof and Hawkins, NRDC, *in* Socolow and Pacala, *Scientific American*, September 2006, p. 57

The elements of this scenario are briefly outlined below.

1. **Electric end-use efficiency (0.54 GtC):** Efficiency improvements in motors, lighting, refrigeration and other electrical equipment reduce total electricity consumption by 40% in 2056 compared to BAU. Resulting total electricity consumption is 4400 billion kilowatt-hours (BkWh), 20 percent greater than current consumption levels. California has demonstrated in practice that such reductions are possible. Sustained policies to promote energy efficiency through a combination of appliance standards, building code enforcement, and utility

efficiency programs have stabilized per capita electricity consumption in California over the last 30 years while national per capita electricity use continued to grow such that per capital electricity consumption in California is now more than 40% lower than in the rest of the country.[12]

2. **Other end-use efficiency (0.28 GtC):** Improvements in building designs and industrial processes result in a 40 percent reduction in non-electric energy consumption by stationary sources compared to BAU. Overall emissions from these sources decline by 15 percent from current levels.

3. **Passenger vehicle efficiency (0.27 GtC):** Widespread use of hybrid vehicles, as well as improvements to conventional vehicles, raises the average fuel economy of the in-use vehicle fleet to 54 miles per, compared with 24 mpg under BAU.

4. **Other transport efficiency (0.23 GtC):** Heavy truck fuel economy increases to 13 mpg, compared with 7 mpg under BAU and aircraft efficiency increases to 105 seat miles per gallon (smpg), compared with 80 smpg under BAU. In addition, smart growth policies reduce total travel demand by 10 percent.

5. **Renewable energy (0.39 GtC):** Renewable energy (e.g. wind and biomass) accounts for 30 percent of total electricity generation by 2050, compared with less than 5 percent under BAU. This much electricity could be supplied by 500 GW of wind (e.g. 250,000 2-MW-turbines). Turbines would be spread over 20 million acres, but the land could also be used for crop production or livestock grazing. In addition, 40 percent of transportation fuel is provided by sources with zero net CO_2 emissions (e.g. cellulosic ethanol with soil carbon increases compensating for fossil carbon inputs; Fischer-Tropsch diesel from biomass with geologic carbon sequestration compensating for fossil carbon inputs; renewable electricity supplied to plug-in hybrids). This corresponds to 80 billion gallons of biofuels, which could be supplied from energy crops grown on 60 million acres of land, assuming productivity of 12 tons/acre.[13] Alternatively, this could be supplied by 40 billion gallons of biofuels plus 520 billion kWh of additional renewable electricity supplied to plug-in hybrids.[14]

6. **Carbon capture and storage (0.32 GtC):** Carbon capture and storage technology is applied to 160 GW of coal-fired integrated gasification combined cycle power plants, capturing 0.19 GtC in 2050. Additional carbon dioxide is captured from natural gas production facilities, large industrial sources, and ethanol plants, contributing 0.12 GtC to the 2050 emission reductions. The total volume of carbon dioxide put into storage would be 30 times the volume currently used for enhanced oil recovery and would be equivalent to 5 times the annual flow of natural gas through buffer storage facilities. In addition, increased thermal

[12] http://www.nrdc.org/air/energy/fcagoals.asp

[13] N. Greene, et al., 2004. *Growing Energy: How Biofuels Can Help End America's Oil Dependence.* (NRDC, New York, 2004)

[14] Assumes 13 kWh displace 1 gallon of gasoline in a plug-in hybrid.

efficiency at power plants from replacing older units reduces emissions by 0.03 GtC.

Conclusion

The carbon cycle is out of balance, causing an accelerating build up of heat-trapping carbon dioxide in the atmosphere that endangers our environment, our health, and our economy. The good news is that with decisive action initiated now we can deploy available technologies to rebalance the carbon cycle in time to avoid the worst consequences of global warming.