Advanced Nuclear Power Feasibility Report

Florida Public Service Commission

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LIST OF ACRONYMS

AFB .... Air Force Base
ANPTC .... Advanced Nuclear Production Tax Credit
ARDP .... Advanced Reactor Demonstration Program
BWR .... Boiling Water Reactor
CCRC .... Capacity Cost Recovery Clause
CFR .... Code of Federal Regulations
CHIPS .... Creating Helpful Incentives to Produce Semiconductors
CNCP .... Civil Nuclear Credit Program
COL .... Combined Operating License
CR3 .... Crystal River Unit 3
CSO .... Commercial Solutions Opening
DAF .... Department of the Air Force
DEF .... Duke Energy Florida
DIU .... Defense Innovation Unit
DOD .... Department of Defense
DOE .... Department of Energy
DON .... Department of the Navy
EAAS .... Energy as a Service
EPA .... Environmental Protection Agency
EPRI .... Electric Power Research Institute
EPZ .... Emergency Planning Zone
F.A.C. .... Florida Administrative Code
F.S. .... Florida Statutes
FCG .... Florida Electric Power Coordinating Group

FDEM .... Florida Division of Emergency Management

FDEP .... Florida Department of Environmental Protection

FDOH .... Florida Department of Health

FOAK .... First-of-a-Kind

FPL .... Florida Power and Light

FPSC .... Florida Public Service Commission

GAIN .... Gateway for Accelerated Innovation in Nuclear

GW .... Gigawatts

GWh .... Gigawatt Hours

IIJA .... Infrastructure Investment and Jobs Act of 2021

INL .... Idaho National Laboratory

IRA .... Inflation Reduction Act

ITC .... Investment Tax Credit

JBSA .... Joint Base San Antonio

kW .... Kilowatt

LCOE .... Levelized Cost of Electricity

LPO .... Loan Program Office

MIT .... Massachusetts Institute of Technology

MW .... Megawatts

MWh .... Megawatt-Hour

NCRC .... Nuclear Cost Recovery Clause

NDAA .... National Defense Authorization Act

NEAC .... Nuclear Energy Advisory Committee

NEIMA .... Nuclear Energy Innovation and Modernization Act of 2019

NOAK .... Nth-of-a-Kind

NOI .... Notice of Intent

NRC .... Nuclear Regulatory Commission

OCC .... Overnight Capital Costs

PEF.. Progress Energy Florida

PPSA .... Power Plant Siting Act

PTC .... Production Tax Credit

PWR.. Pressurized Water Reactor

RFI .... Request for Information

SCO.. Strategic Capabilities Office

SMR .... Small Modular Reactor

TYSP.. Ten Year Site Plan

U.S …………………………………………………………………………...United States

UAMPS.. Utah Associated Municipal Power System

Executive Summary

Chapter 2024-186, Section 21, Laws of Florida, requires the Florida Public Service Commission (FPSC or Commission) to prepare a report on the potential use of nuclear power technologies in the State of Florida. The Commission is required to study and evaluate the technical and economic feasibility of using advanced nuclear power technologies, including small modular reactors, to meet the electrical power needs of the state. Also, the Commission must research means to encourage and foster the installation and use of such technologies at military installations in partnership with public utilities. The Commission is directed to consult with the Florida Department of Environmental Protection (FDEP) and the Florida Division of Emergency Management (FDEM) in the preparation of this report. As the economic regulator of investor-owned utilities in Florida, the FPSC also relied upon the technical expertise of the United States Department of Energy's (DOE) Gateway for Accelerated Innovation in Nuclear program (GAIN).

Florida has a long history of utilizing nuclear generation to meet the electric power needs of the state. Florida currently has four nuclear generating units, Turkey Point Units 3 and 4 and St. Lucie Units 1 and 2, which provide approximately 11 percent of Florida's energy needs. Florida is also home to the only digital nuclear training reactor in the United States.

The Florida Legislature has taken action in the past to encourage the construction of new nuclear generation in the state. In 2006, the Legislature enacted Section 366.93, Florida Statutes (F.S.), creating an alternative cost recovery mechanism for new nuclear construction. The Legislature also amended Section 403.519, F.S., to exempt new nuclear power plants from the requirement to conduct a bidding process for alternative means to meet the need for additional generation, prior to requesting a determination of need from the Commission.

Advanced Nuclear Power Technology

The nuclear reactors operating in Florida presently are classified as generation (Gen) II reactors. Advanced nuclear reactors are classified as Gen III+ and Gen IV. Gen III+ reactors are traditional technologies using more advanced designs, while Gen IV reactors use advanced technologies and materials in their design. Advanced nuclear reactors vary in size. Large reactors are traditional central station generators that can produce over a Gigawatt (GW) of electricity. Small modular reactors (SMRs) are defined as being under 350 Megawatts (MW) in capacity. Microreactors are generally defined as being under 50 MW. At present, the only advanced nuclear reactor design operating in the U.S. is the Westinghouse AP1000, a large, twin unit Gen III+ reactor at Plant Vogtle in Georgia. Presently there are no SMRs or microreactors in operation in the U.S. It appears these designs are technically feasible, but as of yet unproven.

Economic factors are critical to the future of advanced nuclear deployment, as these designs are new and have not yet experienced widespread deployment. One critical component of these factors is the path from First-of-a-kind (FOAK) to Nth-of-a-kind (NOAK), as manufacturers learn to reduce costs without sacrificing safety or reliability as they gain experience building these generators. Likewise, lowering the cost of manufacturing, and thus the final construction costs, helps to drive down the Levelized Cost of Electricity (LCOE) of nuclear power, because the comparatively low fuel costs of nuclear mean that LCOE is driven primarily by construction costs. While the above factors are critical to all types of reactors, there are also additional cost considerations specific to advanced nuclear reactors, as economies of scale and different use cases can lead to distinction in how they can be funded.

The federal government offers numerous incentives for both advanced and traditional nuclear power. An Investment Tax Credit (ITC) was first implemented in 1978, while a Production Tax Credit (PTC) was first offered in 1992. Both have been updated in years since. The DOE also offers grants and loans both for development and deployment of nuclear generation. More recent legislation has also funded numerous projects that are available for the development of nuclear projects. As a result, there are numerous current projects at all scales of reactor design that have either entered active development or are expected to over the coming decade.

Military Applications

The Department of Defense (DOD) and the branches of the U.S. military have also investigated the logistics of the deployment of advanced nuclear power, seeing potential economic and strategic benefits to our military, both at domestic sites and abroad. As a result, energy supply is seen as a major security issue.

The military has multiple ongoing projects to realize the security potential of advanced energy sources. The DOD itself has an active project to test an advanced microreactor design in real-world operating conditions. The Department of the Air Force (DAF) has researched advanced energy sources since shortly after the Department's creation, and currently has numerous projects in development at Air Force Bases (AFB) around the country. Additionally, the Department of the Navy (DON), which has extensive nuclear experience from its deployment of nuclear propulsion, is currently evaluating bases for advanced nuclear generation testing. Finally, the DOD is also planning advanced nuclear generation projects at Army bases.

Recommendations

If the Legislature decides to take legislative or administrative actions to enhance the use of advanced nuclear technologies, there are several approaches that could serve as initial steps in that regard. The Legislature could commission a more comprehensive study beyond the impacts to

Florida’s electricity needs. The Legislature could also expand the categories of cost currently allowed alternative cost recovery under Section 366.93, F.S. The State of Florida could enhance stakeholder engagement and education concerning advancements in nuclear technology and state-of-the-art safety features. Finally, the Legislature could support new state and/or federal grant funding for the deployment of advanced nuclear reactors and establish a workforce development program.

It will be important for the FPSC to continue to have flexibility to approve new cost-based rate schedules specifically for the deployment of SMRs when intended to serve a single customer, such as a data center. The DOD is actively pursuing pilot projects to deploy microreactors at military bases in other states. Florida public utilities, however, have experience owning and operating nuclear power plants, and may be well suited to work in partnership with the DOD at Florida’s many military installations.

Chapter 1 – Introduction

Chapter 2024-186, Section 21, Laws of Florida, requires the Commission to study and evaluate the technical and economic feasibility of using advanced nuclear power technologies, including small modular reactors, to meet the electrical power needs of the state, and research means to encourage and foster the installation and use of such technologies at military installations in the state in partnership with public utilities. In conducting the study, the Commission shall consult with the FDEP and the FDEM.

The Commission is required to prepare and submit a report to the Governor, the President of the Senate, and the Speaker of the House of Representatives, containing its findings and any recommendations for potential legislative or administrative actions that may enhance the use of advanced nuclear technologies in a manner consistent with the energy policy goals in Section 377.601(2), Florida Statutes (F.S.).

Report Overview

In the report that follows, Chapter 2 will provide background on Florida's current nuclear fleet, previous legislative actions taken to encourage the construction of new nuclear generation in the state, and the current regulatory landscape for nuclear electric generation, both federal and state. Chapter 3 evaluates the technical and economic feasibility of advanced nuclear power technologies. Chapter 4 summarizes current federal and state actions intended to help develop this technology, while Chapter 5 explores the application of advanced nuclear power technology on military installations. The final chapter provides observations regarding the development of advanced nuclear technologies in Florida and potential recommended actions on a state level.

Methodology

To begin our research, Commission staff conducted a workshop on advanced nuclear power technology to gather information from subject matter experts. The workshop involved presentations by:

- Dr. Mary Lou Dunzik-Gougar, DOE GAIN program in association with the Idaho National Laboratory (INL),
- Steve Swilley, Electric Power Research Institute (EPRI), and
- Jacob Williams and Lauren Sher from the Florida Electric Power Coordinating Group (FCG).

The presentation from GAIN highlighted the realistic timeline of nuclear deployment, as well as a cost analysis. The presentation from EPRI highlighted the different types of microgrid reactors as well as the implementation timeline. The presentation from FCG highlighted the Florida utilities' perspective on advanced nuclear implementation, as well as federal funding opportunities and incentives. Staff from FDEP and FDEM also participated in the workshop.

Commission staff invited post-workshop written comments providing recommendations for actions that could be taken that may enhance the use of advanced nuclear power technologies in Florida, which were provided by both GAIN and FCG.[1]

[1]All documents, including presentations and post-workshop comments, as well as a video recording from the workshop can be found on the Commission's Website.

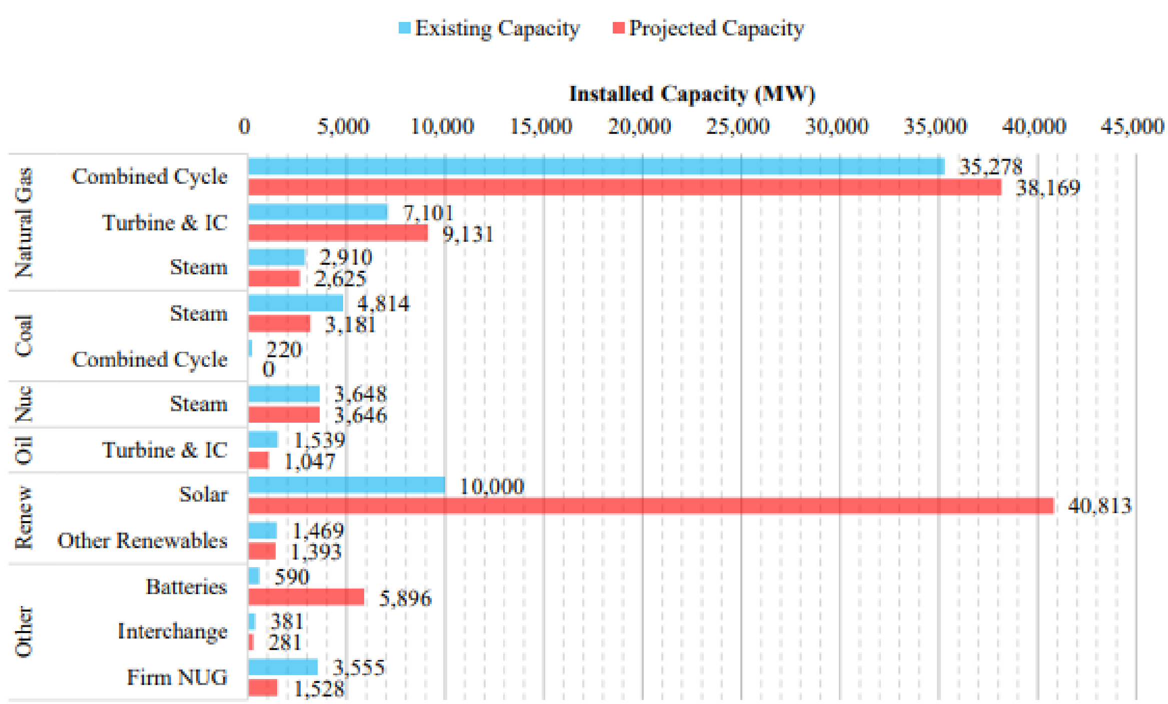
Chapter 2 – Background of Nuclear Generation in Florida

Florida Energy Resource Profile

Nuclear energy provides base-load electric power generation today and will likely remain a major contributor to the state's future power needs. Over the past 20 years, Florida's energy generation mix has become less diverse as natural gas-fired generation has increasingly accounted for approximately 65 percent of the electricity generation in the state.[2]

Each year, generating electric utilities submit a Ten-year Site Plan (TYSP) to the Commission, pursuant to Section 186.801, F.S., which estimates the utility's power generating needs and the general locations of its proposed power plant sites over a 10-year planning horizon. The TYSP summarizes the results of each utility's Integrated Resource Planning process and identifies proposed power plants and transmission facilities. The figure below, taken from the Commission's 2024 review of utility TYSPs, provides an overview of Florida's existing and projected energy generation resource profile, as of December 31, 2023.

Figure 1: State of Florida – Current and Projected Installed Capacity - 2023



Source: FRCC 2024 Regional Load and Resource Plan and TYSP Utilities' Data Responses

[2] Review of the 2024 Ten Year Site Plan

With planned plant additions and retirements throughout the next decade, the generation mix in Florida is expected to diversify. Nuclear generation currently makes up approximately 11 percent of Florida's net energy for load and is expected to remain steady throughout the planning period. Coal generation is expected to continue its downward trend. Natural gas has been the primary fuel used to meet the growth of energy consumption, and this trend is anticipated to continue throughout the next decade. Solar generation is expected to exceed the growth of all other generation sources by the end of the planning period.

Future Considerations and Emerging Trends

Florida's electric utilities must consider changes in regulations and regulatory oversight associated with existing generators and planned generation to meet Florida's electric needs. Developments in U.S. Environmental Protection Agency (EPA) regulations may impact Florida's existing generation fleet and proposed new facilities, impacting the economic feasibility of advanced nuclear reactors. Additionally, any changes in regulatory jurisdiction may change the technical feasibility of advanced nuclear reactors. For example, in December 2024 a coalition that included the states of Texas and Utah, as well as the advanced nuclear reactor company Last Energy, Inc., filed a federal lawsuit in Texas arguing that some microreactors should not require approval by the Nuclear Regulatory Commission (NRC), as discussed in the Regulatory Landscape section of this report.

Electric utilities must also maintain an awareness of emerging trends in energy consumption and generation technologies, and their impacts on the industry. Trends, such as customer adoption of Electric Vehicles (EVs), the potential for growth of data centers due to applications such as artificial intelligence, solar technologies, energy storage, and grid resilience are important for electric utilities to track both to determine future impacts and the best way to address them. These emerging trends may change the resource forecasts above as utilities adapt to the energy landscape. The development of advanced nuclear power technology may also be a factor that alters the future of energy generation in Florida.

Florida's Nuclear Fleet

Florida is the second-largest producer of electricity in the nation, after Texas. In 2022, natural gas fueled about three-fourths of Florida's total in-state net generation, and 8 of the state's 10 largest power plants by capacity and by generation are natural gas-fired. The second-largest source of in-state generation is nuclear power. The state's two nuclear power stations are located on Florida's Atlantic Coast, and typically provide more than one-tenth of the state's net generation.[3]

[3] Review of the 2024 Ten Year Site Plan

Florida currently has two operating nuclear power plants and one decommissioned nuclear power plant.

Turkey Point

Florida Power and Light (FPL) owns the only operating nuclear power plants in the State of Florida. Turkey Point Units 3 and 4, located on Biscayne Bay 24 miles south of Miami, are pressurized water reactors (PWR).[4] Unit 3 began operation in 1972 and Unit 4 began operation in 1974. These two nuclear power units have a combined capacity of approximately 1,600 MW of electricity generation.

In 2012, the NRC approved a 15 percent uprate of Turkey Point Units 3 and 4.[5] On September 18, 2024, the NRC approved the subsequent license renewal of FPL's Turkey Point Nuclear Power Plant Units 3 and 4, enabling the continued safe operation of these units through 2052 and 2053, respectively. This significant approval ensures that the nuclear facility will continue to provide reliable, low-cost and clean energy to FPL customers for the next three decades.[6]

St. Lucie

FPL also operates the St. Lucie Nuclear Power Plant, a twin nuclear power station located on Hutchinson Island, near Port St. Lucie in St. Lucie County. These two units, St. Lucie 1 and 2, are both PWR. Construction for Unit 1 began in 1970, with Unit 2 following in 1977. They entered service in 1976 and 1983, respectively. In 2003, the NRC extended the operating license of the St. Lucie units to 2036 and 2043. In 2008, FPL filed for uprates of both units. In 2012, the uprate modifications were completed, increasing each unit's electric output to 940 MW.[7]

Crystal River (Decommissioned)

The Crystal River Energy Complex, located about 85 miles north of Tampa, is owned by Duke Energy Florida (DEF). Construction of Crystal River Unit 3 (CR3) began in 1968, with the plant entering commercial operation in March 1977. CR3 was a PWR with a net capacity of 860 MW. In 2009, during a project to replace the unit's steam generators, the containment structure experienced a de-lamination event where layers within the concrete walls developed separation. Efforts to replace the section of concrete failed when additional cracking was detected. In 2013, DEF decided to decommission CR3 rather than attempt further reconstruction of the containment vessel. According to the NRC, decommissioning of the unit will be completed in 2037.[8]

Training Reactor at UF

The University of Florida Training Reactor is the only nuclear training reactor in the Southeastern U.S. It was constructed in 1959 on its campus in Gainesville, and is a light-water reactor that

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[4] FPL | Clean Energy | Turkey Point Nuclear Plant
[5] U.S. Nuclear Plant Actual and Expected Uprates by Plant
[6] NRC Authorizes FPL's Turkey Point Nuclear Power Plant to Operate for Another 20 Years - Sep 18, 2024
[7] St. Lucie Nuclear Power Plant | Florida Department of Environmental Protection
[8] Crystal River Unit 3 Nuclear Generating Plant | NRC.gov

operates at a thermal power level of 100 Kilowatt (kW), though it lacks steam generators and turbines and thus does not generate electricity. It uses water and graphite as moderators. In 2015, the reactor completed a multi-year upgrade program that included upgrading its analog controls to digital controls.[9]

Past Legislative Actions

The Florida Legislature has previously taken steps to encourage the construction of new nuclear generation in Florida.

Alternative Cost Recovery

In 2006, the Florida Legislature enacted Section 366.93, F.S., in order to encourage utility investment in nuclear electric generation in Florida.[10] Section 366.93, F.S., authorized the Commission to allow investor-owned electric utilities to recover certain construction costs in a manner that reduces the overall financial risk associated with building a nuclear power plant. The statute required the Commission to adopt rules that provide for, among other things, annual reviews and cost recovery using the existing capacity cost recovery clause (CCRC).[11] The Commission adopted Rule 25-06.0423, Florida Administrative Code (F.A.C.), to implement the statute by creating an annual review and recovery process called the Nuclear Cost Recovery Clause (NCRC).

Under the rule, all prudently incurred pre-construction costs can be recovered directly through changes to the annual capacity cost adjustment factor within the CCRC. Additionally, allowance for funds used during construction on all prudently incurred construction costs is eligible for annual recovery through the CCRC. The rule also provides that utilities may file a petition for a separate proceeding to recover prudently incurred site selection costs. The separate proceeding would be limited to determining prudence and an alternative method of recovery, which could be through the CCRC along with pre-construction costs. In the initial year of the proceeding, it was agreed that site selection costs would be treated the same as pre-construction costs.

Finally, the statute and rule address how costs can be recovered if the project is not completed. If the utility elects not to or is precluded from completing construction of the nuclear plant, the utility will be allowed to recover through the CCRC all unrecovered, prudently incurred site selection,

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[9] https://mse.ufl.edu/research/facilities/

[10] In 2007 the statute was amended to include Integrated Gasification Combined Cycle plants, and in 2008 to include transmission lines and associated facilities. In 2013, the statute was again amended to restrict cost recovery during the licensing process, require Commission approval prior to commencing certain activities, and establishing a timeframe within which the utility must commence construction after obtaining a COL from the NRC.

[11] The CCRC was originally established to provide cost recovery of capacity charges associated with power purchase contracts without changing base rates.

pre-construction, and construction costs. The utility will recover these costs over a period equal to the time during which the costs were incurred or 5 years, whichever is greater.

Following the adoption of the NCRC rules, FPL and DEF, doing business as Progress Energy Florida (PEF) at the time, proposed projects involving the uprate of existing nuclear power plants and the construction of new plants. FPL successfully completed the uprate of Turkey Point Units 3 and 4, as well as St. Lucie Units 1 and 2, resulting in an additional 522 MW of new nuclear generation capacity. FPL also proposed the new construction of Turkey Point Units 6 and 7, which would deploy an advanced nuclear reactor design by Westinghouse, the AP1000. FPL successfully obtained a Combined Operating License (COL) from the NRC for Turkey Point Units 6 and 7 in 2009. However, the project was paused to evaluate the progress of the construction of two AP1000 Units in Georgia at Plant Vogtle. In January of 2014, Section 366.93, F.S., was revised to implement time limits on how long a utility can wait to begin construction after obtaining a COL.[12]

PEF proposed the uprate of CR3. However, as discussed above, this unit was decommissioned prior to completing the uprate project. PEF also proposed the construction of two new AP1000 units in Levy County, Levy Units 1 and 2. The utility obtained a COL for the Levy units in 2016. However, due to economic considerations, plans to construct Levy Units 1 and 2 were cancelled and the COLs were subsequently terminated by the NRC at the request of DEF.

Determination of Need

Also in 2006, the Legislature amended Section 403.519, F.S. Under this section, the FPSC is the exclusive forum for a determination of need for a new power plant. A determination of the need is a mandatory element of an application under the Power Plant Siting Act (PPSA). In determining the need for a power plant, the Commission is to take into account the need for fuel diversity and supply reliability.

This section also has provisions regarding nuclear power plants, specifying the contents of the need determination petition and specifying criteria the Commission shall take into account when determining the need for a nuclear power plant. These include whether the nuclear plant will provide base-load capacity, enhance reliability by improving fuel diversity, and provide the most cost-effective alternative taking into account the need to improve the balance of fuel diversity, reduce dependence on fuel oil and natural gas, reduce air emission compliance costs, and contribute to the long-term stability and reliability of the grid.

Nuclear power plants were exempted from the requirements of the FPSC's Selection of Generating Capacity Rule (Rule 25-22.082, F.A.C.), which requires a utility to conduct a bidding process for alternative means to meet the need for additional generation. This exemption to this rule does not exempt the utilities from using the most prudent mechanisms, including bidding, for the construction of the plant or plant components from vendors and suppliers.

[12] Florida Statutes 366.93

After an affirmative determination of need is granted by the Commission, utility costs incurred prior to commercial operation, including, but not limited to the siting, design, licensing, or construction of the plant shall not be subject to challenge, unless the FPSC finds in a hearing that costs were incurred imprudently.

Regulatory Landscape

There are several agencies, both federal and state, that have a role in the regulation of nuclear power plants. This current regulatory landscape adds complexity to the development and deployment of nuclear power generation technology, and any consideration of further legislative action regarding advanced nuclear power technology should take into account the scope of regulation currently in place. As discussed in Chapter 3, changes in regulatory oversight could impact the speed and ability that companies can bring new advanced nuclear reactors to market, impacting the technical feasibility of these new generation sources. Similarly, economic feasibility can be impacted by any federal or state funding sources made available to offset any construction costs.

Federal Jurisdiction

The Atomic Energy Act of 1954 created the Atomic Energy Commission, which had jurisdiction over both the development and production of nuclear weapons and civilian uses of nuclear materials. The Energy Reorganization Act of 1974 split these functions between the DOE and the U.S. Nuclear Regulatory Commission (NRC). The DOE was given responsibility over the development and production of nuclear weapons and promotion of nuclear power, while the NRC was given regulatory authority over non-defense nuclear power.

Nuclear Regulatory Commission

The NRC was created as an independent agency by Congress in 1974 to ensure the safe use of radioactive materials for beneficial civilian purposes while protecting people and the environment. The NRC regulates commercial nuclear power plants and other uses of nuclear materials, such as in nuclear medicine, through licensing, inspection and enforcement of its requirements. [13]

It is composed of five Commissioners appointed by the President and confirmed by the Senate for 5-year terms. There are four regional offices which implement the NRC's programs in the states covered by the respective regions. The four regions cover the Northeast, the Southeast, the Midwest and the West/Southwest. The NRC primarily focuses on three areas: (1) reactors; (2) materials; and (3) waste.

Reactors

The NRC regulates both operating and new reactors, including reactor and operator licensing. This includes commercial reactors used to generate electric power, as well as reactors used for research,

[13] *See* ABOUT NRC, https://www.nrc.gov/about-nrc.html (last visited Feb. 2025).

testing, and training. Oversight activities include inspections, assessments of performance, enforcement of actions, investigations of allegations of wrongdoing by NRC licensees, and incident responses.[14]

The NRC issues licenses in one of two ways: (1) a two-step process under Title 10 of the Code of Federal Regulations (10 CFR) Part 50; and (2) an alternative process for a combined license that provides a construction permit and an operating license with conditions for plant operation under 10 CFR Part 52.

The two-step process under 10 CFR Part 50 requires a company proposing a nuclear power plant to submit a Safety Analysis Report containing design information and criteria for the proposed reactor, a comprehensive environmental impact assessment for the proposed plant, and information for antitrust review for the proposed plant. Staff at the NRC reviews the application focusing on site characteristics, including surrounding population, seismology, and geology; design of the power plant; the plant's anticipated response to hypothetical situations; plant operations, including the applicant's technical qualifications; discharge from the plant into the environment; and emergency plans. The NRC may allow the licensee to conduct some activities prior to issuance of a construction permit if certain requirements are met, such as restoration guarantees if the permit is rejected and assurances that the proposed site is a suitable location. The applicant must finally submit a Final Safety Analysis Report to support its application for an operating license describing the final design of the facility as well as its operational and emergency procedures.

The combined license process under 10 CFR Part 52 authorizes construction of the facility much like the construction permit described under the two-step process above. The application must contain essentially the same information and specify the inspections, tests, and analyses that the applicant must perform. It also specifies acceptance criteria necessary to provide reasonable assurance that the facility has been constructed and will be operated in agreement with the license and applicable regulations. After issuance of a combined license, the NRC authorizes operation of the facility only after verifying that the licensee completed required inspections, tests, and analyses, and that acceptance criteria were met.[15]

A November 2024 analysis by the Nuclear Innovation Alliance, *Advanced Nuclear Reactor Technology: A Primer*, examined the SMR and Microreactor designs currently under review at the NRC.[16] The report identified thirteen SMR designs currently under review, as well as seven microreactor designs. At the time the report was issued, six SMR designs were at the pre-application engagement stage, with one microreactor design at the pre-application discussion

[14] *See* NUCLEAR REACTORS, https://www.nrc.gov/reactors.html (last visited Nov. 13, 2024).
[15] *See* BACKGROUND ON NUCLEAR POWER PLANT LICENSING PROCESS, https://www.nrc.gov/reading-rm/doc-collections/fact-sheets/licensing-process-fs.html (last visited Nov. 13, 2024).
[16] https://nuclearinnovationalliance.org/sites/default/files/2024-11/Primer%20-%202024.pdf

stage. The remaining seven SMR designs and six microreactor designs were further along in the process.

On December 30, 2024, a coalition that included the states of Texas and Utah, as well as the advanced nuclear reactor company Last Energy, Inc., filed a federal lawsuit in Texas arguing that some microreactors should not require approval by the NRC. The lawsuit alleges that the NRC licensing process, as outlined by the Atomic Energy Act of 1954, is only intended for reactors it deems "capable of making use of special nuclear material in such quantity as to be of significance to common defense and security, or in such a manner as to affect the health and safety of the public." In this case, the microreactors produced by Last Energy, Inc. are designed with a 20 MW capacity and it is argued in the lawsuit should be exempt from the NRC's licensing requirements, but still be subject to applicable state-level requirements. Refer to the section below on State Jurisdiction for additional details on the state-level regulatory landscape.

Materials

The NRC's Office of Nuclear Material Safety and Safeguards (ONMSS) regulates activities that provide for the safe and secure production of nuclear fuel used in commercial reactors; the safe storage, transportation, and disposal of high-level radioactive waste and spent nuclear fuel; and the transportation of other radioactive materials. This office also develops and oversees the regulatory framework for the safe and secure use of nuclear materials; medical, industrial, and academic applications; uranium recovery activities; low-level radioactive waste sites; and the decommissioning of previously operating nuclear facilities and power plants.[17]

In addition to this, thirty-nine states (termed "Agreement States"), have entered into agreements with the NRC that give the states the authority to license and inspect byproduct, source, or special nuclear materials used or possessed within their borders. The National Materials Program is the overall framework within which the NRC and Agreement States function to carry out their respective regulatory programs for radioactive material.[18]Florida became an Agreement State in 1964 through an agreement with the Atomic Energy Commission prior to the creation of the NRC. Under this agreement, Florida took over jurisdiction over byproduct materials, source materials, and special nuclear materials in quantities not sufficient to form a critical mass. These are under the jurisdiction of the Florida Department of Health (FDOH).

The NRC maintains jurisdiction over the construction and operation of any production or utilization facilities; the export from or import into the U.S. of byproduct, source, or special nuclear material; the disposal into the ocean or sea of byproduct, source, or special nuclear waste materials; and the disposal of such other byproduct, source, or special nuclear material as the NRC determines should not be disposed of without a license from the NRC. The Agreement also allows the NRC to continue issuing rules and regulations concerning national defense and to protect restricted data or guard against the loss or diversion of special nuclear material. Florida and the NRC agreed to

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[17] *See* NUCLEAR MATERIALS, https://www.nrc.gov/materials.html (last visited Nov. 13, 2024).
[18] *See* OFFICE OF NUCLEAR MATERIAL SAFETY AND SAFEGUARDS, https://scp.nrc.gov/ (last visited Nov. 13, 2024).

keep each other informed and to cooperate with each other in formulating standards and regulatory programs and to protect against the hazards of radiation. Lastly, the NRC retains the power to terminate or suspend the Agreement on its own initiative after reasonable notice and opportunity for hearing if the NRC finds that such termination or suspension is required to protect public health and safety.[19]

Waste

The NRC regulates four kinds of waste: (1) Low-level waste, including radioactively contaminated protective clothing, tools, filters, rags, medical tubes, and other such items; (2) waste incidental to reprocessing, which is waste byproducts that result from reprocessing spent nuclear fuel; (3) high-level waste, including used nuclear reactor fuel; and (4) uranium mill tailings, which are the residues remaining after the processing of natural ore to extract uranium or thorium.[20]

The ONMSS develops and implements NRC policy for the regulation and safe management and disposal of spent fuel and high-level waste. Additionally, this office develops guidance for environmental compliance and oversees the decommissioning and cleanup of contaminated sites, safe management and disposal of low-level waste, and uranium recovery activities.[21]

Department of Energy

The DOE's Office of Nuclear Energy has identified five goals to address challenges in the nuclear energy sector:

(1) enable continued operation of existing U.S. nuclear reactors;
(2) enable deployment of advanced nuclear reactors;
(3) develop advanced nuclear fuel cycles;
(4) maintain U.S. leadership in nuclear energy technology; and
(5) enable a high-performing organization.[22]

The Nuclear Energy Advisory Committee (NEAC) provides independent advice to the Office of Nuclear Energy on scientific and technical issues that arise in the planning, managing, and implementing of DOE's nuclear energy program. NEAC is composed of expert representatives from universities, industry, and National Laboratories. NEAC meets twice a year to advise the Secretary of Energy on issues regarding national policy and scientific aspects of nuclear issues of concern to DOE.[23]

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[19] *See* Agreement Between the Atomic Energy Commission and the State of Florida, July 10, 1964; *see also* Ch. 404, Fla. Stat. (2024).
[20] *See* RADIOACTIVE WASTE, https://www.nrc.gov/waste.html (last visited Nov. 13, 2024).
[21] *See* OFFICE OF NUCLEAR MATERIAL SAFETY AND SAFEGUARDS, https://www.nrc.gov/about-nrc/organization/nmssfuncdesc.html (last visited Nov. 13, 2024).
[22] *See* OFFICE OF NUCLEAR ENERGY, https://www.energy.gov/ne/about-us (last visited Nov. 13, 2024).
[23] *See* NUCLEAR ENERGY ADVISORY COMMITTEE, https://www.energy.gov/ne/nuclear-energy-advisory-committee (last visited Nov. 13, 2024).

Additionally, DOE oversees 17 National Laboratories that conduct complex scientific research and development.[24] These National Laboratories support scientists and engineers from academia, government, and industry, providing access to specialized equipment, research facilities, and technical staff. Work at the labs includes research into new energy technologies, protecting national security, and advancing new industries critical to global leadership in science and innovation.[25]

State Jurisdiction

Florida Department of Environmental Protection

The PPSA, Sections 403.501-.518, F.S., controls the licensing of steam and solar power plants in Florida that generate 75 MW or more. The certification replaces all local and state permits, except those necessary under federal programs. Although siting certificates are approved by the Governor and Cabinet acting as a Siting Board, the FDEP is responsible for coordinating the certification process. The FDEP Siting Coordination Office and the FDEP Office of General Counsel provide administrative and legal support for the certification process. Local governments wherein a power plant is to be built participate in the siting process. The certification process addresses permitting, land use and zoning, and property interests. Certification grants approval for the location of a power plant and its associated facilities, such as electrical transmission lines carrying power to the grid. Florida's certification process does not include licenses required by the federal government, such as those required by the NRC. The Siting Board issues the certification; however, in non-contested cases, the FDEP Secretary may issue a certificate. There is an extensive review process for certification including an initial need determination by the FPSC, a land use determination, public noticing and public meetings, comprehensive agency reports, project analyses, a certification hearing and a Siting Board hearing if the project is disputed, and lastly, a final order on certification. Certification is a life-of-the-facility authorization and the considerations involved in the application review are extensive.[26]

Nuclear power plants operators have the option to obtain certification before obtaining separate licenses, permits, and approval for construction of support facilities necessary to construct the electric power plant itself. Such support facilities may include, but are not limited to, access and on-site roads, rail lines, electrical transmission facilities to support construction, and facilities necessary for waterborne delivery of construction materials and project components. If the utility has not yet sought certification for a nuclear plant when it begins construction of these support facilities, the utility must file a statement with FDEP declaring that construction of the support facilities is necessary for the timely construction of the proposed power plant and identifying those facilities that the utility intends to seek licenses for and construct prior to or separate from

[24] *See* NATIONAL LABORATORIES, https://www.energy.gov/national-laboratories (last visited Dec. 2, 2024).
[25] *See* The National Laboratories, https://nationallabs.org/ (last visited Dec. 2, 2024).
[26] *See* POWER PLANT SITING ACT, https://floridadep.gov/water/siting-coordination-office/content/power-plant-siting-act (last visited Nov. 13, 2024).

certification of the project. All support facilities necessary for the construction of the power plant are then incorporated into the final certification upon completion of construction.[27]

FDEP also regulates electric and magnetic fields generated by electrical transmission lines under the Florida Electric Transmission Line Siting Act.[28] The Siting Coordination Office reviews required compliance reports submitted by companies that construct or operate transmission lines.

Florida Public Service Commission

The Commission has authority over electric utilities in the State of Florida. Under Section 403.519, F.S., on request by an applicant or on its own motion, the Commission must begin a proceeding to determine the need for an electrical power plant. Specifically for proposed nuclear power plants, the Commission must hold a hearing within 90 days after the filing of the petition to determine the need and must issue an order granting or denying the petition within 135 days after the date the petition is filed. In deciding whether to grant or deny the petition, the Commission must consider the need for base-load capacity and the balance of power plant fuel diversity. The Commission must also consider whether the nuclear power plant provides the most cost-effective source of power, taking into account the need to improve the balance of fuel diversity, reducing dependence on fuel oil and natural gas, reducing air emission compliance costs, and the long-term stability and reliability of the electric grid.[29]

The Commission also oversees cost recovery mechanisms, discussed above, for costs incurred in the siting, design, licensing, and construction of nuclear power plants in order to promote electric utility investment in such plants.[30]

Florida Division of Emergency Management

The FDEM is tasked with coordinating the response between state and local agencies to a nuclear power plant emergency, as well as updating and coordinating the response plans with other organizations.[31] FDEM has a series of emergency classification levels for events at nuclear power plants.[32]

In the event of a disaster at a nuclear power plant, FDEM has a Radiological Emergency Plan in place for how to deal with the disaster. FDEM is responsible for receiving notification of an

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[27] *See* 403.506(3), F.S.
[28] *See* Sections 403.52 – 403.5365, F.S.
[29] *See* 403.519(4)(b), F.S.
[30] *See* 366.93, F.S.
[31] *See* RADIOLOGICAL EMERGENCY PROGRAM, https://www.floridadisaster.org/dem/response/technological-hazards/rep/ (last visited Nov. 13, 2024).
[32] *See* NUCLEAR POWER PLANTS EMERGENCY CLASSIFICATION LEVELS, https://www.floridadisaster.org/dem/response/technological-hazards/rep/nuclear-power-plants-emergency-classification-levels/ (last visited Nov. 13, 2024).

emergency from the nuclear power plants, verifying information contained in the notification, and alerting appropriate state, local, and federal emergency response personnel.[33]

Florida Department of Health

The FDOH has Environmental Radiation Programs to respond to threats to public health and safety from incidents involving nuclear power plants. FDOH responds to all radiation incidents and emergencies, including unexpected radiation releases from nuclear power plants, transportation accidents, lost or stolen radioactive sources, and contamination of a facility or the environment. To prepare for these incidents, FDOH trains its staff and other emergency personnel in emergency response and decontamination procedures and dose assessments. FDOH staff learn how to respond to nuclear reactor emergencies during annual training exercises at the state's nuclear power plants.

At nuclear power plants, FDOH conducts environmental monitoring programs. Thermoluminescent detectors surrounding each power plant site identify direct radiation and special air sampling stations identify radioactive particulate emissions. FDOH staff also collects and analyzes other samples, including vegetation, fish, citrus, watermelon, milk, garden vegetables, shoreline sediment, beach sand, drinking water, surface water, and ground water.

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[33] *See* THE STATE OF FLORIDA RADIOLOGICAL EMERGENCY MANAGEMENT PLAN, https://www.nrc.gov/docs/ML0822/ML082261370.pdf (last visited Nov. 13, 2024).

Chapter 3 - Advanced Nuclear Power Technology

Advanced nuclear power technology maintains the existing benefits of current nuclear power technology, while offering improved safety, scaling, and output features, as well as increased industrial applications and other use cases.

Advanced reactors are developed in different sizes and generation capacities. Although an evolving topic, the DOE recently classified large nuclear reactors as usually having around 1,000 MW capacity, small modular reactors (SMRs) as having anywhere from about 50 to 350 MW capacity, and microreactors as having less than 50 MW.[34] It is important to note that as the characteristics of power output, reactor type, and amount of fuel used in the reactor process changes, the categorization of advance nuclear reactors may also need to be addressed. For example, GAIN, in consultation with EPRI and the Nuclear Energy Institute, produced a Taxonomic Guidance on Advanced Reactors that includes a medium sized reactor ranging up to 600 MW.

Figure 2 - GAIN Categories of Advanced Nuclear Reactors

Size	Operating (MW – Thermal)	Output (MW – Electric)
Micro	<=15	<=50
Small (SMR)	150<=900	50<=300
Medium	1000<=1800	300<=600
Large	>1800	>600

Source: GAIN Taxonomic Guidance on Advanced Reactors[35]

For ease and standardization of information in this report we relied on the recent DOE classifications of reactors.

Technical Feasibility

Advanced nuclear reactors continue a trend of generational improvements in nuclear power technology. Gen II reactors – the majority of the current domestic fleet – are more economical and reliable than the first generation of reactors, while improvements in Gen III reactors are in the areas of fuel technology, thermal efficiency, modularized construction, safety systems (including more passive safety features), and standardized design.[36] Gen II reactors came into service

[34] U.S. DOE, "Pathways to Commercial Liftoff: Advanced Nuclear," p. 20, September 2024, <https://liftoff.energy.gov/advanced-nuclear-2/>, accessed October 28, 2024.
[35] <https://gain.inl.gov/content/uploads/4/2023/11/Taxonomic-Guidance-On-Advanced-Reactors.pdf>
[36] Goldberg & Rosner, "Nuclear Reactors: Generation to Generation," American Academy of Arts & Sciences, January 2011, <https://www.amacad.org/publication/nuclear-reactors-generation-generation>, accessed December 13, 2024.

beginning in the late 1960s, while Gen III reactors first entered service in the mid-1990s.[37] All nuclear reactors in service in Florida are Gen II.

This report highlights two types of advanced reactor designs that have current NRC approval and therefore can be considered technically feasible for construction. Large advanced nuclear technology has been deployed in the U.S. and its benefits are beginning to be realized. Although SMR and micro advanced nuclear technologies appear technically feasible to construct, there are no current operational reactors to review.

Advanced nuclear reactors are classified as belonging to two generations of nuclear technology: Gen III+ and Gen IV**.** Gen III+ reactors use the same fuel and coolant as Gen II and Gen III reactors and work similarly to traditional reactors: they generate energy using fission reactions and use water as coolants and moderators.[38] Gen III+ reactors are safer than Gen III reactors with simplified and updated controls and more passive safety features. Gen IV reactor designs also use fission reactions but with a variety of fuels and coolants.[39] Coolants include molten salts, liquid metals such as sodium, lead, and lead-bismuth, and gases such as helium or carbon dioxide.

Gen III+ and Gen IV reactors also vary by type of fission reactor: thermal or fast neutron. Thermal reactors use a moderator. Fast neutron reactors do not use moderators, and they require the use of fuel that has a higher concentration of fissile material. Some thermal and fast neutron reactors, referred to as breeder reactors, generate nuclear fuel during their reactions.[40]

Gen III+ reactors have been deployed in the U.S., while Gen IV reactors are still being developed. The main improvements of Gen III+ reactors are enhanced safety features and potential lower costs. Gen III+ reactor features include:

- Standardized designs to expedite licensing, reduce capital cost and reduce construction time.
- Simpler and more rugged design, making them easier to operate and less vulnerable to operational upsets.
- Higher availability and longer operating life – typically 60 years.
- Further reduced possibility of core melt accidents.
- Substantial grace period, so that following shutdown the plant requires no active intervention for (typically) 72 hours.
- Stronger reinforcement against aircraft impact than earlier designs, to resist radiological release.

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[37] Ibid.

[38] A moderator is a material, such as water or graphite, used in a reactor to slow down high-velocity neutrons. They are used because slower moving neutrons more efficiently spark fission reactions.

[39] Nuclear fusion reactors exist, but they are still in experimental stages.

[40] Congressional Research Service, Advanced Nuclear Reactors: Technology Overview and Current Issues, updated April 18, 2019, <https://crsreports.congress.gov/product/pdf/R/R45706/2>, accessed October 30, 2024.

- More efficient fuel use, with some estimates showing around 17 percent greater efficiency than Gen II reactors.[41]

Gen IV reactors share many of the same standardized design and passive safety features as Gen III+ reactors while expanding industrial applications and other use cases. These applications and cases include distributed electric power applications, electricity and heat waste applications, and high-temperature process heat applications.[42]

Large Reactors

The NRC has certified three large Gen III+ advanced nuclear reactor designs: Korea Electric Power Corporation's Advanced Power Reactor 1400 (APR1400), GE Hitachi's Economic Simplified Boiling Water Reactor (BWR), and Westinghouse's AP1000.[43] GE Hitachi's BWR is designed to produce 1,520 MW of electricity.[44] The APR1400 and AP1000 are PWRs. Both BWRs and PWRs are thermal reactors that use water as a coolant and moderator. The APR1400 has a net generation capacity of 1,400 MW, while the Westinghouse AP1000 has a generation capacity of around 1,100 MW.[45,46]

The AP1000 is the only design of large advanced nuclear reactor currently in commercial service in the U.S., at Plant Vogtle in Waynesboro, Georgia.[47] The following include a description of the specifics of Westinghouse's AP 1000.

- Figure 3 is an internal view of the reactor,
- Figure 4 includes a demonstration of the power plant's footprint,
- Figure 5 highlights the AP1000 safety features.

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[41] World Nuclear Association, Advanced Nuclear Power Reactors, updated April 1, 2021, <https://world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-power-reactors/advanced-nuclear-power-reactors>, accessed October 30, 2024.

[42] NARUC and NASEO, Energy and Industrial Use Cases for Advanced Nuclear Reactors, p. 6, published October, 2024, <https://www.naseo.org/data/sites/1/documents/publications/ANSC_Nuclear_Cases_Final.pdf>, accessed November 20, 2024.

[43] U.S. NRC, Design Certification Applications for New Reactors, updated May 22, 2023, <https://www.nrc.gov/reactors/new-reactors/large-lwr/design-cert.html#issued>, updated November 20, 2024.

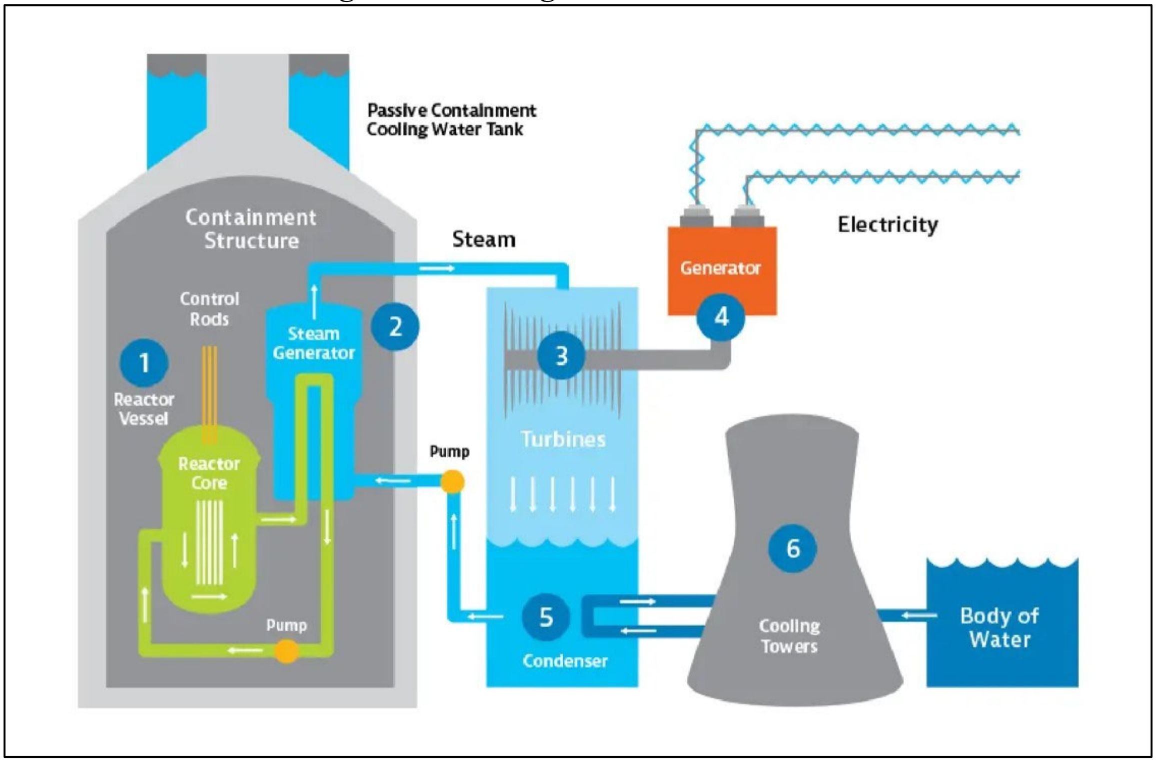
[44] GE Hitachi, Economic Simplified BWR General Description Book, published June 1, 2011, <https://www.gevernova.com/nuclear/carbon-free-power/large-reactors>, accessed November 20, 2024.

[45] Kepco, Major Features of Korean Reactors, <https://home.kepco.co.kr/kepco/EN/G/htmlView/ENGBHP00103.do?menuCd=EN07030103>, accessed December 17, 2024.

[46] Westinghouse, AP1000 Reactor Design Overview, <https://westinghousenuclear.com/energy-systems/ap1000-pwr/overview/>, accessed October 14, 2024.

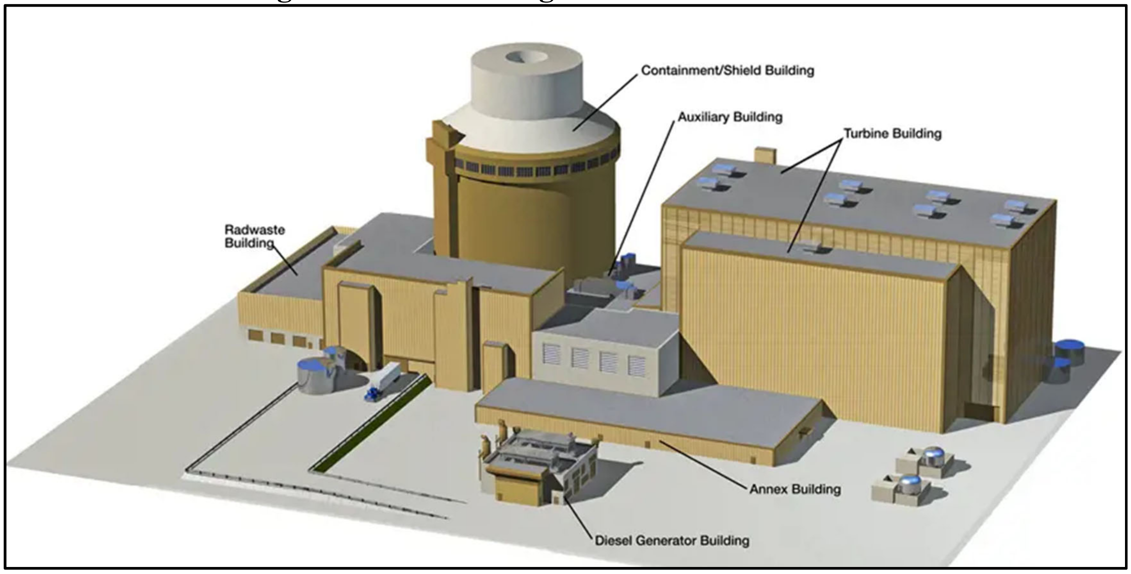
[47] Georgia Power, Plant Vogtle Unit 4 enters commercial operation, released April 29, 2024, <https://www.georgiapower.com/company/news-hub/press-releases/vogtle-unit-4-enters-commercial-operation.html>, accessed October 23, 2024.

Figure 3: Westinghouse AP1000



Source: Westinghouse

Figure 4: The Westinghouse AP1000 Plan



Source: Westinghouse

AP1000 Reactor Design Features

The AP1000 reactor design features include:

- Simplified safety systems, normal operating systems, control room, construction techniques, and instrumentation and control systems
- 60 years operational design
- 93 percent capacity factor (represents how often a unit is able to produce electricity during a given time span)
- 18-24 month fuel cycle (amount of time a reactor can produce power until it must be refueled)
- Fully passive safety systems [48,49]

AP1000 Passive Safety Features

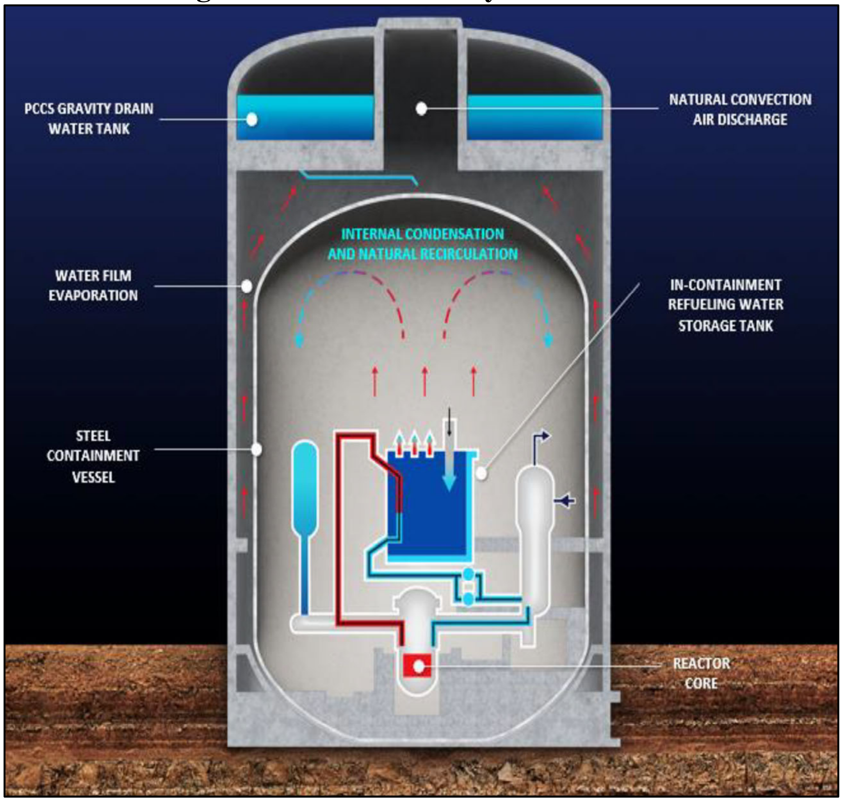
The AP1000 is designed to reach and sustain safe shutdown conditions without operator action, and without the need for Alternating Current (AC) power or pumps in the event of a design-basis accident by relying on gravity, natural circulation and compressed gases to keep the core and the containment from overheating.

Other AP1000 safety features include:

- Systems that activate automatically to respond to the day-to-day changes in the reactor coolant system temperature, pressure, or both, caused by changes in the reactor's power output. These provide a first level of defense to reduce the likelihood of unnecessary actuation and operation of the safety-related systems.
- In-vessel Retention of Core Damage feature that drains the high capacity in-containment refueling water storage tank water into the reactor cavity in the event that the core has overheated, providing cooling on the outside of the reactor vessel to prevent vessel failure and subsequent spilling of molten core debris.
- Fission Product Release prevention features, including fuel cladding, reactor coolant pressure vessel and piping boundary, along with a steel containment vessel. Fuel cladding provides the first barrier to the release of radiation. The reactor coolant pressure vessel and piping boundary provide independent barriers to prevent the release of radiation. The steel containment vessel, in conjunction with the surrounding shield building, provides additional protection by establishing a third barrier and by providing natural convection air currents to cool the steel containment.[50]

[48] Westinghouse, AP1000 Design, <https://westinghousenuclear.com/energy-systems/ap1000-pwr/overview/>, accessed October 14, 2024.
[49] Westinghouse, Improved Nuclear Power Plant Operations, <https://westinghousenuclear.com/energy-systems/ap1000-pwr/operations-and-maintenance/>, accessed October 14, 2024.
[50] Westinghouse, Nuclear Safety - Unequaled Design, <https://westinghousenuclear.com/energy-systems/ap1000-pwr/safety/>, accessed October 14, 2024.

Figure 5: AP1000 Safety Features



Source: Westinghouse

Small Modular Reactors

SMRs are around one tenth the physical size of traditional large nuclear reactors, with a generating capacity of 50 to 350 MW. As the name denotes, SMRs are designed to be modular in order to standardize production, which drives down costs and facilitates construction. SMRs have a lifespan of 60 or more years. Initially SMRs may be more expensive than large reactors on a MW basis, but they may be better suited than large reactors for certain applications, such as replacing smaller retiring coal plants or industrial processes requiring high temperature heat. SMRs may also offer potential siting, construction, and financial advantages.

There are a variety of SMR designs under development. Some designs use the same coolant and fuel as large Gen III+ reactors. Other designs use different coolants, such as gas, liquid metal, or molten salt, as well as different or no moderators. Some designs use different fuels than the current generation of reactors. SMRs also utilize passive safety features. The World Nuclear Association listed several advanced U.S. SMR designs (table below). These reactors are near deployment, or have had deployment attempted, while other designs are at various earlier stages of development.

Figure 6: U.S. Small Reactors for Near-term Deployment – Development Well Advanced[51]

Name	Capacity	Type	Developer
BWRX-300	300 MW	BWR	GE Hitachi, USA
Xe-100	80 MW	HTGR	X-energy, USA
NuScale Power Module	77 MW	PWR	NuScale Power + Fluor, USA
SMR-160	160 MW	PWR	Holtec, USA + SNC-Lavalin, Canada
CNSP (Combined Nuclear/Solar Plant)	300 MW	PWR/solar thermal system	Holtec, USA
PRISM	311 MW	SFR	GE Hitachi, USA
Natrium	345 MW	SFR	TerraPower + GE Hitachi, USA
ARC-100	100 MW	SFR	ARC with GE Hitachi, USA

Source: World Nuclear Association

In addition to BWR and PWR designs, there are a variety of Gen IV reactor designs which include:

- Gas-Cooled Fast Reactors are fast neutron reactors that typically use helium gas as a coolant with no moderator. They can be designed to produce from 0.5 MW to 2,400 MW.
- High Temperature Gas Reactors are thermal reactors that typically use helium gas as a coolant with graphite as a moderator. Very High Temperature Reactors are a type of high temperature gas reactor that reaches reactor temperatures greater than 750 degrees Celsius. They are often designed as SMRs with capacities under 300 MW.
- Lead-Cooled Fast Reactors are fast neutron reactors that use molten lead or lead-bismuth alloy as a coolant with no moderator. They can be designed to produce 25 MW to 450 MW.
- Molten Salt Reactors are thermal or fast neutron reactors that typically use molten fluoride salt as a coolant with moderator use depending on reactor type. They can be designed to produce up to 600 MW.
- Sodium-Cooled Fast Reactors are fast neutron reactors that typically use liquid sodium as a coolant with no moderator. They can be designed to produce from 50 to 1,500 MW.
- Supercritical Water-Cooled Reactors are thermal or fast neutron reactors that use supercritical water as a coolant with water typically used as a moderator. They can be designed to produce between 300 and 1,700 MW.[52]

In the U.S., NuScale Power's VOYGR SMR is the first Gen IV SMR design to receive approval from the NRC.[53] It has come closest to commercial deployment. In 2014, Utah Associated Municipal Power Systems (UAMPS) proposed replacing coal-fired power plants with NuScale

[51] World Nuclear Association, Small Nuclear Reactors, accessed November 12, 2024, <https://world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-power-reactors/small-nuclear-power-reactors>, updated February 16, 2024.
[52] Resources for the Future, Advanced Nuclear Reactors 101, published March 26, 2021, <https://www.rff.org/publications/explainers/advanced-nuclear-reactors-101/>, accessed November 20, 2024.
[53] U.S. Nuclear Regulatory Commission, Design Certification - NuScale US600, updated March 14, 2024, <https://www.nrc.gov/reactors/new-reactors/smr/licensing-activities/nuscale.html>, accessed October 30, 2024.

Power's VOYGR SMR. In 2015, the project was formally launched and designated the Carbon Free Power Project (CFPP) as part of its long-term strategy to reduce carbon emissions.

The CFPP originally called for the construction of NuScale Power's VOYGR SMR, containing twelve 77 MW power modules at the Idaho National Laboratory site.[54] It progressed through all early planning stages and was on track for a January 2024 filing of a Combined License application at the NRC. However, by 2020, multiple municipalities had withdrawn or reduced the amount of electricity they would purchase through the CFPP because of cost overruns and delays from the scheduled 2026 operational date. The reduced subscription rate led to concerns of rising costs for the remaining cities, which ultimately led to the cancellation of the CFPP in November 2023.[55,56] NuScale Power asserts that despite the cancellation, many lessons were learned that will benefit deployment of its SMRs in the future, including being able to use the Combined License application as a reference for future projects.[57]

NuScale Power Modular Reactor Design

The NuScale Power Module is the smallest PWR with natural circulation. It can generate 77 MW of electricity. Multiple power modules can be combined in a power plant with the largest plant design, the VOYGRTM-12, allowing up to 12 power modules for a total output of 924 MW (gross).[58] The module is factory-built and transportable to the plant site by ship, rail, or truck, and the plant design also incorporates many commercial, off-the-shelf items.

The NuScale Power Module has a three meter diameter pressure vessel and convection cooling, with the only moving parts being the control rod drives. It uses standard light-water reactor fuel in normal PWR fuel assemblies (which are 2 meters long), with up to a 21-month refueling cycle.[59]

NuScale Power Module Reactor Features

The NuScale Power Module will use compact Helical Coil Steam Generators that provide a large heat transfer surface area in a small volume and maximize natural circulation flow in the primary loop. The high strength steel containment vessel is immersed in the cooling pool and acts as a heat exchanger to transfer reactor heat to the pool water in order to limit containment pressure and as a passive heat sink for heat removal under loss-of coolant accident conditions.

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[54] Idaho National Laboratory, Carbon Free Power Project, <https://inl.gov/trending-topics/carbon-free-power-project/>, accessed November 25, 2024.

[55] Power Magazine, "Shakeup for 720-MW Nuclear SMR Project as More Cities Withdraw Participation," published October 29, 2020, <https://www.powermag.com/shakeup-for-720-mw-nuclear-smr-project-as-more-cities-withdraw-participation/>, accessed November 25, 2024.

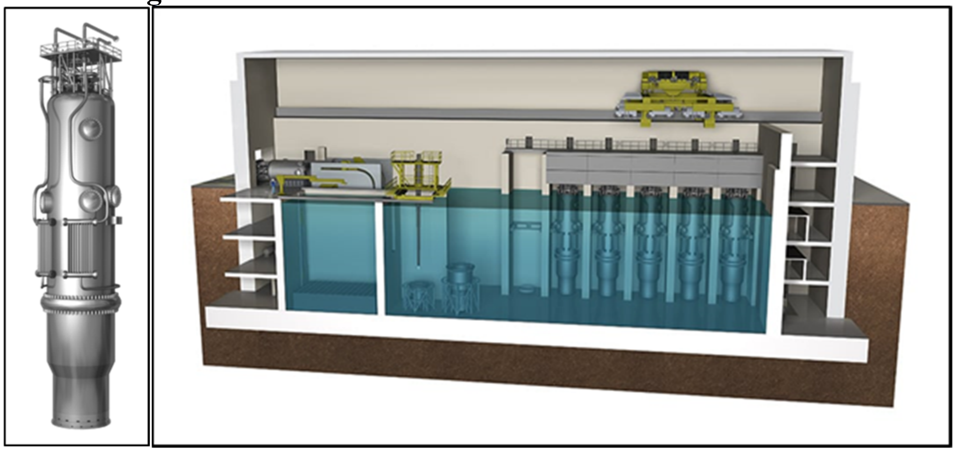
[56] UAMPS Carbon Free Power Project, Press Release, published November 8, 2023, <https://www.uamps.com/Carbon-Free>, accessed October 30, 2024.

[57] Ibid.

[58] NuScale, VOYGR Power Plants, <https://www.nuscalepower.com/en/products/voygr-smr-plants>, accessed October 14, 2024.

[59] World Nuclear Association, Advanced Nuclear Power Reactors, updated April 1, 2021, <https://world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-power-reactors/advanced-nuclear-power-reactors>, accessed October 30, 2024.

Figure 7: NuScale Power Module and VOYGR Plant



Source: NuScale

NuScale Safety Features

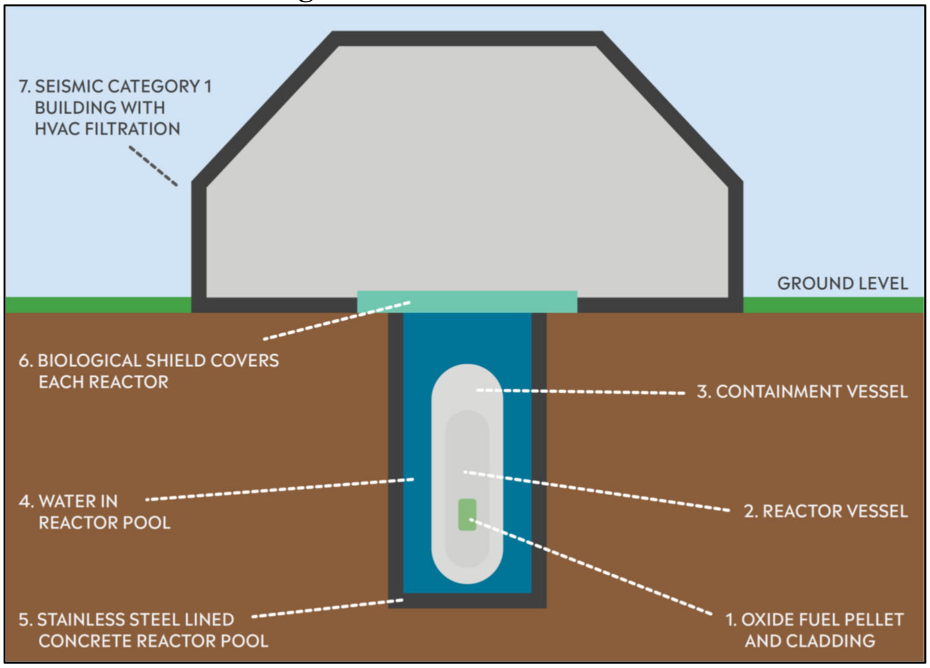
NuScale's Power Module SMR safety features include:

- The ability to safely shut down and self-cool indefinitely with no operator action, no AC or Direct Current (DC) power, and no additional water. This is a first for commercial nuclear power.
- A reactor design that eliminates the need for large coolant piping and pumps.
- A small nuclear fuel inventory, with each NuScale Power Module housing approximately five percent of the nuclear fuel contained in a conventional 1,000 MW nuclear reactor.
- A high-pressure containment vessel with redundant passive decay heat removal and containment heat removal systems, that is submerged in an ultimate heat sink for core cooling in an underground reactor pool structure housed in an earthquake-resistant reactor building.[60]
- An Emergency Planning Zone (EPZ), the area surrounding a plant where special considerations and management practices are pre-planned and exercised in case of an emergency, that extends only as far as the site boundary (as opposed to 10 miles for current U.S. plants).[61]

[60] Nuclear Energy International, "U.S. NRC validates NuScale's Emergency Planning Zone boundary methodology," October 25, 2022, <https://www.neimagazine.com/news/us-nrc-validates-nuscales-emergency-planning-zone-boundary-methodology-10115990/>, accessed October 31, 2024.

[61] Nuclear Energy International, "U.S. NRC validates NuScale's Emergency Planning Zone boundary methodology," October 25, 2022, <https://www.neimagazine.com/news/us-nrc-validates-nuscales-emergency-planning-zone-boundary-methodology-10115990/>, accessed October 31, 2024.

Figure 8: NuScale's Barriers



Source: NuScale

Microreactors

Microreactors are small advanced nuclear reactors generating less than 50 MW. These reactors can operate as part of the electric grid or independently for other uses such as generating heat for industrial applications. Most are designed to be portable and could be hauled by a tractor-trailer. Interest in these very small reactors is driven by a number of factors, including the need to generate power on a small scale in remote locations, at deployed military installations, and in locations recovering from natural disasters.[62]

In addition to the several microreactor designs more akin to that of a traditional nuclear reactor, there is also a Gen IV microreactor, Heat Pipe Cooled Reactors design. The Heat Pipe Cooled Reactor uses no coolant, while using a control drum often made of metal hydride alloys as a moderator. These microreactors are designed to produce less than 10 MW.[63]

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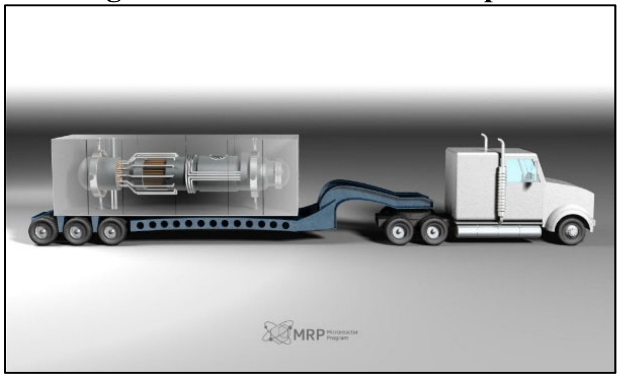
[62] Idaho National Laboratory, Microreactors, <https://inl.gov/trending-topics/microreactors/>, accessed October 30, 2024.

[63] Science Direct, Heat Pipe Cooled Reactor, <https://www.sciencedirect.com/topics/engineering/heat-pipe-cooled-reactor>, accessed November 20, 2024.

Figure 9: Microreactor Transport



Source: Idaho National Laboratory

Microreactor features include:

- Factory production and modularity: most microreactor components are intended to be factory produced to increase standardization, learning rate, and cost predictability
- Transportability: could be shipped to remote areas and moved from one location to another by truck, ship, or plane
- Streamlined siting and installation: factory produced modules are intended to be shipped to location, reducing the need for on-site construction
- Grid independence: co-location with company or facility that agrees to purchase power
- Longer refueling cycle: most designs have 3-10 years between refueling (which leads to the colloquial term "nuclear batteries")
- Use of a variety of coolants and fuels
- Passive safety features[64]

The World Nuclear Association listed several U.S. microreactor designs (table below). These and other designs are at various stages of development.

[64] U.S. DOE, "Pathways to Commercial Liftoff: Advanced Nuclear," p. 28, September 2024, <https://liftoff.energy.gov/advanced-nuclear-2/>, accessed October 28, 2024.

Figure 10: U.S. Microreactor Designs Being Developed[65]

Name	Capacity	Type	Developer
Aurora	1.5 MW	HPCR	Oklo, USA
eVinci	0.2-5 MW	HPCR	Westinghouse, USA
NuScale micro	1-10 MW	HPCR	NuScale, USA
MMR-5/-10	5 or 10 MW	HTGR	UltraSafe Nuclear, USA
Holos Quad	3-13 MW	HTGR	HolosGen, USA
Xe-Mobile	1-5 MW	HTGR	X-energy, USA
BANR	50 MW	HTGR	BWXT, USA
Gen4 module	25 MW	LFR	Gen4 (Hyperion), USA
Hermes prototype	35 MW	MSR	Kairos, USA

Source: World Nuclear Association

Other Use Cases

Advanced nuclear reactors are able to be used in a variety of applications and other use cases that previous generations of nuclear reactors are not. These other use cases include distributed electric power applications, electricity and heat waste applications, and high-temperature process heat applications.[66]

Distributed electric power applications and use cases include providing electric service at remote locations and locations where reliability of power and size of the reactor is important, such as mining operations, oil and gas extraction, data centers, spacecraft, and military bases (see Chapter 5 for military applications). Electricity and heat waste applications and use cases include heating local buildings, desalination, and carbon capture processes.[67] Excess heat can also be used with heat exchanger pumps to provide district cooling.[68] High-temperature process heat applications include using the high temperatures generated by the nuclear reaction for chemical industrial applications, steel, glass, or cement production, and hydrogen production.[69]

Large advanced nuclear technology has been deployed in the U.S., and its benefits are beginning to be realized. SMR and micro advanced nuclear technologies appear technically feasible, but as of yet, remain unproven. The economic challenge is the greatest hurdle to the deployment of these nascent technologies.

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[65] World Nuclear Association, Small Nuclear Reactors, accessed November 12, 2024, <https://world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-power-reactors/small-nuclear-power-reactors>, updated February 16, 2024.

[66] NARUC and NASEO, Energy and Industrial Use Cases for Advanced Nuclear Reactors, p. 6, published October, 2024, <https://www.naseo.org/data/sites/1/documents/publications/ANSC_Nuclear_Cases_Final.pdf>, accessed November 20, 2024.

[67] Ibid, p.10-14.

[68] International Atomic Energy Association, The Use of Nuclear Power Beyond Generating Electricity: Non-Electric Applications, posted October 18, 2021, <https://www.iaea.org/newscenter/news/the-use-of-nuclear-power-beyond-generating-electricity-non-electric-applications>, accessed December 18, 2024.

[69] NARUC and NASEO, Energy and Industrial Use Cases for Advanced Nuclear Reactors, p. 10-14, published October, 2024, <https://www.naseo.org/data/sites/1/documents/publications/ANSC_Nuclear_Cases_Final.pdf>, accessed November 20, 2024.

Economic Feasibility

Meeting future electricity demand with the expansion of advanced nuclear power technology requires consideration of many economic factors, including the ability to reduce costs, the costs of electricity, and federal support. This section discusses the economics of how reactor type and changing production levels affect costs.

First-of-a-Kind (FOAK) to Nth-of-a-Kind (NOAK)

Cost estimates are critical in determining the type and number of reactors to be built. Cost analysis often quantifies differences in cost by classifying reactors by production order using FOAK and NOAK. The first units produced (FOAK projects) are the most expensive, but as additional units are produced, efficiency gains reduce the cost of production until NOAK costs are realized. NOAK projects are at a cost minimum, because efficiency gains have been maximized.

Currently two large advanced reactors are in commercial service in the U.S., while no commercial advanced SMRs or microreactors have been built. Advanced nuclear plant costs are currently at FOAK or near FOAK levels, but significant cost reductions can be realized with additional deployment. Given the importance of reducing costs in encouraging deployment, the U.S. DOE published its Pathways to Commercial Liftoff: Advanced Nuclear (Liftoff) report to detail estimates and methods of achieving these reductions.[70] The DOE Liftoff report was the primary source utilized for developing the economic feasibility portion of this report. Although there are multiple reliable sources of information, the Liftoff report was used as a substitute for in-house expertise in the developing advanced nuclear reactor market.

The Liftoff report states that savings from learning by producing the first few units result in estimated cost reductions of around 45 to 60 percent between the first and third plant deployed of a given reactor concept.[71] After publication of the Liftoff report, the Idaho National Laboratory, Argonne National Laboratory, and the Massachusetts Institute of Technology created a framework for quantifying pathways from FOAK to NOAK costs. The framework identifies learning effects that can be adjusted to evaluate their impact on cost reduction:

- **Design completion**: when construction begins with lower design completion, there are typically more licensing amendments and rework, resulting in delays and cost increases
- **Design maturity:** novel designs with complex material science that require components that have never been built before will likely have higher costs and risks
- **Cross-site standardization**: the more standardized builds are, the lower the costs of subsequent units as design modifications and engineering evaluations are minimized
- **Orderbook quantity:** bulk order discounts can reduce costs for all reactors, including the first reactor

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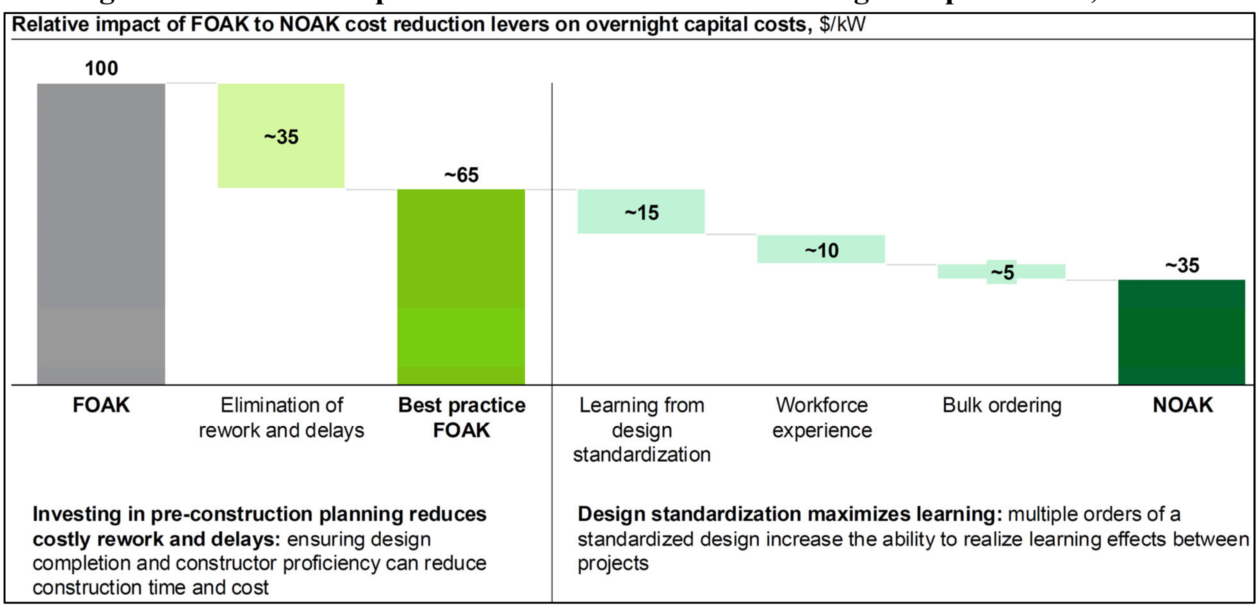
[70] U.S. DOE, "Pathways to Commercial Liftoff: Advanced Nuclear," September 2024, <https://liftoff.energy.gov/advanced-nuclear-2/>, accessed October 16, 2024.
[71] Ibid, p. 32..

- **Supply chain proficiency:** a combination of contractor experience and best practices implemented by the contractor
- **Construction contractor proficiency:** contractor's ability to effectively plan and execute nuclear megaprojects
- **Architect/engineer contractor proficiency**: lower proficiency leads to redesigning components, delays, and higher indirect costs[72]

Other major factors identified in the Liftoff report in progressing from FOAK to NOAK costs include investments in pre-construction planning to eliminate rework or delays and labor productivity gains from experience. The figure below estimates the reduction in overnight capital cost (OCC) due to elimination or rework and delays, learning from design standardization, workforce experience, and bulk ordering.[73] It shows that FOAK OCC's could be reduced around 35 percent through best practices, as well as a further 30 percent reduction by reaching NOAK production levels.[74]

Figure 11: Relative impact of FOAK to NOAK on Overnight Capital Costs, $/kW



Source: Liftoff Report p. 33

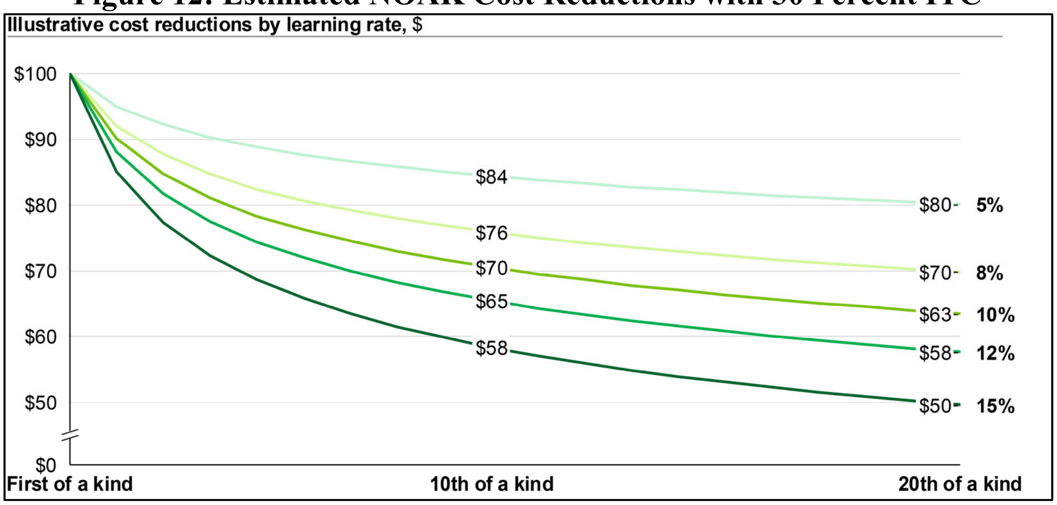
The Liftoff report asserts that the greatest cost reduction opportunities are likely to come from labor cost reductions from learning by doing, from having standardized construction processes or process management, and from co-processing of tasks and proper hand-offs that reduce total

[72] U.S. DOE, "Pathways to Commercial Liftoff: Advanced Nuclear," p. 33, September 2024, <https://liftoff.energy.gov/advanced-nuclear-2/>, accessed October 16, 2024.
[73] Overnight capital cost is the cost of capital without financing charges.
[74] U.S. DOE, "Pathways to Commercial Liftoff: Advanced Nuclear," p. 33, September 2024, <https://liftoff.energy.gov/advanced-nuclear-2/>, accessed October 16, 2024.

construction time. It suggests that lesser cost reductions can also be achieved through supply chain development and modularization.[75]

The report also identifies additional cost factors. Construction duration affects total costs by impacting finance costs, while also potentially exposing projects to the risk of changes in the economic and political environments.[76] Another factor in cost reduction is bulk ordering. The Liftoff report states that bulk orders of over 10 reactors could lead to a cost reduction of around 15 percent compared to a single build without an order book. It suggests that a builders' consortium of asset owners spreading early construction costs or a buyers' consortium of pooling demand for an average price with a committed orderbook of 10 or more units can significantly reduce the financial risks involved, with additional savings possible by siting multiple reactors at the same location.[77] The figure below estimates the reductions in NOAK costs based on different learning rates and the number of units with a 30 percent ITC. It shows costs decreasing as the number of units deployed increases, with higher learning rates leading to lower costs.[78,79]

Figure 12: Estimated NOAK Cost Reductions with 30 Percent ITC



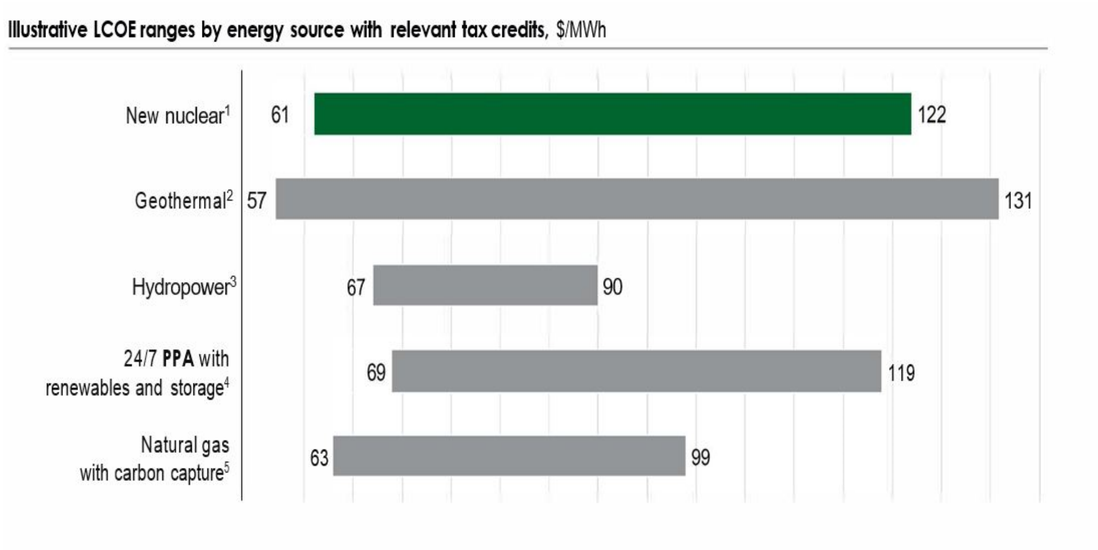
Source: Liftoff report p.36

[75] U.S. DOE, "Pathways to Commercial Liftoff: Advanced Nuclear," p. 34, September 2024, <https://liftoff.energy.gov/advanced-nuclear-2/>, accessed October 16, 2024.
[76] Ibid, p. 34.
[77] U.S. DOE, "Pathways to Commercial Liftoff: Advanced Nuclear," p. 34, September 2024, <https://liftoff.energy.gov/advanced-nuclear-2/>, accessed October 16, 2024.
[78] The ITC is discussed in the federal support section.
[79] U.S. DOE, "Pathways to Commercial Liftoff: Advanced Nuclear," p. 36, September 2024, <https://liftoff.energy.gov/advanced-nuclear-2/>, accessed October 16, 2024.

Levelized Cost of Electricity (LCOE)

The LCOE is the average cost per unit of electricity generated to cover the costs of building and operating a power plant over its lifetime. It is an industry practice to utilize the LCOE when comparing generation options. It includes factors such as capital expenditures, operations expenditures, capacity factor, fuel costs, taxes, resource availability, cost of capital, and efficiency.[80] The Liftoff report included LCOE estimates for nuclear and other energy resources. The figure below compares LCOEs of various clean, firm energy sources.

Figure 13: Illustrative LCOE Ranges of Clean Firm Sources



Source: Liftoff report p. 11

Construction costs can drive around 70 to 80 percent of nuclear's LCOE, while operating costs are low and predictable. This predictability compares favorably with natural gas, where rather than construction costs, the LCOE is strongly influenced by fuel prices that can create volatility in operating costs.[81] LCOE does not reflect all of the value of nuclear generation, including lowering interconnection and transmission costs, providing consistent power generation, and having operating life which exceeds the typical 30 year amortization of project construction costs.[82]

Large Gen III+ Reactor Cost Factors

Large advanced nuclear reactors are physically larger with higher corresponding electricity outputs than other advanced reactors, and the greater size of these reactors presents multiple economic benefits and challenges. These reactors benefit from economies of scale. Gen III+ are larger multi-

[80] Science Direct, Levelized Cost of Electricity, <https://www.sciencedirect.com/topics/engineering/levelized-cost-of-electricity>, accessed November 25, 2024.
[81] U.S. DOE, "Pathways to Commercial Liftoff: Advanced Nuclear," p. 36, September 2024, <https://liftoff.energy.gov/advanced-nuclear-2/>, accessed October 16, 2024.
[82] Ibid, p. 37-38.

unit nuclear plants and have the lowest production costs, with generating costs at multi-unit plants being 30 percent cheaper per MW than single unit plants. Economies of scale also mean lower cost per MW because fixed costs are spread across greater capacity than in smaller plants.[83]

Large reactors also face some economic drawbacks. It is more difficult to reach NOAK costs, given the high cost of large reactors due to megaproject issues.[84] Larger reactors face longer construction times than smaller reactors. Construction time for large light water reactors varies by degree of cost overruns. Construction with no cost overruns has a median completion time of 60 months, while construction with some and significant cost overruns have median completion times of 82 and 125 months, respectively. Longer construction times lead to increased financing costs and greater risk of possible adverse political, economic, and other conditions.[85]

Plant Vogtle

As previously discussed, the Westinghouse AP1000 is the only advanced large reactor design currently in commercial service in the U.S., Plant Vogtle units 3 and 4 located in Waynesboro, Georgia.[86] These reactors entered commercial operations on July 31, 2023, and April 29, 2024.[87]

The original budget for Plant Vogtle Units 3 and 4 was approximately $14 billion, while the final cost was around $32 billion. In 2017, Georgia Power's parent corporation Southern Company took over the project management role and reset of the project budget to around $26 billion, especially after accounting for COVID impacts (supply chain issues, labor shortages, changes in regulatory requirements).[88]

Plant Vogtle Units 3 and 4 were lengthy and expensive construction projects but they demonstrate the viability of large Gen III+ advanced nuclear reactors. Future AP1000 deployments will benefit heavily from these projects. In fact, it has been suggested by some in the nuclear energy sector that Plant Vogtle Unit 4 may have realized as much as a thirty percent cost savings compared to Unit 3. Additional cost and schedule improvements are expected for subsequent AP1000s, as is typical for projects following a FOAK deployment. One MIT study points to a potential 26 to 53 percent reduction in construction cost for the next AP1000 to be deployed in the U.S.[89] Factors driving the anticipated cost reduction include: the fact that the AP1000 design is now fully complete and

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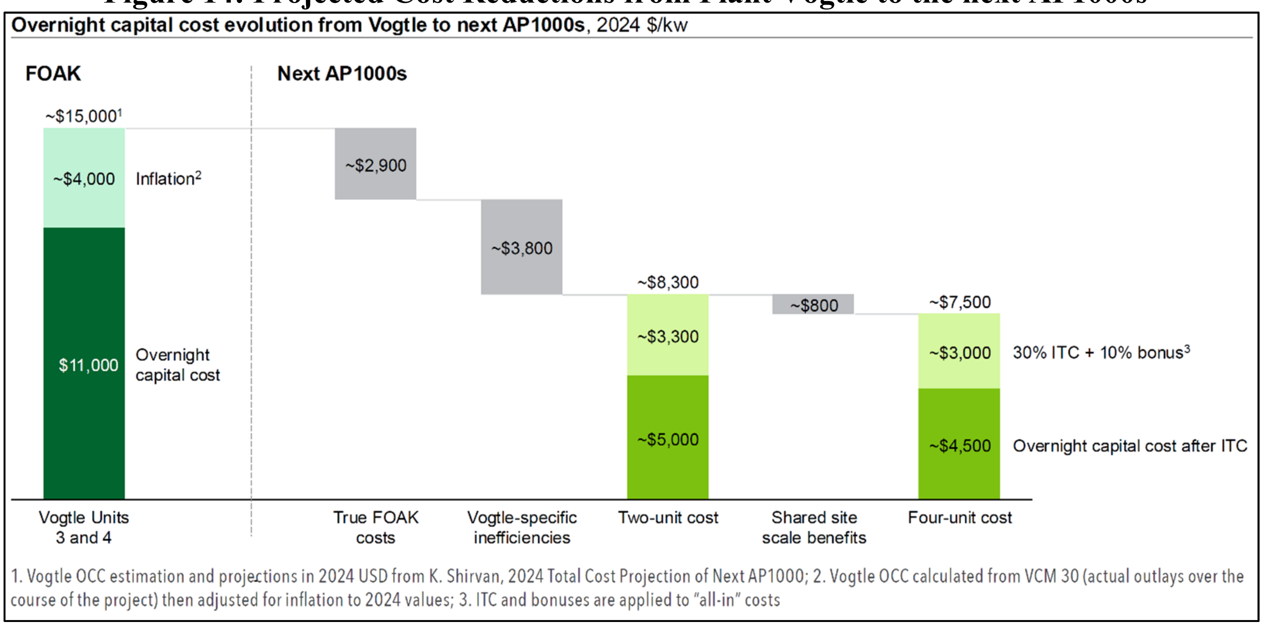
[83] U.S. DOE, "Pathways to Commercial Liftoff: Advanced Nuclear," p. 26, September 2024, <https://liftoff.energy.gov/advanced-nuclear-2/>, accessed October 16, 2024.
[84] Ibid, p. 26.
[85] Abou-Jaoude, Abdalla, et al., "Meta-Analysis of Advanced Nuclear Reactor Cost Estimations," Revision 2, p. 76-77, U.S. DOE, July 2024, <https://www.osti.gov/biblio/2371533>, accessed October 14, 2024.
[86] Four AP1000 reactors are also in service in Sanmen and Haiyang, China, with eight more under construction. An additional four approved for construction with two in Guanxi Province and two in Guangdong Province.
[87] Georgia Power, Plant Vogtle Unit 4 enters commercial operation, released April 29, 2024, <https://www.georgiapower.com/company/news-hub/press-releases/vogtle-unit-4-enters-commercial-operation.html>, accessed October 23, 2024.
[88] U.S. DOE, "Pathways to Commercial Liftoff: Advanced Nuclear," p. 47, September 2024, <https://liftoff.energy.gov/advanced-nuclear-2/>, accessed October 16, 2024.
[89] Shirvan, Koroush, "Overnight Capital Cost of the Next AP1000," Center for Advanced Nuclear Energy Systems, MIT, published March 2022, <https://canes.mit.edu/overnight-capital-cost-next-ap1000>, accessed October 16, 2024.

approved by the NRC; the supply chain to deliver AP1000 components is now established; and a trained tradecraft, technical, and project management workforce with experience executing AP1000 construction projects now exists.[90]

According to the Liftoff report, the OCC of Plant Vogtle Units 3 and 4 was around $15,000 per kW in 2024 dollars.[91] In the U.S. DOE's assessment, removing true FOAK costs and Plant Vogtle-specific issues results in a pre-ITC OCC estimate of around $8,300 per kW, and including the ITC (with one adder) would further reduce the costs by 40 percent to around $5,000 per kW.[92] Further AP1000 deployments would be eligible for Investment Recovery Act support (see section on federal support), which could decrease the LCOE to below $100 per megawatt-hour (MWh), even after increased interest rates and inflation.[93,94] The report also suggests that reduced cost and shorter construction time would further reduce the projected LCOE to around $60/MWh.[95] The projected decrease in OCC from further AP1000 deployments are illustrated in the figure below.

Figure 14: Projected Cost Reductions from Plant Vogtle to the next AP1000s



Source: Liftoff report, p. 54.

Note: These projected costs are for the next AP1000 deployment; they do not reflect NOAK costs.

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[90] Williams, Bradley J., et al., "Opportunities for AP1000 Deployment at Existing and Planned Nuclear Sites," Idaho National Laboratory, p. 2, published August 1, 2024, <https://www.osti.gov/biblio/2437758>, accessed October 16, 2024.

[91] 1,000 kilowatts equal one megawatt.

[92] U.S. DOE, "Pathways to Commercial Liftoff: Advanced Nuclear," p. 53, September 2024, <https://liftoff.energy.gov/advanced-nuclear-2/>, accessed October 16, 2024.

[93] A megawatt-hour is the energy equivalent to one megawatt used continuously for one hour.

[94] U.S. DOE, "Pathways to Commercial Liftoff: Advanced Nuclear," p. 54, September 2024, <https://liftoff.energy.gov/advanced-nuclear-2/>, accessed October 16, 2024.

[95] Ibid, p. 54.

Small Modular Reactor Cost Factors

SMRs are around one tenth the size of large nuclear reactors, and they generate up to one third of the electricity. Their smaller size and outputs present different economic benefits and challenges than large reactors.

SMRs will enjoy several economic benefits. Their modular designs should help reduce construction costs by maximizing design standardization and factory production. In order to benefit from economies of scale, more than half of SMR total production costs should be incurred in factory production.[96] Their smaller size means that SMR projects require less capital for construction with lower overall costs, and it also leads to shorter construction times. The median construction completion time is projected to be 43 months with no cost overruns, 55 months with some cost overruns, and 71 months with significant cost overruns.[97] The lower overall cost for SMRs also means that less capital will be required, leading to lower financing and overall costs. Also, less labor is required for construction, so if the labor environment is constrained, SMRs may be more cost-effective than larger reactors. They may also be able to achieve some cost savings by utilizing retired coal power plant sites and making use of existing transmission infrastructure. Around 80 percent of almost 400 coal power plant sites have the characteristics needed to host a nuclear reactor.[98] SMRs' lower overall cost could entice more companies to invest, helping them to more quickly move from FOAK costs towards NOAK costs.

SMRs also face some economic challenges. Their smaller size means that they will likely be more expensive per MW for FOAK projects. To overcome diseconomies of scale, SMRs will likely need around 50 percent of OCC occurring in factory production.[99] The large number of different SMR designs could hamper deployment by delaying the cost benefits from moving from FOAK to NOAK production. The Liftoff report states that 5 to 10 reactors of the same design are needed to catalyze putting SMRs into commercial service as construction costs are largely expected to decrease based on repeat building and learning by doing.[100] They have yet to be put into commercial service in the U.S., so the true nature of FOAK costs for SMRs is unknown.

[96] U.S. DOE, "Pathways to Commercial Liftoff: Advanced Nuclear," p. 27, September 2024, <https://liftoff.energy.gov/advanced-nuclear-2/>, accessed October 16, 2024.
[97] Hansen, J., et al., "Investigating Benefits and Challenges of Converting Coal Plants into Nuclear Plants," Revision 2, U.S. DOE, published September 13 2022, <https://inldigitallibrary.inl.gov/sites/sti/sti/Sort_62780.pdf>, accessed October 14, 2024.
[98] U.S. DOE, "Pathways to Commercial Liftoff: Advanced Nuclear," p. 17, September 2024, <https://liftoff.energy.gov/advanced-nuclear-2/>, accessed October 16, 2024.
[99] Ibid, p. 27.
[100] U.S. DOE, "Pathways to Commercial Liftoff: Advanced Nuclear," p. 3, September 2024, <https://liftoff.energy.gov/advanced-nuclear-2/>, accessed October 16, 2024.

Microreactor Cost Factors

Microreactors include the smallest reactor designs. Their very small size and outputs present unique economic benefits and challenges. The U.S. has no commercial microreactors in service. Cost uncertainty is high due to nascence.

Microreactors have several economic advantages. Their small size means that they can have greater factory production outputs, aiding in standardization and capital cost reduction. Microreactors have longer fuel cycles than larger reactors, with most lasting 3 to 10 years before refueling. Microreactors' small scale should reduce the need for operators.[101] Microreactors can also benefit from the same subsidies and programs as other reactors and from other programs like the Accelerating Deployment of Versatile, Advanced Nuclear for Clean Energy (ADVANCE) Act of 2024(discussed in Chapter 4) which requires the NRC to develop guidance to license and regulate microreactor designs.[102] Given microreactor designers are considering factory fabrication to deploy multiple units of a standardized design, the NRC is proactively engaging with stakeholders and developing licensing strategies to support the effective and timely licensing of microreactors of a standardized design.[103] Microreactors could serve multiple use cases at military bases and remote applications such as mining, rural communities, industrial operations, and disaster relief, replacing expensive diesel generators.

Microreactors also face significant potential economic disadvantages. They have diseconomies of scale with likely higher cost per MW than larger reactors, and they will likely need mass production in order to be cost-effective, with as much as 70 to 80 percent of microreactor OCC occurring in factory production.[104] Orders of 30 to 50 reactors may be needed to justify the business case for microreactor factories.[105]

Regulatory Cost Considerations

As described in Chapter 2 of this report, the Commission is the agency charged with the economic regulation of utility service providers. Florida's investor-owned utilities petition the Commission to recover the costs of providing electric service, including the costs associated with the construction, operation, and maintenance of energy generation facilities. The traditional rate-making process allows for these investments to be recovered through base rates of all ratepayers. Rates are established for different customer classes based upon cost of service studies. Customer classes that are more costly to serve will generally have higher rates, but the total cost is spread among all ratepayers since the new power plant serves all customers. The general principle in cost

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[101] Ibid, p. 28.
[102] U.S. DOE, "Newly Signed Bill Will Boost Nuclear Reactor Deployment in the United States," July 10, 2024, <https://www.energy.gov/ne/articles/newly-signed-bill-will-boost-nuclear-reactor-deployment-united-states>, accessed October 16, 2024.
[103] U.S. DOE, "Pathways to Commercial Liftoff: Advanced Nuclear," p. 28, September 2024, <https://liftoff.energy.gov/advanced-nuclear-2/>, accessed October 16, 2024.
[104] U.S. DOE, "Pathways to Commercial Liftoff: Advanced Nuclear," p. 28, September 2024, <https://liftoff.energy.gov/>, accessed October 16, 2024.
[105] Ibid.

allocation is that the cost causer should pay. It is important to balance the costs and risks associated with the FOAK deployment of technologies with the ratepayer in mind. Signing power purchase agreements with large companies or investing with a consortium have been identified as ways to improve the business case for investing in advanced nuclear technologies.

Recent and Future Deployments

The federal government is encouraging deployment through the Advanced Reactor Demonstration Program (ARDP).[106] The ARDP has supported the demonstration of two advanced nuclear reactors, X-energy's XE-100 and TerraPower's Natrium reactor.[107] Besides federal projects, some energy companies have recently announced plans for advanced nuclear deployments. PacifiCorp, a regulated utility, announced a joint feasibility study with TerraPower of deploying up to five Natrium SMR reactors in its territory, in addition to one demonstration reactor in Wyoming.[108] Duke Energy announced that it is planning to deploy up to 600 MW of advanced nuclear power in North Carolina and South Carolina by 2035, while Holtec International announced that it is planning to build two 300 MW SMRs at its Palisades site in Michigan.[109,110]

In order to progress from FOAK to NOAK costs, more deployments are needed; however, given the potential risk to ratepayers, regulated utilities may be reluctant to be first movers in advanced nuclear without a partner. Without first movers, supply chain standup will be less efficient, gains from learning will not be realized, and construction costs will not decrease. A way of moving past this stalemate is for large customers, including technology or industrial companies, to commit to long-term offtake at above market prices from advanced nuclear power.[111]

As described below, several large companies have reached agreements for forthcoming advanced nuclear technology deployments, particularly to provide reliable power to their data centers. In several cases, advanced nuclear power generation is viewed as a carbon-free method of meeting energy and industrial needs. Given that high costs are the main barrier to advanced nuclear deployments, these early projects may prove critical in helping to reduce costs from FOAK levels to NOAK levels, potentially spurring further deployments.

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[106] U.S. DOE, "Advanced Reactor Demonstration Program", <https://www.energy.gov/ne/advanced-reactor-demonstration-program>, accessed November 5, 2024.
[107] Ibid.
[108] PacifiCorp, "TerraPower and PacifiCorp announce efforts to expand Natrium technology deployment," posted October 27, 2022, <https://www.pacificorp.com/about/newsroom/news-releases/additional-Natrium-reactors.html>, accessed October 14, 2024.
[109] Duke Energy, "Duke Energy responds to constructive Carolinas Resource Plan decision by North Carolina Utilities Commission", posted November 2, 2024, <https://news.duke-energy.com/releases/duke-energy-responds-to-constructive-carolinas-resource-plan-decision-by-north-carolina-utilities-commission>, accessed December 9, 2024.
[110] Holtec International, "First Two SMR-300 Units Slated to be Built at Michigan's Palisades Site for Commissioning by Mid-2030", posted December 4, 2023, <https://holtecinternational.com/2023/12/04/first-two-smr-300-units-slated-to-be-built-at-michigans-palisades-site-for-commissioning-by-mid-2030/>, accessed October 28, 2024.
[111] U.S. DOE, "Pathways to Commercial Liftoff: Advanced Nuclear," p. 41, September 2024, <https://liftoff.energy.gov/advanced-nuclear-2/>, accessed October 16, 2024.

Data Centers

The growth in Artificial Intelligence (AI), the Internet of Things, and other data-intensive computing functions is increasing the demand for data centers. The market for IT infrastructure and data centers is expected to more than double globally from $153 billion in 2020 to $317 billion in 2026.[112] This growth in data centers will require significantly more electricity. According to EPRI, data center electricity demand is projected to increase from around 4 percent of total U.S. electricity demand in 2023 to as much as 11 percent in 2030.[113]

IBM defines a data center hyperscaler as "a massive data center that provides extreme scalability capabilities and is engineered for large-scale workloads with an optimized network infrastructure, streamlined network connectivity and minimized latency."[114] These hyperscalers have been driving much of the need for new generation in recent years. In order to meet this increased demand for reliable power, while achieving corporate goals of reducing carbon emissions, data center hyperscalers have been turning to all types of advanced nuclear technology. Recent company announcements of advanced nuclear technology support for data centers are listed below.

Standard Power

On October 10, 2023, NuScale Power announced that it had reached an agreement with Standard Power, a provider of computing resources like servers, storage, and networking on demand to advanced data processing companies, to develop two facilities powered by SMRs to provide nearly 2,000 MW of electricity for its nearby data centers.[115] ENTRA1 Energy LLC has a partnership with NuScale where it develops, finances, owns and operates energy production plants powered by the NuScale SMR Technology.[116]

Equinix

In an April 2, 2024, Securities and Exchange Commission filing, Co-location company Equinix announced that it has agreed to purchase 500 MW in advanced nuclear power using microreactors from Oklo Inc.[117]

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[112] Building, Design + Construction Network, "Global edge data center market to cross $300 billion by 2026, says JLL," published August 8, 2024, <https://www.bdcnetwork.com/home/news/55166298/global-edge-data-center-market-to-cross-300-billion-by-2026-says-jll>, accessed November 25, 2024.

[113] EPRI, Powering Data Centers: U.S. Energy System and Emissions Impacts of Growing Loads report, published October 30, 2024, <https://www.epri.com/research/products/000000003002031198>, accessed November 25, 2024.

[114] https://www.ibm.com/think/topics/hyperscale-data-center

[115] NuScale Power, "Standard Power Chooses NuScale's Approved SMR Technology and ENTRA1 Energy to Energize Data Centers," published October 6, 2023, <https://www.nuscalepower.com/en/news/press-releases/2023/standard-power-chooses-nuscales-approved-smr-technology-and-entra1-energy-to-energize-data-centers>, accessed November 25, 2024.

[116] Ibid.

[117] Data Center Dynamics, "Equinix signs deal to procure up to 500MW of nuclear power from Oklo reactors – makes $25m pre-payment," published April 5, 2024, <https://www.datacenterdynamics.com/en/news/equinix-signs-deal-to-procure-up-to-500mw-of-nuclear-power-from-oklo-smrs-makes-25m-pre-payment/>, accessed November 25, 2024.

Prometheus Hyperscale

On May 23, 2024, Oklo announced a deal to supply Prometheus Hyperscale (formerly Wyoming Hyperscale) with 100 MW using its microreactors. [118]

Oracle

On September 10, 2024, Oracle Corporation Chairman Larry Ellison announced that it is designing a data center that will require more than a GW of electricity. The data center will be powered by three SMRs.[119] The company has not yet announced further details.

Google

Google announced on October 14, 2024, that it had signed an agreement to purchase up to 500 MW of power from multiple SMRs developed, constructed, and operated by Kairos Power. The agreement would see the first SMR running by 2030, with additional reactors deployed through 2035.[120]

Amazon

Amazon has announced multiple projects to power its data centers with SMRs. On October 16, 2024, Amazon stated that it had signed an agreement with Energy Northwest to purchase power from four X-energy designed SMR reactors that should be ready in the early 2030s. The first phase of the project is expected to generate 320 MW, with the option to increase to a total of 960 MW. Energy Northwest will build, own, and operate the reactors. Amazon also announced that it will invest in X-energy's manufacturing capacity to develop SMR equipment.[121] X-energy announced that it had received approximately $500 million in equity investment from a group including Amazon's Climate Pledge Fund, Citadel Founder and CEO Ken Griffin, affiliates of Ares Management Corporation, NGP, and the University of Michigan. X-energy and Amazon plan to establish and standardize a deployment and financing model to develop projects in partnership with infrastructure and utility partners to bring more than 5 GW online by 2039.[122] Additionally, Amazon signed an agreement with Dominion Energy to explore developing an SMR near Dominion's existing North Anna nuclear power station adding at least 300MW in power to the

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118 Data Center Dynamics, "Oklo to supply 100MW of nuclear power to Wyoming Hyperscale," published May 24, 2024, <https://www.datacenterdynamics.com/en/news/oklo-to-supply-100mw-of-nuclear-power-to-wyoming-hyperscale/>, accessed November 25, 2024.

119 CNBC, "Oracle is designing a data center that would be powered by three small nuclear reactors", published September 10, 2024, <https://www.cnbc.com/2024/09/10/oracle-is-designing-a-data-center-that-would-be-powered-by-three-small-nuclear-reactors.html>, accessed January 25, 2025.

120 Google, "New nuclear clean energy agreement with Kairos Power", posted October 14, 2024, <https://blog.google/outreach-initiatives/sustainability/google-kairos-power-nuclear-energy-agreement/>, accessed October 28, 2024.

121 Amazon, "Amazon signs agreements for innovative nuclear energy projects to address growing energy demands", posted October 16, 2024, <https://www.aboutamazon.com/news/sustainability/amazon-nuclear-small-modular-reactor-net-carbon-zero>, accessed October 28, 2024.

122 X-energy, "Amazon Invests in X-energy to Support Advanced Small Modular Nuclear Reactors and Expand Carbon-Free Power," published October 16, 2024, <https://x-energy.com/media/news-releases/amazon-invests-in-x-energy-to-support-advanced-small-modular-nuclear-reactors-and-expand-carbon-free-power>, accessed November 25, 2024.

Virginia region.[123] On November 26, 2024, Amazon announced that it is offering $334 million to support a multi-year feasibility study of Xe-100's at Hanford with Energy Northwest, as part of its October agreement with Dominion.[124]

Meta

On December 3, 2024, to support its AI innovation and sustainability objectives, Meta announced that it had issued a request for proposals to identify nuclear energy developers to help with developing SMRs or large reactors to add 1-4 GW of new nuclear generation capacity in the US.[125]

Switch Data Centers

On December 18, 2024, Switch, Inc. announced that it had signed a non-binding agreement with Oklo to provide its data centers with 12 GW of electricity through 2044 using Oklo microreactors.[126]

As advanced nuclear technology projects are being considered, the economics of deployment continue to be a challenge. In order to facilitate deployments, the federal government has taken steps to support the development of advanced nuclear technology, as discussed in the next chapter.

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123 Amazon, “Amazon signs agreements for innovative nuclear energy projects to address growing energy demands”, posted October 16, 2024, <https://www.aboutamazon.com/news/sustainability/amazon-nuclear-small-modular-reactor-net-carbon-zero>, accessed October 28, 2024.

124 Cascade PBS News, “Amazon offers $334M for nuclear reactors to be built at Hanford”, posted November 26, 2024, <https://www.cascadepbs.org/news/2024/11/amazon-offers-334m-nuclear-reactors-be-built-hanford>, accessed January 25, 2025.

125 Meta, “Accelerating the Next Wave of Nuclear to Power AI Innovation”, posted December 3, 2024, <https://sustainability.atmeta.com/blog/2024/12/03/accelerating-the-next-wave-of-nuclear-to-power-ai-innovation/>, accessed January 25, 2025.

126 Oklo, “Oklo and Switch Form Landmark Strategic Relationship to Deploy 12 Gigawatts of Advanced Nuclear Power, One of the Largest Corporate Clean Power Agreements Ever Signed,” posted December 12, 2024, <https://oklo.com/newsroom/news-details/2024/Oklo-and-Switch-Form-Landmark-Strategic-Relationship-to-Deploy-12-Gigawatts-of-Advanced-Nuclear-Power-One-of-the-Largest-Corporate-Clean-Power-Agreements-Ever-Signed/default.aspx>, accessed January 25, 2025.

Chapter 4 – Federal and State Activities

The federal government provides incentives for the deployment of advanced nuclear technology through various federal support mechanisms such as tax credits, U.S. DOE grants and loans, streamlined administrative procedures for nuclear energy generation facilities, and workforce development programs.

Figure 15 – Current Federal Funding Opportunities

Federal Tax Credits

- IRS Incentives[1]
- **IRC Sec:**
    - 30% ITC (48E) is a technology-neutral ITC for the COD year of the facility
    - \$30.0/MWh[1] PTC (45Y) is a technology-neutral, emissions-based PTC for facilities placed in service after 2025
- \$18/MWh advanced nuclear tax credit under Section 45J for new nuclear generation for facilities built before 2021[1]
- 45X manufacturer credit may be of interest to certain equipment and component manufacturers

DOE Grants

- Gen III + SMR Pathway to Deployment Program[2]
    - \$800 MM for up to two projects focused on first mover support
    - \$100 MM used for fast follower support spread out across multiple awards
- Low Enriched Uranium (LEU) Enrichment Acquisition Program
    - Up to \$3.4 B focused on securing a non-Russian supply chain
        - \$2.7 B has already been appropriated to DOE who will then sell the LEU to operating U.S. facilities

DOE Loans

- DOE Loan Program Office (LPO) can provide loan to support Advanced Nuclear projects
    - LPO originally allocated \$310 B for Title 17 financing
        - ~\$60 B remaining
    - Funds must be committed by September 2026 and used by September 2031
- LPO has recently provided support to two nuclear projects
    - \$12 B in loan guarantees for Vogtle
    - \$1.5 B loan guarantee for Palisades restoration

1) Many of the tax credit programs cannot be stacked
2) Program is focused on project teams made up of developers, suppliers, customers, etc.

Source: Florida Electric Power Coordinating Group

Tax Credits

Investment Tax Credit (ITC) was first enacted by the Energy Tax Act of 1978 as a temporary 10 percent credit for businesses that used energy sources other than oil and natural gas. The ITC was designed to reduce U.S. consumption of those energy sources and to encourage the commercialization of other energy technologies and resources.[127] Currently, the ITC provides an initial credit of 6 percent of investment costs for certain clean energy projects, and can be increased to 30 percent if labor requirements are met. Labor requirements include ensuring construction

[127] Congressional Research Service, "The Energy Credit or Energy Investment Tax Credit (ITC)", updated April 23, 2021, <https://crsreports.congress.gov/product/pdf/IF/IF10479>, accessed November 5, 2024.

wages meet or surpass prevailing rates and that the required minimum work is done by those enrolled in apprentice programs.

Additionally, the ITC increases by 10 percent if domestic content requirements are met and by a further 10 percent if located in an energy community. Domestic content requirements refer to certifying that manufactured components (i.e. steel and iron) of an applicable project were produced in the U.S. Energy communities include brownfield sites, decommissioned nuclear plants, or former coal sites. If all requirements are met, the ITC will recoup a maximum of 50 percent of project costs. [128]

Over time, the ITC has been extended and expanded to include more carbon-neutral energy production sources, including advanced nuclear energy. The Inflation Reduction Act of 2022 (IRA) extended the ITC for facilities constructed before 2025 and created a tech-neutral clean electricity ITC for electricity generation facilities placed in service from 2025 to 2032, or until emissions are reduced to 25 percent of 2022 levels.[129]

The expansion of the IRA allows nuclear facilities to benefit from the ITC. The ITC for facilities constructed before 2025 is technology-specific and includes solar, fiber-optic solar, fuel cells, small wind, waste energy recovery properties, micro turbines, and combined heat and power systems.[130] The new ITC can apply to any facility regardless of technology as long as the facility produces zero or negative greenhouse gas emissions.[131]

Production Tax Credit (PTC) was first enacted by the Energy Policy Act of 1992 as a per-kilowatt-hour credit for electricity generated using wind and closed-loop biomass.[132] The PTC provides an initial credit of \$5.5/MWh of clean energy production which can be increased to \$27.5/MWh if labor requirements are met. The PTC can also be increased by 10 percent each if domestic content requirements are met and the facility is built in an energy community. The maximum a facility could receive from the PTC would be \$33/MWh for 10 years.[133] The PTC has been repeatedly extended and expanded to include more carbon-neutral energy production sources.

[128] Levi Morin Larsen et al., "Effects of the U.S. Inflation Reduction Act on SMR economics", *Frontiers in Nuclear Engineering*, Vol. 3, updated May 2024, <https://www.frontiersin.org/journals/nuclear-engineering/articles/10.3389/fnuen.2024.1379414/full>, accessed November 5, 2024.
[129] Internal Revenue Service, "Clean Electricity Investment Credit", updated October 16, 2024, <https://www.irs.gov/credits-deductions/clean-electricity-investment-credit>, accessed November 5, 2024.
[130] Congressional Research Service, "The Energy Credit or Energy Investment Tax Credit (ITC)", updated April 23, 2021, <https://crsreports.congress.gov/product/pdf/IF/IF10479>, accessed November 5, 2024.
[131] Internal Revenue Service, "Section 45Y Clean Electricity Production Credit and Section 48E Clean Electricity Investment Credit." Federal Register Vol. 89, no. 107, updated June 3, 2024, <https://www.federalregister.gov/documents/2024/06/03/2024-11719/section-45y-clean-electricity-production-credit-and-section-48e-clean-electricity-investment-credit>, accessed November 5, 2024.
[132] Congressional Research Service, "The Renewable Electricity Production Tax Credit: In Brief", updated April 29, 2020, <https://crsreports.congress.gov/product/details?prodcode=R43453>, accessed November 5, 2024.
[133] Levi Morin Larsen et al., "Effects of the U.S. inflation reduction act on SMR economics", Frontiers in Nuclear Engineering, Vol. 3, updated May 2024, <https://www.frontiersin.org/journals/nuclear-engineering/articles/10.3389/fnuen.2024.1379414/full>, accessed November 5, 2024.

Like the ITC, the IRA has extended the PTC to facilities constructed before 2025 and created a technology-neutral clean electricity PTC for new electricity generation facilities.[134] This expansion allows nuclear facilities to benefit from the PTC.[135]

The IRA is not the only source of tax credits benefiting nuclear energy projects. The Advanced Nuclear PTC was the first tax credit to directly address nuclear generation facilities. The ANPTC originates in the Energy Policy Act of 2005 but was renewed in the Bipartisan Budget Act of 2018 to include advanced nuclear facilities placed in service after 2020. The ANPTC provides an additional $18/MWh for new nuclear generation facilities for the first 8 years of production. The credit is limited to 6,000 MW of total electric generating capacity.[136] One important note is that most of the federal tax credits cannot be used in tandem with each other.

Grants and Loans

The U.S. DOE provides grants and loans to assist in the development and deployment of nuclear reactors. The Generation III+ Small Modular Reactor Program provides $800 million in grants for up to two first-mover teams and $100 million in grants for additional deployments.[137] The application window for funding under the program was open from October 16, 2024, to January 17, 2025.[138] The Low Enriched Uranium Enrichment Acquisition Program provides $2.7 billion to the DOE to sell domestic low enriched uranium to operating U.S. facilities. This program is intended to facilitate domestic sourcing of fuel for nuclear plants.[139]

The DOE Loan Program Office (LPO) provides loans to support Advanced Nuclear projects. The LPO was originally allocated $310 billion for the Title 17 Clean Energy Financing program, and there is $60 billion remaining for other projects. Title 17 financing was established by the Energy Policy Act of 2005 to support clean energy development and energy infrastructure reinvestment with the goal of reducing greenhouse gas emissions. Title 17 was amended by the IRA to include certain state-supported projects and projects focused on legacy energy infrastructure. The IRA leveraged additional loan authority and funding for projects that feature innovative energy technology. Through the program, borrowers can access loans from the Treasury's Federal Financing Bank, which is backed 100 percent by DOE guarantees of "full faith and credit" or

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134 Internal Revenue Service, "Clean Electricity Production Credit", updated October 28, 2024, <https://www.irs.gov/credits-deductions/clean-electricity-production-credit>, accessed November 5, 2024.
135 Congressional Research Service, "The Renewable Electricity Production Tax Credit: In Brief", updated April 29, 2020, <https://crsreports.congress.gov/product/details?prodcode=R43453>, accessed November 5, 2024.
136 Internal Revenue Service, "Section 45J Credit for Production of Electricity from Advanced Nuclear Power Facilities", Notice 2023-24, <https://www.irs.gov/pub/irs-drop/n-23-24.pdf>, accessed October 16, 2024.
137 U.S. DOE, "Generation III+ Small Modular Reactor Program", <https://www.energy.gov/oced/generation-iii-small-modular-reactor-program>, accessed November 5, 2024.
138 Ibid.
139 U.S. DOE, "DOE Announces $2.7 Billion From President Biden's Investing in America Agenda to Boost Domestic Nuclear Fuel Supply Chain", posted June 27, 2024, <https://www.energy.gov/articles/doe-announces-27-billion-president-bidens-investing-america-agenda-boost-domestic-nuclear>, accessed November 5, 2024.

partial guarantees of debt from the DOE.[140] The LPO provided loan guarantees totaling $12 billion to Georgia Power Company, Oglethorpe Power Corporation, and Municipal Electric Authority of Georgia to support the Plant Vogtle AP1000 deployments.[141,142]

The DOE also offers other assistance to nuclear projects. The Infrastructure Investment and Jobs Act of 2021 (IIJA) provides support for nuclear energy through the funding of two programs, the Civil Nuclear Credit Program (CNCP) and the Advanced Reactor Demonstration Program (ARDP). The CNCP provides $6 billion in funding to maintain the existing nuclear fleet and prevent premature shutdowns.[143] The IIJA provided $2.5 billion in funding for the ARDP for advanced nuclear reactor demonstrations. Other ARDP related programs include $651 million for the ARDP Risk Reduction program and $55 million for the ARDP Advanced Reactor Concepts 2020 (ARC-20) program.[144] The ARDP has supported the demonstration of two advanced nuclear reactors, X-energy's XE-100 and TerraPower's Natrium reactor, as mentioned in the previous chapter.[145]

The Creating Helpful Incentives to Produce Semiconductors (CHIPS) and Science Act of 2022 includes significant support for nuclear energy. The CHIPS Act provides funding for national nuclear university research infrastructure, $55 million for existing university facilities and $390 million for new facilities including four new research reactors. The legislation provided $15 million for a University Nuclear Leadership Program which provides support for nuclear research, including non-technical nuclear research aimed to increase engagement with nuclear energy systems. Importantly, it also provides $800 million for the research, development and demonstration of advanced nuclear reactors.[146]

Administrative Improvements

Apart from more direct financial incentives, the federal government has passed legislation to encourage nuclear development and deployment through the lowering of costs and administrative barriers. The Nuclear Energy Innovation and Modernization Act (NEIMA) of 2019 aimed to create a more efficient process for licensing advanced nuclear reactors. It required the NRC to establish

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[140] U.S. DOE, "Title 17 Clean Energy Financing", <https://www.energy.gov/lpo/title-17-clean-energy-financing>, accessed November 5, 2024.

[141] U.S. DOE, "Advanced Nuclear Energy Projects", <https://www.energy.gov/lpo/advanced-nuclear-energy-projects>, accessed November 5, 2024.

[142] U.S. DOE, "Vogtle", <https://www.energy.gov/lpo/vogtle>, accessed November 5, 2024.

[143] U.S. DOE, "Civil Nuclear Credit Program", updated September 27, 2024, <https://www.energy.gov/gdo/civil-nuclear-credit-program>, accessed November 5, 2024.

[144] U.S. DOE, "Pathways to Commercial Liftoff: Advanced Nuclear," p. 30, September 2024, https://liftoff.energy.gov/advanced-nuclear-2/, accessed December 13, 2024.

[145] U.S. DOE, "Advanced Reactor Demonstration Projects", <https://www.energy.gov/oced/advanced-reactor-demonstration-projects-0>, accessed November 5, 2024.

[146] CHIPS and Science Act, Public Law No: 117-167 (2022), <https://www.congress.gov/bill/117th-congress/house-bill/4346>, accessed November 25, 2024.

performance metrics for licensing and other regulatory actions as well as develop a regulatory framework for advanced nuclear technologies.[147] Additionally, the legislation included a pilot program for providing predictable fees regarding licensing for uranium producers.[148]

The ADVANCE Act of 2024 decreases licensing application fees for advanced reactors, increases staffing for NRC reviews, provides for prize awards for deployment, and eliminates costs associated with pre-application activities and early site permits at DOE sites. Furthermore, it requires 25-month deadlines for NRC license issuance after receiving an application, requires the NRC to develop guidance to license and regulate microreactor designs, and increases permitting speed for sites with retired or retiring fossil fuel generation and brownfield sites.[149]

Additional federal support for advanced nuclear may be forthcoming. On December 4, 2024, U.S. Senator Jim Risch (R-Idaho) introduced the Accelerating Reliable Capacity (ARC) Act to accelerate investment in new commercial nuclear projects by minimizing cost overrun risk. If passed, the ARC Act would establish a limited risk reduction program for building new commercial reactors by providing a backstop for unforeseen costs through enhanced financing terms. The program would benefit three or more next generation nuclear energy projects to jumpstart commercialization.[150]

Workforce Development

The DOE has administered several workforce development programs to train workers and equip them with the skills necessary to meet the country's energy demands. This includes initiatives like the Energy Auditor Training Grant Program, the Career Skills Training Program, and the State-Based Home Energy Efficiency Contractor Training Grant Program. The U.S. DOE also administers the Nuclear Safety Training and Workforce Development Program, which will provide $100 million for university-led partnerships with technical and community colleges, National Laboratories, and industry to train people in two topic areas: (1) demonstration and implementation; and (2) training needs and curriculum development. An initial round of $50 million awards will be announced in the spring of 2025 with applications closing on January 14, 2025. Additionally, another $50 million will be available for a second round of awards, depending on appropriations. The program has three main aims: (1) to ensure the nuclear fleet is built and

[147] The NRC has proposed to revise the NRC's regulations by adding Part 53, a risk-informed, performance-based, and technology-inclusive regulatory framework for commercial nuclear plants in response to NEIMA.
[148] U.S. Senate Committee on Environment & Public Works, "Nuclear Energy Innovation and Modernization Act (NEIMA)", <https://www.epw.senate.gov/public/index.cfm/neima>, accessed November 25, 2024.
[149] U.S. DOE, "Newly Signed Bill Will Boost Nuclear Reactor Deployment in the United States", posted July 10, 2024, <https://www.energy.gov/ne/articles/newly-signed-bill-will-boost-nuclear-reactor-deployment-united-states>, accessed November 5, 2024.
[150] Senator Risch, "Risch Introduces Bill to Accelerate New Nuclear Investment", posted December 4, 2024, <https://www.risch.senate.gov/public/index.cfm/2024/12/risch-introduces-bill-to-accelerate-new-nuclear-investment>, accessed December 13, 2024.

maintained by a skilled workforce ready to meet the demands of the industry, (2) to build on existing industry-recognized safety credentials, and (3) to establish associations to help ensure the current nuclear workforce meets the skilled training needs of the industry.

Workforce development programs can contribute to the maintenance and expansion of the current nuclear fleet. Workforce development for nuclear energy has the potential to create new employment opportunities and spur economic growth while meeting the state's energy demands.[151] Another DOE workforce development program is the Good Jobs in Clean Energy Prize, which provides $3.3 million in awards to foster coalition-building in communities nationwide, with a focus on creating quality, accessible jobs and developing an inclusive workforce in the clean energy sector.[152]

The federal government offers a variety of support for advanced nuclear deployments. In addition to supporting advanced nuclear technology for civilians, the federal government has interest in exploring the military application of this technology, as will be discussed in the next chapter.

Recent State Nuclear Initiatives

Numerous states have also taken steps to change their state's regulatory environment, particularly with SMRs in mind. During the Commission's stakeholder workshop, FCG's Next Generation Nuclear Workgroup provided a snapshot highlighting its view of state-level legislation or policies it deems to have pro-SMR policies/incentives, restrictive nuclear environments and those who have yet to move forward in either direction. Additionally, FCG included a listing of state activities in the advanced nuclear reactor space, included below. It is important to note that as with other parts of this report, this is not intended as a total inventory of actions as the market for advanced reactors continues to develop.

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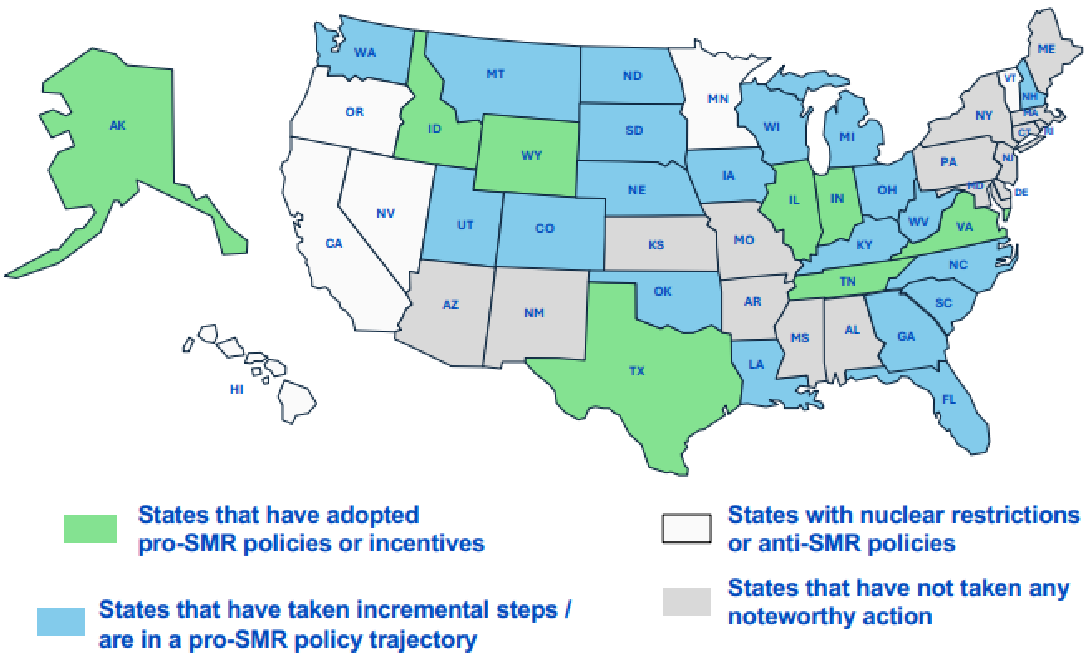
[151] DOE, "Nuclear Reactor Safety Training and Workforce Development Program", <https://www.energy.gov/ne/nuclear-reactor-safety-training-and-workforce-development-program>, accessed December 2, 2024.

[152] Interagency Working Group on Coal & Power Plant Communities & Economic Revitalization, Good Jobs in Clean Energy Prize, <https://energycommunities.gov/funding-opportunity/good-jobs-in-clean-energy-prize/>, accessed December 19, 2024.

Figure 16: SMR State Legislation and Policy



Source: Florida Electric Power Coordinating Group, *Industry Report on Policy & Regulatory Issues Related to Advanced Nuclear Development*[153]

Some of the highlights of recent state activities include:

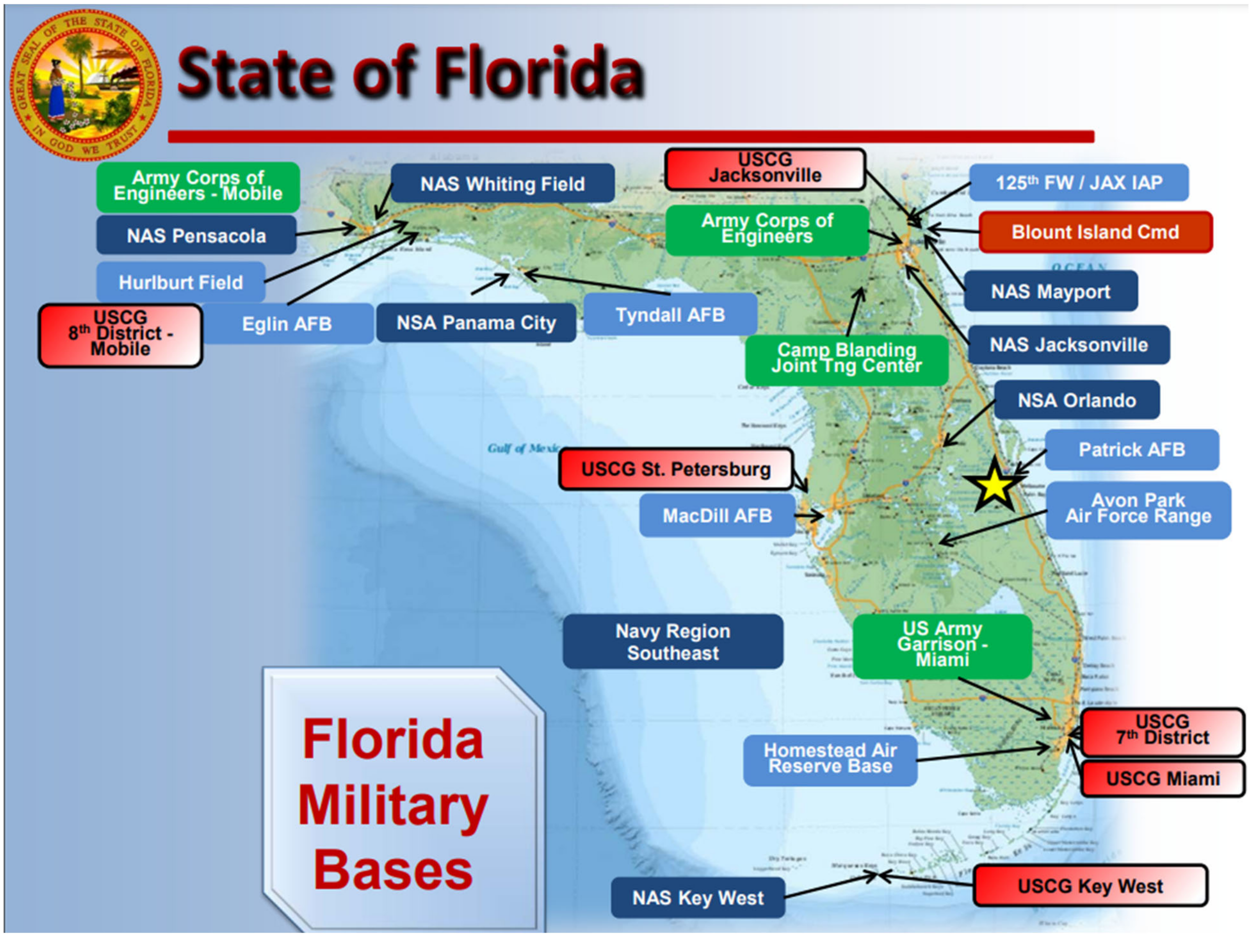
- **Alaska**: Senate Bill 177 was enacted in 2022, making it easier to obtain permits for microreactors in Alaska
- **Illinois**: House Bill 2473 was enacted in 2023, starting the process for the creation of a regulatory structure for the construction of SMRs, and requires the state to perform a study that will inform rules for regulating SMRs, which is set to be adopted by state regulators by January 2026
- **Iowa**: HF 2279 was enacted in 2024, allowing for advanced ratemaking for utilities with nuclear facilities
- **Tennessee**: Governor Bill Lee stated his support for SMRs, and partnered with the state's General Assembly to create a $50 Million nuclear fund in the state's 2023-2024 budget, to help support nuclear development and manufacturing
- **Texas**: Governor Greg Abbott directed the Public Utility Commission to sponsor the Advanced Nuclear Task Force in 2023. See additional discussion of Texas's activities in the section of this report that discusses military installations.

[153] https://www.floridapsc.com/pscfiles/website-files/PDF/Home/FCG%20NGNW%20Industry%20Report%20FPSC%20Workshop%20090524.pdf

- **Virginia**: Virginia Power Innovation Fund was established in 2023, providing $10 Million in support of the development of advanced energy technology, including SMRs
- **Wyoming**: Wyoming enacted legislation in 2020, to authorize the permitting and operation of SMRs, including allowing the operation on previously existing coal or natural gas generation facilities in 2020.

Chapter 5 - Military Applications

Figure 17: Map of Military Bases in Florida[154]



According to The Office of Military and Defense in the Department of Economic Development, Military and Defense is one of Florida's most significant industry clusters, accounting for over 860,000 direct and indirect jobs and an annual economic impact of $96.6 Billion.[155] Additionally, the Office noted that a recent 2023 DOD report ranked Florida as the fourth highest state in the nation for Defense spending, with $30.2 Billion allocated for Fiscal Year 2022.

Florida's Legislature has emphasized energy independence, resiliency, and the importance of state security with a goal of Florida's energy policy implementation by ensuring a secure, resilient, and reliable energy supply, with an emphasis on a diverse supply of domestic energy resources. As a

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[154] University of South Florida, "Florida Military Bases," <https://sss.usf.edu/resources/format/pdf/Military_Bases.pdf>, accessed March 20, 2025.
[155] Florida Department Of Commerce, "Office of Military and Defense," https://www.floridajobs.org/office-directory/division-of-economic-development/office-of-military-and-defense, accessed March 30, 2025.

part of this report, the Commission was tasked to research means to encourage and foster the installation and use of such technologies at military installations in the state in partnership with public utilities.

The DOD is one of the largest energy consumers globally, and its energy demands are only expected to increase as newer, high-energy-usage military systems are introduced. The White House reported that the DOD consumes 10 million gallons of fuel per day and 30,000 GWh of electricity annually, nearly all of which is obtained through off-site and civilian shared electrical grids. Bases being over reliant on energy obtained through a civilian shared electrical grid is seen as a problem, especially if the base is faced with harsh weather, physical attacks, cyberattacks, or other emergencies. Past administrations have viewed nuclear power as a potential solution to ensure military base power grids remain operational and ready for critical missions.[156]

Recent legislation has paved the way for the DOD's efforts in exploring nuclear energy for military bases. Previous initiatives from the Army resulted in the construction of eight nuclear reactor designs, five of which were portable, from 1954 to 1977; however, the 2019 National Defense Authorization Act (NDAA) is attributed as being the starting point for the DOD's advanced nuclear power research.[157] The 2019 NDAA tasked the Secretary of Energy to develop a report to Congress within one year, outlining the requirements for, and components of, a nuclear energy pilot program. This program entails contracting a third-party company to build and operate at least one microreactor, licensed by the NRC, for DOD facilities by December 31, 2027.[158] Two years later, the 2021 NDAA mandated that military bases essential for critical missions be energy resilient enough to maintain a minimum of 99.9 percent energy availability for energy loads by 2030.[159]

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[156] The White House, "Fact Sheet: Biden-Harris Administration Announces New Steps to Bolster Domestic Nuclear Industry and Advance America's Clean Energy Future," posted May 29, 2024, <https://www.whitehouse.gov/briefing-room/statements-releases/2024/05/29/fact-sheet-biden-harris-administration-announces-new-steps-to-bolster-domestic-nuclear-industry-and-advance-americas-clean-energy-future/>, accessed December 9, 2024. See also, The White House, Executive Order 13972, "Promoting Small Modular Reactors for National Defense and Space Exploration," filed January 13, 2021, <https://www.federalregister.gov/documents/2021/01/14/2021-01013/promoting-small-modular-reactors-for-national-defense-and-space-exploration>, accessed December 9, 2024.

[157] SCO, Jeff Waksman, "Project Pele Overview," p. 4, approved for release May 2022, <https://www.nrc.gov/docs/ML2212/ML22126A059.pdf>, accessed December 13, 2024.

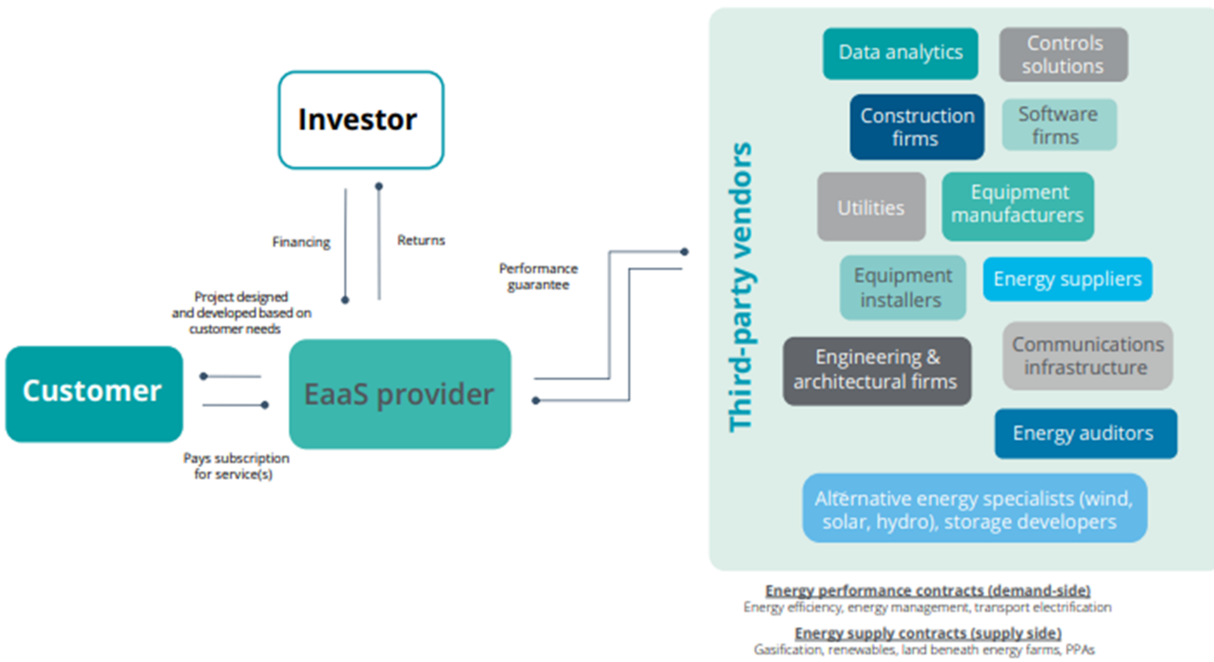
[158] 2019 NDAA, "report on pilot Program for micro-reactors," pp. 86-88, SEC. 327 effective January 2, 2019, <https://www.congress.gov/115/bills/hr5515/BILLS-115hr5515enr.pdf>, accessed December 13, 2024. See also, DAF, "Micro-Reactor Pilot," updated August 2022, <https://www.eielson.af.mil/Portals/40/DAF%20Micro-reactor%20Pilot_2022%20fact%20sheet_PDF.pdf>, accessed December 13, 2024

[159] 2021 NDAA, "Energy resilience and energy security measures on military installations," pp. 130-133, § 2920, effective January 1, 2021, <https://www.congress.gov/116/plaws/publ283/PLAW-116publ283.pdf>, accessed December 13, 2024.

Energy as a Service

To achieve the mandated energy resilience requirements of the DOD, bases that choose to implement nuclear energy technology may adopt the Energy as a Service (EaaS) business model. Under this model, a provider designs and develops an energy infrastructure based on the customer's needs, typically through contracts such as a power purchase agreement. This method entails that a contracted provider invests in and operates the energy infrastructure, handling all aspects of the maintenance and upgrades, while the customer pays for the energy services received without needing to purchase or operate the energy equipment themselves.[160]

Figure 18: The Energy as a Service Model



Source: Deloitte, American Council for an Energy-Efficient Economy. [161]

To test the success of the EaaS model, in February 2023 the Department of the Air Force allocated $10 million to launch a three-year EaaS pilot program at Hanscom AFB in Massachusetts. This initiative was in response to a significant power outage the base experienced in September 2022, caused by an energy system failure at a substation that was built in the 1950s and thus scheduled for replacement. The project is a collaboration between the Air Force Office of Energy Assurance, the companies Eversource and Ameresco, and the Consortium for Energy, Environment, and Demilitarization, who will jointly design, construct, and operate a system of solar arrays and battery energy storage systems to supply renewable energy to the base. The program consists of a

[160] Deloitte, "Energy-as-a-Service: The lights are on. Is anyone home?," published November 15, 2019 <https://www.deloitte.com/uk/en/Industries/energy/perspectives/energy-as-a-service.html>, accessed December 13, 2024.
[161] Ibid, p. 12.

build phase, a year-long operational phase, and a final evaluation phase, with success of the initiative determining whether other bases, particularly those seeking to enhance energy resiliency and transition to nuclear energy, will adopt the EaaS model.[162]

Current Federal Nuclear Energy Initiatives

The DOD has committed to deploying at least one microreactor prototype by 2027, and ensuring that by 2030, bases essential to critical missions are energy resilient enough to maintain a minimum of 99.9 percent energy availability for energy loads. To support these objectives, a variety of initiatives are underway throughout the DOD and its military subordinate departments. The military intends to become an early adopter of advanced nuclear energy to achieve the mandated military resilience, with a particular emphasis on microreactors. For remote bases, microreactors offer an advantage of extended operation between refueling periods. Likewise, bases dependent on off-site energy can use a microreactor as a means of providing independent energy in the event the grid is compromised.[163] The following are military initiatives that are either considering or committed to using nuclear energy to meet the requirements set forth in the NDAAs.

Department of Defense Strategic Capabilities Office – Project Pele

In March 2020, the DOD's Strategic Capabilities Office (SCO) issued a Notice of Intent (NOI) in response to the 2019 NDAA, marking the official start of Project Pele, a project that entails working alongside a third-party company to design a microreactor prototype that meets the program's specific requirements.[164] In April 2022, the SCO announced BWXT Advanced Technologies (BWXT) as the manufacturer of the Pele microreactor, utilizing the company's transportable microreactor design capable of producing between 1 MW and 5 MW of electrical power.[165] The prototype will be constructed by BWXT in Lynchburg, Virginia, where it is scheduled to be separated into four 20-foot long shipping containers and transported to the DOE's Idaho National Laboratory (INL) for testing in 2026. At minimum, the Pele microreactor is expected to operate at the INL for 3 years until it has properly demonstrated it is capable of meeting the military's energy demands. This microreactor demonstrating success under real-world

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[162] Air Force Materiel Command, "Hanscom leaders invest in energy resiliency," posted June 13, 2023, <https://www.afmc.af.mil/News/Article-Display/Article/3427063/hanscom-leaders-invest-in-energy-resiliency/>, accessed December 13, 2024. See also, DAF, "Air Force launches Energy-as-a-Service pilot program at Hanscom AFB," published February 15, 2023, <https://www.af.mil/News/Article-Display/Article/3299294/air-force-launches-energy-as-a-service-pilot-program-at-hanscom-afb/>, accessed December 13, 2024.

[163] The White House, Executive Order 13972, "Promoting Small Modular Reactors for National Defense and Space Exploration," filed January 13, 2021, <https://www.federalregister.gov/documents/2021/01/14/2021-01013/promoting-small-modular-reactors-for-national-defense-and-space-exploration>, accessed December 1, 2024.

[164] Research & Engineering Enterprise, Project Pele, <https://www.cto.mil/pele_eis/>, accessed December 13, 2024. See also, Research & Engineering Enterprise, NOI, released March 2, 2022, <https://www.cto.mil/wp-content/uploads/2022/05/NOI-Distro-A.pdf>, accessed December 13, 2024.

[165] Research & Engineering Enterprise, ROD, released April 15, 2022, <https://www.cto.mil/wp-content/uploads/2022/05/ROD-Distro-A.pdf>, accessed December 13, 2024.

operating conditions could make it the first Gen IV reactor to produce electricity in the U.S., and could make it a model for similar technologies in the future.[166]

Defense Innovation Unit and the U.S. Army

The Defense Innovation Unit (DIU), an organization managed by the DOD, is responsible for addressing military needs by integrating commercial technologies to solve national security challenges, often through direct collaboration with commercial companies. Supporting this mission through the research of nuclear energy, the DIU has been advancing spacecraft nuclear propulsion technologies through initiatives supported by contracts with Ultra Safe Energy and Avalanche Energy, with the objective of conducting a successful orbital prototype demonstration by 2027.[167] As part of more recent developments, the DIU has also partnered with the Army in developing microreactors to enhance energy reliance at Army bases in alignment with the energy objectives set forth in the 2021 NDAA.[168] In June 2024, the Advanced Nuclear Power for Installations (ANPI) program officially begun when the DIU issued a Commercial Solutions Opening (CSO) soliciting microreactor prototype proposals from interested companies. The CSO, which was open for only two weeks, specified that the DIU and the Army are looking for microreactors that can preferably produce between 3 MW and 10 MW of power. Additionally, the CSO stated that top contenders that make it to Phase II will be invited to present their microreactor prototype designs. If the timeline proceeds as planned, the Army is expected to have one or more microreactors operational at its bases by 2030.[169]

Department of the Air Force Projects

The DAF was among the first of the DOD subordinate departments to begin researching nuclear energy in 1946 when the Nuclear Propulsion Program (also known as the Manned Nuclear Aircraft Program) began assessing the feasibility of using nuclear energy for the propulsion of an aircraft.[170] More recently, the DAF has continued to explore nuclear energy as a potential source of reliable

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[166]DOD, "DoD to Build Project Pele Mobile Microreactor and Perform Demonstration at Idaho National Laboratory," published April 13, 2022, <https://www.defense.gov/News/Releases/Release/Article/2998460/dod-to-build-project-pele-mobile-microreactor-and-perform-demonstration-at-idah/>, accessed December 13, 2024. See also, DOD, "DoD Breaks Ground on Project Pele: A Mobile Nuclear Reactor for Energy Resiliency," released September 24, 2024, <https://www.defense.gov/News/Releases/Release/Article/3915633/dod-breaks-ground-on-project-pele-a-mobile-nuclear-reactor-for-energy-resiliency/>, accessed December 13, 2024. See also, BMXT, "BWXT to Build First Advanced Microreactor in United States," posted June 9, 2022, <https://www.bwxt.com/news/2022/06/09/BWXT-to-Build-First-Advanced-Microreactor-in-United-States>, assessed December 13, 2024.

[167]DIU, "Powering the Future of Space Exploration: DIU Launching Next-Generation Nuclear Propulsion and Power," posted May 17, 2022, <https://www.diu.mil/latest/powering-the-future-of-space-exploration-diu-launching-next-generation>, accessed December 13, 2024.

[168] DIU, DIU and U.S. Army To Prototype Advanced Nuclear Power for Military Installations," released June 5, 2024. <https://www.diu.mil/latest/diu-and-u-s-army-to-prototype-advanced-nuclear-power-for-military>, accessed December 13, 2024

[169] DIU, "Advanced Nuclear Power for Installations (ANPI)" Published June 5, 2024 <https://www.linkedin.com/pulse/advanced-nuclear-power-installations-anpi-andy-tennant-vlnhe>, accessed December 13, 2024

[170]Air Force Materiel Command History Office, Jack Waid, "History in Two: Manned Nuclear Aircraft Program," published June 21, 2021, <https://www.afmc.af.mil/News/Article-Display/Article/2664365/history-in-two-manned-nuclear-aircraft-program/>, accessed December 13, 2024.

and clean power for its bases. This effort is backed by the 2019 and 2021 NDAAs, as well as the DAF's recognition that it cannot afford to adequately maintain its current infrastructure portfolio, which accounts for up to 10 percent of DAF's total budget.[171] The DAF has particularly emphasized microreactors for their inherent safety features, ability to safely generate both electrical and thermal energy over extended intervals between refueling, and capacity to operate independently from the electrical grid.[172]

Current DAF projects entail constructing a microreactor at Eielson AFB in Alaska, a simulation project at Hill AFB in Utah to evaluate the integration of a microreactor running alongside existing energy systems, and an energy resilience initiative at Joint Base San Antonio (JBSA) in San Antonio, Texas that could potentially incorporate the use of nuclear energy.

Eielson AFB, Alaska

In response to the 2019 NDAA, the DAF initiated its own microreactor pilot project, motivated by objectives similar to those of the SCO's Project Pele. In September 2020, the DAF issued a Request for Information (RFI) to identify potential sites for the construction and operation of a microreactor, with the goal to have it operational by the end of 2027. In October 2021, the DAF's Office of Energy Assurance recommended Eielson AFB as the optimal location for this project.[173] Several factors contributed to the selection of Eielson AFB, including the base's need for a reliable new energy source to support its growing fleet off the grid, limited access to clean energy alternatives, existing infrastructure, and the region's extreme climate. The planned microreactor will supplement the base's existing coal-powered energy system, providing up to 5 MW of electricity and varying amounts of steam heating.

In September 2022, Eielson AFB issued Request for Proposal to solicit a third-party vendor to own and operate the microreactor. The Request for Proposal was scheduled to close January 31, 2023, and an NOI to award a contract was issued in August 2023, announcing the selection of a vendor; however, a bid protest was filed at the Government Accountability Office, prompting additional proposals to be reviewed. Consequently, the NOI to award a contract was rescinded in September 2023.[174]

In March 2024, the DAF presented a revised timeline indicating that it no longer believes the microreactor will be operational by 2027. Additionally, no definitive start date for construction

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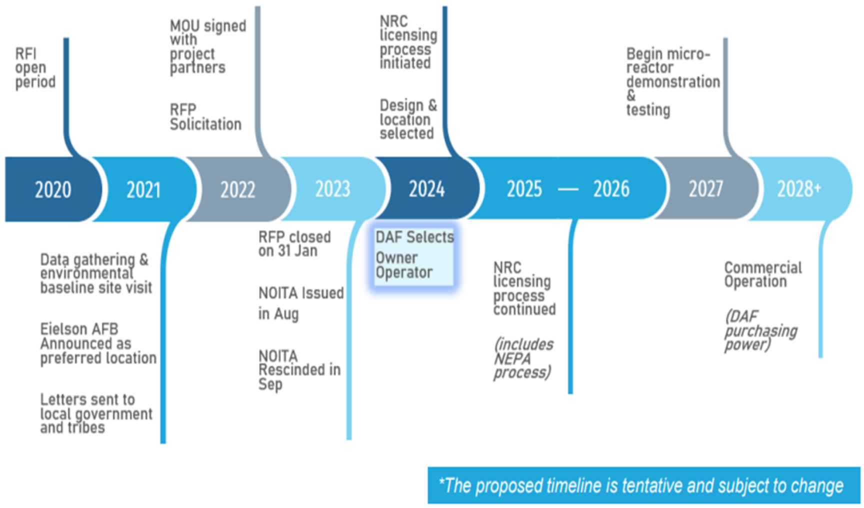
[171]DAF, RFI, Notice ID #FA8903-25-R-1002, "Description," published October 30, 2024, <https://sam.gov/opp/07ce87b378354929a6d10e262a99dc84/view> , accessed December 13, 2024.
[172]DAF, "Department of the Air Force Micro-Reactor Pilot – FAQs," last updated December 2023, <https://www.eielson.af.mil/Portals/40/ENVIRONMENT/Micro-Reactor/DAF%20Micro-Reactor%20FAQs_May%202024.pdf?ver=h6qsv87q72VGP1WE4vZvyw%3d%3d>, accessed December 13, 2024.
[173] Office of the Deputy Assistant Secretary for Environment, Safety, and Infrastructure, "Micro-Reactor Pilot," <https://www.eielson.af.mil/Portals/40/DAF%20Micro-reactor%20Pilot_2022%20fact%20sheet_PDF.pdf>, accessed December 13, 2024.
[174]Eielson AFB, "Microreactor Pilot Program," <https://www.eielson.af.mil/microreactor/>, accessed December 13, 2024.

has been established, as it is contingent on the final selection of a chosen vendor.[175] The revised timeline projects that testing and demonstrations of the microreactor may commence in 2027, with the conclusion of the pilot phase and the commencement of commercial operation potentially occurring in 2028 or later.

Figure 19: Eielson AFB Nuclear Project Timeline



Source: DAF.[176]

Hill AFB, Utah

The DAF is evaluating the feasibility of integrating a commercially produced microreactor alongside existing energy equipment and grid power to ensure continuous base operations during unforeseen circumstances. In March 2023, Hill AFB partnered with Radiant, a company founded by former SpaceX employees with an expertise in simulation software.[177] Radiant's advanced simulation software will be utilized at Hill AFB to identify failure points in the base's existing energy systems, including generators, steam boilers, and grid energy to assess whether nuclear power can enhance the base's energy resilience. Radiant also possesses specialized knowledge in the commercially produced microreactors under consideration at Hill AFB, as the company has been developing the Kaleidos microreactor since August 2020. Kaleidos is a 1 MW portable reactor that, according to the company, can fit into a single shipping container and be installed overnight. Additionally, Radiant asserts that Kaleidos is designed to be meltdown-proof, leak-safe, and capable of operating for 20 years with refueling required every 5 years. Kaleidos is projected

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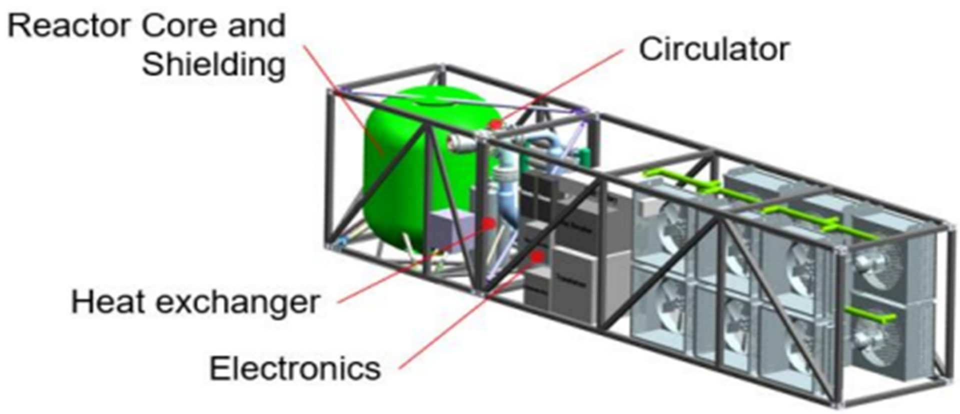
[175] DAF, "Department of the Air Force Micro-Reactor Pilot | FAQs," Updated May 2024, <https://www.eielson.af.mil/Portals/40/ENVIRONMENT/Micro-Reactor/DAF%20Micro-Reactor%20FAQs_May%202024.pdf?>, accessed November 4, 2024.

[176] DAF, Nancy Balkus and Thomas Brown, "Department of the Air Force Micro-Reactor Pilot Program," p. 4, presented March 18, 2024, <https://www.akleg.gov/basis/get_documents.asp?session=33&docid=31724>, accessed December 13, 2024.

[177] Radiant, "Hill AFB Partners with Radiant in Critical Energy Resilience Study," posted March 22, 2023, <https://www.radiantnuclear.com/blog/hill-afb-sbir/>, accessed December 13, 2024.

to be transported to the DOE's INL no later than 2026, where it will undergo comprehensive testing to evaluate its failsafe mechanisms and unique semi-automated control system.[178] Radiant anticipates that the first commercially available reactor could be ready within 2 years of successful testing at INL, with commercial production projected to begin in 2028.[179]

Figure 20: Model of Radiant's Kaleidos Microreactor



Source: Radiant Regulatory Engagement Plan.[180]

Joint Base San Antonio, Texas

Joint Base San Antonio (JBSA), one of the largest AFBs in the country, spends approximately $48.5 million annually on energy consumption and relies heavily on off-site electricity, a dependence that makes the base particularly vulnerable to power disruptions from unexpected events.[181] To address this, a Memorandum of Understanding was signed on February 26, 2024, between JBSA, the City of San Antonio, and City Public Service Energy (CPS Energy) formalizing a partnership to identify sustainable and reliable energy sources to enhance the base's operational capacity and support national security objectives. This partnership also aligns with the city's goal of becoming carbon zero by 2050 and obtaining 100 percent pollution-free electricity by 2030.[182] On October 30, 2024,

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[178] Radiant, "Radiant Secures $100 Million in Series C Funding, Plans Milestone Test at INL's DOME Facility," posted November 14, 2024, <https://www.radiantnuclear.com/blog/series-c-announcement/>, accessed December 17, 2024.

[179] Radiant, "Radiant Successfully Completes Passive Cooldown Test for Kaleidos Nuclear Microreactor," posted October 15, 2024, <https://www.radiantnuclear.com/blog/passive-cooldown-demo/>, accessed December 13, 2024. See also, Radiant, Doug Bernauer, "Why I Started Radiant," posted January 18, 2023, <https://www.radiantnuclear.com/blog/why-i-started-radiant/>, accessed December 13, 2024.

[180] Radiant, DOC-0A3E, Chanson Yang, "Regulatory Engagement Plan," p. 6 approved October 13, 2023, <https://www.nrc.gov/docs/ML2328/ML23286A328.pdf>, accessed December 13, 2024.

[181] Department of Air Force, RFI, Notice ID #FA8903-25-R-1002, "Opportunities," p. 7, published October 30, 2024, <https://sam.gov/opp/07ce87b378354929a6d10e262a99dc84/view>, accessed December 13, 2024.

[182] Joint Base San Antonio, "JBSA to explore resilient energy solutions, signs agreement with City of San Antonio, CPS Energy," published March 7, 2024, <https://www.jbsa.mil/News/News/Article/3699372/jbsa-to-explore-resilient-energy-solutions-signs-agreement-with-city-of-san-ant/>, accessed December 13, 2024. See also, Office of the Federal Chief Sustainability Office, "Federal Sustainability Plan," pp. 17-44, published December 2021, <https://www.sustainability.gov/pdfs/federal-sustainability-plan.pdf>, accessed December 13, 2024.

the DAF issued an RFI seeking third-parties to assist JBSA with projects relating to energy resiliency, demand optimization, supply assurance, and security enhancements. JBSA is interested in exploring the feasibility of nuclear energy, green hydrogen, geothermal, and technologies not yet identified to increase the base's energy resilience. JBSA requested that these companies respond by January 30, 2025.[183] The RFI stated that JBSA will eventually select a company willing to enter into a long-term power purchasing agreement contract to implement the use of the EaaS model; however, interested companies responding to the RFI should not expect to be solicited by JBSA for a contract, as the project is still in the information gathering stage.

The next step of this project entails choosing the energy technology JBSA deems most suitable for both the city and the base. While other technologies are also being considered, the State of Texas is working to ensure that barriers to entry do not hinder JBSA from adopting advanced nuclear technology. On August 16, 2023, the Texas Governor established the Texas Advanced Nuclear Reactor Working Group (Working Group) to explore how nuclear reactors can provide Texas with safe, reliable, and affordable nuclear power. Operating under the guidance of the Public Utility Commission of Texas, the Working Group's primary goal is to promote and facilitate the adoption of advanced nuclear reactor technology within the state.[184] In a report sent to the Texas Governor on November 18, 2024, the Working Group advocated for JBSA to develop an SMR on its base as a solution on its reliance to off-site electricity. The report also highlighted the potential for an SMR being the solution to the increasing energy demand from entities in the San Antonio area. Additionally, the Working Group outlined steps to accelerate JBSA's nuclear energy opportunities, such as identifying state agencies that could assist in the pursuit of nuclear energy, and suggesting the use of funding from the Defense Economic Adjustment Assistance Grant Program to support the development of an SMR on the base.[185] If these incentives are enough to convince JBSA to incorporate the use of nuclear power into its energy infrastructure as its clean energy technology choice, JBSA could be one of the first military installations to incorporate the use of an SMR instead of a microreactor.

Department of the Navy

The Department of the Navy (DON), which oversees two branches of the military, the Navy and the Marine Corps, has been harnessing nuclear energy since the 1950s, initially leveraging this technology to develop advanced submarines capable of extended submerged operations and to

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[183]Department of Air Force, RFI, Notice ID #FA8903-25-R-1002, "Opportunities," p. 8, published October 30, 2024, <https://sam.gov/opp/07ce87b378354929a6d10e262a99dc84/view>, accessed December 13, 2024.

[184]JBSA, "JBSA to explore resilient energy solutions, signs agreement with City of San Antonio, CPS Energy," published March 7, 2024, <https://www.jbsa.mil/News/News/Article/3699372/jbsa-to-explore-resilient-energy-solutions-signs-agreement-with-city-of-san-ant/>, accessed December 13, 2024.

[185]Working Group, "Deploying a World-Renowned Advanced Nuclear Industry in Texas," p. 61, dated November 18, 2024, <https://gov.texas.gov/uploads/files/press/TANRWG_Advanced_Nuclear_Report_v11.17.24c_.pdf>, accessed December 13, 2024.

enhance the propulsion systems of aircraft carriers.[186] More recently, on October 7, 2024, the Navy issued an RFI to solicit input from developers, utilities, and other parties on the feasibility of constructing and operating nuclear power plants on Navy and Marine Corps bases. The DON is exploring nuclear energy as a means to improve energy security and reliability at its bases, reduce dependence on external energy sources, and achieve the energy resilience objectives outlined in the 2021 NDAA. Under this initiative, power plants would be privately owned and operated on under-utilized land within the DON. Contracted companies would be responsible for securing the necessary NRC licenses and for managing all aspects of construction, operation, and nuclear waste disposal. The DON has identified seven bases for potential nuclear power development: Naval Base San Diego (CA), Marine Corps Base Hawaii (HI), Pearl Harbor Naval Shipyard (HI), Marine Corps Air Station Cherry Point (NC), MCB Camp Lejeune (NC), Naval Station Norfolk (VA), and Naval Base Kitsap (WA). Parties interested in responding to the RFI had until November 7, 2024, to submit their proposals; however, the DON emphasized that this RFI was intended solely for informational purposes, and that companies submitting responses should not expect to receive contract offers for a nuclear energy project.[187]

[186]The White House, Executive Order 13972, "Promoting Small Modular Reactors for National Defense and Space Exploration," filed January 13, 2021, <https://www.federalregister.gov/documents/2021/01/14/2021-01013/promoting-small-modular-reactors-for-national-defense-and-space-exploration>, accessed December 9, 2024.
[187]Department of the Navy, "Request for Information: Identification of Potential Shore Installation Contractor Owned/Operated Nuclear Power Plans," published October 7, 2024, <https://sam.gov/opp/0cda6711c0de4550b3bf80e3b98e38db/view>, accessed December 13, 2024.

Chapter 6 –Conclusion

Chapter 2024-186, Section 21, Laws of Florida, requires the Commission to study and evaluate the technical and economic feasibility of using advanced nuclear power technologies, including SMRs, to meet the electrical power needs of the state. Also, the Commission must research means to encourage and foster the installation and use of such technologies at military installations in partnership with public utilities.

The only advanced nuclear reactor design currently operating in the U.S. is the Westinghouse AP1000, a large, twin unit Gen III+ reactor at Plant Vogtle in Georgia. This is the same advanced reactor design that has been approved by the NRC for construction and operation in Florida. Plant Vogtle Units 3 and 4 were lengthy and expensive construction projects but they demonstrate the technical feasibility of large advanced nuclear reactors. Future AP1000 deployments are expected to benefit heavily from these FOAK projects. In fact, Plant Vogtle Unit 4 may have realized as much as a 30 percent cost savings compared to Unit 3, and additional cost and schedule improvements are expected for subsequent AP1000s, as is typical for projects following a FOAK deployment.

A study undertaken for the Idaho National Laboratory examined the potential for deploying AP1000s nationwide. Two sites in Florida were deemed to have good potential for near-term deployment of AP1000s: Florida Power and Light's Turkey Point Generating Station and Duke Energy's previously proposed Levy County site. As discussed in Chapter 2, these sites had COLs issued for dual unit AP1000s.[188] Moving forward with the issued Turkey Point COLs or reinstating the Levy COLs represent the quickest paths forward for new AP1000 deployment in Florida.[189]

Presently there are no SMRs or microreactors in operation in the U.S. However, as stated above, it appears these designs are technically feasible, but as of yet are simply unproven. Economic factors are critical to the future of these types of advanced nuclear deployment, as these designs are new and have not yet experienced deployment. The primary hurdle is moving from FOAK to NOAK deployments, as manufacturers learn to reduce costs as they gain experience building these generators. Likewise, lowering the cost of manufacture, and thus the final construction costs, helps to drive down the LCOE of nuclear power, because the comparatively low fuel costs of nuclear mean that LCOE is driven primarily by construction costs. While the above factors are critical to all types of reactors, there are also additional cost considerations specific to SMRs and microreactors, as economies of scale and different use cases can lead to distinction in how they can be funded.

[188] A COL is an NRC-issued license that authorizes a licensee to construct and (with certain specified conditions) operate a nuclear power facility, such as a nuclear plant at a specific site.

[189] Williams, Bradley J., et al., "Opportunities for AP1000 Deployment at Existing and Planned Nuclear Sites," Idaho National Laboratory, p. 2-5, August 2024, https://www.osti.gov/biblio/2437758, accessed October 16, 2024.

The federal government offers numerous incentives for advanced nuclear power, including tax credits, grants, and loans. Steps have also been taken to improve administrative efficiency related to approving designs and COLs. More recent legislation has also funded numerous programs that are available for the development of nuclear projects. As a result, there are numerous current projects at all scales of reactor design that have either entered active development or are expected to over the coming decade. The DOD has also launched several programs specifically focused on the development of microreactors on military installations.

Recommendations

The Commission was tasked to prepare and submit a report to the Governor, the President of the Senate, and the Speaker of the House of Representatives, containing its findings and any recommendations for potential legislative or administrative actions that may enhance the use of advanced nuclear technologies in a manner consistent with the energy policy goals in Section 377.601(2), F.S.

Florida's energy policy is to ensure an adequate, reliable, and cost-effective supply of energy for the state in a manner that promotes the health and welfare of the public and economic growth. Section 377.601(2), F.S. states the state's energy policy must be guided by the following goals:

(a) Ensuring a cost-effective and affordable energy supply.
(b) Ensuring adequate supply and capacity.
(c) Ensuring a secure, resilient, and reliable energy supply, with an emphasis on a diverse supply of domestic energy resources.
(d) Protecting public safety.
(e) Protecting the state's natural resources, including its coastlines, tributaries, and waterways.
(f) Supporting economic growth.

At the conclusion of FPSC staff's workshop on advanced nuclear technology, described in Chapter 1, staff requested post-workshop written comments from stakeholders. Staff specifically requested any recommendations stakeholders may provide. The FCG's Next Generation Nuclear Workgroup provided several such recommendations:

- Commissioning a more comprehensive study beyond the impacts to Florida's electricity needs. The work could be overseen by a recognized independent Florida body, such as a major university, that would help to define the benefits of new nuclear development in the state, including its influence in attracting new economic development, manufacturing, and workforce development. This study could also include creating an inventory of potential sites for new nuclear development.

- Ensuring cost recovery for preliminary costs incurred during site evaluations in order to mitigate financial risks during the early phases of project development. Cost recovery for these activities could be implemented through changes to Section 366.8255, F.S. (environmental cost recovery) and Section 366.93 F.S. (nuclear cost recovery).

- Enhancing stakeholder engagement and education concerning advancements in nuclear safety. Modern nuclear reactors incorporate state-of-the-art safety features that substantially reduce accident risks. Providing stakeholders detailed information on these safety enhancements will help dispel misconceptions and build public confidence in advanced nuclear energy.

- Moving forward with additional initiatives if the costs associated with advanced nuclear technologies are more certain and demonstrate clear benefits to utility customers. This includes support for new state and/or federal legislation providing increased grant funding for the deployment of advanced nuclear reactors, as well as establishing a workforce development program aimed at training construction and operations teams for new nuclear power plants. This dual approach presents a comprehensive strategy to not only encourage investment but also accelerate progress in advanced nuclear energy.

If the State of Florida decides to encourage further investment in advanced nuclear power in Florida, these recommendations could form the basis of legislative and administrative efforts to that end. As the economic regulator of utilities in the state, the FPSC's role in reviewing a utility's decision to build a particular generation technology is ensuring it is the most cost-effective alternative to meet customers' energy requirements, taking into account the need for reliability and fuel diversity. With regards to the deployment of advanced nuclear, particularly in the context of building SMRs to serve specific customers (e.g., data centers), the Commission will need continued flexibility to approve rate schedules specific to those customers, rather than the standard practice of spreading costs over the general body of ratepayers.

Activity surrounding advanced nuclear power technology seems to have advanced considerably over the last year, and it is likely to continue that trend in the coming year. As the technology matures, and more advanced nuclear plants are deployed throughout the country, Florida can position itself to take advantage of the benefits advanced nuclear can offer. It is important, however, to maintain the perspective that pursuing advanced nuclear power technology is a long-term approach to meeting the power needs of Florida. Licensing and construction of nuclear power plants are long-lead projects, and any regulatory or political changes during the development of long-lead projects adds to the risk of delay, which in turn increases the financial risk.

The DOD is actively pursuing pilot projects to deploy microreactors and possibly SMRs at military bases in other states. Florida public utilities, however, have experience owning and operating nuclear power plants, and may be well suited to work in partnership with the DOD at Florida's many military installations.