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Nuclear Electricity Expansion in New Hampshire

PRESENTED TO THE NEW HAMPSHIRE NUCLEAR STUDY COMMISSION

Rep. Keith Ammon, Chair

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TABLE OF CONTENTS

EXECUTIVE SUMMARY 2

1 INTRODUCTION 2

2 PROBLEM STATEMENT 3

3 METHODOLOGY 3

4 BACKGROUND 4

4.1 NUCLEAR ENERGY 4

4.2 FEDERAL NUCLEAR LEGISLATION 5

4.3 ENERGY IN NEW HAMPSHIRE 6

4.4 ENERGY COSTS 8

5 CASE STUDIES 10

5.1 PLANT VOGTLE 10

5.1.1 PLANT FINANCING 10

5.1.2 COST CHALLENGES 11

5.1.3 IMPACT ON RATEPAYERS 11

5.1.4 GEORGIA ENERGY LANDSCAPE 11

5.2 NUSCALE 12

5.2.1 THE CARBON FREE POWER PROJECT 12

5.2.2 NEXT STEPS 13

5.3 SEABROOK STATION 14

5.3.1 HISTORY 14

5.3.2 PLANT FINANCES 14

5.3.4 FINANCIAL AND COMMUNITY IMPACT 15

6 STATE POLICY OPTIONS 16

6.1 CLEAN ENERGY STANDARD 16

6.2 WORKFORCE DEVELOPMENT AND PUBLIC OUTREACH 17

6.3 TRANSMISSION 18

6.4 FEDERAL PROGRAMS 18

7 CONCLUSION 19

EXECUTIVE SUMMARY

Expanding nuclear energy production is increasingly considered crucial to attaining a dependable, large-scale, low-carbon energy future. In the last 30 years, however, only one reactor in the U.S. has successfully been licensed, constructed, and made operational. Advanced nuclear technology offers a variety of innovative approaches to address some of the challenges associated with traditional nuclear reactors, but it has yet to be fully developed and commercially deployed. In June 2022, the General Court of New Hampshire created the New Hampshire Nuclear Study Commission to investigate the potential implementation of next-generation nuclear reactor technology in the state. The commission asked us to provide further context on their work by researching how state government can contribute to the future of nuclear energy in New Hampshire given the state's deregulated electric power structure. Our case-study analysis covers three nuclear power projects: Plant Vogtle, the most recent nuclear power plant to begin commercial operation in the U.S.; NuScale's Carbon Free Power Project, an advanced nuclear generator project terminated due to financial challenges; and Seabrook Station, New Hampshire's only nuclear power plant. These projects highlight both the financial challenges and benefits of nuclear energy generation. Overall, we find that financial and regulatory hurdles are currently preventing the widespread implementation of advanced nuclear reactors. Nevertheless, we explore potential state actions to aid in the future incorporation of innovative nuclear technologies in New Hampshire within the framework of the state's competition-driven energy market. These include enacting a Clean Energy Standard, implementing workforce development and public awareness initiatives, investing in transmission, and taking advantage of federal programs.

1 INTRODUCTION

Dating back to its inception as a means of commercial energy production in the 1950s, nuclear energy has long been regarded as a more efficient, more reliable, and cleaner alternative to traditional sources of fossil fuel energy.[1] Electricity generation from commercial nuclear power plants first began in the United States in 1958. The prevalence of nuclear energy grew rapidly across the nation, with most U.S. nuclear reactors built in the 20-year period between 1970 and 1990.[2] As of April 30, 2014, 94 commercial nuclear reactors operate at 54 nuclear power plants across 28 states, supplying the country with almost a fifth of its energy since 1990.[3] This is in part due to its value as the most efficient energy source—the electric generation capacity factor of nuclear, or the ratio of actual electrical energy output to its theoretical maximum, is 92.5 percent, compared to coal's 40.2 percent and wind's 35.4 percent. Furthermore, nuclear power reactors do not directly produce carbon emissions,[4] a key distinguishing factor from coal and natural gas energy production and a popular advantage as environmental consciousness increases. Support for the expansion of nuclear energy only continues to grow. In 2023, 57 percent of Americans indicated they favor the production of more nuclear power plants, up from 43 percent only three years prior.[5]

New Hampshire is one of the 28 states in the country currently involved in nuclear energy production.[6] The state's only nuclear power plant, Seabrook Station, began operation in 1990, and is one of two nuclear power plants in New England. Seabrook provides electricity to 1.2 million people and businesses in the region.[7] New Hampshire produced 56 percent of its electricity through nuclear generation at Seabrook in 2021. The Seabrook nuclear station contributes to the state's goal of carbon emission reduction and provides stable energy production, most notably during high peak periods in the summer and winter.[8] Seabrook's operating license received a 20-year extension in March 2019, and is now set to expire in 2050.[9]

In December 2023, the New Hampshire Nuclear Study Commission released its final report detailing significant innovation in the nuclear energy industry. The report focused on the development of advanced reactor technologies that promise less time for construction, improved siting flexibility, and adjustable scalability.[10] The Commission concluded that nuclear power generation is necessary for meaningfully reducing carbon emissions and plays a vital role in maintaining electric grid reliability and affordability alongside renewables.[11]

2 PROBLEM STATEMENT

Despite the benefits and potential of next-generation nuclear reactor technology, across the country, the large-scale expansion of nuclear power generation in the 21st century has yet to occur. Expanding nuclear power generation faces several significant challenges, including high upfront costs, a complex regulatory environment under the Nuclear Regulatory Commission (NRC), the long-term storage and disposal of radioactive fuel, and competition within the electricity market.

Connected to the regional electric grid, the energy landscape of New Hampshire is defined by its deregulated system whereby the state's electricity is supplied by merchant-generators instead of public utilities. Within this competitive market environment, ensuring a resilient energy system while prioritizing cost-efficiency remains a priority for the future of New Hampshire state energy policy.

The state's goal is to adopt a diverse mix of fuel and technology through an all-resource energy strategy.[12] As such, it benefits the state to consider how nuclear reactor technology could contribute to grid reliability while reducing carbon emissions and continuing to meet regional demand. However, with high upfront costs, is new nuclear energy expansion financially viable in the state? While recognizing the realities of New Hampshire's energy system, what actions can the state government take to ensure the reliability, affordability, and sustainability of the state's energy?

3 METHODOLOGY

To provide relevant insight into the current state of nuclear energy generation in the U.S., we conducted three case studies. We cover:

- Vogtle Units 3 and 4 at the Alvin W. Vogtle Electric Generating Plant in Georgia, the site of the most recent nuclear reactors to enter commercial operation in the country;
- NuScale Power's Utah Associated Municipal Power Systems project, which aimed to deploy the first advanced nuclear technology small modular reactor (SMR) design certified by the NRC;
- New Hampshire's Seabrook Station.

In each of these case studies, we focus on plant economics, business operations, and the regulatory environment.

Additionally, we conducted expert interviews with the following individuals:

- David Schlissel, Director of Resource Planning Analysis at the Institute for Energy Economics and Financial Analysis
- Michael Catindig, Investment Banking Associate at Barclays Power & Utilities Group
- Joshua Elliot, Director of the Division of Policy and Programs at the New Hampshire Department of Energy
- Diane Screnci, Senior Public Affairs Officer of Nuclear Regulatory Commission Region I
- Donald Kreis, Consumer Advocate in the New Hampshire Office of the Consumer Advocate

The information learned from these interviews is applied throughout the report, providing key information on the financial challenges of nuclear energy generation and New Hampshire's energy system.

4 BACKGROUND

This section first covers the nuclear industry in the U.S., including an introduction to advanced nuclear technology and an overview of nuclear regulatory systems. A review of past federal and state policies demonstrates the breadth and focus of initiatives targeted at promoting nuclear energy development. Finally, this section contextualizes this information in the energy system of New Hampshire, including takeaways from the New Hampshire 10-Year State Energy Strategy.

4.1 NUCLEAR ENERGY

Nuclear power reactors use the heat produced during atomic fission to boil water and produce pressurized steam. Routed through the reactor steam system, the steam spins large turbine blades that drive magnetic generators to produce electricity.[13] Nuclear fission occurs when a neutron slams into a larger atom, forcing it to excite and split into two smaller atoms—also known as fission products. Additional neutrons are also released that can initiate a chain reaction. When each atom splits, a tremendous amount of energy is released.

Lately, technological innovation has demonstrated the potential to revolutionize future nuclear energy generation. Small modular reactors (SMRs) have received the most attention so far. As the name suggests, these advanced nuclear reactors are a fraction of the physical size of traditional nuclear reactors, have a modular system such that components can be factory-assembled and transported as a unit installation, and harness nuclear fission to generate heat and produce energy.[14] Generally defined as reactors that are 300 megawatts (MWe) or smaller, SMRs contrast with most current U.S. reactors which lie in the 600-1135 MWe range. Their designs can include a single reactor or multiple units grouped together. Advanced SMRs offer many advantages, including the siting flexibility of their relatively small physical footprints, reduced capital investment, ease of manufacturing, and potential for incremental power additions.[15] SMRs are factory-built in standardized units, allowing for quicker deployment and potentially lower costs compared to building large plants on-site. This modularity also enables reactors to be added incrementally as power needs grow. SMRs also offer the advantages of a distinct passive safety system, requiring no human intervention or external power to shut down in the case of an accident.

As of 2022, approximately 80 SMR designs have been developed around the world.[16] Only one, however, has been certified in the U.S. by the NRC.[17] Additionally, most of these designs require fuel that is not yet available at a commercial scale. The uranium fuel that runs the country's existing fleet of nuclear reactors is enriched up to 5 percent with uranium-235, the main fissile isotope that produces energy during a chain reaction. In contrast, high-assay low-enrichment uranium (HALEU) is enriched between 5 percent and 20 percent and is required for most U.S. advanced reactors to achieve smaller designs that get more power per unit of volume.[18]

4.2 FEDERAL NUCLEAR LEGISLATION

Congress has enacted multiple policies to aid nuclear energy development. Here, we review notable legislation that aims to provide support for the research, development, and implementation of nuclear energy.

The Energy Policy Act, passed in 2005, included a production tax credit (PTC) that allows new reactors to qualify for a tax credit due to high construction costs. It also contained a more streamlined tax credit on decommissioning funds to make the process more economically efficient, and federal loan guarantees for advanced nuclear reactors or other emission-free technologies for up to 80 percent of the project cost.[19] Since then, the government has offered other types of support. In 2008, loan guarantees were made available to enable the construction of nuclear power plants. More recently, the Nuclear Energy Innovation and Modernization Act passed with bipartisan support in 2019. The act aimed to add clarity to the certification process for nuclear energy producers and add transparency and efficiency to the Nuclear Regulatory Commission's regulation process.[20]

The Inflation Reduction Act of 2022 directly promoted the expansion of nuclear energy throughout the country. The bill gave newly constructed nuclear power plants the ability to choose between a PTC or an investment tax credit (ITC), both of which lowered the operating costs of nuclear power plants and encouraged their creation.[21] The PTC, dubbed the Clean Electricity Production Tax Credit, awards the production of emission-free power with at least $25 per megawatt-hour during the first ten years of a new advanced plant's operation. The ITC, on the other hand, grants zero-emissions plants that enter service after 2025 with a tax credit worth 30 percent of what was originally invested in the facility.[22] Both credits will phase out when carbon emissions in the electricity-production sector drop 75 percent below what they were in 2022. To support the modernization and revitalization of existing nuclear power plants, the act also provides $250 billion worth of loan guarantees.[23] Just as important as the production of advanced nuclear power plants is the production of their fuel source, HALEU, which is sourced from Russia. The Inflation Reduction Act of 2022 earmarked $700 million for researching sources of HALEU within the United States, an investment that seeks to allow nuclear energy in the country to operate independently and at a reduced cost.[24]

4.3 ENERGY IN NEW HAMPSHIRE

Relative to many other states, New Hampshire has a unique deregulated energy distribution system. In a regulated market, local utility companies produce, sell, and distribute energy under government regulation, and consumers do not have a choice about where they purchase their energy.[25] New Hampshire first started as a regulated electricity distribution system, where electricity was dominated by a state-owned utility, the New Hampshire Public Utilities Commission (NHPUC).[26] New Hampshire's switch to a merchant distribution system occurred in 1996 when the state passed legislation with aims "to reduce costs for all consumers of electricity by harnessing the power of competitive markets."[27] The law requested the NHPUC issue a statewide restructuring plan for all its utilities. This meant that New Hampshire residents could now choose whether to obtain their electricity from a regulated supplier or a competitive energy supplier, finding the electric provider that would best fit their needs.[28]

Today, merchant generators bid into a region-wide competitive wholesale market which is administered by ISO New England (ISO-NE), the regional transmission organization (RTO). ISO-NE is a non-profit organization also responsible for operating the grid and planning for future electricity needs across six New England states: Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, and Connecticut.[29] Utilities can also procure electricity from generators through a contract, usually on a 6-month time scale.[30] Energy suppliers then resell electricity to consumers. Currently, four electric distribution companies operate in New Hampshire, each servicing a specific region: Eversource Energy (Eversource), Liberty Utilities (Liberty), Unitil Energy Systems Inc. (UES), and the New Hampshire Electric Cooperative, Inc. (NHEC).[31] Eversource serves approximately 70 percent of the retail customers in New Hampshire, while Liberty serves about 6 percent. Both UES and NHEC each serve approximately 11 percent of retail customers in New Hampshire.[32] If a New Hampshire resident were to decide to choose a competitive energy supplier, their electric utility would still be responsible for the delivery of electricity and restoring power in the case of an outage. However, the resident would now also be a customer of a competitive energy supplier, buying the actual electricity used.[33]

Notably, New Hampshire's community power law, signed into law in 2019, authorizes municipalities to procure their own power and act as the local distributor. This structure supports residents and businesses to secure lower power rates in the competitive market and allows customers to choose between the base rate and a portfolio with greater proportions of renewable power. Indeed, the

Community Power Coalition of New Hampshire's rates fall below default offerings from every other electric utility in the state.[34] The Coalition was incorporated in 2021 with 13 Municipalities and 1 County.[35] As of April 1, 2024, the Coalition has fifty-seven municipal members and two county members.[36]

As demonstrated by *Table 1*, New Hampshire produces a majority of its energy through nuclear, all of which is generated at Seabrook Station. The rest of New England relies more heavily on natural gas. Since 2000, coal and oil-based generation within the region have experienced a substantial decline and natural gas has emerged as the region's dominant energy source. This shift is reflective of participant state decarbonization goals; however, the share of overall electricity generated by renewable resources would have to significantly increase by 2040 to achieve policy targets from the decarbonization efforts of neighboring states. With regards to advanced nuclear energy, ISO-NE maintains a policy of neutrality, placing greater emphasis on big-picture grid reliability and electricity market administration.[37]

2022	**New Hampshire**		**ISO New England**	
Generation	**Gigawatt hour**	**% of Total**	**Gigawatt hour**	**% of Total**
Nuclear	10,922	58%	27,386	26%
Natural gas	4,502	24%	55,917	53%
Hydroelectric	1,201	6%	6,602	6%
Wood biomass	711	4%	2,960	3%
Wind	482	3%	4,046	4%
Petroleum	445	2%	1,855	2%
Coal	305	2%	348	0%
Other biomass	141	1%	1,797	2%
Other	50	0%	1,762	2%
Solar	4	0%	3,346	3%
Battery	-	0%	(8)	0%
Pumped storage	-	0%	(398)	0%
Grand Total	**(18%) 18,764**	**100%**	**105,612**	**100%**

Table 1: The energy generation mix of New Hampshire and ISO New England [38]

New Hampshire also acts as a net electricity exporter so its energy generation must be considered within the context of the surrounding region. As a net electricity exporter, it is surprising that New Hampshire has the fifth-highest average electricity retail prices among the Lower 48 states.[39] In the 10-Year State Energy Strategy of New Hampshire, prioritizing cost-effective energy policies is the first goal mentioned. The plan stresses that policymakers should pursue market-based mechanisms for achieving cost-effective energy thereby avoiding preferential quotas and fostering a competitive market based on the value of new and emerging technologies.[40]

4.4 ENERGY COSTS

A nuclear power plant project is characterized by high upfront capital costs, a long construction period, low and stable operational costs, and lengthy payback periods. The World Nuclear Association divides costs for a nuclear power plant into four parts:[41]

- Capital costs: the cost of site preparation, construction, manufacture, commissioning and financing a nuclear power plant.
- Plant operating costs: the costs of fuel, operations and maintenance, and a provision for funding the costs of decommissioning the plant and treating and disposing of used fuel and wastes.
- External costs: in the case of nuclear power, it is usually assumed to be zero, but it could include the costs of dealing with a serious accident that are beyond the insurance limit and in practice need to be picked up by the government.
- Other costs: including but not limited to system costs and nuclear-specific taxes.

Despite the high initial capital investment, nuclear plants tend to have relatively low fuel costs, which drive down operating costs compared to natural gas and coal plants. Low fuel costs have from the outset given nuclear energy an advantage compared with coal and gas-fired plants. Uranium, however, must be processed, enriched and fabricated into fuel elements, accounting for about half of the total fuel cost. In the assessment of the economics of nuclear power, allowances must also be made for the storage of radioactive spent fuel and the ultimate disposal of this spent fuel, or the wastes separated from it. Even with these considerations, the total fuel costs of a nuclear power plant in the Organisation for Economic Co-operation and Development (OECD) are typically about one-third to one-half of those for a coal-fired plant and between one-quarter and one-fifth of those for a gas combined-cycle plant.[42] Especially for New Hampshire, where costs of coal and gas are higher than most states, having a low operating cost is essential. It is also important to recognize that siting and local population concerns make the building of new generation difficult in New England, regardless of the type.[43]

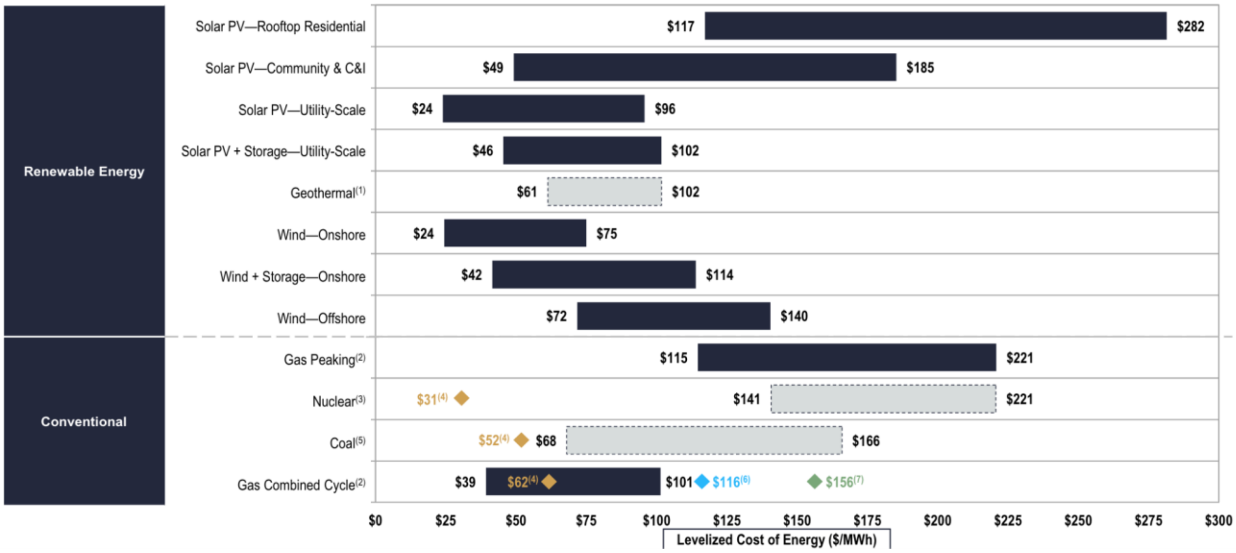

Figure 1: Levelized Cost of Energy Comparison – Unsubsidized Analysis[44]

The costs and benefits of nuclear energy relative to other types of generation are reflected through the prices to consumers. The levelized cost of energy represents the average revenue per unit of electricity generated or discharged to recover the costs of building and operating a generating plant. Nationally, according to Lazard's Levelized Cost of Energy Analysis (*Figure 1*), the levelized cost of nuclear electricity is between $141-$211, whereas coal source is $68-$166 and gas peaking is $115-$221. Notably, utility-scale renewable energy sources like wind and solar tend to cost significantly lower than nuclear. Therefore, the state can continue exploring alternative energy generation sources while waiting for further technological improvements that will eventually bring down the cost of implementing new nuclear generation facilities. *Figure 2* demonstrates that with existing subsidies, the cost of renewable energy could be further brought down. Questions remain, however, as to whether NH has the capacity and potential for commercial scale wind and solar to meet demand.

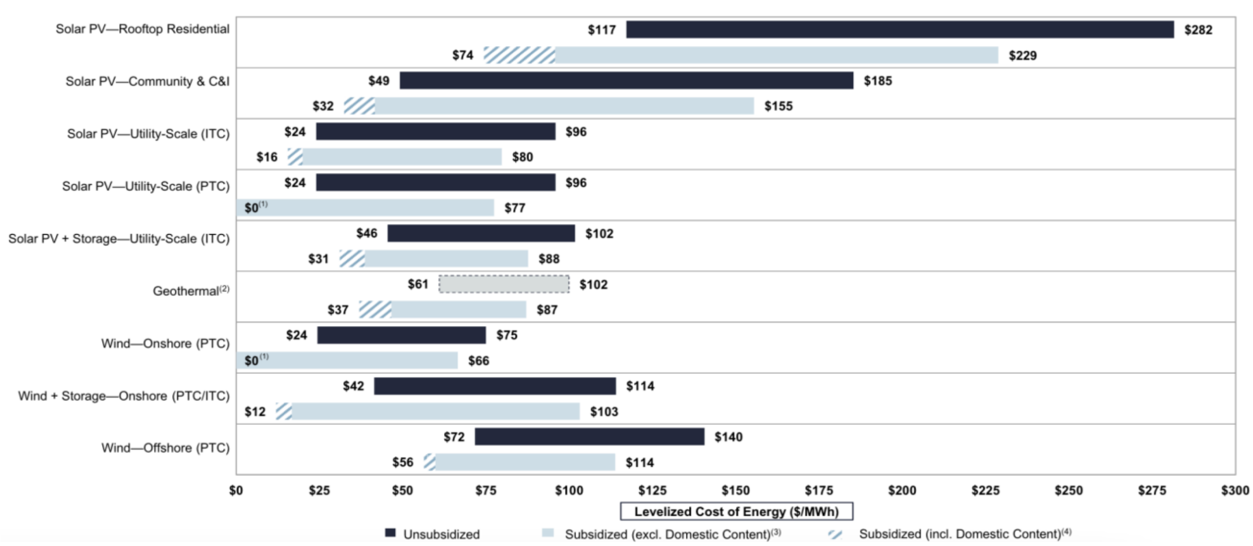

Figure 2: Levelized Cost of Energy Comparison—Sensitive to U.S. Federal Tax Subsidies[45]

5 CASE STUDIES

The following case studies offer insight into nuclear power projects spanning the industry, technology, and geography relevant to this research. Together, they highlight the financial challenges of new nuclear energy development, the utilization of federal support for nuclear development, and long-term benefits of nuclear energy infrastructure.

5.1 PLANT VOGTLE

The Alvin W. Vogtle Electric Generating Plant, commonly known as Plant Vogtle, is a nuclear power plant located in Waynesboro, Georgia. It is jointly owned by a set of electric utilities: Georgia Power (45.7 percent), Oglethorpe Power Corporation (30 percent), Municipal Electric Authority of Georgia (MEAG) (22.7 percent), and Dalton Utilities (1.6 percent). Plant Vogtle is operated by Southern Nuclear Operating Company.

In 2008, Southern Nuclear Operating Company submitted its application for Vogtle Units 3 and 4, adding on to the two existing units that became operational in the late 1980s. Units 3 and 4 were cleared by the NRC in 2012 making the project the first new nuclear power plant to be licensed and begin construction in the United States in more than 30 years.[46] Vogtle Units 3 and 4 each have a generating capacity of 1,100 MWe of electricity.[47] Vogtle Unit 3 entered commercial operation on July 31, 2023 and Unit 4 entered commercial operation on April 29, 2024,[48] making Plant Vogtle "the largest generator of clean energy in the nation."[49]

5.1.1 PLANT FINANCING

Each owner of Plant Vogtle finances its share of the project in a unique way due to the differences between each entity's business model and operating structure. Notably, a construction work in progress (CWIP) tariff established in the 2009 Georgia Nuclear Energy Financing Act also allows Georgia Power to charge customers for financing costs during the time of construction. According to the company, this imposes minor additional costs onto customers in the present but reduces long-term future costs associated with financing.[50]

The construction and operation of Vogtle Units 3 and 4 is also supported by federal financing incentives for nuclear power. In 2010, to lower borrowing costs for the project owners, the Department of Energy announced conditional commitments for $8.3 billion in loan guarantees. President Obama commented that this was necessary to meet growing energy needs, prevent the worst consequences of climate change, and make clean energy profitable.[51] Seven years later, the Trump administration offered an additional $3.7 billion in loan guarantees, despite the project already being billions over budget and years behind schedule.[52] By addressing the capital intensity and upfront costs of the Vogtle projects, these commitments demonstrate bipartisan federal support for nuclear energy development.

5.1.2 COST CHALLENGES

Originally, the reactors were expected to cost $14 billion and be complete by 2017.[53] But Vogtle 3 only entered commercial operation this past summer on July 31st, 2023, and Vogtle 4 entered commercial operation only after another series of delays.[54] With costs calculated near $35 billion, the Vogtle expansion will be the most expensive power plant constructed in history; its supporters, however, argue that this label ignores the externalities of carbon-emitting plants.[55]

Nevertheless, the ballooning cost overruns and construction difficulties of the project are undeniable. Early on, difficult or impossible engineering designs led to quality and cost problems, raising questions about the efficacy of its construction process.[56] In 2017, construction delays ultimately drove the project's main contractor, Westinghouse Electric Co., to file for bankruptcy.[57] The company paid the project owners $3.7 billion to walk away. As delays continued, increasing costs led to lawsuits as utilities sought to shield themselves from paying more of Vogtle's growing expenses. Overall, the construction of Vogtle Units 3 and 4 has highlighted the extreme degree to which upfront financial challenges and tensions may serve to discourage other utilities from pursuing nuclear power development at this time.

5.1.3 IMPACT ON RATEPAYERS

Westinghouse's bankruptcy left the four project co-owners and their customers exposed to cost overruns.[58] For Georgia Power, regulators had to decide who should bear the increased cost burden: the utility's shareholders or ratepayers.

In December 2023, the Georgia Public Service Commission unanimously approved an additional 6 percent rate increase to pay for Georgia Power's $7.56 billion in remaining costs. The rate increase is projected to add $8.95 a month to a typical residential customer's current monthly bill of $157. This is in addition to a $5.42 rate increase that already took effect when Unit 3 began operating over the summer.[59] Due to Georgia's Nuclear Energy Financing Act of 2009, Georgia Power customers have already been paying for Vogtle 3 and 4 for more than a decade. A typical Georgia Power residential customer is expected to have paid $880 for the project's financing costs at the time that both Vogtle reactors went into service.[60] It is estimated that a typical Georgia Power household will spend $45 more on monthly utility bills in 2025 because of the Vogtle nuclear expansion as well as fuel and electric rates hikes.[61] According to the director of utility finance of the Georgia Public Service Commission, cost increases and schedule delays of the project have eliminated any cost benefit to customers on a life-cycle basis.[62]

5.1.4 GEORGIA ENERGY LANDSCAPE

The Vogtle plant has been an important landmark for Georgia Power where coal still accounts for most of the company's generating capacity.[63] But it is worth questioning how much reduced carbon emissions were a driving reason as to why the plant was built given that Georgia does not have a renewable energy standard or a voluntary renewable energy target.[64]

Factors in nuclear development that could be a concern in other states are avoided by Georgia's market and regulatory conditions. The Georgia Public Service Commission (PSC) regulates the state's major investor-owned utility, Georgia Power Company, and has some regulatory authority over other power entities in the state.[65] The PSC has exclusive power to decide what are fair and reasonable rates for services under its jurisdiction. This regulated market directly contrasts with deregulated competition-driven markets where capital-intensive technologies such as nuclear power are inherently less attractive.[66]

5.2 NUSCALE

NuScale's reactor modules are 77 MWe each and can be grouped in plants of up to 12 modules, which are suitable for powering smaller grids, remote areas, or industrial facilities. Utilizing proven pressurized water reactor (PWR) technology, NuScale offers inherent safety features like natural circulation cooling and passive containment in case of emergencies.

5.2.1 THE CARBON FREE POWER PROJECT

In 2021, NuScale Power announced together with Utah Associated Municipal Power Systems (UAMPS) agreements to facilitate the development of the Carbon Free Power Project (CFPP). The project aimed to deploy NuScale Power Modules at the Idaho National Laboratory (INL) and create cleaner, safer and cost-effective carbon-free power for UAMPS member utilities.[67] In 2020, the Department of Energy approved $1.35 billion over 10 years for the plant, subject to congressional appropriations. The department has provided NuScale and others about $600 million since 2014 to support the commercialization of small reactor technologies. NuScale had planned to develop the six-reactor 462-megawatt project with the UAMPS and launch it in 2030, but several towns pulled out of the project as costs rose.[68]

Despite years of significant efforts, in November 2023, UAMPS and NuScale announced that they had mutually agreed to terminate the CFPP price increases due to concerns about the willingness of customers to pay. The announcement sent NuScale's share price down 20 percent.[69] As demonstrated in *Figure 3*, NuScale said in January that target price for power from the plant was $89 per megawatt-hour (MWh), up 53 percent from the previous estimate of $58 per MWh. When the NuScale SMR was canceled in November, its target price of power was $119 per MWh, not including Inflation Reduction Act subsidies, and $89 per MWh with the subsidies. The estimated costs of the UAMPS project rose to $4.2 billion in 2018, then $6.1 billion in 2020, and finally $9.3 billion in 2023, after it was scaled down to 462 MW in 2021.[70] In the end, the costs were clearly too high for UAMPS members to bear. Yet that's not as high as the price of power from an SMR can get. For example, the

CEO of Constellation Energy Corporation, which owns the most nuclear plants in the U.S., sees a price of $150 to $160 per MWh for the power from a new SMR.[71]

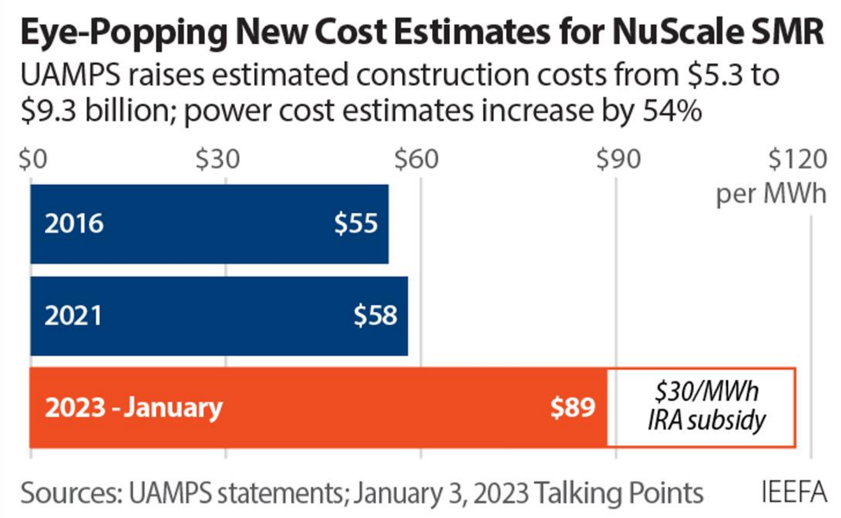

Figure 3: Estimated construction cost for NuScale SMR[72]

5.2.2 NEXT STEPS

After the failure of the CFPP, on November 20th, 2023, NuScale announced its partnership with Oak Ridge National Laboratory (ORNL) to perform a techno-economic assessment, studying a NuScale SMR's ability to implement a cost-effective steam heat augmentation design.[73] The study will be based on process data from a U.S. chemical facility to help the plant meet its electric power and process steam requirements with NuScale's carbon-free, nuclear technology. In this partnership, NuScale will work through the Gateway for Accelerated Innovation in Nuclear (GAIN) initiative, a federal program further explained in Section 6.4, to explore the new decarbonization pathway for chemical plants based on SMR technology.

We can conclude from this case study that commercial implementation of innovative technologies like SMRs have not yet been cost-effective. Given the high prices, subscription demand for the CFPP failed to meet the long-term sustainability goal for the project to continue. Developers cannot sustain the upfront costs given that consumers still have much cheaper alternatives. Therefore, despite the siting flexibility and greater scalability of SMRs, cost challenges are still preventing their implementation. When considering cost overruns, it is important to recognize that the problem is common across all energy sources because planners consistently fail to predict costs.[74] The characteristics of SMRs still hold notable potential to address these overrun concerns, considering their modular designs, siting flexibility, and the future potential for scalar manufacturing.

5.3 SEABROOK STATION

Seabrook Station is one of the only two nuclear power plants in New England. Located in Seabrook, New Hampshire, it generates about 1,244 megawatts of nuclear power per year for the benefit of 1.2 million families and businesses. Majorly owned by NextEra Energy Resources LLC, the plant was issued an operating license in 1986 and began commercial operation in 1990. In March 2019, the NRC approved NextEra Energy's request for a 20-year operating license extension for Seabrook Station, which is set to expire in 2050.[75] The Seabrook nuclear power plant greatly contributes to the electricity exportation of New Hampshire, providing almost 8 percent of New England's power supply.[76]

5.3.1 HISTORY

The Seabrook power plant was first proposed in 1968 when the Public Service Company of New Hampshire (PSNH), now known as Eversource, announced plans to build a nuclear power plant in Newington. Later changed to the Seabrook location, the project was abandoned in 1969. Reinstating the plan in 1972, PSNH proposed two reactors for a nuclear power plant with a total cost of less than $1 billion. Construction started soon after and, after facing delays, costs ultimately totaled $4.3 billion. As a result, the second reactor was only 25 percent completed when the company decided to halt its construction. Total costs of the project added up to $6.2 billion by the time the first reactor came online in 1990.[77]

Due to controversy over safety and environmental concerns, Seabrook has had its share of watchdogs. The C-10 Research and Education Foundation reported safety concerns for Seabrook starting even during its construction period.[78] Despite this start, the plant has run safely for thirty-four years. From 2002-2012, the plant had the fewest number of safety violations in the Northeast, according to a report by the Government Accountability Office.[79]

5.3.2 PLANT FINANCES

New England nuclear stations have increasingly been facing negative trendlines, as aging reactors must compete against power generated by natural gas and overcome resistance from environmental advocates.[80] Vermont Yankee in Vermont shut down in 2014 and Pilgrim Nuclear Power Station in Massachusetts closed in 2019. Today, both of the remaining nuclear plants in New England—Seabrook Station and the two-unit Millstone plant in Connecticut—are facing financial challenges.[81] Seabrook faces low wholesale electricity prices due to competition from cheaper sources of energy. This emerges from inherent characteristics of nuclear technology: nuclear generators must run at full capacity all the time because the technology cannot easily ramp up and down. Within the wholesale market, the addition of new renewable resources has significantly brought down prices at certain times of the day, creating financial strain for nuclear generation despite the continued need for its reliability at times of peak load demand.[82]

According to NetExtra Energy, the plant's expenditures total $312 million, 56 percent ($175 million) of which are allocated for products and services, such as labor.[83] Additionally, in 2023 the town of Seabrook reached an agreement with NetExtra to add an increased tax cost of $40 million in taxes over the course of three years (2021-2023). This was a large development for the town as local government function in New Hampshire relies mostly on property taxes. According to Select Chairman Ravi Ravikumar the new agreement brought down the tax rate from $13.73 per $1,000 of assessed value for 2022 to $13.25 in 2023.[84] The next largest cost for the plant is expected to be its decommissioning. As one of the more recent plants licensed for operation in the United States, Seabrook Station will benefit from being one of the last existing plants to be decommissioned. Taking into consideration the NRC-approved 2050 operating life, on behalf of NextEra Energy Seabrook, TLG Services, Inc. estimated a cost of $1.076 billion on December 31, 2019.[85] Of this, spent fuel storage costs account for approximately 30 percent, or $300 million, of the total decommission cost,[86] with spent fuel expected to stay on site until 2100.[87] Moving forward, some advanced nuclear technology explores fuel recycling methods to extract the remaining energy value of spent fuel from traditional nuclear sites. Should these designs get certified by the NRC and reach a marketable price, the existing infrastructure at Seabrook, including the Seabrook Independent Spent Fuel Storage Installation, would be an asset to adopting this technology.

5.3.4 FINANCIAL AND COMMUNITY IMPACT

Besides contributing greatly to the energy sector of New Hampshire, Seabrook also affects the surrounding communities it is close to. According to a NetExtra analysis of the plant, Seabrook provides higher-paying jobs for hundreds of full-time workers in the Rockingham and Stafford County regions.[88] Financially, Seabrook's expenditures are a benefit to the local economy with every $1 of output producing $1.34.[89] The estimated ongoing operation of the plant through 2032 will also contribute between $2 billion and $2.91 billion to the Massachusetts economy.[90] As seen in *Figure 3*, a variety of other industries benefit from Seabrook as well.

Industry Description	Output	Labor Income	Employment
Power generation and supply	$402,148	$79,205	550
Machinery and equipment maintenance	$25,658	$17,109	184
Investigation and security services	$12,635	$8,840	251
Owner-occupied dwellings	$10,464	-	-
Other support services	$6,489	$2,360	61
Real estate establishments	$6,256	$488	36
Offices of health practitioners	$5,028	$3,296	40
Food services and drinking places	$4,689	$1,844	80
Private hospitals	$4,291	$2,058	34
Monetary authorities	$4,033	$713	11
Other	$53,653	$23,905	553
Total	**$535,344**	**$139,816**	**1,799**

Figure 4: Most-Affected Industries in Local Counties (dollars in thousands)[91]

In addition to economic benefits, Seabrook impacts its surrounding communities through educational and environmental efforts. Home to a Science and Nature Center, it offers educational displays, free programs, aquariums, and a nature trail, all focused on interactive learning. Its location on marshlands close to the Atlantic Ocean contributes to its role in protecting the regional environment.[92]

6 STATE POLICY OPTIONS

Actions from the state government regarding nuclear energy must operate within the framework of New Hampshire's competition-driven energy market and recognize the challenges highlighted throughout the researched case studies. The following options do not seek to promote nuclear energy generation at the expense of market pressures; rather, they offer ways in which state policy related to next-generation nuclear reactors would better enable New Hampshire to take advantage of continued innovation and opportunity occurring within this technology. This is especially important to consider given that Seabrook's license expiration in 2050 could create a large gap in the state's energy production. While there is no guarantee that efforts put towards the expansion of nuclear energy generation will result in the implementation and incorporation of SMRs, preparing the state for new technology is still essential.

6.1 CLEAN ENERGY STANDARD

A Clean Energy Standard could be implemented, adding to or modeled after New Hampshire's existing Renewable Portfolio Standard (RPS). The RPS statute was enacted in 2007 and established the State's renewable energy policy. The statute requires each electricity provider to meet customer load by purchasing or acquiring renewable energy certificates (RECs) that represent generation based on the total MWh supplied.[93] The legislation was enacted because "it is in the public interest to stimulate investment in low emission renewable energy generation technologies within the state," setting a target of 25.2 percent by 2025.[94] The statute has successfully increased the quantity, diversity, and capacity of renewable energy facilities across the state.[95]

The RPS statute established four classes of renewable energy resources from which electricity providers must obtain RECs. Common renewable energy sources are solar, wind, small hydropower existing before 2006, biomass, and geothermal—notably, nuclear power is not included among eligible technologies. Although its inclusion has been suggested in the past, these efforts have not been successful due to fears that this would undermine the original intent of the RPS, flooding the REC market with larger-scale power plants to the detriment of renewable energy diversity.[96]

However, the addition of a Clean Energy Standard to support zero-carbon technology, connected to the existing RPS or under a distinct framework, would offer the same benefits that the RPS has provided for renewable energy development but for advanced nuclear reactor technology and SMRs. Across the country, of the 36 states with RPS laws, Connecticut, Indiana, and Massachusetts allow for nuclear energy to meet RPS requirements, subject to certain limitations.[97] In Connecticut, for example, the eligible nuclear energy must come from a facility built after October 1, 2023. A carefully designed Clean Energy Standard in New Hampshire could incorporate space for advanced nuclear energy without undercutting the market for renewables to receive RECs.

6.2 WORKFORCE DEVELOPMENT AND PUBLIC OUTREACH

Investment into workforce development and public outreach are additional ways to ensure that the state is situated to take advantage of future opportunities in nuclear technology. One option for the state is to draw on existing resources to enact an information campaign. Despite the rising support that nuclear energy has garnered across the nation, an information campaign would aid in spreading more awareness about the technology and clarifying differences between traditional and advanced nuclear energy generation.

Furthermore, certification courses transitioning workers from the oil, gas, and coal industries into the nuclear industry may create opportunities for transferable skills and industry growth. Federal programs such as the State-Based Home Energy Efficiency Contractor Training Grant Program allow states to reduce the cost of training residential energy efficiency and electrification contractors and their employees. The Building Training and Assessment Centers gives grants to institutions of higher education to establish building training and assessment centers to prepare building technicians and engineers to identify and deliver energy efficiency upgrades to businesses and institutional buildings.[98] Programs like these could allow the state to obtain funds to invest further in the promotion of the nuclear energy sector, through both the workforce development and education.

To further prepare the next generation of workers for the nuclear workforce, state policy could focus on proactively developing programs at universities across the state. The federal government supports many grants targeted at expanding research in the nuclear energy field, and the state could take advantage of these. Some include:

- Office of Nuclear Energy: Scientific Infrastructure Support for Consolidated Innovative Nuclear Research (Infrastructure FOA): This program assists entities with acquiring equipment or funding activities to support research, teaching, and education. This can include the purchase, setup, and vendor installation costs for equipment and instrumentation, as well as building modifications that immediately support the installation and operation of the equipment.
- Nuclear Science User Facilities (NSUF): This program funds access to state-of-the-art experimental technology including irradiation testing and Post-Irradiation Examination (PIE) facilities as well as technical assistance including the design and analysis of reactor experiments.[99]
- Nuclear Energy Enabling Technologies (NEET) Crosscutting Technology Development (CTD): This program funds research that supports innovative solutions to crosscutting nuclear energy technology challenges.[100]

- Nuclear Energy University Program (NEUP): These funds support the integration of research and the transfer of knowledge from an aging nuclear workforce to the next generation of workers.[101]

6.3 TRANSMISSION

Further investment in the New England transmission network would provide broad benefits to the region's energy landscape, more easily facilitating the expansion of energy generation which could include advanced nuclear reactors. Inadequate transmission threatens renewable energy development and undermines new energy generation across New England. Abundant onshore wind and solar energy potential in Northern Maine, for example, is constrained by a lack of transmission, and limitations in Northern Vermont and New Hampshire are stifling further renewable energy development.[102] Achieving stronger connections between the north and south of New England will further help achieve respective state renewable energy requirements and enable more efficient use of existing power sources. Without transmission upgrades and expansions, interconnecting new clean energy projects will only become more costly and inefficient.

Some renewable technologies, such as onshore wind, are highly dependent on location, highlighting the importance of additional transmission lines to bring electricity onto the grid.[103] The size and flexibility of advanced nuclear reactors make siting less of an issue; however, investing in transmission infrastructure will only enable more effective and efficient power transfer across New England.

Transmission planning happens through ISO-NE which remains neutral on generation technologies and instead focuses on grid reliability. New Hampshire state policy on transmission infrastructure would operate through the Public Policy Transmission Upgrade (PPTU) process. PPTUs are improvements or additions to the regional transmission system designed to meet state, federal, and local public policy requirements driving transmission needs.[104]

6.4 FEDERAL PROGRAMS

In addition to previously mentioned federal legislation, many federal programs exist to advance nuclear energy within the country. Should New Hampshire decide to pursue nuclear energy more deeply, it should take advantage of the multiple federal programs available to support these types of initiatives.

For example, the Gateway for Accelerated Innovation in Nuclear (GAIN) program supports the development of innovative nuclear technology, connecting technological development in the nuclear space with those in the nuclear energy industry. It provides publicly funded loans, small-business vouchers, and investments in research to private businesses for the development of nuclear energy infrastructure. State policy could better enable energy stakeholders in New Hampshire to take advantage of GAIN and other federal investment opportunities. For instance, Westinghouse in Newington, NH, specializes in large components for nuclear power plants, Manufacturing and Testing

Capabilities for Reactor Vessel Internals, Control Rod Drive Mechanisms, Reactor Coolant Pumps, and other products.[105] The GAIN program may be able to benefit state efforts to expand nuclear energy by providing companies like this with supplemental tools to increase their experimental and research capabilities. This would further develop nuclear and nuclear infrastructure in the specific context of the state of New Hampshire.

The Department of Energy Loan Programs Office is another essential resource that New Hampshire could take advantage of to expand nuclear power within the scope of the state. Tax incentives through the Department of Energy could lessen the stress of upfront construction costs. As mentioned in the NH Nuclear Commission report, taxpayers have the option of "a technology-neutral production tax credit of $25 per megawatt-hour for the first ten years of plant operation or a 30 percent investment tax credit on new zero-carbon power plants placed into operation in 2025 or after."[106]

Other relevant programs include:

- The Consolidated Innovative Nuclear Research Fund
- Office of Nuclear Energy: Scientific Infrastructure Support for Consolidated Innovative Nuclear Research
- Department of Agriculture: Renewable Energy Systems and Energy Efficiency Improvements Program

States and private entities can take advantage of these programs which all aim to promote and expand the industry through research and education, infrastructure expansion, and innovation promotion. Such an initiative could function through the Federal Funds team of the New Hampshire Department of Energy, a new team which we were informed of by the Director of the Division of Policy focused on delivering the benefits from formula grants in the Inflation Reduction Act and the Infrastructures Investment and Jobs Act.[107]

7 CONCLUSION

Through secondary resources, case studies, and expert interviews, the difficulties of further expanding nuclear capacity in New Hampshire are clear. Although Seabrook remains essential to the state's energy generation, economic analysis of Plant Vogtle and NuScale's SMRs demonstrate the financial hurdles that traditional and advanced nuclear technologies continue to face. These challenges are especially pertinent to New Hampshire, a small-government state where competitive merchants supply energy to consumers. There are, however, ways that the state can invest in a sustainable, reliable, diverse energy future that might better enable nuclear power to compete in the energy market. Possible state action includes the development of a clean energy standard that does not undermine renewable energy development, nuclear workforce development and public outreach, investment in the grid's transmission infrastructure, and better facilitating the utilization of federal programs to support nuclear energy development and generation. New Hampshire should seek to foster an environment where new and emerging technologies can flourish by the value they may bring to the market.

Although advanced nuclear reactors and SMRs do not yet appear ready for commercial implementation, the state can remain attentive to the potential held by these technologies.

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