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State Approaches to Retention of Nuclear Power Plants: White Paper

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Executive Summary

In recent years, nuclear generation in the United States has encountered numerous challenges in the face of economic, operational, and policy pressures. In 2014, electricity generated from nuclear power accounted for nearly one-fifth of total net generation in the United States. In that year, nuclear plants generated electricity in 31 states, providing service to consumers within and across their borders. While there are concerns about the management of spent nuclear fuel, nuclear power does provide carbon-free baseload generation, is a reliable and dispatchable resource, contributes to fuel diversity, and is an economic stimulus to local areas. Because the operating cost of a nuclear plant is only minimally affected by the cost of fuel, it is, for the most part, a resource that is more immune to fuel price volatility than other energy resources. However, the nuclear industry now faces economic challenges as it attempts to compete with other energy generation technologies, especially low-cost natural gas-fired generation. Nuclear plants in several states have struggled in today's energy marketplace and regulatory environment, causing closures, abandonment of planned construction, and concerns about future viability. State legislators and regulators have begun to examine the future of existing nuclear power plants within their respective jurisdictions, and are considering policies that focus on either the continued operation or closure of such plants.

This report identifies and summarizes various issues facing the nuclear industry about which states are concerned. Several case studies are examined to see if there are similarities in the pressures that cause cancelled uprates or early closures at these generating stations, and conclude that economic competitiveness appears to be a central factor, but that operational and policy factors may have also had a hand. The report suggests conceptual options for states to consider when exploring their options for retaining their existing nuclear plants in the face of these pressures, including sample practices for states to examine, should they choose to act on the retention of nuclear generating assets within their individual borders, including tax incentives, integrated or other resource planning efforts, resource definitions in state portfolios, dispatchable capacity products, carbon pricing, and/or legislative and regulatory actions that signal support to the nuclear power generating sector.

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1. Introduction

This report serves as an introduction to the challenges faced by existing nuclear units in the United States, and as a starting point for state policymakers to explore options to retain these nuclear power plants in the face of economic, operational, and policy pressures. It is not intended to advocate any position or imply support for any technology or policy direction, but instead to outline the issues and suggest conceptual areas for exploration.

In 2014, electricity generated from nuclear power accounted for nearly a fifth of total net generation in the United States.[1] In that year, nuclear plants generated electricity in 31 states for use both inside their borders and across state lines. Three states had more than half their net electricity generated from nuclear power within their borders, seven states had between one-third and half, and the remaining 21 states had up to one-third generated from nuclear power within their borders. Nineteen states and the District of Columbia (DC)[2] do not have nuclear power plants, although in states participating in regional transmission organizations (RTOs)[3] where wholesale power is bought and sold across state lines, contributions are made to the grid by nuclear resources and (through power purchase agreements) there are instances where groups of customers are served by power generated at nuclear plants.

While there are concerns about the management of spent nuclear fuel, nuclear power does provide a number of benefits that are not directly monetized. Because the operating cost of a nuclear plant is only minimally affected by the cost of fuel, it is, for the most part, a resource that is more immune to fuel price volatility than other energy technologies. However, the nuclear industry now faces economic challenges as it attempts to compete with other resources, especially low-cost natural gas-fired generation.

Nuclear plants in several states have struggled in today's energy marketplace and regulatory environment, causing closures, abandonment of planned construction, and concerns about future viability. State legislators and regulators have begun to examine the future of existing nuclear power plants within their respective jurisdictions, and are considering policies that focus on either the continued operation or closure of such plants.

It appears that three factors create retirement risks for existing nuclear facilities:

- Operational/safety risks, particularly relating to older plants;
- Economic competitiveness, particularly for smaller plants or those with lower operating margins; and,
- Policy and regulatory issues, with particular attention paid to relicensing.

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1 Energy Information Administration. 2015.

2 For the remainder of this report, for the purpose of convenience, the term "state" or "states" will also be applied to the District of Columbia.

3 For the purpose of this document, the term RTO also includes an independent system operator (ISO) since the core functions of both are the same: to operate a regional grid and a wholesale electricity market within that regional grid.

Experts and policy makers have raised questions about preserving the long-term benefits that nuclear power offers in the face of near-term closure risks. Moreover, there are diverse perspectives on whether nuclear energy investments create more trade-offs than the benefits they provide, or close off opportunities for energy policy to move in other directions. While those policy debates are valid, this report focuses on identifying various potential challenges facing the existing nuclear fleet. Several case studies are examined to see if there are similarities in the pressures that cause cancelled uprates or early closures at these stations, and conclude that economic competitiveness appears to be a central factor, but that operational and policy factors may have also had a hand. The report offers conceptual options for states to consider when exploring their options for retaining their existing nuclear plants in the face of these pressures.

To address these issues, states that wish to ensure retention of their nuclear fleet face a clear obstacle, in that they do not have direct policy making levers to keep these plants from closure if they are not economically competitive in the near term. Some indirect policy tools may be available, however: states may want to consider supporting improvements to operational or safety issues; improving the competitiveness of existing nuclear units; and/or establishing policies that accommodate and reward the benefits and unique services provided by nuclear units. Finally, the report identifies sample practices for states to examine, should they choose to act on the retention of nuclear generating assets within their individual borders, including tax incentives, integrated or other resource planning efforts, resource definitions in state portfolios, dispatchable capacity products, carbon pricing, and/or legislative and regulatory actions that signal support to the nuclear power sector.

While recognizing that spent nuclear fuel management is a national issue, this report does not delve into spent nuclear fuel management issues related to nuclear power generation. Neither does this report examine the possible effects of new environmental rules.

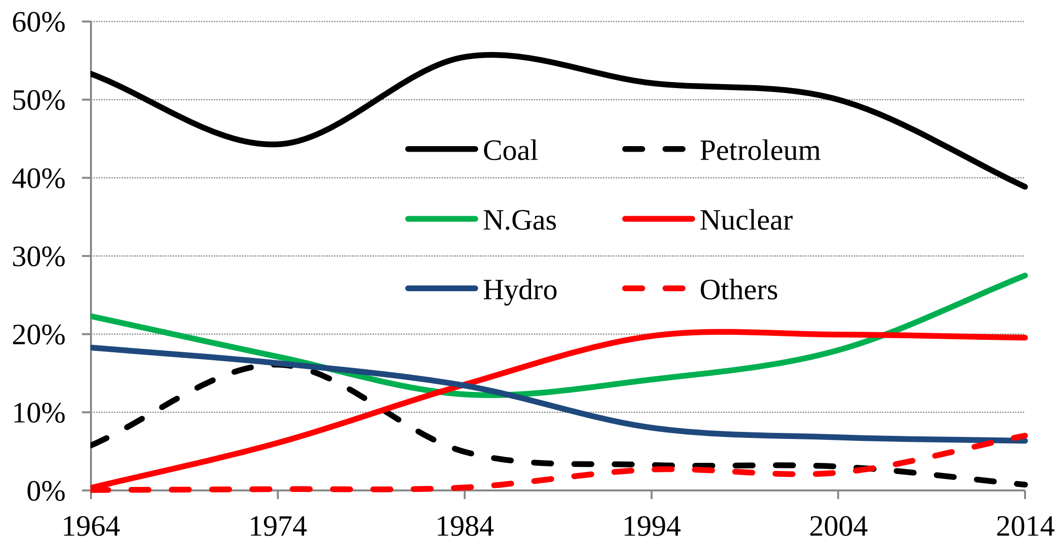
2. Current Status of the U.S. Nuclear Industry

There is abundant information available about the history of the nuclear industry around the world and specifically in the United States.[4] The defense arena led the development of the nuclear industry immediately after World War II. Following that, in the 1950s and 1960s, gradual commercialization of the nuclear power industry took place, leading to the development of an electricity source that currently produces nearly a fifth of the generation in the nation in the last 20 years, nuclear power has supplied nearly one-fifth of the country's electricity generation needs (Figure 1). During this same period, electricity generation from coal and hydro has steadily decreased while the discovery of shale gas has increased the proportion of electricity produced from natural gas. Nuclear generation offers baseload power with no greenhouse gas emissions and low variable operating costs, but high up-front construction costs. These up-front costs combined with other economic factors have limited the widespread expansion of new nuclear

[4] For example, see Navigant Consulting, June 2013, http://www.naruc.org/grants/Documents/Assessment-of-the-Nuclear-Power-Industry-Final%20Report.pdf.

power generation. Economic pressure is being felt by some existing units as well; in four states, plant owners have opted to shut down rather than operate at a loss.

Figure 1. Net Electricity Generation in the U.S. by Energy Resource, 1964-2014



Data source: EIA, *Monthly Energy Review*, April 2015.

An examination of the net generation data by state shows the wide range of electricity generated from nuclear power. A group of 19 states and the District of Columbia do not have any nuclear generating assets but a few of them are served by an RTO (Table 1 below and Table A-1 in the Appendix).

Table 1. In-State* Nuclear Power Plants and Industry Structure, 2014

	With Nuclear Plants	No Nuclear Plants	Total
Vertically Integrated; not served by RTO	6 states (25%) #	7 states	13 states
Vertically Integrated; served by RTO	14 states (27%) #	9 states	23 states
Retail Choice; served by RTO	11 states (48%) #	4 states	15 states
Total	**31 states** (100%) #	**20 states**	**51 states**

* The term state includes the District of Columbia.
# Percentage is based on total electricity generation from nuclear plants in the U.S.
Source: EIA; FERC; and Table A-1 in this report's Appendix.

2.1 Policy and Regulatory Framework

The nuclear industry is different from other electricity generating industries by virtue of its development since World War II. The federal government had, and will continue to have, a critical role in its development, while the states have a complementary role in siting and ensuring its continued viability:

The federal government conducts research and development, licenses the operation of nuclear power plants, ensures operational safety via oversight by the Nuclear Regulatory Commission (NRC), and regulates wholesale market operations via the Federal Energy Regulatory Commission (FERC).

The states oversee the siting of the facilities and, in vertically integrated states, the portfolio mix through development of integrated resource plans and rates paid by utility customers (which, by compensating resources based on their current price offer, selects the resources that generate power).

State options for action are limited in some respects by the above-mentioned division of responsibilities, resulting in pressures that create closure risks for existing plants. Such pressures include economic risk, a primary regulator of which is the FERC; operational and safety risks that are primarily overseen by the NRC; and policy risks that challenge easy assignation (although the NRC's relicensing process may offer one forum for State intervention).

3. Factors and Examples That Create Closure Risks for Nuclear Plants

3.1 Economic Factors

The operational characteristics of nuclear units lend themselves to their use as baseload generation. Historically, nuclear units have enjoyed lower variable costs than other units because of the low price of variable inputs, such as fuel, and as such, have often run as first-bid units in economic merit-order dispatch of power plants. However, the long-standing lower-than-wholesale-average price position for nuclear-generated electricity may be changing. Because wholesale electricity prices are closely tied to wholesale natural gas prices in all but the center of the country,[5] one can often explain wholesale electricity prices by looking at what is happening with natural gas prices, and prices for gas have dropped significantly in the past decade. Although the long-term operating costs of nuclear plants are lower than the wholesale price of electricity generated at other facilities, recent low prices for gas in some parts of the country may imperil the economic competitiveness of nuclear units in the near-term when they compete with the lowest-cost gas-fired units. Nuclear may be more expensive now and less expensive later if gas prices increase: one of the advantages of nuclear energy is that the price of viable nuclear unit expenses (such as uranium) are less volatile than gas and less subject to price spikes.

5 Energy Information Administration, 2015.

3.2 Operational and Safety Factors

It is important to note that the average fuel price is not representative of all costs faced by nuclear generators. Although fuel costs are proportionately small and relatively stable, as a fleet nuclear plants are seeing rising operations and maintenance (O&M) costs. Estimates show a $10/MWh increase in non-fuel O&M costs over the 2006-12 period.[6] These costs will be increasingly important as plants age: the average age of a nuclear plant in the United States is 34 years, and 93 out of 99 reactors have applied for or received license extensions that would allow them to operate past their initial 40-year license period.

The long usable plant life of nuclear power plants may, ironically, present utilities with another problem. Capital expenditures used to keep long-running plants operating must be recovered over a short period of time. Utilities may not be able to recover the costs in the near term for the expenses associated with running a plant that may run for 60 or 80 years. An unforeseen repair, large-scale maintenance, or reliability issue could lead a utility to shut down a plant, rather than invest in repairs. In one example, the Fort Calhoun nuclear plant in Nebraska was in cold shut down for over two years, an operational-based service disruption during which the generator was not earning revenues, thereby compounding questions about its economic competitiveness.[7] Cost overruns have also been notable at some nuclear plants. Crystal River, one of the plants that has been shut down, was ultimately retired in light of cost overruns on repair work. Similar cost overruns have occurred at the Monticello, Grand Gulf, Turkey Point, St. Lucie, and Watts Barr plants.[8]

Finally, safety considerations place pressure on nuclear generators. Public scrutiny makes impeccable safety at a nuclear plant non-negotiable. One of the plants discussed in this paper, the San Onofre Nuclear Generating Station (SONGS) in California, was retired to avert safety concerns. The Fukushima incident (triggered by an enormous earthquake and tsunami) ultimately bankrupted the Fukushima nuclear plant's owners, with an estimated $137 billion in damages.[9] Concerns about public health and safety relating to nuclear power cannot be ignored outright, and the Fukushima tragedy was important in identifying a number of safety improvements that could be made at reactors in the rest of the world, and placed priority on a broad range of investments in safety. The cost of these potential safety measures could reach up to $40 million per unit.[10] Potential new safety measures may be costly for existing plants, and, as the years of usable operation for these plants diminishes, could also become more difficult for a utility to justify economically. The combined factors of lower electricity prices and increased operating costs leave little margin for profit at plants operating in these markets. Shutdowns related to these upgrades, the cost of the upgrades themselves, and the additional public attention

6 Cooper, 2013; p. 9.

7 NRC, 2015. The plant was cleared to restart in December 2013.

8 Cooper, 2013.

9 *Ibid.*

10 Platts, 2013.

paid to broad safety perception issues following Fukushima may create economic or more subtle perceptual barriers to unit retention.

3.3 Policy Factors

The NRC remains the primary regulatory body governing the operational licensing and safety oversight of the nation's nuclear fleet. The Nuclear Energy Institute (NEI) recently concluded that "between 2029 and 2055, all 100 operating [nuclear] reactors will reach 60 years of life. Replacing these with new ones . . . will be a capital-intensive, multi-decade proposition."[11] Three New York state agencies recently commented that states have limited ability to provide incentives to preserve "existing nuclear capacity . . . Instead, under the *Atomic Energy Act of 1954*, the federal government, through the NRC, has primary responsibility for ensuring the safety of nuclear power plants and licensing their operation."[12] A number of plants are nearing the end of their license periods. Units currently under review for their NRC license include:[13]

Byron 1 & 2 / Braidwood 1 & 2	IL
Davis-Besse 1	OH
Diablo Canyon 1 & 2	CA
Fermi, Unit 2	MI
Grand Gulf 1	MS
Indian Point 2 & 3	NY
LaSalle 1 & 2	IL
Seabrook 1	NY
Sequoyah 1 & 2	TN
South Texas Project 1 & 2	TX

Additionally, at least six more plants face license renewal applications in the next ten years. Roughly three quarters of the nuclear units in the country have already engaged in a 20-year license renewal successfully, but any plant being considered for license renewal faces the potential risk of denial, or that public scrutiny, economic issues, or other factors putting pressure on these units will be intense enough that the asset owners will choose not to pursue a license renewal application with the NRC.

Additional policy factors may send signals to investors and operators that the retention of existing nuclear units is not a priority for the state's policymakers, or may even be unwelcome. A number of states have adopted policies discouraging investment in nuclear energy pending a resolution of the persistent long term used nuclear fuel disposal challenge. California, Connecticut, Illinois,[14] Maine, Oregon, West Virginia, and Wisconsin will not allow new

[11] Nuclear Energy Institute, 2014.

[12] New York Department of Environmental Conservation, *et al*. 2014.

[13] Nuclear Regulatory Commission, 2015.

[14] Illinois allows legislative approval of a nuclear plant that may override the waste disposal requirement.

nuclear development until viable used nuclear fuel disposal options are found. Hawaii, Massachusetts, Rhode Island, and Vermont require specific legislative approval for any investment in new nuclear plants, while Maine and Oregon require statewide voter approval. Minnesota has banned new nuclear plants entirely. While these are valid expressions of these states' values concerning new nuclear units and do not relate directly to retention of existing units, it is possible that these moratoria send important signals to investors and operators that nuclear energy is not a supported energy resource in those states, despite the current existence of one or more nuclear power plants.

4. Case Studies of Selected Nuclear Plant Retirements and Cancelled Uprates

Five reactors at four nuclear plants have been permanently closed since 2009. Each has distinct, yet similar, reasons for its closure. Two were shut down for explicit economic reasons; their operators cited the low cost of competing resources in the wholesale electricity market as the primary reason for the closure. One of these two plants also faced vociferous political outcry while its license renewal was being considered. The other three reactors experienced technical malfunctions that were extremely costly to repair. After attempts to repair these plants, their owners chose to close the plants rather than bear further high repair costs.

In addition, two major uprates at existing facilities have been cancelled. Uprates are expansions to the generating capacity and efficiency at an existing unit, so that the same facility can generate more power. While these cancellations do not represent challenges to retirement of existing units, they are a reflection of the challenges faced by nuclear energy as a contributor to the nation's generation portfolio, and illustrate the conceptual risks that need to be managed.

In the following sections, brief descriptions of the conditions surrounding each plant's closure are listed in alphabetical order of the states. This includes attempts made by responsible regulatory and/or policy bodies to examine the future of the plants.

4.1 San Onofre Nuclear Generating Station, California

The San Onofre Nuclear Generating Station (SONGS) was owned by Southern California Edison (SCE), and included three units. Unit 1 of SONGS generated 456 MWe and was retired in 1992, while Units 2 and 3 generated 1,127 MWe each before their retirement.[15] SONGS is being decommissioned due to damage found in the plant's steam generators. One reactor was shut down, and inspections found premature wear on replacement steam generators installed in 2010 and 2011 in Unit 2 and Unit 3. The NRC ordered that Unit 2, already shut down for refueling and replacement of the reactor's vessel head, and Unit 3 were not to be restarted until the cause of the wear was determined. SCE has since begun the decommissioning process for the plant.

15 International Atomic Energy Agency, 2015.

SCE submitted a "Return to Service Report" to the NRC for Unit 2 in 2012, in which SCE proposed operational limitations in order to restart the reactor. The Atomic Safety and Licensing Board ruled that such changes would constitute a new license amendment, and SCE chose shortly thereafter to instead retire both Units 2 and 3.

In October 2012, the California Public Utilities Commission (CAPUC) began Investigation 12-10-013 to determine how the impact of the plant's shutdown and decommissioning would affect utility rates. In November 2014, a settlement was reached that allowed for ratepayer refunds and credits of roughly $1.45 billion. SCE also agreed to stop collection of its Steam Generator Replacement Project and to refund the collected costs of that project, while agreeing to a lower rate of return on prematurely retired assets. Ratepayers still paid for approximately $3.3 billion of power purchases associated with SONGS' outage and the undepreciated net investment in SONGS assets.[16] Further decommissioning costs will be recovered through the CAPUC's Nuclear Decommissioning Cost Triennial Proceeding, Application No. A.12-12-012. In November 18, 2014, CAPUC issued a proposal to approve roughly $4.1 billion for decommissioning SONGS Units 2 and 3.[17]

In terms of the impact of the plant closing on electricity reliability and security, the California ISO (CA-ISO) conducted Local Capacity Technical Studies in 2013-14, including scenarios in which SONGS was and was not able to operate.[18] In addition, CA-ISO completed transmission and voltage support enhancements near SONGS resulting in mitigations work underway throughout the summer of 2015. Despite this effort, CA-ISO has recognized that pressures caused by the SONGS outage and retirement "will require close attention during summer operations – particularly during critical peak days and in the event of wildfires that could potentially force transmission lines out of service."[19]

4.2 Crystal River 3 Nuclear Plant, Florida

The Crystal River nuclear plant in Florida operated at a capacity of 842 MW. Duke Energy acquired the plant in 2012 when it purchased Progress Energy and was regulated by the Florida Public Service Commission (FLPSC).

The plant stopped running after a refueling outage in September 2009, when the plant's containment structure was damaged while work crews attempted to replace steam generators within the plant. Duke Energy decided to decommission the plant rather than undertake the costly repair process. The FLPSC approved a $288 million refund to customers to account for the cost of replacement power resulting from the 2009 Crystal River outage.

[16] California Public Utilities Commission, 2014a.

[17] California Public Utilities Commission, 2014b.

[18] California ISO, 2012, and California ISO, 2013.

[19] California ISO, 2014.

Progress estimated that the repairs would cost between $900 million and $1.3 billion, but had intended to undertake them. However, after acquiring Crystal River, Duke Energy estimated the repair cost between $1.5 and $3.4 billion, and decided not to repair the plant. Duke Energy has permanently shut down Crystal River, and the plant is currently transitioning to a Safe Storage (SAFSTOR) condition.

Florida is not served by an RTO but the Florida Reliability Coordinating Council (FRCC) is responsible for examining reliability impacts of plant closures in the state. The FRCC found that, in conjunction with the retirement of two coal-fired units at the Crystal River site, due to non-compliance with federal mercury and air toxics regulations, the closure of the Crystal River nuclear plant could have an impact on system reliability.[20] Thus, the FRCC recommended extending the life of the coal plants in order to ensure transmission system reliability.

4.3 Vermont Yankee, Vermont

The Vermont Yankee nuclear power plant operated as a merchant generator in Vernon, Vermont. The plant had a capacity of 620 MW and generated 4,700 GWh annually which was about 4% of the New England region's total annual electricity supply.[21] Vermont Yankee shut down on December 29, 2014.[22]

Vermont Yankee began operation in 1972, and employed 625 people by the time its closure was announced. The plant's payroll at that time was roughly $58 million.[23] A report submitted to the Vermont Public Service Board (VTPSB) estimated that keeping the plant running through 2032 would create an average of 1,088 more employees in Windham County, and 260 more employees across the rest of Vermont.[24] Because of these employment estimates, Entergy, Vermont Yankee's owners, applied for a license extension with the NRC in January 2006.[25]

In 2010, however, the Vermont State Senate prevented the VTPSB from considering the continued operation of the plant, a policy decision unique to Vermont. In Vermont, legislative approval is required to extend a "certificate of good" before a plant can operate. Because the Senate did not approve Vermont Yankee's extension, the plant was closed.

The debate regarding Vermont Yankee's certificate of good was contentious, as was the plant's operating history. After the plant applied for its license extension with the NRC, a number of events led to public outcry, and Vermont state officials legally opposed the plant's

20 Florida Reliability Coordinating Council, 2013.

21 Energy Information Administration, 2013.

22 Audette, 2014.

23 Davis, 2014.

24 Heaps, 2012.

25 Nuclear Regulatory Commission, 2015.

license approval. The NRC, however, approved the plant's renewal in March 2011, over the opposition of the State Senate, and Entergy, the plant's owner, subsequently sued the State of Vermont in April 2011. The case resulted in the reversal of the Senate's prior decision, because it was determined that the decision had been focused on the safety aspects of Vermont Yankee.[26]

The courts also noted that the *Atomic Energy Act of 1946* requires that safety remain in the federal domain and that states have no jurisdiction over plant safety. The VTPSB entered into an MOU with Entergy in February 2013,[27] that allowed Vermont Yankee to resume operations and that required Entergy to spend $10 million to promote economic development in Windham County, to ensure site restoration, and to pay $5.2 million for clean energy development.[28] But in August of that year, Entergy announced that the plant would close due to economic considerations. Entergy cited low power prices, high cost structure, and wholesale electricity market design flaws in its announcement of the closure.[29]

ISO New England (ISO-NE), the region's independent system operator, issued a number of reports regarding the impact of Vermont Yankee's closure on the region's system adequacy, reliability, and resiliency. ISO-NE reported that its reliability studies concluded "that the regional power grid could be operated reliably without Vermont Yankee."[30] Earlier studies had called this fact into question, but ISO-NE's 2012 reliability analysis concluded that new system conditions, such as development of new resources, completion of transmission upgrades, and energy efficiency measures, made Vermont Yankee's retirement unlikely to affect system reliability. ISO-NE expressed concern that the plant's retirement might lead to a decrease in resource diversity, but noted that it did not have the authority to prevent a resource from retiring.[31]

4.4 Kewaunee Power Station, Wisconsin

The Kewaunee Power Station, which had a capacity of 556 MW, was purchased by Dominion Resources, Inc. (Dominion) in 2005 from Wisconsin Public Service, a regulated utility. After the company sold the plant, the Public Service Commission of Wisconsin no longer had jurisdiction over rates charged by the facility, so Dominion had to rely on market prices for wholesale electric power to operate the plant.

In April 2011, Dominion announced that it planned to sell Kewaunee because it determined that it could not grow its Midwest nuclear fleet any further. Dominion claimed that Kewaunee's power purchase agreements (PPAs) were ending due to low wholesale electric prices; new PPAs would make the plant uneconomical to run. By 2012, no buyer had come

26 *Entergy Nuclear Vermont Yankee v. Shumlin*, No. 12-707 (2d Cir. 2013).

27 Vermont Public Service Board, 2014.

28 *Ibid*.

29 Entergy, 2013.

30 ISO New England, 2013.

31 *Ibid*.

forward and Dominion announced that it would close the plant.[32] Dominion reserved $578 million for the plant's decommissioning.[33]

The economic impact of the plant's closure has been significant. At the time of its closure, Kewaunee Power Station employed 655 full time employees, roughly 12% of Kewaunee County's employees.[34] With just 20,500 residents, this county is the smallest in the U.S. that has experienced a nuclear plant closure, creating hardship for those who previously had jobs at the facility.

After Dominion's announcement of the closure, the regional grid operator, Midcontinent Independent System Operator (MISO), conducted a reliability assessment and concluded that the closure of Kewaunee would not violate any reliability responsibilities. In February 2013, MISO announced that Kewaunee could be retired, and Dominion ceased generation at the plant in December 2013.[35]

4.5 Cancellation of Uprates at Two Existing Plants: Limerick and LaSalle

The nuclear power industry has successfully uprated capacity factors across much of the fleet, but a pair of cancelled uprates proves illustrative of economic pressures facing the industry. In 2013, Exelon announced it was not moving forward with a planned $2.3 billion investment in its LaSalle nuclear units in Illinois and the Limerick nuclear plant in Pennsylvania.

Such an investment would have increased generating capacity at these plants by a combined 1,300 MW. Exelon explained that the economics of the investment no longer made financial sense and dropped the plan, paying its suppliers $100 million in penalties for the cancellation.[36]

4.6 Common Issues Addressed At Four Closed Plants

Much of the criticism leveled in the public domain against nuclear power plants centers on the management of spent nuclear fuel and the concern over potential accidents. The case studies in this paper illustrate that these factors did not result in closure of these plants. Rather, economic factors played a central role in these closures, either because they were losing money or because the cost of making repairs or making improvements was too high.

The Crystal River plant was closed in the face of costly repairs. The FLPSC worked to

32 Dominion, 2012.

33 Wald, 2013a.

34 Seely, 2012.

35 Dominion, 2013.

36 Wald, 2013b.

limit some of the plant's impact on ratepayers by approving refunds, and Duke recovered the cost of damages through insurance claims, not rates. In this situation, repairing the plant would have required up to $3.4 billion of additional ratepayer money, which made keeping the plant in the rate base prohibitively expensive.

Safety was more prominently an issue in California's case study, but economics were still the inevitable basis for the shutdown. The San Onofre plant was closed in order to avert safety issues that, if repaired, would have proven too costly. Similar to the FLPSC, the CAPUC approved a refund to ratepayers. In both cases, ratepayer advocates noted that these refunds were unlikely to cover all of the associated costs of purchased replacement power. However, returning the plants to service would also have been expensive for ratepayers. These closures speak to the high level of maintenance and management required at each plant in the United States' nuclear fleet, and the additional costs brought about by their longevity.

The closures at Vermont Yankee and the Kewaunee Power Station are somewhat different, in that both plants operated as merchant generators. The cost of electricity generated by these plants competed with wholesale electricity prices and they were unable to operate in such economic conditions. A similar situation extends to other nuclear plants, particularly those that operate in deregulated energy markets. These plants have no mechanism for cost recovery from their states' commissions, and must compete in a market that they insist does not properly compensate them for their advantages, such as reliability and carbon-free emissions.

The case of cancelled uprates at LaSalle and Limerick reflect the high relative cost of nuclear power plant construction versus the relative simplicity and ease of permitting and constructing other resources. The siting and licensing challenges for these units were more easily addressable because of the existing units that had paved the way for site use. Exelon's emphasis on unfavorable economics suggests that with inexpensive alternatives available, the cancellation of these uprates was an economic decision – and considering the $100 million penalty it paid, that the economics of the alternatives must have been considerably advantageous. The Limerick and LaSalle case studies may also indicate some of the less- measurable public pressure and policy impediment issues that complement an economic case for using other resources.

5. Costs, Benefits, and Policy Limitations

5.1 Costs Specific to Existing Nuclear Power Plants

Nuclear power plants incur expenses for decommissioning, spent nuclear fuel management, and safety-related expenditures, as well as for other technical expenses dealing with real and perceived risks that are specific to this technology.

Policy obstacles to long-term management of used nuclear fuel have been a well-documented challenge for plant operators in the United States. Until halted by the courts in

2014, power plant operators in the U.S. were required to pay a mill[37] per kWh charge for the construction of long-term used nuclear fuel storage facilities. Such funds were contributed into for 20 years, but no used nuclear fuel storage facilities were constructed. The end of this policy removed a charge that had contributed to the negative competitiveness of nuclear power plants without improving the status quo of used nuclear fuel management.

5.2 Non-Remunerated Benefits of Existing Nuclear Power Plants

Nuclear power affords a number of benefits to the system that are not associated with revenue. For example, nuclear offers dispatchable baseload power with very low greenhouse gas emissions and low, stable fuel costs. A recent study has shown that nuclear generating plants provide the highest number of direct local jobs and workforce income than any other generating technology.[38] However, no price advantage is afforded to units with stable prices over time, only to those plants that have immediate price advantages. If natural gas prices dip low, it will outcompete nuclear with increasing regularity in the near (2-4 year) term. The difficulty of acquiring long term natural gas PPA agreements suggests that the gas price horizon may be valid for less than five years. A decision to close a nuclear plant based on this price horizon may seem ill-advised if in six years the price of gas is not only volatile but high.

Intermittent energy resources, such as solar, wind and other renewables, also have near term cost advantages resulting from subsidies and other incentives, but may not offer the reliability and capacity benefits provided by nuclear power. Capacity markets that remunerate dispatchable capacity resources may be helpful in providing payment for services and system operational benefits that do not currently earn direct revenue.

Nuclear power emits no carbon during power generation. However, this paper does not intend to explore the implications of new environmental rules governing carbon emissions, beyond simply noting that if these rules result in carbon pricing, this could provide some advantage to all non-fossil units. Carbon pricing could potentially increase the operating costs of some or all carbon-emitting resources without increasing the cost of non-carbon emitting resources such as nuclear.

Nuclear may provide overall system price-reduction benefits by supplying power at a stable price. There is currently no payment stream for resources whose price stability reduces the overall impact of volatility on the economics of the system. Later in this paper we explore whether state regulatory commissioners and other policymakers may have a role in creating opportunities to monetize these benefits.

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[37] One mill is 0.1 cent, or $0.001.

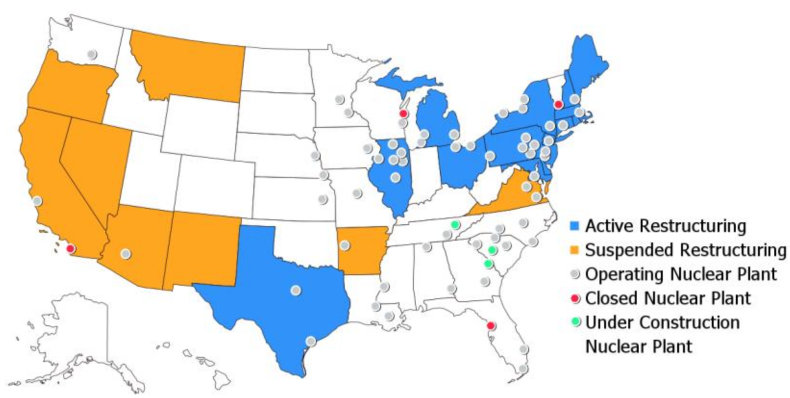
[38] Harker and Hirschboeck, 2010.

5.3 Limitations Posed by Restructuring

The status of the electricity market across the U.S. (Figure 2) drives the manner in which state policy makers, including both legislators and utility regulators, are able to influence the retention of nuclear power plants. Some policymakers may attest that they have unbundled generation from their utilities and have no authority over generation, and argue that states that are vertically integrated have powers that they do not have to order continued operation of nuclear units by fiat. Others in RTO states may have no nuclear units in-state and assert that retention of existing units is not their concern. Both ideas are ill-founded.

Vertically integrated or restructured, no state has the ability to order non-economic merit dispatch outside the context of a program that specifically enumerates those resources (as in PURPA or renewable portfolio standard qualifying facilities). The proliferation of interstate power flows (particularly in RTO footprints) shows that states that may not have nuclear plants in their own state may well be served by nuclear units in other states. As such, every state commission is faced with the same set of problems: that the retention of existing nuclear is a challenge for any state that exchanges electricity with states that have nuclear plants within their borders, and that the only policy levers available to state commissions to affect the retention of existing nuclear facilities are indirect levers. These are explored in Section 6 of this paper.

Figure 2. Electricity Restructuring and Nuclear Power Plants



Source: Authors' construct with data from U.S. Energy Information Administration and Inside Climate News.

Figure 2 illustrates the states in which nuclear power plants are located, including the type of utility market structure within that state. The blue states are those in which the electric industry is restructured, e.g., customers have retail choice and the state utility regulatory commission does not have jurisdiction over the price of electric supply in that state. The states with no color are vertically integrated with traditional rate regulation. The orange colored states are vertically integrated as well, but suspended restructuring at some point after originally doing so. Nuclear plants are noted as dots: grey dots are currently operating; red dots are recently closed; and green dots are plants under construction. Nearly half of the nuclear plants are located in restructured markets while the other half are in vertically integrated states, where five additional reactors are under construction. Among recent plant closures, two operated as merchant generators that sold their power into neighboring wholesale electricity markets. Estimates of “at-risk” plants vary,[39] but most at-risk plants are currently located in restructured states.

While the economic risks faced by nuclear plants are most acutely felt in states that are restructured, economic challenges persist in vertically integrated states as well. Kewaunee, located in Wisconsin – still vertically integrated – is one such plant, as are other plants that are currently addressing economic, operational, and policy pressures. In such states, however, policymakers may have more policy tools available to encourage nuclear plant retention.

6. Policy Options That May Assist Retention

6.1. Implementing Measures Supporting Retention

This paper has thus far identified three types of risks affecting retention of nuclear power: economic, operational, and policy risks. However, many of these risks are intertwined, and the list below of potential conceptual approaches to ameliorating one or more of these risks does not differentiate whether the pressure it seeks to alleviate is economic, operational, or policy-based.

The approaches included in this paper have been informed by a fairly recent resolution of the Illinois House of Representatives. In May 2014, this body adopted HR 1146 that requested four state agencies -- the Illinois Commerce Commission, the Illinois Power Agency, the Illinois Environmental Protection Agency, and the Illinois Department of Commerce and Economic Opportunity -- to prepare report(s) that would address “issues related to the premature closure of nuclear power plants.”[40] Based on some of the outcomes outlined in the resulting report, and on the summaries of nuclear plant retention in various states (as listed in the next section of this paper), states may consider the following measures to retain or encourage nuclear power plants within their individual jurisdiction. However, states need to recognize that they may be limited in using these measures, depending on whether their state has restructured and allows retail choice. Nevertheless, some conceptual approaches to explore are listed below.

- Allow investments in nuclear unit uprates and improvements to draw from specific state funds as a complement to funds from the rate base. (See Alaska’s authorization of the use of its state public power fund for this purpose described later in this paper).
- Supplement decommissioning funding with general utility rates, augmenting per-kilowatt hour charges on sales.
- Provide tax incentives for investments in nuclear (such as has been explored for new

[39] Cooper, 2013, and Douglass, 2013.

[40] Illinois Commerce Commission, et al., 2015.

units in Utah).

- Allow property tax exemptions for investments in the facility (such as property acquisitions for post-Fukushima upgrades, or for uprates at existing facilities).
- Allow enhanced return for investments in nuclear power (as has been authorized in Virginia). This could also be explored as a higher return on equity for investments in nuclear safety.
- Establish carbon pricing or incentives compensating generation output (i.e., kWhs) with specific price-supported non-carbon-emitting units.
- Highlight nuclear energy in resource planning and state energy planning. Although investments may deviate from a plan, articulation of support for nuclear in this context (as was done in states like Mississippi and South Carolina) may prove a subtle but effective way to signal support.
- Create an economic product that recognizes the dispatchability of units. Building on the notion of a capacity product (as is used in some RTO markets in the Eastern Interconnection), this would be a “dispatchable capacity” product for callable units that meet reliability criteria.
- Revise renewable portfolio standards to partially (or fully) account for nuclear generation. The establishment of clean energy standards that recognize nuclear units in some way may also be an incentive for retention.
- Create a state team to explore policy obstacles and potential opportunities for the retention of existing nuclear units. This group could explore the retention problem using the same inquiries, technical investigations, and other policy-development avenues to identify risks, create transparency about issues related to retention, and initiate public processes to determine solutions. This approach has been used in other policy areas at state commissions, such as cybersecurity and energy efficiency.
- Consider passing legislation offering support for nuclear energy. Such legislation signals investors and other decision-makers that the state is committed to, and supportive of, nuclear energy.

6.2 Impacts of Negative Policy Signals

As explored in Section 3, a number of states have adopted laws discouraging new nuclear units and potentially creating the perception that it is not a supported resource in these states. Measures that support existing nuclear units may come into conflict with legislative and regulatory policies that discourage the resource, and those exploring retention options available to states may wish to start by understanding the existing landscape of laws and other policies.

Some states have reversed their stance on nuclear power. Alaska repealed its moratorium on nuclear power with SB 220 in 2010. This bill also allowed owners of small modular reactors to apply for funding from Alaska’s Power Project Fund.

Kentucky passed a moratorium on new nuclear plants, but legislation in 2012 allowed the use of nuclear technologies in industrial processes. Industrial facilities are allowed to enrich depleted uranium tails, process metals contaminated with radioactive materials, recycle or reprocess nuclear fuel, and support nuclear-assisted coal or gas conversion processes.

6.3. Recent Actions by State Legislators and Regulators

This section gives an overview of recent actions by various state legislatures and utility commissions. An examination of such actions provides a glimpse of what states may consider to retain and/or encourage siting and operation of nuclear generating plants in their states.

Illinois

The Illinois legislature passed a non-binding resolution that supports the role of nuclear power in the state's generation mix, while the House of Representatives called for state and federal measures to protect nuclear power. The House also required state agencies to study the economic impacts of nuclear closures, the societal cost of increased greenhouse gas emissions, and the viability of market-based solutions.

Indiana

Indiana expanded its definition of clean energy projects to include nuclear energy. Specifically, clean energy projects in Indiana include projects that enhance nuclear safety and reliability, the purchase of fuels or energy by a nuclear plant, and electric transmission that serves a nuclear plant. Financial incentives are offered to utilities, including timely recovery of construction expenses, three percent return on shareholder equity, and cost recovery of expenses related to the acquisition of nuclear fuel. The state also allows cost recovery for studies, analyses, and development of life cycle management processes for nuclear plants.

Iowa

Iowa instructed select utilities to examine the feasibility of new nuclear plants, supported by ratepayers. Utilities were also allowed to raise rates to pay for new investments that shift generation from high-carbon sources to low-emission plants. The Iowa Utilities Board (IUB) is also allowed to specify ratemaking principles that apply to newly constructed plants. These principles include return on equity, depreciable life, and recovery of stranded costs. When advanced rate determination is made, the IUB is permitted to apply non-traditional ratemaking mechanisms.

Kansas

Kansas has enacted legislation that exempts property purchased to construct a new nuclear plant or expand an existing plant from state property taxes.

Ohio

The PUC of Ohio (PUCO) included nuclear power in its renewable portfolio standards. Under Ohio law, 25% of energy (kWh) sold in 2025 must be from alternative energy sources. The commission split this requirement evenly between renewable sources and advanced energy resources, which include Generation III nuclear technologies, as defined by NRC. The PUCO order was prompted by the Ohio legislature's 2008 mandate of portfolio standards.

South Carolina

South Carolina passed legislation in 2007 that allowed the South Carolina PSC (SCPSC) to grant project development orders for nuclear projects, as well as review orders for baseload facilities. Additionally, legislation in 2009 ordered development of a comprehensive state energy plan that encourages clean energy sources, including nuclear power.

Texas

The Texas state legislature gave the PUC of Texas the ability to regulate decommissioning funds for up to six new nuclear plants. The commission sets the amount paid annually by nuclear plant owners, and, if the fund is not sufficient to cover the costs of decommissioning, extra decommissioning costs can be recovered from rates. Texas has also allowed local taxing authorities to grant abatements on property taxes for new nuclear plants. These abatements can last up to 10 years.

Utah

Utah passed a joint resolution in 2009 that expressed support for new nuclear plants. Utah has also included nuclear power within its definition of renewable energy and renewable energy projects. The state offers tax incentives to utilities developing renewable energy projects within selected development zones. The state revised its tax incentive for alternative energy development in 2012 to include nuclear fuel.

Virginia

Virginia suspended its restructured market in 2007. This policy change included a voluntary renewable portfolio standard based on a percentage of generation, excluding nuclear power. Nuclear power plant operators are also able to collect an enhanced rate of return.

Washington

Washington created a Nuclear Energy Task Force in 2014, focused on the regional generation of nuclear power. The task force was directed to consider the environmental impact of each life-cycle dollar spent on nuclear power technology.

Wyoming

Wyoming created a Nuclear Energy Production Task Force in 2011. The task force studied methods to encourage nuclear power in the state, and examined, among other things, tax incentives and state laws.

7. Conclusions

The nuclear industry is experiencing some growth in a number of areas. Nuclear power units are being constructed in Georgia, South Carolina, and Tennessee. Small modular reactors are being designed to expand the opportunities in a number of states. Despite these areas of opportunity, the near-term economic, operational, and potential policy challenges to keeping the benefits provided by existing nuclear units may be more impactful to the system if certain risks are not identified and understood. Among them are the issues of used nuclear fuel management as well as the impacts of EPA's power sector regulations. While the authors of this report have avoided these topics, they recognize that the two issues will affect decision-making processes by nuclear power generators in the next decade.

On their surface, the options available to states to retain their nuclear fleet may not be obvious. Asking questions proactively, and exploring potential funding, tax, operational, and other supportive mechanisms may allow state regulators to be better positioned to understand the risks and provide perspectives on realistic options for managing them. This report does not intend to recommend any direction forward, but to catalyze debate over the best path forward; state utility regulators are well-positioned to lead this conversation.

APPENDIX

Table A-1. Consumption, Generation, RTOs, and Retail Choice by State, 2014

State	Generation from All Resources (000 MWh)	Generation from Nuclear Resources (000 MWh)	Nuclear as % of All Resources	Total Electricity Consumption (000 MWh)	Generation less Consumption (000 MWh)	Served by RTO [41]	Retail Choice
Alabama	149,963	41,244	27.5%	90,380	59,583		
Alaska	6,149	0	0.0%	6,182	(33)		
Arizona	112,379	32,321	28.8%	75,948	36,431		
Arkansas	61,581	14,481	23.5%	47,146	14,435	MISO; SPP	
California	197,705	16,986	8.6%	258,595	(60,890)	CAISO	
Colorado	54,001	0	0.0%	53,474	527		
Connecticut	33,605	15,841	47.1%	29,359	4,246	ISONE	Y
Delaware	7,627	0	0.0%	11,179	(3,552)	PJM	Y
District of Columbia	65	0	0.0%	11,192	(11,127)	PJM	Y
Florida	231,062	27,868	12.1%	225,712	5,350		
Georgia	125,957	32,570	25.9%	135,618	(9,661)		
Hawaii	9,998	0	0.0%	9,406	592		
Idaho	15,176	0	0.0%	23,179	(8,003)		
Illinois	202,352	97,858	48.4%	140,167	62,185	MISO; PJM	Y
Indiana	115,634	0	0.0%	104,043	11,591	MISO; PJM	
Iowa	57,123	4,152	7.3%	46,949	10,174	MISO	
Kansas	50,043	8,558	17.1%	40,385	9,658	SPP	
Kentucky	90,737	0	0.0%	76,717	14,020	PJM	

[41] CAISO – California ISO; MISO – Midcontinent ISO; PJM – PJM Interconnection; ISONE – ISO New England; SPP – Southwest Power Pool.

State	Generation from All Resources (000 MWh)	Generation from Nuclear Resources (000 MWh)	Nuclear as % of All Resources	Total Electricity Consumption (000 MWh)	Generation less Consumption (000 MWh)	Served by RTO [41]	Retail Choice
Louisiana	103,992	17,311	16.6%	87,825	16,167	MISO; SPP	
Maine	13,154	0	0.0%	11,991	1,163	ISONE	Y
Maryland	38,015	14,343	37.7%	61,655	(23,640)	PJM	Y
Massachusetts	31,124	5,769	18.5%	53,487	(22,363)	ISONE	Y
Michigan	105,821	31,246	29.5%	102,701	3,120	MISO; PJM	Y
Minnesota	56,825	12,707	22.4%	67,447	(10,622)	MISO	
Mississippi	54,864	10,151	18.5%	49,573	5,291	MISO	
Missouri	88,074	9,276	10.5%	82,466	5,608	MISO; SPP	
Montana	30,243	0	0.0%	14,028	16,215	MISO	
Nebraska	39,610	10,102	25.5%	29,877	9,733	SPP	
Nevada	36,193	0	0.0%	34,424	1,769	CAISO	
New Hampshire	19,584	10,168	51.9%	10,975	8,609	ISONE	Y
New Jersey	67,465	31,507	46.7%	73,541	(6,076)	PJM	Y
New Mexico	32,125	0	0.0%	22,997	9,128	SPP	
New York	136,275	43,039	31.6%	145,759	(9,484)	NYISO	Y
North Carolina	128,904	40,967	31.8%	132,818	(3,914)	PJM	
North Dakota	36,113	0	0.0%	17,063	19,050	MISO	
Ohio	134,602	16,284	12.1%	148,557	(13,955)	PJM	Y
Oklahoma	70,299	0	0.0%	60,110	10,189	SPP	
Oregon	59,719	0	0.0%	46,930	12,789		
Pennsylvania	221,709	78,715	35.5%	146,492	75,217	PJM	Y
Rhode Island	6,293	0	0.0%	7,643	(1,350)	ISONE	Y
South Carolina	97,095	52,419	54.0%	81,722	15,373		

State	Generation from All Resources (000 MWh)	Generation from Nuclear Resources (000 MWh)	Nuclear as % of All Resources	Total Electricity Consumption (000 MWh)	Generation less Consumption (000 MWh)	Served by RTO [41]	Retail Choice
South Dakota	11,530	0	0.0%	12,198	(668)	MISO	
Tennessee	80,257	27,670	34.5%	98,253	(17,996)	PJM	
Texas	437,236	39,287	9.0%	378,726	58,510	ERCOT; MISO; SPP	Y
Utah	43,587	0	0.0%	29,934	13,653		
Vermont	6,997	5,061	72.3%	5,547	1,450	ISONE	
Virginia	77,323	30,221	39.1%	111,841	(34,518)	PJM	
Washington	115,363	9,497	8.2%	92,553	22,810		
West Virginia	81,162	0	0.0%	32,688	48,474	PJM	
Wisconsin	60,767	9,447	15.5%	69,046	(8,279)	MISO	
Wyoming	49,458	0	0.0%	17,181	32,277		
U.S. Total	**4,092,935**	**797,067**	**19.5%**	**3,723,681**	**369,254**		

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