NIRS Nuclear Information and Resource Service
6930 Carroll Ave., Suite 340 • Takoma Park, MD 20912
301-270-6477 • www.nirs.org • nirs@nirs.org • @nirsnet

Nuclear Reactor Closures

Practical, Cost-Effective Solutions for Communities and the Climate

by Tim Judson **November 2018**

Energy systems in the United States are undergoing a historic transition—most rapidly in the electricity sector. Legacy power plants (primarily, coal and nuclear) are becoming uneconomic and/or inefficient to operate, and are being retired. Electricity demand is also declining due to improving energy efficiency and other demand management systems, disproving decades-old assumptions about the relationship between energy consumption and economic growth. At the same time, wind and solar photovoltaics (PV) have been the fastest growing energy sources in recent years, driven by a combination of policy incentives, substantial decreases in costs, and ongoing improvements in technology.

Like coal plants that have been shut down in large numbers over the last several years, a similar trend is developing with nuclear power reactors. Seven of 105 operating reactors have retired since 2013,[1] and another twelve are planned over the next seven years.[2] Some assessments have predicted that as many as half of the nuclear power plants in the U.S. will be uncompetitive by 2020.[3] While there is disagreement about how quickly and in what order nuclear plants might be retired, the economic conditions for nuclear energy are continuing to worsen, with rising operating costs, rapid growth of renewables, sustained low energy prices, and a decreasing role for "baseload" generation sources. Department of Energy officials recently indicated that nuclear energy only has about a decade left before it starts to become irrelevant in the U.S. energy supply.[4]

Nuclear Power in Perspective

It is easy to overestimate the importance of nuclear power. Everything about it is big: the cost, the timescales, the size, the risk, the danger, the waste. Everything, that is, but the amount of energy it actually provides. After sixty years and hundreds of billions in direct and indirect subsidies,[5] nuclear power still only generates 20% of electricity in the U.S. Counting transportation, heating, and other sectors, nuclear accounts for just 8.6% of all energy production, nationwide. That is barely significant compared to fossil fuels, which still make up 61% of electricity generation and 86% of energy sources, nationwide. On a local level, nuclear ranges from 0% of electricity in 20 states and Washington, DC, to 58% in South Carolina. States with nuclear power tend to have less fossil fuel generation, averaging 58%; and states without nuclear average 64% fossil fuels. Phasing out uneconomical reactors will not make it much harder, if at all, to phase out fossil fuel generation. States that

1 2013: Kewaunee (Wisconsin); Crystal River, unit 3 (Florida); San Onofre, units 2 and 3 (California). 2014: Vermont Yankee. 2016: Fort Calhoun (Nebraska). 2018: Oyster Creek (New Jersey).

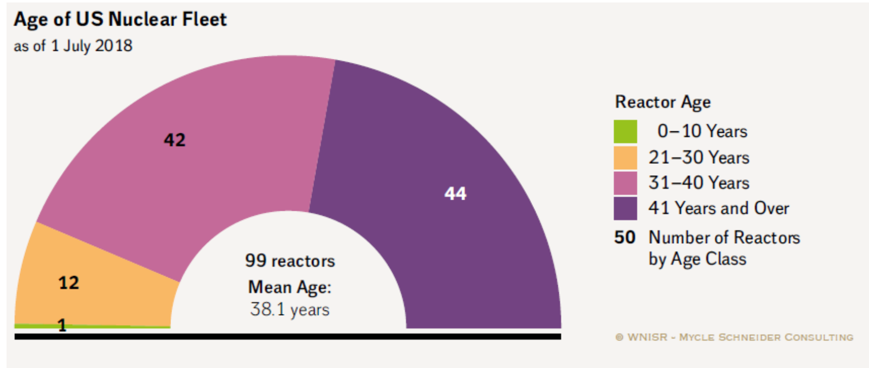
2 2019: Pilgrim (Massachusetts); Three Mile Island, unit 1 (Pennsylvania). 2020: Indian Point, unit 2 (New York); Davis-Besse (Ohio); Duane Arnold (Iowa). 2021: Indian Point, unit 3; Perry (Ohio); Beaver Valley, unit 1 (Pennsylvania); Beaver Valley, unit 2. 2022: Palisades (Michigan). 2024: Diablo Canyon, unit 1 (California). 2025: Diablo Canyon, unit 2.

3 Polson, Jim. "More Than Half of America's Nuclear Reactors Are Losing Money." Bloomberg. June 14, 2017. https://www.bloomberg.com/news/articles/2017-06-14/half-of-america-s-nuclear-power-plants-seen-as-money-losers

4 Nuclear Energy Advisory Committee. "Meeting Minutes: July 9, 2018." U.S. Department of Energy. https://www.energy.gov/sites/prod/files/2018/07/f54/July%202018%20Meeting.v0_0.pdf

5 Koplow, Doug. Nuclear Power: Still Not Viable Without Subsidies. Union of Concerned Scientists. February 2011. https://www.ucsusa.org/nuclear-power/cost-nuclear-power/nuclear-power-subsidies-report

are committed to reducing greenhouse gas emissions need to adopt policies that steadily, rapidly, and cost-effectively drive increases in renewable energy and energy efficiency.



Sources: WNISR, with IAEA-PRIS, 2018

A practical assessment of the conditions facing the nuclear industry shows that it is not realistic to assume that nuclear power can or will play a meaningful role in addressing climate change. A panel of the National Academy of Sciences recently concluded that nuclear power will be incapable of playing a role in reducing greenhouse gas emissions in the critical mid-century timeframe.[6] Almost all currently operating reactors have already received 20-year extensions on their original forty-year licenses, but the vast majority of reactors that have retired did so long before their licenses would have expired, due to mechanical failures, safety problems, and/or poor economics. A second round of license extensions is under consideration, but would entail significant investments that could only make aging reactors even less competitive and more expensive to operate.

At the same time, nearly all proposals to build new reactors under the "Nuclear Renaissance" program have proven too expensive and technically complicated, with twenty-eight out of thirty proposed reactors either cancelled or indefinitely suspended. New "advanced" reactor designs are decades away from commercialization and would require unprecedented levels of direct government sponsorship in order to be deployed at any significant level. The NAS panel concluded that policy rationales for the type of government intervention necessary to reverse these trends are inadvisable or infeasible, and do not change the underlying problems of technological barriers and poor economics.

While some argue that nuclear is necessary to reduce GHG emissions, such analyses do not take these practical considerations into account. At a threshold level, continuing to operate existing reactors does nothing to *reduce* GHG emissions from current levels; dramatically expanding renewable energy, efficiency, and other zero-GHG-emitting resources is the only way to end GHG emissions. Crucially, states that have adopted nuclear subsidies have not conducted studies or planning to determine whether maintaining existing nuclear reactors is truly necessary to achieve their emissions goals, in what amounts, and in what timeframes. Demonstrated technological and economic performance of renewables, energy efficiency and complementary, low-GHG technologies shows that more cost-effective, economically productive, and environmentally benign options are available. In fact, renewables are already expanding at rates that can supplant substantial amounts of nuclear generation in short periods of time, without sustained increases in fossil fuel generation.[7]

This generational transition in energy technologies could be unduly hindered by attempting to preserve a role for outdated, uneconomic infrastructure, such as nuclear reactors designed in the 1960s. Subsidizing aging, unprofitable reactors, for instance, both diverts large financial resources from investments in new technologies and infrastructure, and it slows down renewable energy growth.[8]

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6 Morgan, M. Granger, Ahmed Abdulla, Michael J. Ford, and Michael Rath. "US nuclear power: The vanishing low-carbon wedge." Proceedings of the National Academy of Sciences of the United States of America. 115 (28) 7184-7189. July 10, 2018. http://www.pnas.org/content/115/28/7184

7 Texas now generates 50% more electricity from wind than it does from nuclear power. In just three years (2014-2017), the state expanded electricity from wind by 27 million MWh--as much as four reactors being subsidized in New York state. Over the same time period, four other states each increased renewable energy in amounts greater than nuclear reactors can generate: California (14.5 million MWh of solar); Iowa (5.2 million MWh of wind); Kansas (8 million MWh of wind); and Oklahoma (12 million MWh of wind). See: Energy Information Administration. "Net Generation by State by Type of Producer by Energy Source (EIA-906, EIA-920, and EIA-923)." U.S. Department of Energy. September 2018.
https://www.eia.gov/electricity/data/state/annual_generation_state.xls

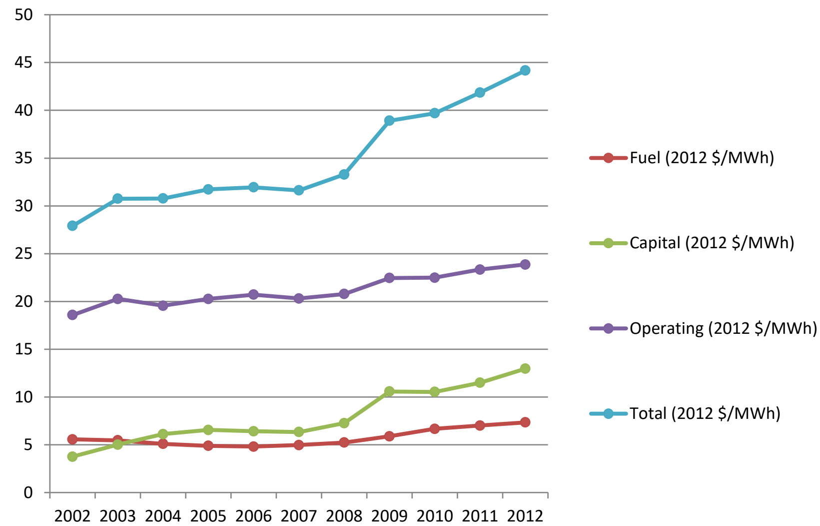
8 Cooper, Mark. "Power Shift: The Deployment of a 21st Century Electricity Sector and the Nuclear War to Stop It." Institute for

New Subsidies for Old Reactors: A Nuclear Dead End

Large corporations that own nuclear and coal power plants are concerned about their profitability, and are pushing for policies that would subsidize those assets to make them profitable regardless of whether they are cost-competitive. These measures have proved highly controversial, for a number of reasons: high cost to consumers; environmental impacts; and effects on energy markets and technological competitors. Measures proposed to bail out coal power plants have failed, thus far, due to either insufficient legislative support or legal challenges. However, four states have adopted policies to subsidize nuclear reactors: New York (2016), Illinois (2016), Connecticut (2017), and New Jersey (2018).

These policies have carried enormous direct consumer costs, and major opportunity costs, despite efforts by consumer and environmental advocates to mitigate those impacts. Programs in New York[9] and Illinois[10] are subsidizing seven nuclear reactors to the tune of up to $10 billion, over 10-12 years.[11] Nuclear subsidy programs authorized in Connecticut and New Jersey could be similarly expensive and long-term—expected to cost upwards of $300 million per year in each state, extendable for ten years or more.[12] While subsidies in New York and Illinois were predicated on averting the announced closures of five reactors, the reactors to be subsidized in Connecticut and New Jersey are recognized to be profitable. Their owners have argued that they would likely close them nevertheless because the level of profitability is not high enough to justify the continued investment and risk of narrowing profit margins in the future.[13] None of the subsidy programs include

Average Annual Nuclear Operating Cost (2012 $/MWh)



Source: Nuclear Energy Institute 2014.

Energy and the Environment, Vermont Law School. June, 2015. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2745357
Lovins, Amory. "Do coal and nuclear generation deserve above-market prices?" The Electricity Journal. 30, 22–30. July 2017. https://www.sciencedirect.com/science/article/pii/S1040619017301227

9 James A. FitzPatrick; R. E. Ginna; Nine Mile Point, units 1 and 2.

10 Clinton; Quad Cities, units 1 and 2.
Exelon Corp. "Exelon Notifies Nuclear Energy Regulator of Plans to Close Clinton and Quad Cities: NRC notification is first procedural milestone for retirement of the two nuclear energy facilities." Press Release. June 22, 2016. http://www.exeloncorp.com/newsroom/nrc-retirement-notification-of-quad-cities-and-clinton

11 Subsidies to New York reactors are projected to total as much as $7.6 billion over 12 years (2017-2029).
Judson, Tim. "Too Big to Bail Out: The Economic Costs of a National Nuclear Power Subsidy." Nuclear Information and Resource Service. November 2016.
https://www.nirs.org/wp-content/uploads/2016/11/Report-TooBigToBailOut-NIRS.pdf
Illinois subsidies are projected to total $2.35 billion over 10 years (2017-2027). Daniels, Steve. "How Exelon will keep getting bailout money in Illinois—whether it needs it or not." Crain's Chicago Business. August 2, 2017. https://www.chicagobusiness.com/article/20170802/NEWS11/170809972/how-exelon-will-keep-getting-bailout-money-in-illinois-whether-it-needs-it-or-not

12 Connecticut subsidies could amount to $330 million per year, in five-year contracts.
Energyzt Advisors, LLC. "Financial Assessment: Millstone Nuclear Power Plant." April 2017.
https://www.nirs.org/wp-content/uploads/2018/10/ENERGYZT_Assessment_of_Millstone_201704_FINAL.pdf
New Jersey subsidies are estimated to cost consumers $300 million per year, in extendable three-year periods. The Board of Public Utilities must submit a report to the governor within ten years evaluating the costs and benefits of the program.
https://www.njleg.state.nj.us/2018/Bills/S2500/2313_I1.HTM
DiSavino, Scott. "New Jersey governor signs nuclear power subsidy bill into law." Reuters. May 23, 2018. https://www.reuters.com/article/us-new-jersey-pseg-exelon-nuclear/new-jersey-governor-signs-nuclear-power-subsidy-bill-into-law-idUSKCN1IO2RL

13 Nash, James, and Nicholas Pugliese. "Nuclear plants are profitable. Should NJ electric customers be asked to pay more?" Bergen Record. February 21, 2018. https://www.northjersey.com/story/news/watchdog/2018/02/21/nuclear-plants-profitable-should-nj-electric-customers-asked-pay-more/336011002/

a practical plan for phasing out the reactors when the current subsidies expire, nor do they provide for contingency plans if reactors close regardless of subsidies (for instance because of mechanical failures, nuclear accidents, or major maintenance costs). This creates weaknesses in the states' climate targets and energy planning. No commercial reactor in the world has yet operated for 50 years, yet nearly all of the reactors in question are nearing that age. All reactors that have closed in the past, have done so long before their federal licenses expired, due to cost-prohibitive maintenance needs, utility planning decisions, or poor economic outlooks. Without such planning, states could find themselves in the same position regardless of having provided billions in subsidies: facing threats of precipitous reactor closures unless already-costly subsidies are extended yet again. If states' climate targets include retaining nuclear generation at current levels, they must at least develop plans for what they will do when reactors eventually shut down.

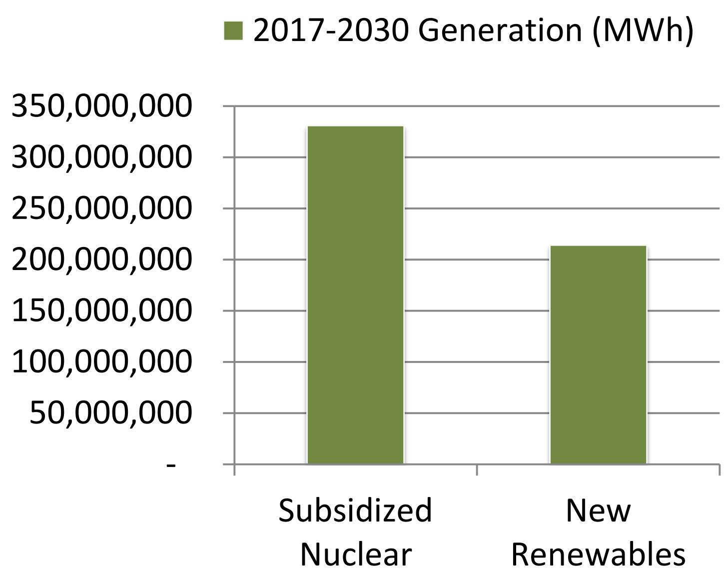
From Lose-Lose, to Win-Win

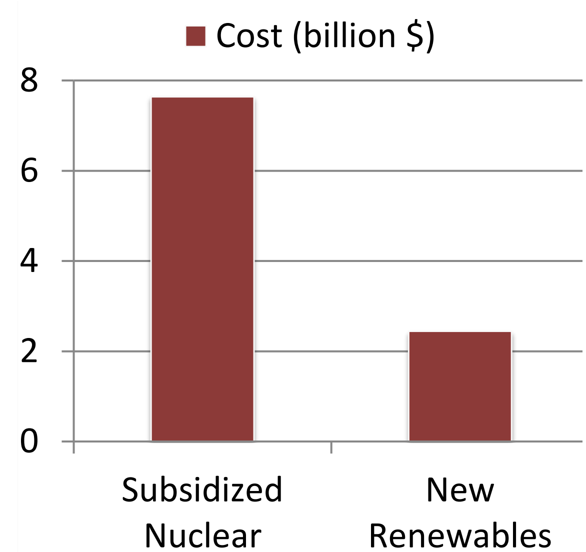
Nuclear generators, in particular, present policymakers with significant challenges, both technical and political. They tend to employ large workforces and pay significant amounts in property taxes. This makes the economic impacts of their closures daunting for local communities and politically sensitive for state policymakers. Nuclear reactors are among the largest power plants on the grid, and they tend to operate at 100% power nearly all of the time—essentially locking up immense amounts of market share within regional power markets. When a reactor retires, it creates enormous opportunity for new renewable projects to enter the market, but it can lead to near-term increases in fossil fuel generation and greenhouse gas emissions.

Coal and nuclear corporations are pressing for more subsidies and other supports, at both the state and federal levels. FirstEnergy and Exelon are seeking legislation in Ohio and Pennsylvania, and changes to market pricing rules in PJM. The Trump administration is considering an intervention into electricity markets nationwide, through an unprecedented application of the Federal Power Act and/or the Defense Production Act.

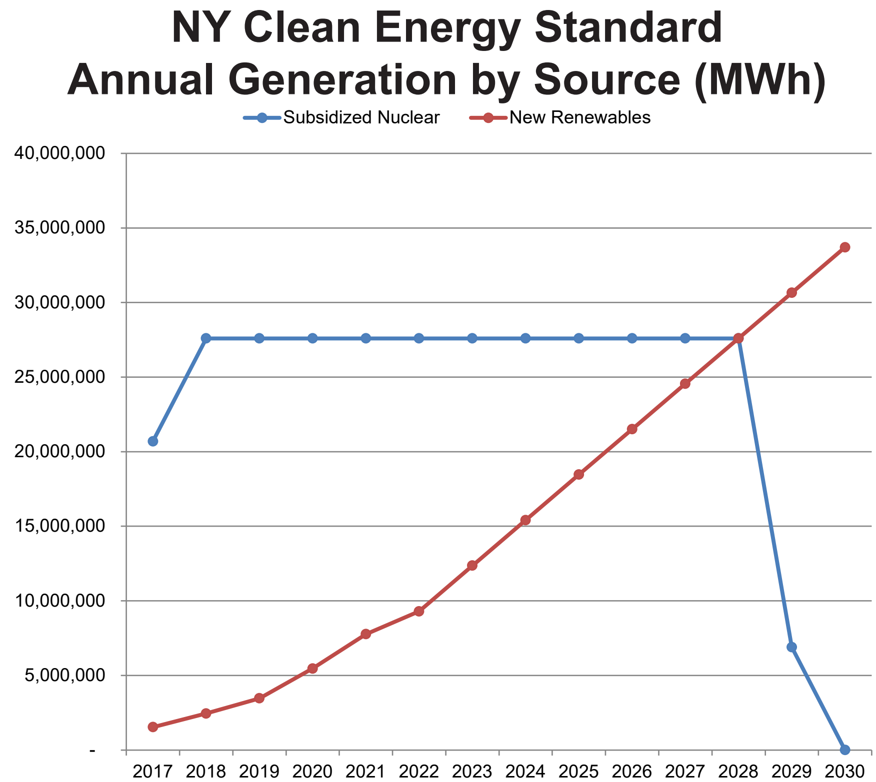
Practical, proactive solutions to the concerns around power plant closures are needed, so as to prevent hasty and uneconomical investments, and to ensure consistency with states' long-term goals for reducing greenhouse gas emissions, improving energy affordability, and advancing economic development. State and federal policymakers must first recognize that the electricity system is changing, and that trying to slow down that process carries major opportunity costs. Rather than propping up old infrastructure that will have to retire and be replaced relatively soon, states should encourage innovation and modernization in ways that ensure the best outcomes for consumers, local communities, workers, and the environment. In fact, there are both good examples of where this has been done recently in the U.S., and ways to build on established policies and procedures.

NY Clean Energy Standard (2017-2030) - Total Generation (MWh) and Costs ($)





Phaseouts vs. Bailouts



This white paper identifies a way to manage reactor closures that is more economical, reduces risk, mitigates impacts on communities and workers, protects the environment, ensures compliance with emissions goals, and maximizes opportunities for economic development.

This proposal is based on well-established, proven methods for addressing the first of those concerns: ensuring power plant retirements do not affect reliable electricity service. Utilities, regulators, and grid operators have dealt with hundreds of power plant retirements (labeled, "deactivations") throughout the country, over decades. The pace of deactivations has certainly accelerated in recent years, with the retirements of so many coal plants. Established regulatory processes for managing deactivations have been tested through this experience, and they have thus far proven capable of managing the retirement of hundreds of generating units without compromising system reliability. In most cases, regulators and grid operators have not identified any potential reliability impacts and power plants have been able to retire according to their owners plans. This has even been true when a large amount of generation capacity in a given region is scheduled to retire in a short window of time. For instance, in 2016, the New York Independent System Operator (NYISO) evaluated the planned closures of eight power plants (2,500 MW) within an 18-month period, and found that there would be no system reliability impacts.[14]

In some cases, a particular deactivation has been found to create potential reliability problems, and regulators have implemented measures to resolve it without requiring the power plant owner to modify their plans to shut down. For instance, in 2018, PJM Interconnection evaluated the announced deactivations of four nuclear generators in Ohio and Pennsylvania (3,954 MW), over an 18-month period--in addition to over 25 previously reviewed deactivations--and found that there would only be minor transmission issues which will be addressed through cost-effective upgrades.[15]

In some cases, though, the grid operator has found it necessary to defer shutting down the plant because alternatives to address a problem can't be implemented quickly or cost-effectively enough. The plant owner is then prohibited from retiring the plant until other measures can be implemented and, in the meantime, is provided a special tariff that covers the plant's operating and maintenance costs ("going forward costs"). These "Reliability Must Run" (RMR) contracts, or "Reliability Support Services Agreements" (RSSAs) can be quite expensive, as well as disruptive to competitive market operations, so regulators generally limit their duration.

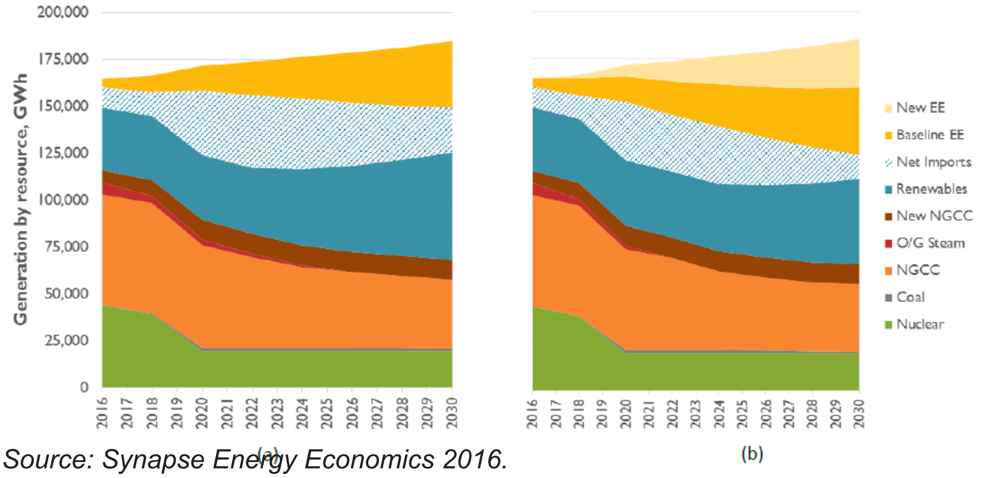
In some cases, the evaluation of alternatives results in more timely and cost-effective solutions than were previously anticipated. For instance, in 2014, Exelon informed NYISO and the NY Public Service Commission

14 New York Independent System Operator. "Generator Deactivation Assessment: James A. FitzPatrick Nuclear Generating Facility." April 22, 2016. https://www.nyiso.com/public/webdocs/markets_operations/services/planning/Planning_Studies/Reliability_Planning_Studies/Generator_Deactivation_Assessments/FitzPatrick_Generator_Deactivation_Assessment_2016-04-22.pdf

15 PJM Interconnection. "Generation Deactivation Notification Update." Presentation to PJM Transmission Expansion Advisory Committee. May 3, 2018. https://www.pjm.com/-/media/committees-groups/committees/teac/20180503/20180503-teac-generation-deactivation-notification.ashx

that it intended to close the R.E. Ginna reactor. NYISO identified a transmission vulnerability that needed to be addressed before Ginna could retire, and the PSC ordered the local utility, Rochester G&E, to negotiate a RSSA for Ginna. Initially, the PSC and NYISO anticipated the duration of the RSSA would need to be at least 3.5 years, and potentially up to five years. Through evaluating the reliability issue in greater detail, RG&E identified a much faster and less costly transmission upgrade, which shortened the RSSA to just two years. The cost of the RSSA proved expensive, costing RG&E consumers over $160 million in above-market payments for Ginna's power, but the upgrade was completed on-time and on-budget, saving consumers at least $120 million in subsidies that would otherwise have been paid to Ginna.

Projected Impacts of Energy Efficiency Standard Proposed in New York



Source: Synapse Energy Economics 2016.

There has been a recent case where a grid operator was found to be managing deactivations ineffectively. This was not because of the number of power plant closures or resulting grid reliability problems. Rather, it was due to the grid operator failing to create clear procedures to determine when, for how long, and at what price RMR are justified. In 2015, FERC found that NYISO had failed to develop rates, terms, and conditions for RMR service.[16] This created concerns about whether NYISO would be able to ensure "the continued reliable and efficient operation of the grid, and of NYISO's markets." The solution was not to create uneconomic subsidies to prevent power plants from closing, but to put transparent, consistent, cost-effective procedures in place to ensure the grid remains reliable when they do.

Proactive Transition Planning

The following concerns have been identified in relation to potential reactor closures:

- Electricity system reliability
- Greenhouse gas emissions
- Impacts on workers and communities

Through both regulated deactivation processes and recent state-level policymaking related to reactor closures, it is evident that much better outcomes can be achieved without assuming it is necessary to subsidize aging nuclear reactors. There is a limitation in current policies and procedures, though, which only capture reliability impacts.

For states where utilities are vertically integrated, utility commissions generally require utilities to conduct forward-looking planning for investments in their transmission and distribution systems, both to ensure adequate, cost-effective investments in maintaining reliability and satisfying other policy and regulatory goals. Integrated Resource Plans are an appropriate venue for utilities, regulators, and stakeholders to proactively develop plans to phase out reactors based on technical and economic criteria, while expanding renewables, efficiency, and other emissions-reduction technologies.

Two utilities have developed such phase-out plans for reactors in recent years: Pacific Gas & Electric's decision to phase-out the Diablo Canyon Nuclear Power Plant (2 reactors, 2200 MW), rather than pursue NRC license extensions; and the Omaha Public Power District, with the Fort Calhoun Nuclear Power Plant (480 MW).[17]

16 Federal Energy Regulatory Commission. "Order Instituting Section 206 Proceeding and Directing Filing to Establish Reliability Must Run Tariff Provisions (Docket No. EL15-37-000)." February 19, 2015.
https://www.ferc.gov/whats-new/comm-meet/2015/021915/E-8.pdf?csrt=12754444765216798281
https://www.ferc.gov/media/news-releases/2015/2015-1/02-19-15-E-6.asp#.W9n0o_ZRe71

17 Omaha Public Power District. "Resource Planning Update." May 12, 2016. http://www.oppdlistens.com/files/9014/6307/5823/

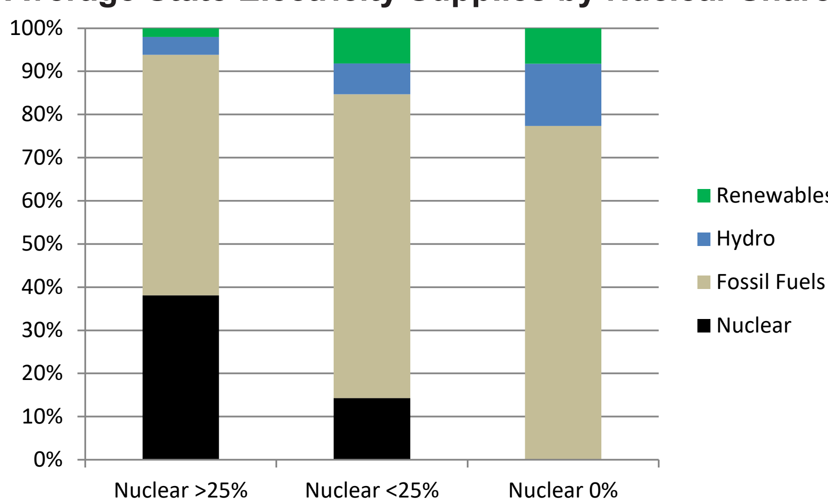
In both cases, the utilities recognized that the continued operation of the reactors was not economically justified, and that it would be more cost-effective to pursue renewables and efficiency to achieve emissions-reduction goals. In the case of PG&E, the utility identified that continuing to operate Diablo Canyon would make achieving California's emissions reduction and renewable energy goals difficult.[18] Because reactors have limited ability to adjust their power output, Diablo Canyon would create congestion in the transmission system as solar generation continues to expand in California. PG&E determined it would be better to phase Diablo Canyon out, while increasing investments in energy efficiency and solar. Through the plan, the utility has made a commitment to achieving 55% renewable energy by 2030, surpassing California's 50% by 2030 standard.

The Bailout Bind

In states with competitive electricity markets, reactors are generally operated by merchant power companies that are not subject to such comprehensive system planning. Power plant development and retirement is primarily driven by wholesale market rules and economic trends. Most of the reactors slated to retire operate in such markets. One of the purported advantages of moving to competitive electricity markets was that states need not play such an active role in the fates of coal plants and nuclear reactors. In fact, many of these same nuclear reactors were bailed out 20 years ago to the tune of $135 billion (2018$), in deals with utility companies intended to facilitate the transition to competitive markets.[19] Policymakers in most such states have not had sufficient policies and procedures in place to assess the impacts of reactor closures when they are announced.

This relative policy vacuum has given power plant owners an advantage in pressuring regulators and lawmakers for subsidies and bailouts: threatening that major decisions must be made imminently that could close reactors *en masse*, resulting in mass layoffs, precipitous losses of tax revenue, and spikes in GHG emissions. Without established regulatory processes for responding to such situations, four states have been pressured to provide exorbitantly large, long-term subsidies, with no plans for phasing out and supplanting nuclear with renewables. For instance, under New York's Clean Energy Standard, the state has thus far spent about 200 times as much money on nuclear subsidies than on developing new renewables toward the program's 50% renewable energy standard. Renewables will prove up to six times more cost-effective than nuclear subsidies in achieving New York's 2030 emissions target, but the state did not consider any alternatives to subsidizing nuclear, nor did it incorporate any plans for ramping up renewables and efficiency when reactors close.[20] This need not be the case.

Average State Electricity Supplies by Nuclear Share



Reactor Closures: A Practical, Cost-Effective Approach

Existing procedures for managing the reliability impacts of power plant retirements can be adapted to address other impacts of reactor closures consistently, transparently, and cost-effectively. As proposed by Alliance for a Green Economy and NIRS to the New York Public Service Commission in 2016,[21] this would entail a two-track process, through

May_Board_Presentation-final_SECURED.pdf

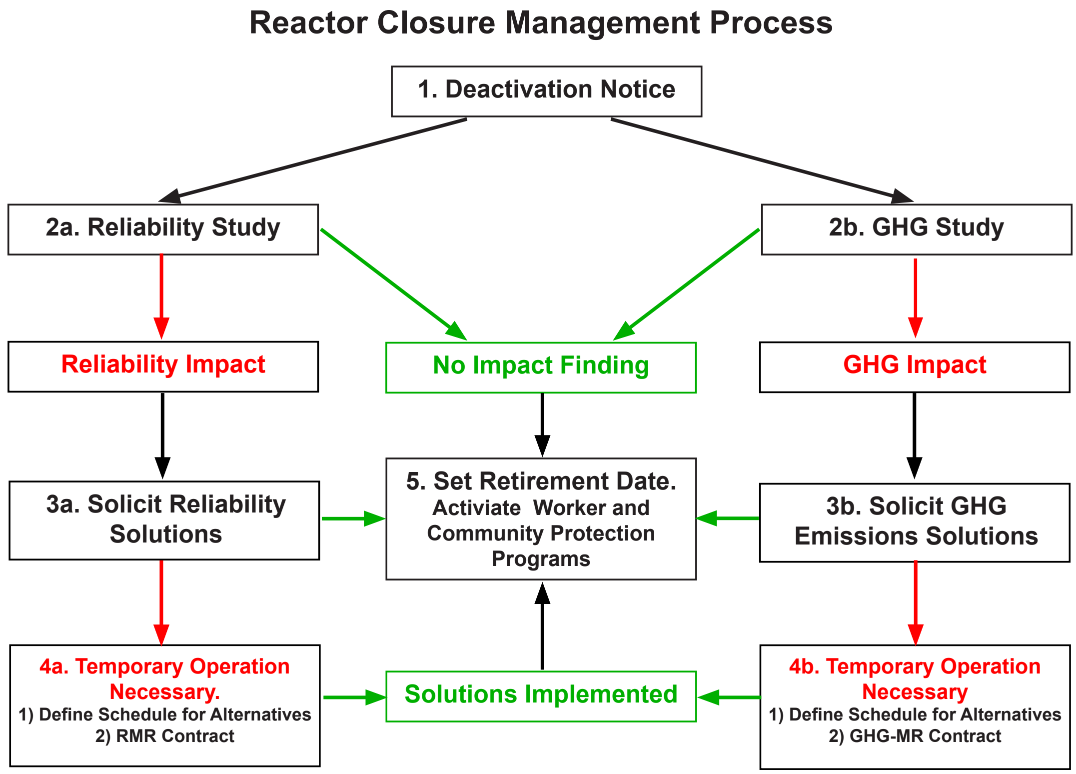
18 LaCount, Robert. Joint Proposal for the Orderly Replacement of Diablo Canyon Power Plant with Energy Efficiency and Renewables. M. J. Bradley & Associates. June 21, 2016. https://www.pge.com/includes/docs/pdfs/safety/dcpp/MJBA_Report.pdf

19 Koplow 2011.

20 Judson, Tim. "Too Big to Bail Out: The Economic Costs of a National Nuclear Power Subsidy." Nuclear Information and Resource Service. November 2016. https://www.nirs.org/wp-content/uploads/2016/11/Report-TooBigToBailOut-NIRS.pdf

21 Alliance for a Green Economy, and Nuclear Information and Resource Service; with Council on Intelligent Energy and Conservation Policy, and Sierra Club-Atlantic Chapter. Comment filed in New York State Public Service Commission cases 15-E-0302 and 16-E-0270. July 22, 2016. http://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId={03DA-

which emissions impacts are evaluated and addressed, in parallel with reliability impacts.



1. **Deactivation Notice:** Owners that are planning to retire a nuclear reactor should be required to file notices of intent to do so at least one year in advance with the state agency that regulates utilities.
2. **Reliability and Emissions Studies:** The notice of intent to retire should trigger two analyses to be completed:
   a. A reliability study performed by the grid operator, to determine whether any transmission, distribution or supply impacts must be addressed.
   b. A greenhouse gas emissions study, performed by the relevant state agencies, to determine whether or not the reactor closure would jeopardize the state's ability to meet its GHG targets.
3. **Search for Alternatives:** If it is found that the reactor closure would create a reliability concern and/or jeopardize GHG emissions goals, a competitive solicitation should be conducted to address those needs.
   a. The retiring nuclear generator could be eligible to compete in this process, with due consideration of costs and environmental impacts.
   b. Reliability solutions should also be evaluated to determine whether they would jeopardize the state's GHG goals. Those that would must be excluded.
4. **Transitional Nuclear Subsidies:** In the event that an emissions issue is identified, but no solutions are found that cost-effectively mitigate the emissions impact within the necessary timeframe, an analogous process to a RMR would be triggered (nominally, a "GHG Must Run" contract, or GHG-MR).
   a. The utility commission must oversee the negotiation and implementation of a contract that provides the reactor owner with revenues strictly limited to the minimum amount necessary to cover the reactor's going forward costs, for the least amount of time.
   b. The utility commission must determine the minimal timeframe for implementing alternatives, and oversee their implementation.
   c. In case the reactor owner changes its decision to retire at the end of the GHG-MR, the contract should require the reactor owner to refund consumers for investments they subsidized from which it will profit by continuing to operate the reactor.
5. **Closure and Transition Process:** If these evaluations conclude that the reactor can close without any reliability concerns and without jeopardizing GHG goals, the reactor owner should be authorized to proceed with its schedule for retiring the reactor.
   a. A worker and community transition plan should be activated to assist affected employees, municipalities and school districts with the economic transition.[22]

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22 The transition program should be established and funded in advance, and be available to address closures of all power generation facilities, not just nuclear reactors. Below, we provide a proposal for the creation and revenue sources for these activities.

Supporting and Enabling Policy Measures

This procedure can be most effective with supporting policies and programs in place:

- **Statewide emissions targets**--covering all sectors, including transportation, heating, industry, and agriculture. As more energy use shifts to efficient, electricity-driven systems (electric vehicles, heat pumps, etc.), emissions in the electricity sector can't be evaluated in isolation. Some interim increases in electricity sector emissions may facilitate significantly greater reductions in transportation and heating, for instance.
- **Integrated energy and emissions planning**--a statewide plan for achieving emissions targets, necessary to evaluate alternatives to nuclear. Increasing investments in emissions-reduction programs can be more cost-effective than nuclear subsidies. With a robust plan for reducing emissions across all sectors, incremental increases in numerous programs can ensure the emissions impact of reactor closures is mitigated quickly and seamlessly.
- **Community and workforce transition programs**--establishing and funding programs to mitigate the economic impacts on workers and local communities. No community or worker should be left behind as a result of policy decisions and macroeconomic trends over which they have no control, even when they benefit the state as a whole. Putting programs in place to address power plant closures proactively can be significantly more cost-effective than subsidizing plants' continued operation.[23] Nuclear reactors present unique opportunities to do this because their owners are required to set aside hundreds of millions of dollars to fund radiological decommissioning and cleanup, which can take 10-20 years.
- **Renewable energy policies**--including enforceable procurement standards and policies; programs to facilitate siting and permitting or renewable energy facilities; and incentives and assistance to help communities maximize the benefits.

Greenhouse Gas Emissions Targets

There is no rational way to determine that subsidies for nuclear power are necessary to reduce GHG emissions without setting clear, comprehensive goals and developing plans and policies to achieve them. Many states and municipalities have adopted emissions reduction targets, such as 40% reductions in GHG emissions from 1990 levels by 2030 and 80% by 2050. Several have also adopted energy policies and programs in order to meet such targets. Merely keeping an existing reactor operating does not reduce GHG emissions; nuclear generators themselves are merely part of the status quo. GHG emissions targets rely primarily on development of new renewable and other low-GHG resources to supplant fossil fuel generation. The most that retaining nuclear generation through subsidies can do is to mitigate against increases in fossil fuel generation in the years immediately following the reactor's planned closure.

However, other factors should be considered. For instance, it is generally accepted that greenhouse gas emissions in the near-term will have a greater impact on climate change than those emitted later. It is also accepted that cumulative greenhouse gas emissions should be taken into account over the period between now and 2030, not just the greenhouse gas emissions created in the year 2030. As a matter of good climate policy, it is advisable to establish overall GHG emissions budgets and/or interim emissions benchmarks (say, between now and 2030). Such standards would enable states to track the performance of their energy programs and make adjustments as needed.

Community and Worker Protection

Ensuring a responsible and effective economic transition for communities and workers impacted by power plant closures will reduce the political friction in making energy policy decisions. Eliminating GHG emissions will place the energy sector on the cusp of a fundamental, generational transition, of similar scope and scale to economic globalization. This transition is necessary, and must take place rapidly, but deindustrialization in many communities has created well-justified hesitation about job losses and economic stability. Unless states

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23 Azulay, Jessica, and Tim Judson. "Replacing FitzPatrick: How the Closure of a Nuclear Reactor Can Reduce Greenhouse Gasses and Radioactive Waste." Alliance for a Green Economy and Nuclear Information and Resource Service. October 22, 2015. https://www.nirs.org/wp-content/uploads/2016/07/replacingthefitzpatricknuclearreactor.pdf

and/or the federal government ensure that workers and communities land on their feet, the energy transition could become paralyzed by political backlash and inertia.

The best option for communities and workers affected by the transition is to provide for a seamless transition into the new green economy. If an appropriate portion of renewable energy and storage facilities and jobs can be located in communities that have historically hosted fossil fuel and nuclear power plants, that would be ideal. Unfortunately, such a scheme cannot work universally, since the ideal location for renewable resources (e.g., wind and solar) will not always be in the same localities. For nuclear reactor closures, the planning should also include retention of the workforce for a timely and responsible decommissioning. It is critical that as nuclear plants close, the billions of dollars accumulated in decommissioning trust fund accounts are leveraged to maximize the impact of community and worker transition programs.

A cost-effective suite of programs and services that would reduce the economic hardship and uncertainty of the energy sector transition would include:

- Transitional revenue support for municipalities and school districts.
- Economic development to recruit new industries and employers.
- Retention of 40-50% of existing nuclear worker jobs for decommissioning.
- Transfers/rehiring of workers to other reactors or utility divisions.
- Economic support, retraining, and job placement for workers who do lose their jobs.
- Early retirement for workers nearing the end of their careers.

Such a program for a nuclear reactor could cost around $40 million/year for 5-10 years, with costs decreasing after the first three or four years.[24] That is one-half to one-third the annual cost of subsidies for a reactor in Illinois, New Jersey, or New York, and the total cost would be up to a factor ten lower than the cost of nuclear subsidies over the full 10-12 years.

There must be dedicated funding for worker and community transition to ensure resources are available when needed. For instance, a $1/MWh surcharge (0.1 cents/kWh) on electricity consumption would generate $4 billion/year, nationwide. Such a sum is far less, on a state-by-state basis, than subsidies for uneconomic nuclear reactors alone. Less regressive ways to raise these funds could also be considered, for instance, through corporate income taxes.

Nuclear in the Context of Climate Change and Phasing Out Fossil Fuels

There is a growing consensus on the urgency of taking action to mitigate the scale and scope of global climate change. This imperative has been elevated by a report issued in October 2018 by the Intergovernmental Panel on Climate Change (IPCC). According to the IPCC report, global greenhouse gas (GHG) emissions must be reduced by 45% by 2030, and reach net zero by 2050.[25] The report also shows that doing so is still feasible and affordable, but immediate action is necessary. As one news report aptly summarized: "The details in the report are worth understanding, but there's one simple critical takeaway point: we need to cut GHG pollution as much as possible, as fast as possible."[26]

Because fossil fuels constitute about 85% of total energy use worldwide and in the US,[27] eliminating GHG emissions will require replacing the vast majority of our current energy sources, and the infrastructure to integrate renewable energy sources with energy storage and intelligent supply-demand management systems.

There is a good basis for the IPCC's guarded optimism about the feasibility of achieving zero or negative

24 Azulay, Jessica, and Tim Judson. "Replacing FitzPatrick: How the Closure of a Nuclear Reactor Can Reduce Greenhouse Gasses and Radioactive Waste." Alliance for a Green Economy and Nuclear Information and Resource Service. October 22, 2015. https://www.nirs.org/wp-content/uploads/2016/07/replacingthe-fitzpatricknuclearreactor.pdf

25 Intergovernmental Panel on Climate Change. "Summary for Policymakers of IPCC Special Report on Global Warming of 1.5ºC approved by governments." Press Release. October 8, 2018. http://www.ipcc.ch/pdf/session48/pr_181008_P48_spm_en.pdf

26 Nuccitelli, Dana. "There's one key takeaway from last week's IPCC report." The Guardian. October 15, 2018. https://www.theguardian.com/environment/climate-consensus-97-per-cent/2018/oct/15/theres-one-key-takeaway-from-last-weeks-ipcc-report

27 British Petroleum. BP Statistical Review of World Energy: 67th edition. June 2018. https://www.bp.com/content/dam/bp/en/corporate/pdf/energy-economics/statistical-review/bp-stats-review-2018-full-report.pdf

GHG emissions. Reports by Lazard[28] and Deloitte[29] conclude that wind and solar are now the least-cost sources of electricity (without subsidies), and costs are continuing to decline. Costs of electricity storage, offshore wind, and other complementary technologies are now declining along similar trajectories. Deloitte's most recent assessment suggests that growth of renewables will not only continue to increase, but it will support the development of supporting technologies, as well:

> Having only recently been recognized as a "mainstream" energy source, renewable energy is now rapidly becoming a preferred one. … These trends will likely continue to strengthen through two mutually reinforcing virtuous circles. The deployment of new technologies will help further decrease costs and improve integration. This will enable a growing number of energy consumers to procure their preferred energy source and accelerate national energy transitions across the world.

In addition, energy efficiency is still recognized as the lowest-cost energy resource,[30] with net cost savings exceeding direct costs to consumers. Through requiring utilities to meet increasing energy efficiency standards, states can deploy energy efficiency as a resource at scale with nuclear reactors and other power plants.[31]

Given the wide disparities between states' levels of reliance on nuclear (see "Nuclear Power in Perspective," above), nothing more is required of states to reduce their use of nuclear along with fossil fuels in achieving the necessary trajectory for ending GHG emissions. In fact, there are a growing number of scientific and engineering studies which show the feasibility of achieving 100% renewable energy by 2050.[32] The keys to such a widespread transformation of the energy sector are maximizing efficiency and cost-effectiveness through consistent policy, planning, and coordination; and preventing hardship to workers and communities in the process.

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NIRS

Nuclear Information and Resource Service

6930 Carroll Ave., Suite 340 • Takoma Park, MD 20912

301-270-6477 • www.nirs.org • nirs@nirs.org • @nirsnet