Union of Concerned Scientists

EXECUTIVE SUMMARY

The Nuclear Power Dilemma

Declining Profits, Plant Closures, and the Threat of Rising Carbon Emissions

HIGHLIGHTS

Many nuclear power plants have shut down in recent years due to economic, safety, and performance challenges. Without policies to replace retired nuclear power generation with low-carbon energy technologies, utilities could turn to natural gas and coal to fill the gap—hampering our ability to reduce heat-trapping emissions to the level needed to limit the worst impacts of global warming.

To help the electricity sector continue its transition to cleaner energy sources, federal and state policies must properly value the climate benefits of all low-carbon technologies. At the same time, any financial support targeted specifically for existing nuclear plants must be coupled with strong consumer protections, stringent safety requirements, and investments in renewables and energy efficiency.

For decades, nuclear power has provided most of the nation's carbon-free electricity. However, the owners have shut down many nuclear plants in the last five years or announced plans to close them well before their operating licenses expire, generating a discussion among policymakers and regulators about the impact of early retirements. The primary reasons for these early closures are the economic challenges brought on by cheap natural gas, diminished demand for electricity, falling costs for renewable energy, rising operating costs, and safety and performance problems. The possibility that the nation will replace existing nuclear plants with natural gas and coal rather than low-carbon sources raises serious concerns about our ability to achieve the deep cuts in carbon emissions needed to limit the worst impacts of climate change.

As of the end of 2017, 99 reactors at 60 power plants provided 20 percent of US electricity generation. The owners have retired six reactors at five plants since 2013, slated seven reactors at five more plants to retire over the next eight years, and threatened to close five reactors at four more plants in the next few years if they do not receive new financial support.[1] In addition, Illinois, New Jersey, and New York now provide financial support to keep 10 reactors at seven plants operating for at least 10 more years.

The economic challenges facing nuclear plants are part of a historic transition in the US electricity sector. Over the last decade, natural gas generation and renewable energy generation from wind and solar have grown rapidly as their prices

Entergy Nuclear/Creative Commons (Flickr)

The two reactors at New York's Indian Point nuclear power plant are slated to close in 2020 and 2021. Governor Andrew Cuomo has made a commitment that the closure will not cause an appreciable increase in carbon emissions; New York's strong renewable energy and energy efficiency policies will help the state meet this commitment.

have fallen. Combined with investments in energy efficiency, these energy sources have largely replaced generation from retiring coal plants, resulting in a 28 percent reduction in US power-sector emissions of carbon dioxide (CO_2) below 2005 levels in 2017. While nuclear power's share of electric power production has remained relatively flat over the past decade, most analysts project that share to decline in the future without additional financial or policy support.

The transition already has resulted in many benefits, including lower electricity prices, technological innovation, a cleaner environment, and increased customer control over energy use. However, in the absence of national policy to reduce carbon emissions, the transition has undervalued all types of low-carbon sources of electricity and underpriced natural gas and coal relative to their damage to the climate.

The Union of Concerned Scientists (UCS) has assessed the economic viability and performance of most of the nuclear power plants operating in the United States, analyzing which ones are most at risk of early retirement and evaluating the main factors that affect competitiveness. We also identified reactors that have been safe, reliable performers and those with troubled performance records. In addition, using a national model of the electricity sector, UCS has analyzed the impacts on the US electricity mix, CO_2 emissions, and consumer electricity bills of three scenarios for retiring nuclear plants early and two scenarios based on the introduction of national policies to reduce carbon emissions.

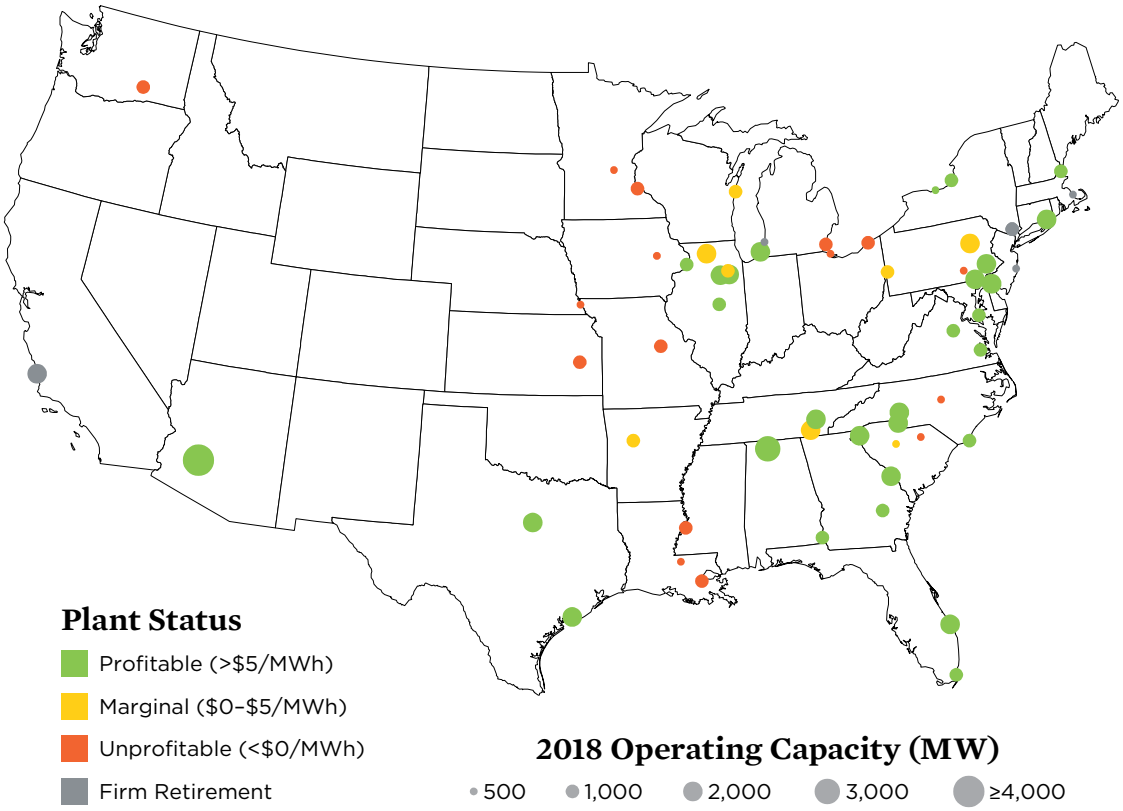
Assessing the Profitability of Today's Nuclear Power Reactors

Using projections from S&P Global Market Intelligence,[2] UCS estimated the annual operating margins (revenues minus costs) for 92 nuclear reactors at 55 plants, excluding from the analysis seven reactors at five plants slated to close in the next eight years. The plants derive revenue in three ways: selling electricity into regional wholesale power markets; providing capacity to ensure the availability of adequate generation during times of peak demand; and, in the case of seven plants, receiving financial support for their zero carbon–emissions attributes from three states. The costs, which cover fuel, capital expenses, and fixed and variable operations and maintenance, are based primarily on annual data collected by the Electric Utility Cost Group for the Nuclear Energy Institute. Profitability is assessed based on the average annual operating margin over the five-year period from 2018 to 2022. Unprofitable plants have average annual operating margins below $0 per megawatt-hour (MWh). Marginal plants have operating margins between $0 and $5 per MWh. We deemed plants above $5 per MWh as profitable. The analysis covers plants owned by regulated, investor-owned utilities and public power utilities, as well as merchant generators, which are not regulated by state public utility commissions. The analysis does not reflect any additional revenue collected from consumers through rates.

The UCS analysis found that:

- ***More than one-third of existing plants, representing 22 percent of total US nuclear capacity, are unprofitable or scheduled to close*** (Figure ES-1). On average, projected operating costs exceed revenues between 2018 and 2022 for 16 nuclear plants in addition to five plants scheduled for retirement. These 21 plants accounted for 22.7 gigawatts (GW) of operating capacity in 2018. The annual average cost of bringing unprofitable plants to the breakeven point is $814 million, for a total of more than $4 billion over five years. Merchant plants are more susceptible to market forces and have a higher risk of retirement, but regulated and public power plants are not immune from these pressures. Ten of the 21 plants are merchant plants (10.5 GW), including four (4.2 GW) that are slated to close and six (6.3 GW) that have a higher risk of closing in the future. Eleven of the 21 plants are regulated plants (12.3 GW), including one (2.2 GW) that is slated to close by 2025 and 10 that have a lower risk of closing because they currently receive cost recovery from ratepayers. Eight additional plants are marginally profitable (15 GW), including five merchant plants (9.8 GW) and three regulated plants (5.2 GW).
- ***Single-reactor plants are more at risk than multiple-reactor plants.*** More than three-quarters of the total capacity from smaller, single-reactor plants is unprofitable or marginal compared with 20 percent from larger, multiple-reactor plants, which have greater economies of scale.
- ***The Midwest and Mid-Atlantic states have the most plants at risk of early retirement.*** The Midcontinent Independent System Operator has the greatest unprofitable nuclear capacity (8.3 GW, 63 percent of its total nuclear capacity) due to lower-than-average wholesale electricity prices and a higher concentration of single-reactor plants. PJM Interconnection in the Mid-Atlantic states has the most marginal capacity (8.6 GW, 25 percent of its total nuclear capacity).
- ***Seventeen states have plants that are unprofitable or scheduled to close*** (Figure ES-2, p. 4). Ohio, Louisiana, and Minnesota have the highest amount of unprofitable capacity. Pennsylvania, Illinois, and Tennessee have the most marginal capacity. California and New York have

FIGURE ES-1. US Nuclear Power Plants at Risk of Early Closure or Slated for Early Retirement



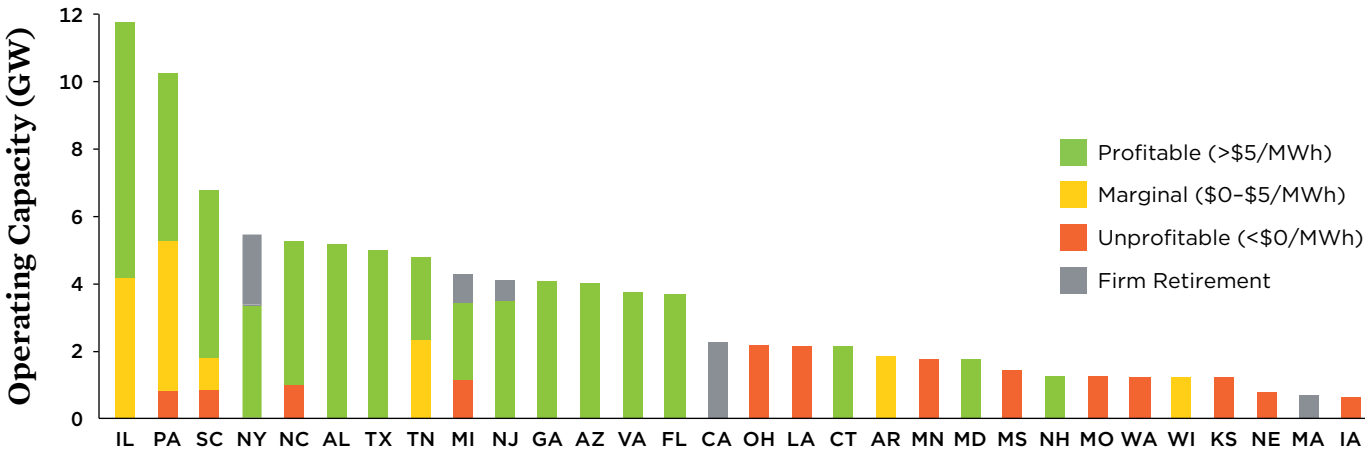
More than one-third of existing plants, representing 22 percent of US nuclear capacity, are unprofitable or scheduled to close.

the most capacity scheduled to close. Financial support has helped make five unprofitable or marginal plants in Illinois, New Jersey, and New York profitable. Such support also has boosted the revenues of one plant in New York and one in New Jersey even though the UCS analysis suggests that these were already profitable.

- ***Most plant owners have reactors that are unprofitable or scheduled to close.*** Exelon owns the most US nuclear capacity (20 GW) by far; about one quarter of that capacity is unprofitable or marginal. Entergy is retiring 40 percent of its nuclear capacity with the pending closure of three plants in Massachusetts, Michigan, and New York, and its remaining capacity is unprofitable or marginal. More than half of FirstEnergy's nuclear capacity is unprofitable, with the remainder categorized as marginal. Notably, all of the assets of a few companies that own only one or two nuclear plants, like Xcel Energy, are unprofitable compared with cheaper alternatives available in the market.
- ***Natural gas prices, nuclear costs, and CO_2 prices have the biggest impact on profitability.*** The amount of unprofitable nuclear capacity could increase from 16.3 GW under our reference case assumptions to 42.7 GW (42 percent of total US nuclear capacity) with higher nuclear costs and 28.7 GW with lower natural gas prices over the next five years. In contrast, the amount of unprofitable capacity could decline to 10.6 GW with lower nuclear costs, 7 GW with higher natural gas prices, and 1.4 GW with a national CO_2 price of $25 per ton in 2020, rising 5 percent per year.

Because most plant-level cost data are proprietary, and because factors not included in our analysis can affect profitability and retirement decisions, owners of distressed plants should be required to submit detailed economic data to regulators to demonstrate financial need. Our analysis estimates the profitability of specific nuclear plants based on the best available data and cannot substitute for a careful financial review of each facility.

FIGURE ES-2. Nuclear Capacity at Risk of Early Closure or Slated for Early Retirement, by State



Of the 30 states with nuclear power plants, 17 states have nuclear capacity that is unprofitable or scheduled to close.

Analyzing the Impact of Carbon Reduction Policies and Retiring Reactors Early

Using the National Renewable Energy Laboratory's Renewable Energy Deployment System model, UCS analyzed the impact of early plant retirements and carbon-reduction policies on the US electricity mix, CO_2 emissions, and consumer electricity bills through 2035. We chose that date to assess the potential near-term impacts from retiring unprofitable or marginal reactors before their operating licenses expire, which occurs for most US reactors between 2030 and 2050. We examined six main scenarios:

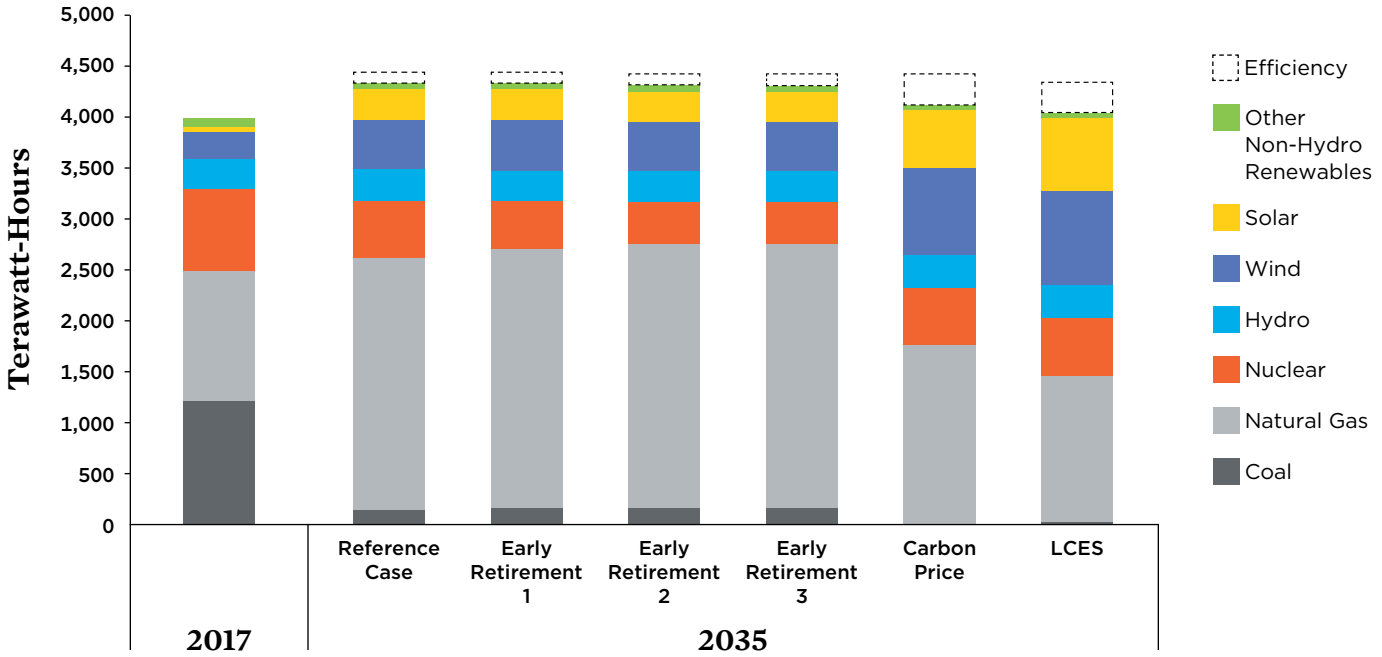
- **Reference Case:** No new policies are enacted and no nuclear reactors are retired early beyond the five plants already slated to close.
- **Three Early Retirement Cases:** No new policies are enacted, and early retirements range from 13.7 GW to 26.8 GW over the next eight years. These cases assume the early retirement of plants that fail our economic screening test based on the profitability assessment described above. Two cases use our reference case assumptions: early retirement case 1 only includes merchant plants; early retirement case 2 includes a mix of merchant and regulated plants. Early retirement case 3 assumes lower natural gas prices and only includes merchant plants.
- **National Carbon Price Case:** New policies set a $25 per ton price on CO_2 in 2020, increasing 5 percent per year.
- **National Low-Carbon Electricity Standard (LCES) Case:** The LCES increases from 45 percent in 2020 to 60 percent by 2030 and 80 percent by 2050.

The UCS analysis found that:

- ***Without new policies and with low natural gas prices, early nuclear retirements are replaced primarily with natural gas and coal.*** Closing the at-risk plants early could result in a cumulative 4 to 6 percent increase in US power sector carbon emissions by 2035 (0.7 billion to 1.25 billion metric tons) from burning more natural gas and coal. This pathway would make it more difficult for the United States to achieve deep cuts in carbon emissions.
- ***State and national carbon-reduction policies would help preserve existing nuclear generation and diversify our nation's electricity mix.*** Nuclear and hydropower stays at reference case levels and non-hydro renewable energy generation (primarily wind and solar) more than triples from 10 percent of total US power generation in 2017 to 36 percent by 2035 under the carbon price case and 41 percent by 2035 under the LCES case. Energy efficiency reduces generation by nearly 9 percent by 2035 under both cases (Figure ES-3).
- ***Carbon-reduction policies can prevent an overreliance on natural gas.*** Under the two scenarios with new policies to encourage low-carbon energy sources (carbon price and LCES), natural gas generation is 31 percent to 44 percent lower than in early retirement case 1.

- ***A national carbon price, an LCES, or other policies that preserve existing nuclear generation and increase investments in renewable energy and energy efficiency significantly reduce CO_2.*** Cumulative CO_2 emissions from the US power sector are 19 percent (4 billion metric tons) lower in the LCES case and 28 percent (5.7 billion metric tons) lower in the carbon price case through 2035 compared with early retirement case 1 (Figure ES-4, p. 6). A National Research Council study found that US power-sector emissions would need to fall more than 90 percent below 2005 levels by 2040 to meet US climate goals. Achieving that requires a cumulative reduction in power-sector CO_2 emissions of 33 percent by 2035 (6.6 billion metric tons) compared with early retirement case 1. Both the carbon price and LCES cases take the US power sector most of the way toward meeting these targets.
- ***Carbon-reduction policies reduce NO_X and SO_2 emissions, leading to tangible health and economic benefits.*** Primarily by reducing coal generation, the carbon price and LCES policy cases help cut other air pollutants: sulfur dioxide (SO_2) emissions are 61 to 68 percent lower than the early retirement case 1 in 2035; nitrogen oxides (NO_X) are 41 to 42 percent lower. NO_X and SO_2 contribute to smog and soot, both of which exacerbate asthma and other heart and lung diseases and can result in significant disability and premature death. CO_2 emissions contribute to global warming and other climate impacts that can impair human health and safety. The climate and public health benefits average $22 billion each year, adding up to a total of $132 billion under the LCES case to $227 billion under the carbon price case cumulatively from 2018 through 2035 compared with early retirement case 1.
- ***The emissions reductions and increases in clean energy spurred by the two carbon-reduction policies are affordable.*** Savings from investments in energy efficiency offset most of the cost increases from investments in low-carbon technologies. Average monthly electricity bills for a typical household under the two policy cases are only 1.0 to 1.4 percent higher in 2035 than in the early retirement case 1, amounting to a modest electricity bill increase of $0.74 to $1.03 per month. The carbon price case could offset most of those costs by returning to consumers a portion of the $28 billion in average annual carbon revenues between 2020 and 2035. Overall, the benefits

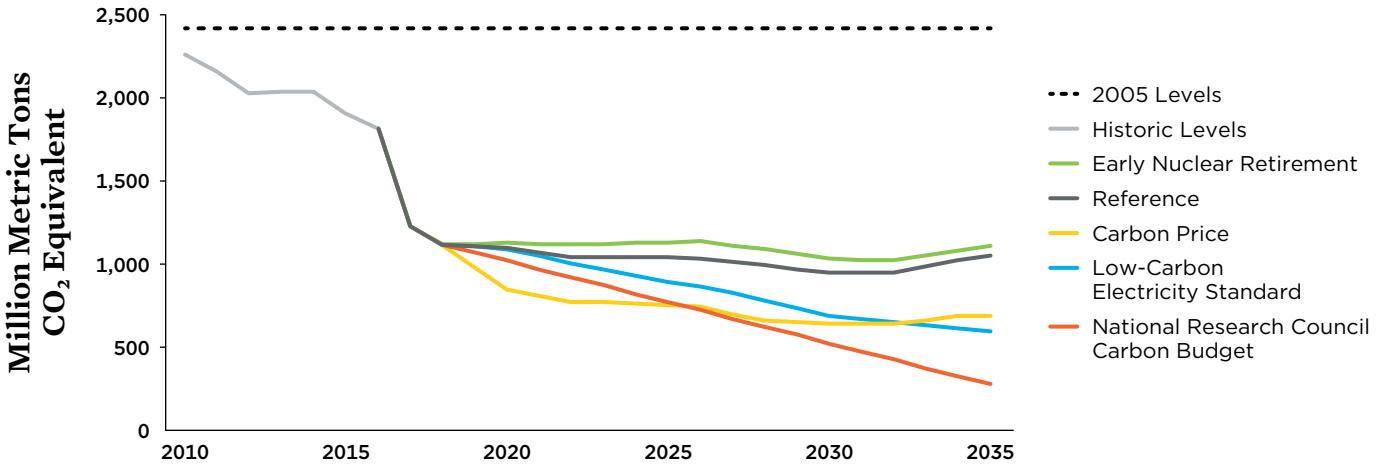
FIGURE ES-3. The US Electricity Generation Mix, 2017 and 2035



Carbon-reduction policies would diversify the US electricity mix by maintaining existing nuclear generation, increasing investments in energy efficiency and renewable energy, and preventing an overreliance on natural gas.

Note: Early retirement case 1 only includes 9 merchant plants (13.7 GW). Early retirement case 2 includes a mix of 21 merchant and regulated plants (26.8 GW) under our reference case assumptions. Early retirement case 3 assumes lower natural gas prices and only includes 15 merchant plants (26.3 GW).

FIGURE ES-4. US Power Plant CO_2 Emissions



Under a reference case with low natural gas prices and no new policies, closing at-risk nuclear plants before their operating licenses expire could result in a cumulative increase in US power-sector CO_2 emissions of up to 6 percent by 2035 from burning more natural gas and coal. The carbon-policy cases reduce CO_2 emissions by 19 to 28 percent cumulatively by 2035. A National Research Council study found that to meet US climate goals, power-sector emissions would need to fall to more than 90 percent below 2005 levels by 2040.

exceed the costs of implementing the policies, resulting in cumulative net benefits of $61 billion under the LCES case and $234 billion under the carbon price case by 2035.

Evaluating Reactor Safety Performance

While an accident or terrorist attack at a US nuclear reactor could severely harm public health, the environment, and the economy, it would also jeopardize the prospects for US nuclear energy for decades and limit available options to meet near-term carbon reduction targets. It is thus essential that policymakers and other stakeholders consider financial support only for nuclear reactors that meet or exceed current safety standards.

UCS proposed using information from the Reactor Oversight Process (ROP) of the Nuclear Regulatory Commission (NRC), which rates the safety performance of each reactor on a quarterly basis. Only reactors with the highest safety rating—indicating they meet all safety regulations—would be eligible for financial support. Between 2000 and 2018, the NRC gave reactors its top rating 80 percent of the time, and its second highest rating 15 percent of the time. When a reactor dropped out of the top category, it took an average of one year for it to return to that category.

However, the industry's trade organization, the Nuclear Energy Institute (NEI), has proposed that the NRC change the ROP, including merging the highest and second-highest safety ratings, which would effectively render it meaningless. Under this scheme, all US reactors today would have the highest safety rating. If the NRC makes this change, we could no longer recommend that reactors with the highest rating qualify for support.

To lower operating costs, US reactor owners and the NEI have been pressuring the NRC for decades to reduce inspections and weaken safety and security standards. For example, in response to this pressure, the NRC has made its security inspections far less challenging, reducing its mock terrorist attacks from three scenarios to one. And after the 2011 Fukushima accident, the NRC required less rigorous safety upgrades than its own task force recommended. It also refused to require the transfer of spent nuclear fuel from overcrowded pools to safer dry storage casks.

Economic assistance to at-risk plants would help alleviate financial pressures—and could reduce industry pressure on the NRC to cut corners. However, policymakers will need to monitor the situation and adjust their subsidy policies accordingly if the NRC weakens its standards.

Recommendations

New public policies are needed to properly value low-carbon energy and prevent the replacement of nuclear plants with

large quantities of natural gas. Failure to put such policies in place will set back state and national efforts to achieve needed emissions reductions. In today's market, the prices of fossil fuels are artificially low in most regions because they do not reflect the cost to society of harmful carbon emissions. Strong climate and clean energy policies will address this market failure and ensure that low-carbon energy sources replace nuclear plants when they eventually retire. Until such policies are in place or natural gas prices rise significantly, owners of economically at-risk nuclear reactors will continue asking policymakers for financial assistance.

To address this challenge, policymakers should consider the following recommendations for designing effective state and national policies and conditions:

ADOPT STRONG STATE AND FEDERAL POLICIES THAT SUPPORT ALL LOW-CARBON TECHNOLOGIES

- **Adopt carbon pricing.** A robust, economy-wide cap or price on carbon emissions would address a key market failure and provide a level playing field for all low-carbon technologies. A national carbon cap or price could achieve the greatest carbon reductions for the lowest cost, but states can also adopt such policies. Two examples are the Regional Greenhouse Gas Initiative capping carbon emissions from power plants in nine Northeastern states and California's economy-wide cap-and-trade program, which is a key component of the state's broader strategy to reduce total global warming emissions 40 percent below 1990 levels by 2030.

Duke Energy/Creative Commons (Flickr)

Pennsylvania has the most marginally profitable nuclear capacity in the United States, and also has promising renewable energy potential. (Above, the North Allegheny Windpower Project in west central Pennsylvania). However, Pennsylvania has relatively low renewable and efficiency standards compared to other states. Strengthening these policies will ensure that, when nuclear power plants eventually retire, Pennsylvania and other states will be able to continue providing clean, reliable electricity to homes and businesses.

Further, states can use revenue from carbon-pricing policies to support investments in energy efficiency, advanced low-carbon technologies, and consumer protections, such as energy rebates for low-income families. State public utility commissions should also require regulated utilities to include an increasing price on carbon in their resource plans to reflect the possibility of future regulation of CO_2 emissions at the federal and state levels.

- **Adopt low-carbon electricity standards.** A well-designed LCES could help prevent the early closure of nuclear plants while allowing renewable energy technologies, new nuclear plants, and fossil fuel plants with carbon capture and storage to compete for a growing share of low-carbon generation. Existing nuclear plants should be included in a separate tier, as New York State has done, to limit costs to ratepayers and avoid market-power issues due to limited competition among a small number of large plants and owners. New York also has combined an LCES with a zero-energy credit program to provide financial support only to existing nuclear plants that need it, with support adjusted as market conditions change. Along with an LCES, states should adopt complementary policies that encourage investments in energy efficiency.

CONDITION FINANCIAL SUPPORT ON CONSUMER PROTECTION, SAFETY REQUIREMENTS, AND INVESTMENTS IN RENEWABLES AND EFFICIENCY

Policies that value the low-carbon attributes of nuclear power, renewable energy, energy efficiency, grid modernization, and all other low-carbon technologies are critical for state and national efforts to significantly reduce emissions and help limit climate impacts. However, where policymakers are considering temporary financial support aimed exclusively at mitigating the early closing of nuclear plants to prevent carbon emissions from rising, that support must be coupled with strong clean energy policies, efforts to limit rate increases to consumers, and strong requirements around safety, security, transparency, and performance.

- **Require plant owners to open their financial books and demonstrate need.** States should require plant owners requesting financial support to open their books to state regulators and the public. Transparent regulatory proceedings help minimize the cost to ratepayers. Profitable nuclear plants should not receive financial assistance; doing so would give their owners a windfall profit while overcharging consumers without significantly reducing emissions.

- **Limit and adjust financial support for unprofitable nuclear plants.** To protect consumers and avoid windfall profits, make financial support for distressed plants temporary. Further, periodically assess whether continued support is necessary and cost-effective, adjusting it to account for changes in market and policy conditions. To the extent possible, base adjustments on competition across all low-carbon sources, including energy efficiency. If this type of competition is not feasible, rigorously apply least-cost planning principles reflecting a reasonable cost of carbon. Programs that make only nuclear plants eligible for financial support for an arbitrary number of years could misallocate funds toward relatively expensive ways to reduce CO_2 emissions.
- **Ensure that qualifying plants maintain strong safety performance.** To help ensure that financial support to the owners of existing nuclear reactors yields the intended benefits, states should consider it only for reactors that meet the NRC's highest safety rating, indicating they meet all safety requirements. For reactors that drop in safety performance, continued financial support should depend on a return to the NRC's highest performance rating within 18 months (the average time plus a 50 percent margin).
- **Strengthen renewable energy and efficiency standards.** States that provide financial assistance to existing nuclear plants also should strengthen policies that stimulate the growth of low-carbon renewable energy—for example, renewable electricity standards—as well as energy efficiency programs and policies. While providing financial support for distressed nuclear plants, New Jersey and New York have increased renewable standards to require that 50 percent of all electricity sales to consumers come from renewable sources by 2030 and Illinois strengthened its 25 percent by 2025 renewable standard. These states also strengthened energy efficiency standards to require minimal annual electricity savings of 2 to 3 percent.
- **Develop transition plans for affected workers and communities.** Nuclear power plants are an important source of local jobs and tax revenues. Plant owners can work with states and communities to attract new businesses, helping replace lost jobs and tax revenues. For example, 2018 legislation in California includes a $350 million employee-retention fund and an $85 million community impact–mitigation fund for Diablo Canyon, which is slated to close in 2025. Because the spent fuel produced during the lives of operating reactors has no place to go, it is likely to remain on site for a considerable period. This alone justifies substantial payments to host communities, which must store spent fuel for many years, something never contemplated when the plants were licensed.
- **Address other state and local issues.** Nuclear plants affect resources subject to state jurisdiction, such as the use of local water supplies for cooling and the impact of cooling-water discharges. Some plants are involved in state regulatory proceedings around such issues, and the results could cost enough to lead to a plant's closure. Such requirements need to be vigorously enforced.

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ENDNOTES

1. On July 30, 2018, NextEra Energy announced plans to retire the 615 MW Duane Arnold plant in Iowa in 2020, five years before the scheduled expiration of its power purchase agreement with Iowa utilities. Exelon also shut down the Oyster Creek plant in New Jersey on September 17, 2018. Because both of these events occurred after we had completed our analysis, we included Duane Arnold in our economic analysis rather than listing it as a firm retirement and we listed Oyster Creek as a firm retirement instead of as a closed plant.
2. S&P Global Market Intelligence is a division of S&P Global, which provides news, data, and analysis for individuals, companies, and government entities.

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