

## Why did the Three Mile Island Unit 1 reactor close?

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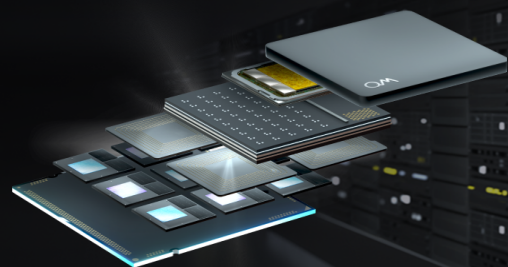
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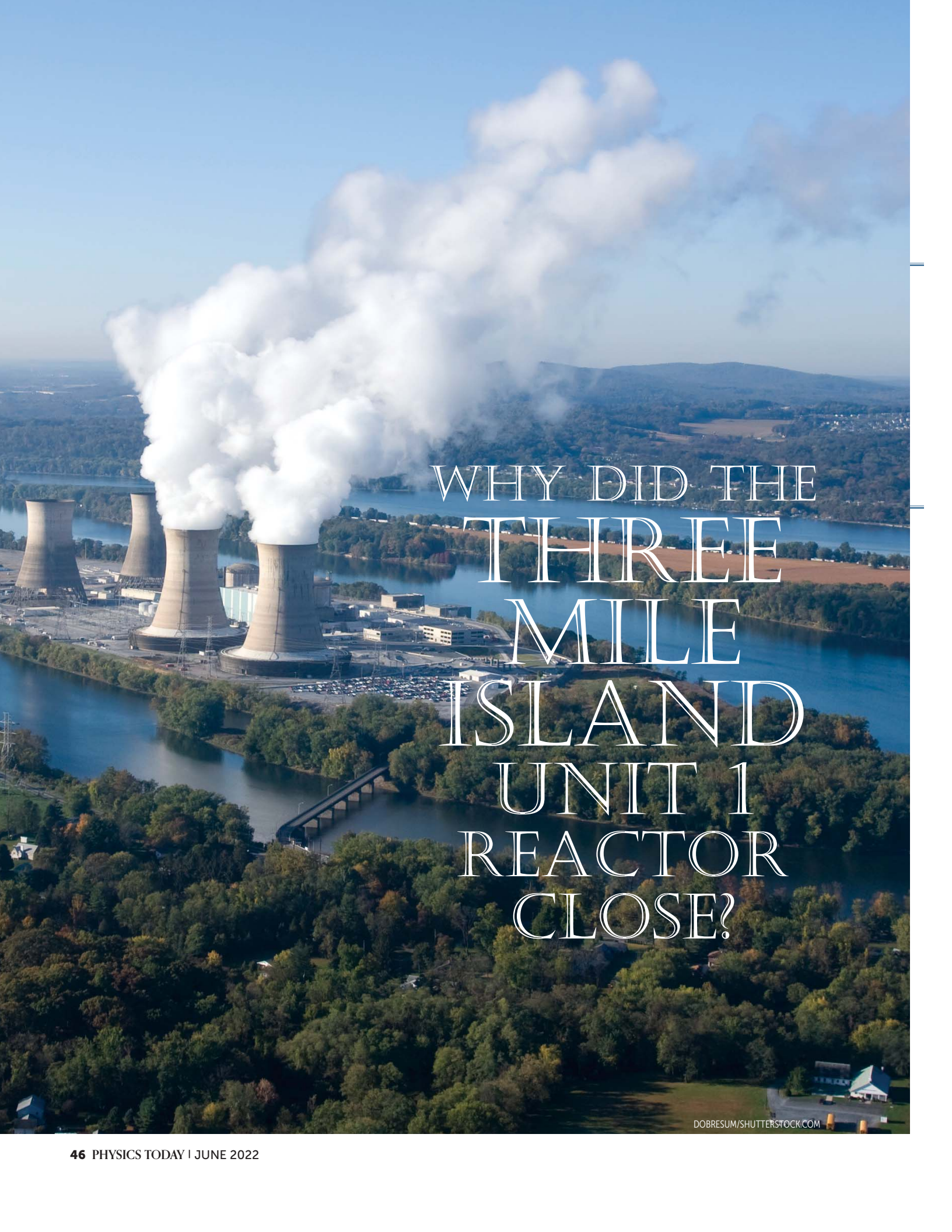
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## Hannah Pell, Ryan Hearty, and David Allard

**Navigating the future of US commercial nuclear power requires understanding how regional energy markets, state regulations, and community activism influence the life span of nuclear plants.**

**O**n 30 May 2017, Exelon Generation (now Constellation Energy) announced its plan to shut down Unit 1 of the Three Mile Island (TMI) nuclear power plant, located on the eponymous stretch of land in the Susquehanna River in south-central Pennsylvania. That closure by the largest operator of nuclear plants in the US is the first step in a decommissioning process that's required by the Nuclear Regulatory Commission to be completed within a 60-year time frame. TMI had two pressurized water-reactor units; the iconic cooling towers, shown in the opening image, are a stark visual contrast to the rolling farmland surrounding them. After the infamous 1979 accident, Unit 2 was defueled and has remained in a monitored storage condition.<sup>1</sup> EnergySolutions acquired Unit 2 in December 2020 and is now managing the early stages of decommissioning it.

For the six years following the 1979 accident, the power plant's owner, Metropolitan Edison, worked to restart the Unit 1 reactor. But the company faced technical complications, legal challenges, and contentions among local activists,<sup>2</sup> fueled in part by mishandled communications (see Hannah Pell's piece "Three Mile Island and lessons in crisis communication," *Physics TODAY* online, 5 May 2020). The Unit 1 reactor was eventually restarted in 1985, changed ownership, and went on to supply electricity to more than 800 000 homes for decades thereafter. Despite the fact that the unit was licensed to operate until 2034, it was ultimately shut down on 20 September 2019.

In its *Annual Energy Outlook 2021* report,<sup>3</sup> the US Energy Information Administration projected that planned nuclear power plant retirements across the US fleet will result in less total nuclear electricity generation capacity in 2050 than in 2020. Figure 1 highlights that decline, and several reasons explain the decrease: historically low natural-gas prices, limited growth in electricity demand, state-level clean-energy initiatives, and increased competition from renewable energy. Commercial nuclear power has reached a crossroads, and navigating its future in the US will require an understanding of the regional factors that led to this point and the hidden costs and potential unintended consequences of such premature closures. What were those costs for TMI, and why did Unit 1 close more than a

decade sooner than the end of its operating license?

One reason is that TMI and other nuclear power plants have struggled to compete in the regional electricity market controlled by the Pennsylvania–New Jersey–Maryland Interconnection, or PJM. Figure 2 shows the territory served by PJM. According to current Pennsylvania energy policies, nuclear power is not categorized as clean energy. And shale development, which uses the extremely productive technique of hydraulic fracturing, or "fracking," has driven down market prices for electricity over the past decade. Thus nuclear power is forced to economically compete with the historically low prices

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of natural gas and state-subsidized renewable energy sources that are protected from market volatility. Additionally, TMI's place in the particular labor and environmental politics of Pennsylvania complicated the legislative efforts to financially rescue the plant.

Our use of TMI as a case study of the challenges that nuclear power faces underscores the need for a narrowed focus on localized causes and effects of prematurely retired nuclear power plants. Regional energy markets, state-specific energy policies, and local interests significantly influence the life span of nuclear facilities. Although we are not pronuclear in the sense that we support the energy resource for its own sake, we believe that TMI's premature closure will negatively affect the broader goals of supplying cleaner energy and improving the well-being of Pennsylvania's citizens. There's no free lunch when providing reliable, affordable, and carbon-free energy, and a comprehensive cost analysis is crucial for navigating a just energy transition.

### Cheap natural gas

Pennsylvania is an energy-exporting state and has a complex history with innovative energy technologies.<sup>4</sup> It's an epicenter of the fracking revolution. The oil and gas extraction technique has existed for more than a century, but advances over the past few decades in seismic imaging, financial arrangements for leases of large amounts of land, and refinement of directional drilling have allowed companies to tap into vast and previously unrecoverable oil and gas deposits in shale. The rich Marcellus and Utica shale formations encompass much of eastern Ohio; western, north-central, and northeastern Pennsylvania; southwestern New York; and West Virginia. New York banned shale development in 2014. Pennsylvania's state legislature, on the other hand, has largely supported shale development because of its economic benefits.

Shale development in the region has dramatically increased electricity sales from gas-fired plants on the PJM market. PJM Interconnection is a regional transmission organization that manages the distribution of 180 gigawatts of power generation across 13 states and Washington, DC. PJM partially manages

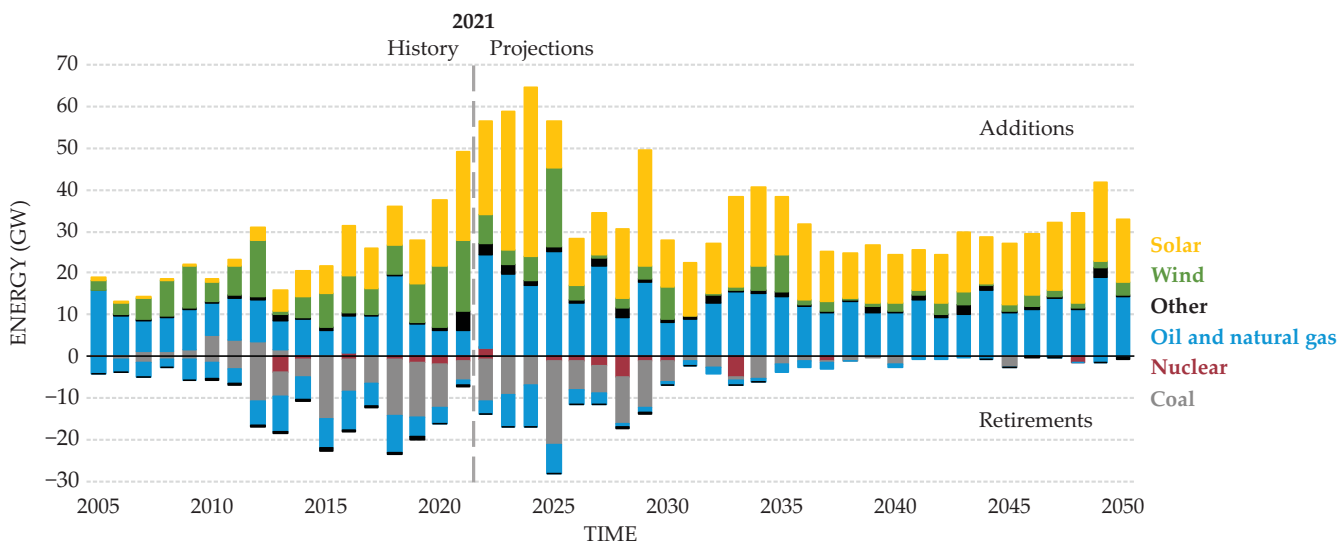
electricity rates for consumers by overseeing wholesale energy markets, which include annual auctions that ensure which plants will supply future energy demands. According to PJM, competition has helped ensure a less expensive, more reliable, and cleaner supply of electricity.

The price for wholesale energy, however, has been driven so low in recent years that TMI was unable to compete in the PJM system. In its report of the 2018–19 auction results, PJM concludes that the low cost of natural gas contributed to higher-capacity market offers from other energy-production resources across the PJM system, particularly nuclear power. In 2019, gas-fired power plants surpassed nuclear power plants as the largest suppliers of in-state electric energy for the first time, and Pennsylvania is predicted to provide 40% of the total US gas production by 2040. Since 2014 TMI's Unit 1 reactor has been unable to participate in the PJM market auction because the price per megawatt it offered was too high; other, cheaper providers have met the predicted demand.

Although shale development has created a near-term boom in cheap natural gas and has provided thousands of jobs in Pennsylvania, it has also generated heated concerns. The pollution and health hazards of oil and gas activities, to say nothing of the long-term effects of increased greenhouse gas emissions, have mostly been dismissed by those who benefit from shale development, even as potential harms have been claimed by activists.<sup>5</sup> Like the questions of nuclear power's benefits and costs in the 1970s and 1980s, the so-called fracking debate is complicated and won't be easily resolved.<sup>6</sup> The point, however, is that Pennsylvania continues to support shale development because of the promise of low-cost natural gas and the economic growth it offers to local communities, many of which have endured financial stress over the past few decades. Meanwhile, TMI and other nuclear power plants struggle to remain financially viable in the PJM region.

### Flawed regional markets

When TMI opened in the mid 1970s, utilities in Pennsylvania were vertically integrated, meaning that they controlled the gen-



**FIGURE 1. THIS TIMELINE** of US electricity capacity shows how various generation sources have been added and retired over time. Nuclear power, in particular, has experienced a decreasing trend. (Courtesy of the US Energy Information Administration.)

eration, supply, and distribution of power to consumers. Ratepayers couldn't choose where their electricity came from. In 1996 the Pennsylvania legislature passed the Electricity Generation Customer Choice and Competition Act, which deregulated the state's wholesale energy market. The law fundamentally restructured the way in which electricity is consumed by separating supply from distribution. According to the act, it is in the public interest for ratepayers to choose their electricity providers, "as long as safe and affordable transmission and distribution service is available at levels of reliability that are currently enjoyed by the citizens and businesses of this Commonwealth." Today nearly all electricity production in Pennsylvania is generated by privately owned power plants.<sup>7</sup>

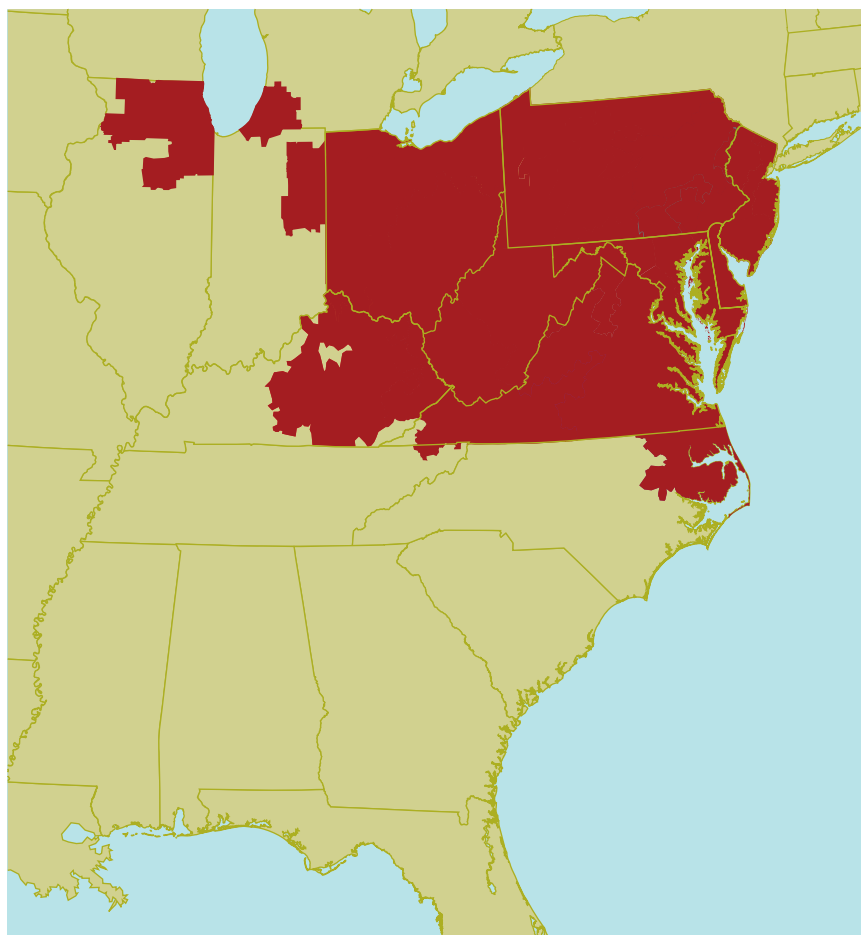
One of the principal reasons for the decision to shutter TMI's Unit 1 reactor, according to Exelon, was "market flaws" in the PJM Interconnection that "fail to recognize the environmental and resiliency benefits from TMI and other zero-carbon nuclear energy plants across the Commonwealth." Notably, Unit 1 wasn't the only nuclear plant in the PJM region whose electricity couldn't be sold in that system. Exelon's Byron and Dresden plants in Illinois also failed to clear the 2018 auction. The Beaver Valley plant located near Pittsburgh was also at risk for early closure by FirstEnergy Solutions (now Energy Harbor Corp), although it has since been rescued by legislative action.

Neighboring states, including New York, New Jersey, and Ohio, have created policies to financially support their nuclear power plants. (The nuclear subsidies bill in Ohio, however, was repealed after a bribery scandal behind the legislation was uncovered.) Pennsylvania, a state experiencing a much larger boom in shale development, has not.

Federal regulators, the Pennsylvania legislature, and PJM share responsibility for energy management in the state. Those groups have different interpretations on two important concepts that underlie the market rules and affect the fate of nuclear power plants: grid resiliency and renewable energy.

The resilience of the grid is a measure of its capacity to withstand disruptions that would cause widespread power outages. In 2017 the US Department of Energy proposed that the Federal Energy Regulatory Commission (FERC) impose a rule to require independent system operators and regional transmission organizations, including PJM, to account for grid resiliency in their pricing. The rule would have benefited nuclear power in particular given its significant baseload contribution to grid supply.

Because Pennsylvania was particularly vulnerable to plant closures—even in 2020 the state ranked third nationally for coal production and second for nuclear power—legislators in



**FIGURE 2. THIS MAP** shows the territory served with electricity by the Pennsylvania–New Jersey–Maryland Interconnection. (Courtesy of PJM.)

the state House and Senate voted overwhelmingly for resolutions urging FERC to adopt the pricing rule. But FERC unanimously rejected DOE's proposed rule and instead initiated a new proceeding asking independent system operators and regional transmission organizations to evaluate the resiliency and reliability of power-generation sources.

Stakeholders have debated whether nuclear power is "clean" and have concluded that plants such as TMI are ineligible for crucial state subsidies received by other power producers. The problem is that "clean" is not only a vague and relative metaphor but one that greatly affects how different power producers compete in the PJM market.

In 2004 the Pennsylvania legislature passed the Alternative Energy Portfolio Standards Act (AEPS), which mandates that a minimum percentage of all electricity sold must be produced from "renewable and environmentally beneficial sources." It established two tiers of eligible energy sources: A minimum of 8% of total electricity production must come from Tier I, which includes solar, wind, low-impact hydropower, geothermal, biomass, and fuel cells; and a minimum of 10% from Tier II, which includes waste coal, municipal waste, and other nonrenewables. Nuclear power was not included in either tier. Thus TMI and other plants missed out on the newly created alternative-energy credit system that increases the economic viability of various energy sources. (The 15-year timeline for companies to reach the standards ended in 2021, and local environmental groups

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are calling for updated legislation to increase the percentages outlined in the initial standards.)

### Legislative and public (in)action

Exelon cited the lack of a clear state policy solution as another factor for its inability to reverse TMI's premature retirement. Some Pennsylvania lawmakers, motivated to keep the state's fleet of nuclear power plants running, tried and failed to correct what they viewed as disadvantages to nuclear power caused in part by assumptions about grid resiliency and definitions of clean energy. They have tended to draw attention to nuclear energy's reliability as a baseload source and have leveraged rhetoric about "good-paying jobs" to make their point.

In anticipation of TMI's Unit 1 potential closure in 2019, state representative Tom Mehaffie (R-106) sponsored a House bill named the Keep Powering Pennsylvania Act (HB 11). It proposed to amend the AEPS to include nuclear power as a Tier III energy source. The amendment would correct market flaws by ensuring that 50% of electricity purchased by companies would come from Tier III. State senator Ryan Aument (R-36)—cochair of the first-of-its-kind bicameral Nuclear Energy Caucus—sponsored a similar Senate bill.

At an 11 March 2019 event announcing the bill, Mehaffie (shown in figure 3) said that "the markets do not treat all clean sources of energy the same, and they do not penalize polluters. As state legislators, we need to take a step back, recognize this, and we need to truly take into account the cost of doing nothing." That cost, according to Mehaffie, was excessive to consumers: an estimated \$788 million annually in higher electricity bills, which would amount to roughly \$2.39 more per month per household, compared with the \$500 million to cover the nuclear subsidies in Tier III proposed in HB 11. That would lower the additional monthly household cost to \$1.77.

Opponents—including the oil and gas industry, some environmental groups, manufacturers, and consumer advocates—view nuclear power's lack of market competitiveness as a positive outcome. "We urge Pennsylvania legislators to shift their focus from preserving the aging energy sources of the past and instead look ahead toward real climate solutions that will advance a clean energy future in our Commonwealth," the Conservation Voters of Pennsylvania said in a March 2019 press release. Some swiftly framed the proposed subsidy as a bailout that was further perpetuated by a No Nuke Bailout mailing campaign funded by the American Petroleum Institute and a coalition of special-interest groups forming the Citizens Against Nuclear Bailouts. Meanwhile, PennFuture, a nonpartisan environmental

advocacy group, published a report estimating the various ways in which the Pennsylvania state and local governments provided \$3.8 billion in 2019 in fossil-fuel subsidies.<sup>8</sup>

Neither the House nor the Senate bill ever made it to the floor. "We, the legislature, let you down," Mehaffie said during a TMI closing event on 20 September. The bill was cosponsored by 20 state representatives, including David Hickernell (R-98), whose jurisdiction includes TMI. In an 8 May 2019 statement, he said, "If we had an industry that wanted to bring 16,000 jobs to Pennsylvania, as a Legislature we would bend over backward to make that happen. But we weren't willing to do anything to save family-sustaining jobs that are already here."

Given the high stakes of TMI's retirement, we might have expected local residents to protest the closing, or at least voice their opinions, especially given TMI's influence in the region. Its presence is symbolic not only of decades of local labor participation and energy production but of lingering unease from the 1979 accident; figure 4 shows the cooling towers following the accident. Many citizens, however, had no strong opinion either way. According to a March 2019 poll by the Center for Opinion Research at nearby Franklin and Marshall College, a little more than half—55%—of voters believed that nuclear energy should be one component of Pennsylvania's long-term energy strategy, and exactly 50% favored the proposal to add nuclear power to the AEPS.<sup>9</sup> Ultimately, the public was indifferent—neither for nor against its premature closure. As PennLive reported on the day it was shuttered: "Three Mile Island closes with a whimper, and a whisper."

### Weighing local labor loss

Exelon officials were not the only ones drawing attention to the loss of jobs that resulted from TMI's closing. At a 23 May 2018 hearing called "Value of Nuclear Power to Pennsylvania Labor," state senator Aument asked, "If the situation were reversed and we had an opportunity in this Commonwealth to attract



**FIGURE 3. TOM MEHAFFIE**, a Pennsylvania state representative, unveils the Keep Powering Pennsylvania Act in Harrisburg in March 2019. (Courtesy of Marie Cusick, StateImpact Pennsylvania.)





**FIGURE 4. THE COOLING TOWERS** of Three Mile Island are shown here following the 1979 partial meltdown at Unit 2 (right). Unit 1 (left) was restarted in 1985. (Courtesy of NRC File Photo, CC BY-NC-ND 2.0.)

3 000 jobs for a manufacturing facility, . . . could you imagine the effort underway in this building today to put in place economic incentives, tax credits, to attract these jobs to Pennsylvania?" Although Aument and other Pennsylvania legislators tried to galvanize support to keep TMI open, preventing the loss of jobs failed to attract the same public support legislators receive when they create new ones.

Stakeholders are not in agreement over the short- and long-term effects of TMI's closing on the local economy. In its 41-page report on its post-shutdown decommissioning activities for TMI Unit 1, Exelon dedicates only two paragraphs to socio-economics. The report notes that "impacts are neither detectable nor destabilizing and that mitigation measures are not warranted" as a result of the decreased workforce.<sup>10</sup> Exelon employed roughly 675 people at TMI. That number, however, does not include ancillary contractors nor the additional 1500 workers contracted for outages every 18–24 months.

Regardless, the argument over the number of jobs attached to TMI's closure distracts from the necessary conversation about disrupted livelihoods. The rhetoric of "good-paying jobs" fails to recognize the complexity, stability, or availability of work by reducing the idea of a job to the paycheck earned.<sup>11</sup> Decisions that prioritize short-term economic gains have the potential to leave behind an entire TMI community.<sup>12</sup> The changing energy sector offers many promises of new good-paying jobs, but job retention is and will remain an important factor in managing a just energy transition.<sup>13</sup>

## Environmental costs

The environmental costs of nuclear closures are predicted to significantly affect Pennsylvania's carbon-free energy efforts. The state was home to nine nuclear reactor units on five power plant sites before TMI's Unit 1 closure. Nuclear power alone accounted for 93% of Pennsylvania's zero-carbon energy, which emitted no sulfur oxides, nitrous oxides, or particulate matter. "We believe that the loss of today's nuclear fleet would be a terrible blow to the progress already made in reducing Pennsylvania's contribution to climate change and would hamstring all of our combined efforts moving forward," testified Davitt

Woodwell, then president of the Pennsylvania Environmental Council, before the Nuclear Energy Caucus on 19 June 2018.

According to a March 2019 analysis by Andrew Place, then a Pennsylvania Public Utility commissioner, if the 2019 rate increase in AEPS Tier I energy resources remained constant, it would take Pennsylvania 12.6 years to replace the carbon-free electricity that TMI Unit 1 produced. Despite the long replacement time, Place was vocally opposed to HB 11. The Pennsylvania Department of Environmental Protection projects that carbon dioxide emissions from the electricity sector will increase partially because of nuclear power plant closures and replacement by natural gas.

Nuclear power generation, however, does have negative environmental consequences because of its extractive practices, which include uranium mining and enrichment and utilization of uranium-235, and because of the ongoing national problem of storing and disposing of radioactive waste. Such activities have historically caused inequitable harm to vulnerable communities.<sup>14</sup> Additionally, regulatory reliance on quantitative risk analysis for predicting potential accident scenarios and other possible consequences of nuclear operations raise questions about reactors being safe enough.<sup>15</sup>

TMI Unit 1, shown in figure 4 before the 2019 closure, is currently being defueled and placed in a safe storage condition. In its post-shutdown report, Exelon states that the potential environmental impacts of TMI's Unit 1 decommissioning, including on water quality of the Susquehanna River, air quality, and aquatic ecology, are expected to be small. On-site independent spent-fuel storage installations, however, do hold high-level radioactive waste, given the federal government's failure to provide an option for permanent disposal, so their environmental legacy remains a concern to state officials. The Pennsylvania Department of Environmental Protection will be closely monitoring the site throughout the decommissioning process.

## Nuclear at a crossroads

The closure of TMI Unit 1 in 2019 was accelerated by fracking and expanded natural-gas production in Pennsylvania over the past decade; the lack of state or regional subsidies to nuclear power plants for generating "clean," or at least carbon-free, energy under the AEPS; and the absence of a mechanism to reward nuclear power for its 24-7 baseload reliability and resiliency. Additional financial support might have made all the difference, as Exelon suggested in 2017. But for some grassroots organizations, the situation appeared as an unnecessary bailout for a highly profitable energy corporation playing power politics. Despite efforts to galvanize support for HB 11 by some legislators and labor unions, many stakeholders had no strong opinion either way on TMI Unit 1's closure.

The narrow calculus of energy prices on the regional market may benefit ratepayers in the short term, but it also obscures disruptions to local residents. Speaking strictly in financial terms often fails to capture the environmental, labor, community, and political costs of shuttering a nuclear plant. In TMI's

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case, the cause for Unit 1's closure was primarily market driven, according to Exelon, but examining arguments for keeping it open has uncovered potential unintended consequences of the permanent shutdown. Federal interventions such as the recently established Department of Energy Civil Nuclear Credit Program may help alleviate nuclear power plants' financial difficulties by addressing inequities in state-level energy-market structures. Such policies will be imperative for the industry's long-term economic viability.

How the various and often hidden costs are weighed against one another is a crucial conversation for navigating a fair and just energy transition and for maintaining the current fleet of nuclear power plants. Doing so will require a regionally focused discussion of nuclear energy production and a broadened cost-benefit analysis from regional transmission organizations, state and federal legislators, and citizens. The analysis should include a conversation about what regional well-being is and how nuclear energy might sustain it.

*The opinions stated in this article are the authors' alone and should not be attributed to any commercial, government, or academic entity. Hannah Pell began employment with EnergySolutions after this article was completed but before it was published.*

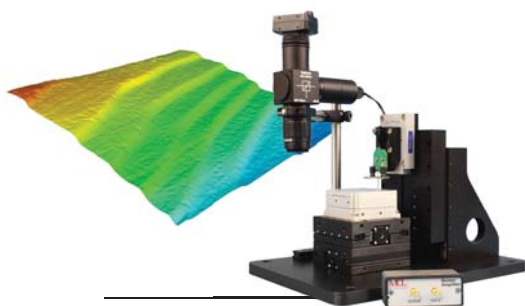
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