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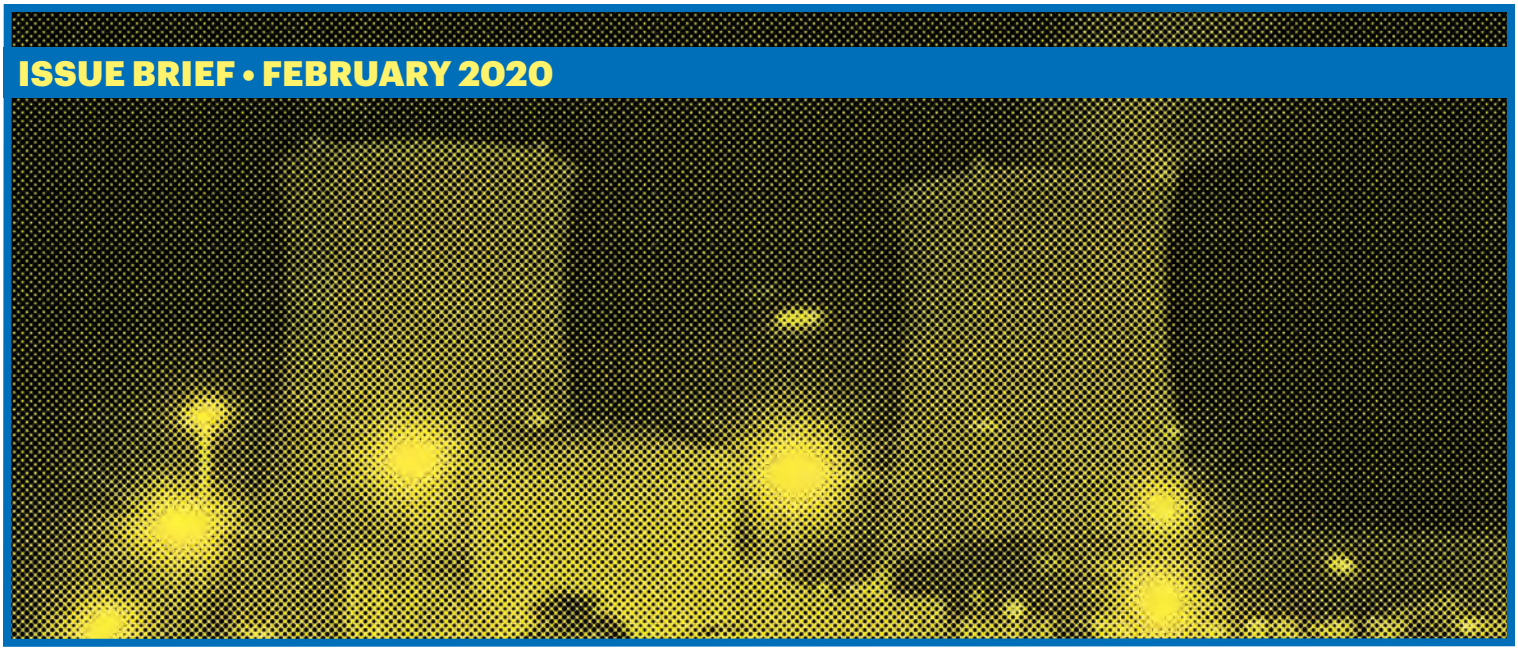

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Meltdown: The Dangerous Nuclear Option for Climate Control

The climate crisis grows more urgent. Droughts, floods, wildfires, food shortages, extreme weather and other threats to human life sweep the globe.[1] Clear-eyed advocates and policy makers call for the only solutions that will stave off environmental catastrophe: ending the use of fossil fuels, banning fracking and making an immediate and just transition to clean, renewable energy. Others call for timid half-measures like so-called market-based solutions and dirty "renewables" like biogas. Most dangerous of all, though, are those who peddle false solutions to the climate crisis. One such false solution that supporters persistently push hearkens to the last century: nuclear power. Neither clean nor renewable, nuclear power comes at a significant cost to the environment and the public.[2]

Nuclear power is often promoted as a climate solution because it releases fewer climate-destroying emissions during electricity generation than fossil fuels. But across its full life cycle, nuclear is not emissions free.[3] Nuclear plants also require large quantities of water, making the industry vulnerable to climate-related drought conditions and heat waves.[4] Construction is slow and expensive.[5] And radioactive waste poses one of the biggest threats because there are no good disposal options.[6] To stave off the catastrophic impacts of climate change, we must — and can — shift to 100 percent clean, renewable electricity by 2030.

Nuclear Power Plants in the United States

There are currently 59 operational nuclear power plants (97 total reactors) scattered across 30 states.[7] The United States generates more electricity from nuclear plants than any other country, double that of second-place France.[8] In 2018, U.S. nuclear power

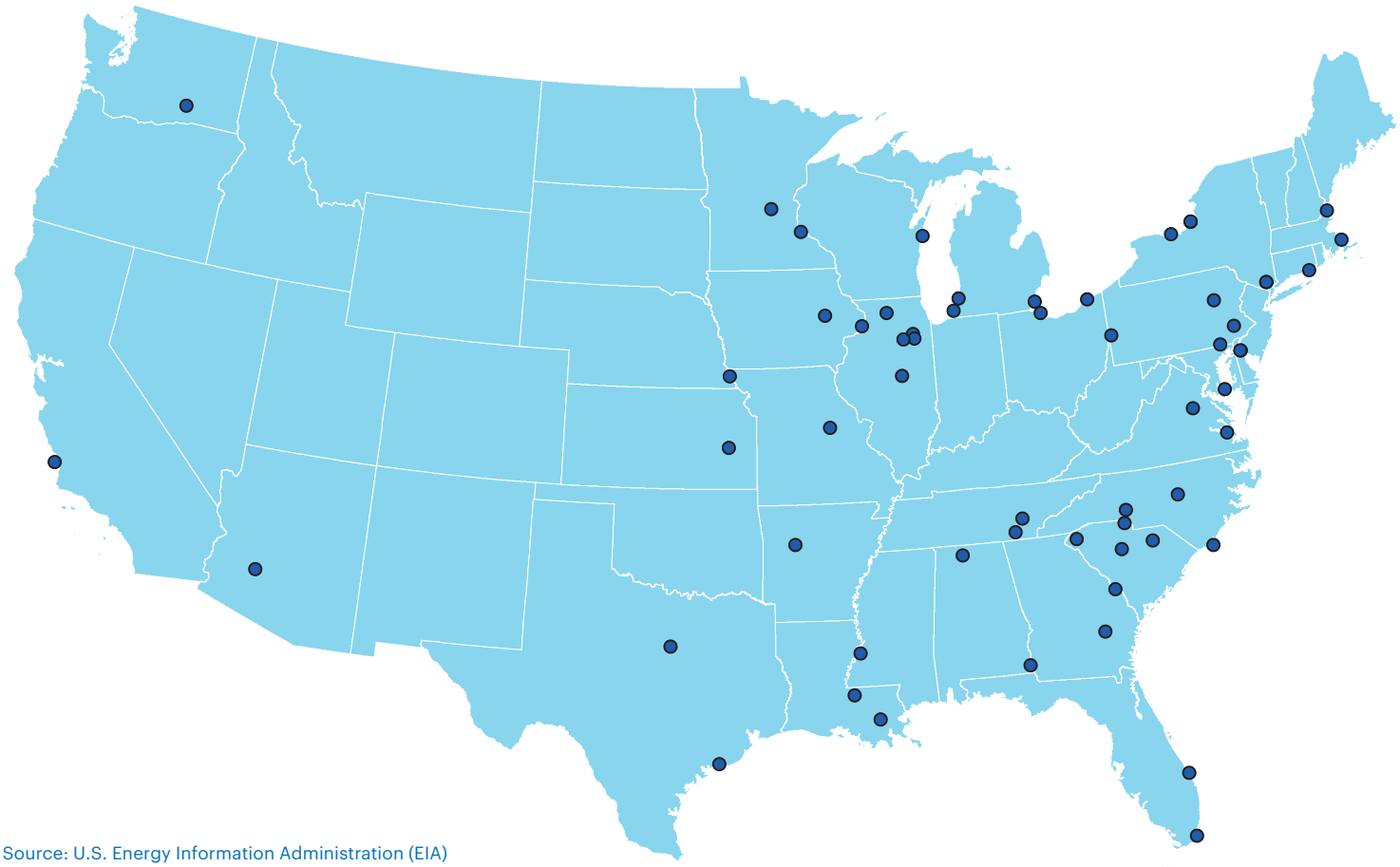
plants generated more than 800 billion kilowatt-hours of energy — 20 percent of the country's electricity; nuclear power ranks third as an energy producer in the United States, behind natural gas and coal.[9]

As of July 2019, seven nuclear power plants (nine reactors) had announced plans to retire after struggling to compete with cheaper energy sources. One of these — the notorious Three Mile Island facility in Pennsylvania — has since retired.[10] Despite economic challenges, some plants (like Davis-Besse and Perry in Ohio) were rescued by taxpayer-funded state subsidies.[11] Two new reactors are under construction in Georgia and are projected to begin operating in 2021 and 2022.[12]

The current fleet of nuclear plants is aging and plagued by crumbling infrastructure. Roughly half of the nuclear reactors in the country have been operating since before the 1980s and longer than the 40 years the Nuclear Regulatory Commission (NRC) originally licensed reactors to operate.[13] Many of the plants are outrageously operating on 20-year extensions, and the NRC has started authorizing renewals that allow reactors to operate for 80 years — double the time frame that some of the structures were built to last.[14] The NRC dismisses aging issues and claims that safeguards are in place to ensure that facilities can safely operate for the extended periods.[15] Evidence suggests otherwise.

Analyses by the NRC's own researchers concluded that nuclear power plants are susceptible to cracks and corrosion; aging could become a problem for those operating on extended licenses.[16] In 2009, just one week after New Jersey's Oyster Creek nuclear plant was granted a 20-year operating extension, leaks from the plant's aging pipes were discovered in and around the facility.[17] While Oyster Creek is no longer operating,[18] other nuclear power plants continue to put the public and environment at risk under the false narrative that these plants provide clean, renewable energy.

Figure 1: Nuclear Power Plants in the United States[21]



Source: U.S. Energy Information Administration (EIA)

Historically, undesirable facilities are placed in communities that are already socially and economically disadvantaged because they have less political power; expanding nuclear power will only exacerbate such injustices. Nuclear power plants are frequently located in lower-income communities and communities of color, and larger proportions of African Americans live within the emergency planning zones than outside.[19] From the 1950s to the 1980s, uranium mining occurred mostly on indigenous lands, disproportionately exposing indigenous peoples to toxic pollution.[20]

Nuclear Power Is Not Clean, Renewable or Safe

Supporters of nuclear energy have promoted its expansion as an opportunity to tackle the climate crisis, reduce air pollution and decrease our reliance on fossil fuels.[22] But nuclear is not a solution. Proponents must not ignore emissions from the broader life cycle, the many health impacts associated with the radioactivity, the vulnerability that nuclear power plants face in an already changing climate, and the problems associated with the continued dependence on uranium.

Greenhouse Gas Emissions

Nuclear power is frequently mischaracterized as carbon free, but these claims focus solely on direct emissions from electricity generation and leave out the climate-destroying emissions associated with the full life cycle of nuclear.[23] A fuller and more accurate accounting, which includes key components of the nuclear life cycle such as mining, milling and enriching uranium to produce nuclear fuel, as well as power plant construction, reveals that the nuclear energy sector is carbon intensive. In some cases, the nuclear life cycle emits as much carbon dioxide per kilowatt-hour as natural gas plants to meet those demands.[24]

Several lifecycle studies found that while nuclear may produce fewer greenhouse gases per unit of energy than fossil fuels, emissions are significantly higher than from wind and solar power.[25] Wind energy, for example, produces 7 to 25 times less carbon dioxide pollution compared to nuclear.[26] Despite nuclear's carbon footprint, several states have incorporated nuclear power into their clean energy or renewable energy standards.[27]

Public Health Threats

One of the most common concerns about nuclear power is the threat of a nuclear accident or reactor meltdown. Disasters at the Fukushima Daiichi (Japan, 2011) and Chernobyl (Ukraine, 1986) nuclear power plants resulted in major releases of radioactive material, fatalities among first responders, mass evacuations, long-term abandonment of areas around the disasters and increased incidence of acute radiation syndrome, cancer and mental health impacts.[28] Children and the elderly are particularly vulnerable: the risk of thyroid cancer increased significantly in children after Chernobyl, and death rates among the elderly tripled in the three months following Fukushima due to stressors from relocation.[29]

The Three Mile Island meltdown (Pennsylvania, 1979) led to the evacuation of 195,000 people after serious damage to the reactor. Fortunately, health effects from the radioactive release were found to be negligible.[30] Based on a global analysis of incidents at nuclear power plants, uranium-related sites and storage sites for radioactive waste, scientists have predicted "a 50 percent probability of a Fukushima-like event (or more costly) every 60-150 years, and a Three Mile Island event (or more costly) every 10-20 years."[31]

Nuclear energy also poses occupational health risks to workers. Prolonged exposure to low levels of radiation, such as that faced by workers in nuclear power plants, can increase the risk of death from leukemia.[32] Mining and milling uranium has been linked to a number of health problems. Exposure to radon from uranium mining increases the risk of lung cancer: lung cancer deaths in miners have been observed at rates five times greater than in the general population.[33]

Compounding the public health burdens, these risks come with significant economic costs. As of 2011, more than 7,000 uranium-related workers received $713 million from the U.S. government for associated health impacts such as lung cancer and silicosis.[34]

Cleanup costs after nuclear disasters are also astronomical. The Fukushima disaster is estimated to cost Japan $460 billion to $640 billion.[35]

Water

The relationship between nuclear power plants and water complicates the heralding of the sector as a solution to climate change. Not only does nuclear power threaten water supplies, but the operation of plants is highly vulnerable to a changing climate.[36] Nuclear power plants withdraw and consume significant amounts of water to produce electricity with steam engines and to cool process water. For every megawatt-hour of electricity produced, nuclear plants on average consume roughly 750 gallons of water, whereas solar and wind generation use on average 125 gallons and less than 1 gallon, respectively.[37] Nuclear is consistently among the energy sources that require the most water, in some cases using more water than fossil fuels.[38]

Heavy reliance on water makes nuclear power plants vulnerable to a changing climate where extreme weather events are more prevalent. Droughts, water shortages and increasing water temperatures can reduce electricity generation at facilities or cause temporary shutdowns.[39] For example, Brown's Ferry Nuclear Plant in Alabama shut down temporarily in response to a drought in 2007.[40] High water and air temperatures force plants to reduce electricity output, especially in the summer when demand is highest, making them an unreliable energy source.[41]

Nuclear power plants also release heat into aquatic environments. Water is used in nuclear plants to condense the steam needed for electricity generation; it is warmed during the process, then typically discharged back into rivers, lakes and oceans.[42] This thermal pollution harms ecosystems.[43] Thermal pollution from power plants can lead to declining fish populations and promote algal blooms that produce harmful toxins.[44]

Climate change and warmer waters have pushed nuclear power plants to reduce their output with greater frequency to comply with temperature limits for receiving waters and limit damage to the environment.[45] But limits on how warm the water can be before being used as cooling water within the plant also restrict operations at nuclear plants. One unit at Millstone Power Station, which provides Connecticut with half of its electricity, was forced to shut down for almost two weeks in 2012 when temperatures in Long Island Sound were too high.[46]

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Finally, water contamination is a reality surrounding nuclear power. An *Associated Press* investigation found that 74 percent of nuclear power plants had leaked radioactive tritium into ground water from aging pipes.[47] While most leaks remained within the facility boundaries, some migrated offsite and contaminated private drinking wells.[48] Officials have said that the levels of tritium posed no health threat, but the presence of tritium can often indicate that other more powerful radioactive isotopes may have leaked as well.[49] Uranium mining also threatens water supplies when they become contaminated with uranium during extraction and flooding.[50]

Uranium

A major factor for "renewable" energy sources is the expectation that the resource should not deplete. Fossil fuels such as natural gas and coal are finite resources. Alternatively, the sun will continue to shine and the wind will continue to blow, regardless of how much of this energy is harnessed by solar panels and wind turbines. Nuclear power plants depend on uranium which, like fossil fuels, will run out with use.

Given the size of uranium reserves and the current rate of uranium mining and use, research suggests that just 127 years' worth of uranium remains.[51]

Expanding the nuclear power fleet would deplete this limited resource sooner. While alternative sources and technologies exist to delay depleting uranium reserves, they do not eliminate the risk of nuclear weapons proliferation (see advanced nuclear box on page 6).[52]

Mining and enriching uranium also fails to meet the criteria for a clean energy source. For one, extraction, which includes open-pit mining, can contaminate water and emit naturally occurring radon and methane from underground into the air.[53] After uranium is mined and processed, it must be enriched before being used in a nuclear reactor; enrichment is the process that removes impurities from the mined natural uranium and increases the concentration of the uranium-235 to a level needed to fuel nuclear reactors.[54]

Uranium-contaminated wastewater has polluted environments around mines, including aquifers and springs near the Grand Canyon.[55] Spills of uranium tailings (toxic and radioactive waste produced as uranium ore is processed and enriched) and uranium hexafluoride (the form of uranium used during enrichment) around the mines have released harmful pollutants comparable to those at the Three Mile Island incident.[56] A massive spill in 1979, for example, released more than 90 million gallons of radioactive wastewater and 1,100 tons of uranium waste in New Mexico, devasting Navajo lands and contaminating drinking water. Decades later, nearby residents still face widespread contamination due to inadequate cleanup and remediation.[57]

Nuclear's Radioactive Waste Problem

Radioactive waste is produced throughout the nuclear power cycle. This waste includes mine and mill tailings, spent fuel rods (which contain used nuclear fuel in slender tubes that provided fuel to the nuclear reactors) and waste produced when decommissioning plants.[58] Fuel rods used in reactors generate electricity for up to 18 months before becoming "spent" nuclear waste.[59] Spent fuel is highly radioactive and remains so for thousands of years.[60] Spent fuel can quickly emit lethal amounts of radiation, making safe storage and disposal a critical challenge.[61]

The global consensus for safe, long-term disposal has been to store high-level radioactive waste such as spent fuel rods deep underground in geologic repositories, but the United States has yet to establish such a storage site.[62] Despite the absence of a safe and acceptable storage facility, nuclear power plants continue to operate.

As of 2018, spent fuel from nuclear power plants totaled over 250,000 metric tons of heavy metals like uranium and plutonium globally.[63] In the United States, approximately 2,000 metric tons of radioactive waste is produced annually — as of 2017, roughly 80,000 metric tons of waste had been generated and was being stored with short-term measures at 75 reactor sites across more than 30 states.[64] The short-term measures used to store nuclear waste include spent fuel pools and dry cask storage. Roughly three-quarters of spent fuel is stored in pools never meant for long-term storage.[65] The pools are designed to cool spent fuel rods, prevent overheating, and protect workers and the public from radiation before being transferred to dry casks and a long-term geologic repository.[66]

Because no permanent repository exists, the pools contain spent fuel rods at a higher density than originally intended and hold more than five times more radioactivity than nuclear reactor cores, but they lack the same level of containment and protection as reactors.[67] Water loss in the pools can lead to dangerous radiation levels in the surrounding area or allow the fuel assemblies to overheat, catch fire and explode, as was the case during the Fukushima Daiichi disaster.[68] The lack of adequate structural protection and reliance on maintaining water levels makes spent fuel pools particularly vulnerable to natural disasters or terrorist attacks that could cause the pools to lose water and lead to devastating environmental and public health impacts.[69]

Like spent fuel pools, dry casks are mostly stored onsite and are designed for temporary storage, but they are generally considered a safer option that is less susceptible to mechanistic failures (for example, water loss) or threats.[70] While safer, dry casks can only accommodate older spent fuel that has already been cooled in pools.[71] Still, just 25 percent of nuclear

waste is stored in dry casks, and spent fuel that is older than five years could be transferred from pools to dry casks at an estimated $3 billion to $7 billion over 10 years.[72]

Private companies such as Holtec International are seeking approvals to build interim storage facilities to collect spent fuel from commercial nuclear power plants around the country, despite the risk of transporting waste across the country and opposition from nearby communities, governments, and agriculture, oil and gas industries.[73] Even still, with licensing reviews and environmental impact studies, it would be years before these companies could start accepting waste.[74] Deep Isolation Inc. has proposed using horizontal drilling methods, such as those used for unconventional oil and gas extraction and fracking, to inject and bury nuclear waste deep underground in horizontal drillholes.[75]

While regulators, legislators, utilities and private companies mull over how to best handle the highly radioactive waste, nuclear power plants continue to add to the problem and put nearby communities at increasing risk. Without a good solution to safely reduce and dispose of the waste, these plants cannot be allowed to operate under business-as-usual.

Nuclear Energy Economics

Beyond the fact that nuclear energy is neither carbon free nor clean, it is also expensive and uneconomical. Cheap natural gas has already undercut the competitiveness of nuclear power, and renewables such as wind and utility-scale solar are already cheaper than nuclear power.[84]

Per kilowatt-hour, new nuclear power plants cost 2.3 to 7.4 times more than onshore wind or utility-scale solar.[85] Fixed construction and technology costs typically decrease over time, but the cost of constructing nuclear plants has risen steadily since the 1960s.[86] Just in the last decade, the unsubsidized levelized costs for nuclear power increased by 26 percent, while

Advanced Nuclear Is Not the Silver Bullet

The challenges facing nuclear energy expansion and radioactive waste disposal have built a movement around "advanced" nuclear energy (i.e., the development of new or next-generation nuclear technologies). Proponents of nuclear argue that advanced nuclear will save the planet by reducing emissions, construction time and the cost of nuclear power plants,[76] but these technologies are a false solution.

First, nuclear energy is not emissions free (see page 3). Second, advanced nuclear is expensive. With technologies still under development, advanced nuclear needs to be propped up by research subsidies that could be better spent on building out true, clean renewables. Even the industry's leading association, the Nuclear Energy Institute, admits that "the government has to have more skin in the game" for advanced reactors to take off because of the high costs.[77] The industry needs governments to make purchasing agreements,[78] which would inherently undermine agreements for clean, renewable energy. Small modular reactors manufactured in factories before being assembled onsite are often peddled as a solution to the high capital costs, but they are likely to have higher operational costs compared to traditional reactors.[79]

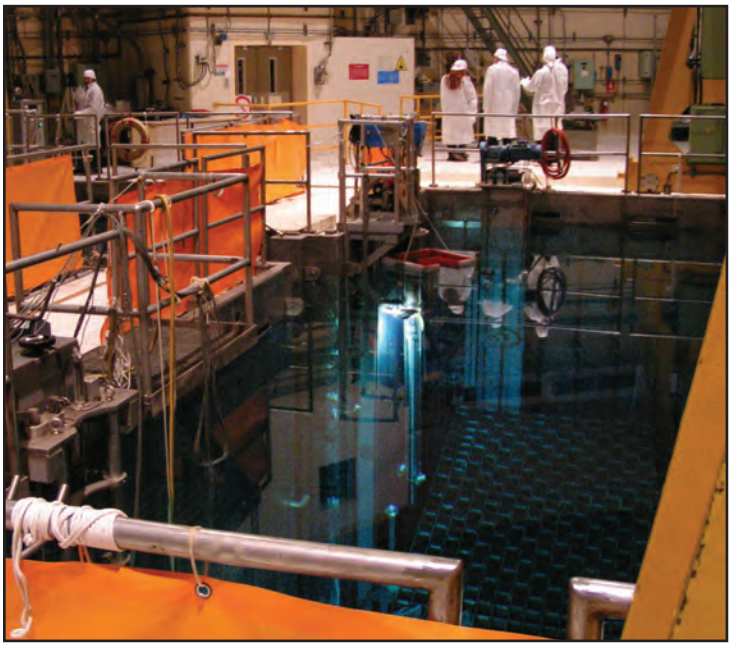
Third, advanced nuclear faces similar resource and waste challenges as traditional reactors.[80] TerraPower seeks to develop a nuclear reactor that produces 80 percent less nuclear waste, but there are no set plans to build such a reactor and it would at most be a 500 megawatt reactor built no sooner than 2025.[81] New reactor designs, such as breeder and fast reactors, can produce less waste, but this increases the risk of nuclear weapons proliferation as it produces more plutonium used to make nuclear bombs.[82] Even still, the new designs do not eliminate waste entirely, and there is no waste disposal solution.

Moreover, because the technologies are still under development, frequently delayed and years away from deployment,[83] they cannot be expected to solve the climate crisis, which requires us to transition to clean renewables by 2030.

utility-scale solar and wind energy costs declined by 89 percent and 70 percent, respectively.[87] Battery storage costs have also dropped 84 percent in the last decade and are expected to continue falling.[88]

Operating costs exceed revenue in more than a quarter of the country's nuclear reactors, while low profitability and high capital costs make constructing nuclear power plants and reactors challenging and less favorable to investors.[89] Compared to other sources of electricity generation, nuclear power is economically riskier.[90] Construction costs at the two most recent projects in the United States — two reactors each at the Vogtle plant in Georgia and the V.C. Summer plant in South Carolina — are more than double initial estimates, which eventually ended the V.C. Summer project.[91] Vogtle, still under construction, was originally estimated to cost $14 billion, but estimates increased to $29 billion in 2017.[92]

Waste disposal is also costly. To construct just one permanent geological repository could cost billions.[93] The United States spends roughly $500 million a year storing radioactive waste from nuclear power plants; this is expected to increase as the inventory grows.[94] As plants retire and revenues stall, covering the cost of storage for hundreds of thousands of years becomes even more challenging.



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Spent fuel is meant to be cooled and stored temporarily in pools (see above), but a lack of long-term disposal options have left spent fuel pools overcrowded.

Taxpayers Subsidize Nuclear Power

High costs have forced the nuclear power industry to rely heavily on government subsidies, including insurance subsidies, loan guarantees and direct payments like zero-emission credits.[95] Insurance subsidies ensure that the government — taxpayers — will cover the cost of a nuclear accident beyond a set "cap," because insurance companies refuse to fully cover nuclear power plant liabilities.[96] Loan guarantees, such as the $8.3 billion authorized by the Obama administration for Southern Co.'s new Vogtle reactors, help limit the economic risk of expanding nuclear power.[97] Building a new fleet of nuclear power plants would require an estimated $500 billion in federal loan guarantees.[98] A global study found that if nuclear plants relied solely on private investments there would be an average of $5 billion in losses for each plant.[99]

Low natural gas prices have also contributed to small profit margins at nuclear power plants. Subsequently, several companies have threatened early retirement without financial support or incentives to continue operating, such as extra payments for producing "zero-emission" electricity or access to more favorable renewable energy markets where nuclear plants would not compete with natural gas.[100] The Trump administration's Department of Energy has stated that the federal government does not have the authority to provide economic support for nuclear power plants and that they should instead look to state governments for support.[101]

In the last several years, many states have made moves to bail out nuclear power companies at the ratepayer's expense (see Table 1 on page 8). The bailouts generally involve commitments to purchase electricity from nuclear plants as a zero-emissions or carbon-free source in an effort to save jobs and meet clean energy targets, which undermines the expansion of real clean, renewable energy such as wind and solar. Companies have secured hundreds of millions of dollars a year, amounting to billions over the length of some contracts, after lobbying campaigns that cost just a few million dollars.

In New Jersey, PSEG Power and Exelon spent a combined $2.6 million in lobbying efforts in 2017

and secured close to $300 million a year for two nuclear power plants that are still profitable.[102] In 2018, FirstEnergy Solutions spent $2.7 million in Ohio on lobbying and public relations firms to pass Ohio House Bill 6.[103] Millions more were spent by FirstEnergy and dark-money political groups on campaign contributions and advertising to pass the bill, which secures $1.1 billion in subsidies over six years, rescues Ohio's nuclear power plants and weakens the state's clean energy program.[104]

Federal and state subsidies should instead be directed to genuinely clean, renewable energy sources like wind and solar. Studies have shown that, given the high subsidies that nuclear power plants depend on, it is more economical to replace them with clean energy and energy efficiency upgrades.[111] In New York, continuing to support nuclear with handouts from taxpayers through 2050 could cost the state over $32 billion; replacing the plants with wind generation could save $7.9 billion.[112]

Regulatory Influence

The nuclear energy industry also has important sway on the regulatory front. Take, for example, the U.S. Nuclear Regulatory Commission, an independent agency tasked with regulating the "civilian use of radioactive materials," including nuclear power plants, to ensure safety and protect public health and the environment.[113] Like other regulatory agencies, the NRC is compromised by the lobbyist / policymaker revolving door and is influenced by pressure from the industry it regulates. Annie Caputo, for example, is a former nuclear energy lobbyist and one of the five NRC commissioners.[114]

The NRC has also allowed the leading nuclear trade association, the Nuclear Energy Institute (NEI), to help shape and contribute to its regulatory guides, and has even delayed emergency shutdowns to avoid hurting a facility's revenues, despite concerns about corrosion on that facility's reactor.[115] (This facility, Davis-Besse Nuclear Power Station, is the same facility

TABLE 1 • State-Level Nuclear Power Plant Bailouts

State	Nuclear Power Plants	Value of Subsidy	Status	Notes
Connecticut[105]	Millstone	10-year energy purchasing contract	Approved, Sept. 2019	The energy price for the purchase agreement had not been made public as of September 2019. Millstone is still profitable.
Illinois[106]	Clinton, Quad Cities	$2.4 billion over 10 years/ $235 million per year	Passed, Dec. 2016	Exelon, the operator, is seeking additional support for four nuclear power plants that did not receive support from the 2016 deal. All of the plants are still profitable.
New Jersey[107]	Hope Creek, Salem	$280 million per year for three years	Passed, May 2018	The Hope Creek and Salem nuclear plants were profitable at the time the subsidy was approved. The agreement is to be reassessed after three years.
New York[108]	FitzPatrick, Ginna, Nine Mile Point	$7.6 billion over 12 years	Passed, Aug. 2016	
Ohio[109]	Davis-Besse, Perry	$150 million per year	Passed, July 2019	In addition to the nuclear power plant bailout, Ohio House Bill 6 (HB6) also provides subsidies for two coal-fired power plants and weakens standards for energy efficiency programs and renewables.
Pennsylvania[110]	Three Mile Island, Beaver Valley, Limerick, Peach Bottom, Susquehanna	$500 million per year	Died in committee, 2019	Three Mile Island retired in September 2019. Beaver Valley is set to retire by 2021. The remaining nuclear plants are still profitable.

recently rescued by Ohio's nuclear bailout.) The NRC, at the NEI's request, had proposed reducing NRC-led reactor safety inspections and replacing them with industry self-assessments, although the NRC has since walked back the proposal after pushback from the House Energy and Commerce Committee and the House Appropriations Committee.[116]

NEI's political action committee spent nearly $570,000 in 2018 trying to influence the political process surrounding energy issues.[117] The NEI has poured more than $33 million into federal lobbying since 1999.[118] In addition to the trade group, the NRC was lobbied by at least another 24 different entities in 2019, including Contran Corp., a holding company that includes a nuclear waste management subsidiary, and NextEra Energy, a power company that operates nuclear plants.[119]

Conclusion

Nuclear energy harms the environment, threatens public health and fails to address the global climate crisis. The intractable problem of storing highly radioactive waste makes nuclear energy a dangerous and shortsighted option for energy production. Instead, it is time to move forward with cleaner, safer and renewable energy sources like wind and solar. The transition to renewables has grown increasingly more affordable, technically feasible and politically acceptable, while similar factors have idled for nuclear power.[120]

Drastic reductions in carbon emissions are necessary to avoid a global warming increase of 1.5 degrees Celsius as early as 2030 and to curb the devastating climate-related threats that come with it.[121] Proponents of nuclear argue that expanding nuclear power is the only way to fully and rapidly decarbonize the electricity grid and reach climate goals,[122] but we cannot meet this timeline with nuclear. Nuclear power plants take an estimated 10 to 19 years from initial planning, permitting and construction to operation and electricity generation, compared to just 2 to 5 years for utility solar and wind, while producing up to 37 times more emissions per kilowatt-hour than wind energy.[123]

New nuclear power technologies that could be constructed more quickly, cost less or reduce nuclear waste are years to decades away from being commercially available, and still require significant financial investments for development.[124] Meanwhile, technology exists to support a transition to 100 percent clean, renewable energy backed up by storage and transmission at prices lower than current energy costs.[125] At least six states each have the potential to generate as much electricity as all of the country's nuclear power plants from wind energy alone.[126] Redirecting the funds used to prop up nuclear plants to renewable energy can reduce carbon dioxide emissions faster and more efficiently than continuing to source electricity from nuclear power.[127] We cannot invest more time, energy or money into supporting and expanding nuclear power under the false notion that it is a safe and clean energy source, when real solutions exist in wind and solar.

Food & Water Watch recommends:

- Invest in a green energy public works program that fosters a rapid transition to 100 percent clean, renewable and safe energy by 2030.
- Divert federal and state subsidies that prop up nuclear power to investments in clean energy and energy efficiency.
- Halt further bailouts of nuclear power plants.
- Stop state and local permitting of nuclear power plants to sell electricity as renewable energy or on renewable energy markets.
- Demand that the Nuclear Regulatory Commission stop extending licenses on existing nuclear power plants.
- Begin decommissioning nuclear power plants.
- Stop the production of radioactive nuclear waste.
- Fully fund fair and just transition programs for nuclear power plant workers.

Endnotes

1 Field, Christopher B. et al. Intergovernmental Panel on Climate Change (IPCC). "Climate Change 2014. Impacts, Adaptation, and Vulnerability: Summary for Policymakers." 2014 at 4 and 6.

2 Montoya Bryan, Susan. "US Senate panel takes up what to do with nuclear waste." *Associated Press*. June 27, 2019; Rashad, S. M. and F. H. Hammad. "Nuclear power and the environment: Comparative assessment of environmental and health impacts of electricity-generating systems." *Applied Energy*. Vol. 65, Iss. 1-4. April 2000 at 211; Wealer, Ben et al. DIW Berlin. "High-priced and dangerous: Nuclear power is not an option for the climate-friendly energy mix." *DIW Weekly Report*. Vol. 9. July 24, 2019 at 236; Jacobson, Mark Z. (2019). "Evaluation of Nuclear Power as a Proposed Solution to Global Warming, Air Pollution, and Energy Security." In *100% Clean, Renewable Energy and Storage for Everything*. Cambridge: Cambridge University Press at 5. Page numbers presented are pdf pages from draft sections of the book in press and may not reflect the page numbers after publication in 2020. Pre-published document and pages on file with Food & Water Watch (FWW).

3 Rashad and Hammad (2000) at 211; Pearce, Joshua M. "Limitations of nuclear power as a sustainable energy source." *Sustainability*. Vol. 4, Iss. 6. June 7, 2012 at 1175; Sovacool, Benjamin K. "Valuing the greenhouse gas emissions from nuclear power: A critical survey." *Energy Policy*. Vol. 36, Iss. 8. August 2008 at 2960.

4 Macknick, Jordan et al. "Operational water consumption and withdrawal factors for electricity generating technologies: A review of existing literature." *Environmental Research Letters*. Vol. 7, No. 4. December 20, 2012 at 1; Neuhauser, Alan. "Nuclear power, once seen as impervious to climate change, threatened by heat waves." *U.S. News*. July 1, 2019.

5 Strauch, Yonatan. "Beyond the low-carbon niche: Global tipping points in the rise of wind, solar, and electric vehicles to regime scale systems." *Energy Research & Social Science*. Vol. 62. April 2020 at 9 and 10; Lazard. "Lazard's Levelized Cost of Energy Analysis — Version 13.0." November 2019 at 2, 7 and 10; "Ramp up nuclear power to beat climate change, says UN nuclear chief." *UN News*. October 7, 2019.

6 Jantz, Eric. "Environmental racism with a faint green glow." *Natural Resources Journal*. Vol. 58, No. 2. Summer 2018 at 255; Montoya Bryan, Susan. "New Mexico governor says no to high-level nuclear waste." *Associated Press*. June 7, 2019; Nevada Commission on Nuclear Projects. Presented to The Governor and Legislature of the State of Nevada. "Report and Recommendations of the Nevada Commission on Nuclear Projects." January 2017 at 17 to 20; Long, Jane C. S. and Rodney C. Ewing. "Yucca Mountain: Earth-science issues at a geologic repository for high-level nuclear waste." *Annual Review of Earth and Planetary Sciences*. Vol. 32. May 2004 at 369 to 370, 393 and 394.

7 FWW analysis of U.S. Nuclear Generation and Generating Capacity 2019 P. U.S. Energy Information Administration (EIA). Monthly Nuclear Utility Generation (MWh) by State and Reactor. May 2019. Available at https://www.eia.gov/nuclear/generation/index.html. Accessed July 2019; Sholtis, Brett. "Three Mile Island nuclear power plant shuts down." *NPR*. September 20, 2019.

8 EIA. International Energy Statistics Nuclear Electricity Net Generation. Available at https://www.eia.gov/beta/international/data/browser. Accessed July 2019.

9 EIA. "Monthly Energy Review." DOE/EIA-0035. May 2019 at Table 7.2b at 126.

10 EIA. "Electric Power Monthly With Data for July 2019." September 2019 at Table 6.6 at 169 to 175; Sholtis (2019).

11 Tomich, Jeffrey. "Ohio rolls back RPS, boosts nuclear. Here's why it matters." *E&E News*. July 24, 2019; EIA (September 2019) at Table 6.6 at 169 to 175; EIA. "Electric Power Monthly With Data for May 2019." July 2019 at Table 6.6 at 167 to 173.

12 EIA (July 2019) at Table 6.5 at 164 and 165.

13 FWW analysis of 2017 Form EIA-860 Data — Schedule 3, "Generator Data" (Operable Units Only). EIA. Available at https://www.eia.gov/electricity/data/eia860/. Accessed July 2019; U.S. Nuclear Regulatory Commission (NRC). "Reactor License Renewal." October 2018 at 1.

14 NRC (2018) at 1; Balaraman, Kavya. "FPL's Turkey Point first US nuclear plant to get license out to 80 years." *Utility Dive*. December 6, 2019.

15 NRC (2018) at 1 and 3.

16 Dunn, Darrell S. et al. NRC. Office of Nuclear Regulatory Research. "Containment Liner Corrosion Operation Experience Summary: Technical Letter Report — Revision 1." April 2, 2011 at v and vi; Donn, Jeff. "Part I: AP Impact: US nuke regulators weaken safety rules." *Associated Press*. June 20, 2011.

17 Donn, Jeff. "Part II: AP Impact: Tritium leaks found at many nuke sites." *Associated Press*. June 21, 2011.

18 FWW analysis of EIA data (May 2019).

19 Jantz (2018) at 254 to 255; Kyne, Dean and Bob Bolin. "Emerging environmental justice issues in nuclear power and radioactive contamination." *International Journal of Environmental Research and Public Health*. Vol. 13. July 12, 2016 at 4.

20 Jantz (2018) at 251 to 252.

21 FWW analysis of Power Plants, excludes Three Mile Island. EIA. April 2019. Available at https://www.eia.gov/maps/layer_info-m.php. Accessed August 2019.

22 Shellenberger, Michael. "Big pro-nuclear victory in US gives momentum to global nuclear expansion." *Forbes*. July 24, 2019; Montoya Bryan (June 27, 2019); "Ramp up nuclear power to beat climate change, says UN nuclear chief." (2019).

23 Sovacool (2008) at 2950 and 2951; Pearce (2012) at 1175; Cebulla, Felix and Mark Z. Jacobson. "Carbon emissions and costs associated with subsidizing New York nuclear instead of replacing it with renewables." *Journal of Cleaner Production*. Vol. 205. December 2018 at 884.

24 Pearce (2012) at 1175; Cebulla and Jacobson (2018) at 884.

25 Sovacool (2008) at 2960; Jacobson, Mark Z. and Mark A. Delucchi. "Providing all global energy with wind, water, and solar power, Part I: Technologies, energy resources, quantities, and areas of infrastructure, and materials." *Energy Policy*. Vol. 39, Iss. 3. March 2011 at 1156.

26 Sovacool (2008) at 2960; Jacobson and Delucchi (2011) at 1156.

27 Mufson, Steven. "Competition drives nuclear industry to look for millions in subsidies." *Washington Post*. May 24, 2018; Grossman, Karl. "New York approves $7.6 billion bailout of nuclear power plants." *HuffPost*. August 3, 2016; State of New York. Public Service Commission. Cases 15-E-0302 & 16-E-0270 (2016); Ohio Admin. Code. 4901:1-40-04 (B)(4).

28 Hasegawa, Arifumi et al. "Health effects of radiation and other health problems in the aftermath of nuclear accidents, with an emphasis on Fukushima." *Lancet*. Vol. 386, Iss. 9992. August 2015 at 479, 480, 481, 483, 484 and 485; Kamiya, Kenji et al. "Long-term effects of radiation exposure on health." *Lancet*. Vol. 386, Iss. 9992. August 2015 at 469 and 475; Lelieveld, J. et al. "Global risk of radioactive fallout after major nuclear reactor accidents." *Atmospheric Chemistry and Physics*. Vol. 12. May 12, 2012 at 4246; Braxton Little, Jane. "Fukushima residents return despite radiation." *Scientific American*. January 16, 2019.

29 Hasegawa et al. (2015) at 484; Kamiya et al. (2015) at 475.

30 Hasegawa et al. (2015) at 480 and 481; NRC. "Three Mile Island Accident." June 2018 at 1 and 2.

31 Wheatley, Spencer et al. "Reassessing the safety of nuclear power." *Energy Research & Social Science*. Vol. 15. May 2016 at 97 and 98.

32 Leuraud, Klervi et al. "Ionising radiation and risk of death from leukaemia and lymphoma in radiation-monitored workers (INWORKS): An international cohort study." *Lancet Haematology*. Vol. 2, Iss. 7. July 2015 at 277, 279 and 280.

33 Dewar, Dale et al. "Uranium mining and health." *Canadian Family Physician*. Vol. 59, Iss. 5. May 2013 at 469; Schubauer-Berigan, Mary K. et al. "Radon exposure and mortality among white and American Indian uranium miners: An update on the Colorado Plateau cohort." *American Journal of Epidemiology*. Vol. 169, No. 6. February 2009 at 719, 721 to 722; Brugge, Doug and Virginia Buchner. "Health effects of uranium: New research findings." *Reviews on Environmental Health*. Vol. 26, Iss. 4. December 1, 2011 at 238.

34 Brugge and Buchner (2011) at 235.

35 Denyer, Simon. "Eight years after Fukushima's meltdown, the land is recovering, but public trust is not." *Washington Post*. February 20, 2019.

36 Donn (June 21, 2011); Neuhauser (2019).

37 Meldrum, J. et al. "Life cycle water use for electricity generation: A review and harmonization of literature estimates." *Environmental Research Letters*. Vol. 8, No. 1. March 12, 2013 at 13.

38 Macknick et al. (2012) at 6.

39 *Ibid*. at 2; Neuhauser (2019).

40 Macknick et al. (2012) at 2.

41 Neuhauser (2019).

42 Jacobson (2019) at 4 to 5.

43 Verones, Francesca et al. "Characterization factors for thermal pollution in freshwater aquatic environments." *Environmental Science & Technology*. Vol. 44, Iss. 24. November 2010 at 9364; Jebakumar, Jebarathnam Prince Prakash et al. "Impact of coastal power plant cooling system on planktonic diversity of a polluted creek system." *Marine Pollution Bulletin*. Vol. 133. August 2018 at 378 and 379.

44 Jebakumar et al. (2018) at 378 and 379; Kowalski, Kathiann M. "Harmful Lake Erie algal blooms worsened by power plant pollution." *Energy News Network*. January 25, 2016.

45 Neuhauser (2019).

46 Singer, Stephen. "Millstone to seek permission to use warmer water for cooling." *Associated Press*. February 19, 2013.

47 Donn (June 21, 2011).

48 *Ibid*.

49 *Ibid*.

50 Dewar et al. (2013) at 469; Jacobs, Jeremy P. "Enviros claim 'severe' flooding at uranium mine." *E&E News*. August 21, 2019.

51 Jacobson (2019) at 5.

52 *Ibid*. at 5 and 6.

53 Dewar et al. (2013) at 469; Sovacool (2008) at 2955; Jacobs (2019).

54 Sovacool (2008) at 2951 to 2952.

55 Jacobs (2019).

56 NRC. "Uranium Mill Tailings." October 2016 at 1; NRC. "Uranium Enrichment." March 2016 at 1; Brugge and Buchner (2011) at 233.

57 Gilbert, Samuel. "Church Rock, America's forgotten nuclear disaster, is still poisoning Navajo lands 40 years later." *Vice News*. August 12, 2019.

58 International Atomic Energy Agency (IAEA). (2018). *Status and Trends in Spent Fuel and Radioactive Waste Management*. No. NW-T-1.14. Vienna: IAEA at 5, 7 and 10; National Research Council. (2006). *Safety and Security of Commercial Spent Nuclear Fuel Storage: Public Report*. Washington, DC: The National Academies Press at 16 to 17; Sovacool (2008) at 2952.

59 Dewar et al. (2013) at 470.

60 *Ibid*.

61 Hedin, Allan. Swedish Nuclear Fuel and Waste Management Co. "Spent Nuclear Fuel — How Dangerous Is It? A Report from The Project 'Description of Risk'" Technical Report 97-13. March 1997 at v and vi.

62 Jacobson (2019) at 14; U.S. Government Accountability Office (GAO). "Commercial Nuclear Waste: Resuming Licensing of the Yucca Mountain Repository Would Require Rebuilding Capacity at DOE and NRC, Among Other Key Steps." GAO-17-340. April 2017 at 2; Ramana, M. V. "Nuclear power: Economic, safety, health, and environmental issues of near-term technologies." *Annual Review of Environment and Resources*. Vol. 34. July 28, 2009 at 136; Nuclear Energy Agency (NEA). Organisation for Economic Co-operation and Development (OECD). "Moving Forward With Geological Disposal of Radioactive Waste." NEA No. 6433. 2008 at 3 and 7.

63 IAEA (2018) at 35 and 36.

64 Rogers, Kenneth A. "Fire in the hole: A review of national spent nuclear fuel disposal policy." *Progress in Nuclear Energy*. Vol. 51, Iss. 2. March 2009 at 286; GAO (2017) at 1.

65 IAEA (2018) at 36; Alvarez, Robert. Institute for Policy Studies. "Spent Nuclear Fuel Pools in the U.S.: Reducing the Deadly Risks of Storage." May 2011 at 7 and 8.

66 National Research Council (2006) at 20 and 38.

67 Alvarez, Robert et al. "Reducing the hazards from stored spent power-reactor fuel in the United States." *Science and Global Security*. Vol. 11. 2003 at 1; Alvarez (2011) at 1 and 6; National Research Council (2006) at 36 and 40.

68 National Research Council (2006) at 38 and 39; Alvarez (2011) at 4.

69 National Research Council (2006) at 36, 38 and 57; Alvarez (2011) at 4.

70 Alvarez (2011) at 61 and 68.

71 National Research Council (2006) at 70.

72 Alvarez (2011) at 2 and 21.

73 Montoya Bryan (June 7, 2019).

74 Dillon, Jeremy. "NRC board to review species habitat concern for Texas site." *E&E News*. August 26, 2019.

75 Muller, Richard A. et al. "Disposal of high-level nuclear waste in deep horizontal drillholes." *Energies*. Vol. 12, Iss. 6. May 29, 2019 at 1, 3 and 24.

76 Goldstein, Joshua S. et al. "Nuclear power can save the world." *New York Times*. April 6, 2019; "Ramp up nuclear power to beat climate change, says UN nuclear chief." (2019); NEA. OECD. "Small Modular Reactors: Nuclear Energy Market Potential for Near-term Deployment." NEA No. 7213. 2016 at 9, 10 and 19.

77 Nuclear Energy Institute (NEI). "Advanced nuclear." Available at https://www.nei.org/advocacy/build-new-reactors/advanced-nuclear. Accessed September 2019 and on file with FWW.

78 *Ibid*.

79 NEA (2016) at 9 and 10.

80 Jacobson (2019) at 6.

81 Stang, John. "The rebirth of nuclear power could come from Bellevue, if Congress approves." *Crosscut* (WA). August 15, 2019.

82 Jacobson (2019) at 5, 6, 11 and 12.

83 Schneider, Mycle et al. Mycle Schneider Consulting. "The World Nuclear Industry: Status Report 2019." September 2019 at 19.

84 EIA. "Nuclear Power Outlook: Issues in Focus From the *Annual Energy Outlook 2018*." May 2018 at 4; Lazard (2019) at 2, 7 and 10.

85 Jacobson (2019) at 1.

86 Lazard (2019) at 7; Wealer et al. (2019) at 237.

87 Lazard (2019) at 7.

88 Henbest, Seb et al. Bloomberg New Energy Finance. "New Energy Outlook 2019." 2019 at Executive Summary.

89 Mufson (2018); Cebulla and Jacobson (2018) at 884; Ramana (2009) at 130.

90 Ramana (2009) at 130 and 132.

91 EIA (2018) at 5; Wealer et al. (2019) at 238.

92 Wealer et al. (2019) at 238.

93 Ramana (2009) at 136.

94 Jacobson (2019) at 9.

95 Pearce (2012) at 1179; Cooper, Mark. Vermont Law School. Institute for Energy and the Environment. "All Risk, No Reward for Taxpayers and Ratepayers: The Economics of Subsidizing the 'Nuclear Renaissance' With Loan Guarantees and Construction Work in Progress." November 2009 at 1; NEI. "Zero-Emission Credits." April 2018 at 2 and 3.

96 Pearce (2012) at 1179; Zelenika-Zovko, I. and J. M. Pearce. "Diverting indirect subsidies from the nuclear industry to the photovoltaic industry: Energy and financial returns." *Energy Policy*. Vol. 39, Iss. 5. May 2011 at 2627.

97 Hullinger, Logan. "Exelon spent millions in lobbying after announcing TMI closure." *York* (PA) *Dispatch*. April 2, 2019.

98 Williams, Selina. "Update: US government loan guarantees for new nuclear too small-NRC." *Dow Jones Newswires*. March 10, 2008.

99 Wealer et al. (2019) at 236, 239 and 243.

100 NEI (2018) at 2 and 3; Kail, Benjamin. "Stakeholders clash over Millstone's future." *Day* (CT). January 12, 2018.

101 Morehouse, Catherine. "DOE has no 'regulatory or statutory ability' to create coal, nuclear bailout, says Perry." *Utility Dive*. June 12, 2019.

102 Mufson (2018); New Jersey Election Law Enforcement Commission. [News release]. "Lobbying Annual Reports 2017." March 8, 2018 at 2.

103 Tobias, Andrew J. "Nuclear bailout bill shows how big money can be put to work in the Ohio Statehouse." *Cleveland.com*. May 23, 2019.

104 Funk, John. "FirstEnergy Solutions moves to ditch union contracts for bailed out plants, drawing Democrats' ire." *Utility Dive*. August 5, 2019; Tobias (2019); Keller, Russ. Ohio Legislative Service Commission. Legislative Budget Office. "H.B. 6 133rd General Assembly. Fiscal Note & Local Impact Statement." July 31, 2019 at 1, 2 and 3.

105 Kail, Benjamin. "Millstone, utilities finalize 10-year contract." *Day* (CT). September 18, 2019.

106 Daniels, Steve. "Does lobbying pay? Ex-Exelon exec highlights former employer as poster child." *Crain's Chicago Business*. March 28, 2018; Walton, Rod. "Illinois passes subsidy bill to save state's nuclear power plants." *Electric Light & Power*. December 2, 2016; Daniels, Steve. "Exelon's hand is out for more nuke subsidies — and a power market referee cries foul." *Crain's Chicago Business*. March 22, 2019; Daniels, Steve. "There's plenty of pain in store for Exelon, too, if it shutters nukes." *Crain's Chicago Business*. November 8, 2019.

107 Mufson (2018).

108 Grossman (2016).

109 Tomich (2019); Funk (2019); Keller (2019) at 1, 2 and 3.

110 Maykuth, Andrew. "'Goal is not to bail out Exelon': Pennsylvania's $500 million nuclear rescue bill pushes clean energy." *Philadelphia Inquirer*. April 3, 2019; Brady, Jeff. "Three Mile Island Nuclear Plant to close, latest symbol of struggling industry." *NPR*. May 8, 2019; Sholtis (2019).

111 Cebulla and Jacobson (2018) at 885.

112 *Ibid*. at 886 and 890.

113 NRC. "The NRC: Who We Are and What We Do." February 2018 at 2 and 6.

114 Knickmeyer, Ellen. "Nuclear industry pushing for fewer inspections at plants." *Associated Press*. March 14, 2019.

115 Sullivan, John. "U.S. nuclear regulator lets industry help with the fine print." *ProPublica*. April 13, 2011.

116 Knickmeyer (2019); Dillon, Jeremy. "NRC drops bid to allow more industry self-inspections." *E&E News*. August 28, 2019.

117 Center for Responsive Politics. "Nuclear Energy Institute, Summary." Available at https://www.opensecrets.org/pacs/lookup2.php?cycle=2018&strID=C00239848. Accessed June 2019.

118 U.S. Senate. Lobbying Disclosure Act Database. Searched registrant and client lobbying for Nuclear Energy Institute. Available at https://soprweb.senate.gov/index.cfm?event=selectfields. Accessed June 2019.

119 Center for Responsive Politics. Open Secrets Database. "Nuclear Regulatory Commission, Agency Profile 2019." Available at https://www.opensecrets.org/lobby/agencysum.php?id=078&year=2019. Accessed June 2019; Bloomberg. "Waste Control Specialists LLC." Available at https://www.bloomberg.com/profile/company/0005383D:US?cic_redirect=true. Accessed June 2019; NextEra Energy, Inc. and Florida Power & Light Company. Filing 10-K. U.S. Securities and Exchange Commission. December 31, 2018 at 7 and 8; Krikorian, Shant. IAEA. [Press release]. "IAEA bolsters partnership with Nuclear Energy Institute." September 20, 2018.

120 de Coninck, Heleen et al. IPCC. "Chapter 4: Strengthening and Implementing the Global Response." In *Special Report: Global Warming of 1.5°C*. 2018 at 315.

121 Allen, Myles et al. IPCC. "Global Warming of 1.5°C: Summary for Policymakers." 2018 at 4, 9 and 12.

122 Goldstein et al. (2019); Siegel, Jim. "Ohio nuclear plant bailout plan encourages other zero-carbon energy." *Columbus Dispatch*. April 12, 2019; Singer, Stephen. "Connecticut commits to nuclear power, ending debate over Millstone's future." *Hartford Courant*. December 28, 2018; Mufson (2018).

123 Jacobson (2019) at 1 and 6 to 7.

124 Stang (2019); NEA (2016) at 9, 10 and 19; Jacobson (2019) at 6.

125 Diesendorf, Mark and Ben Elliston. "The feasibility of 100% renewable electricity systems: A response to critics." *Renewable and Sustainable Energy Reviews*. Vol. 93. October 2018 at 318, 320 and 323; Brown, T. W. et al. "Response to 'Burden of proof: A comprehensive review of the feasibility of 100% renewable-electricity systems.'" *Renewable and Sustainable Energy Reviews*. Vol. 92. May 11, 2018 at 840; Iaconangelo, David. "Cheap batteries could soon replace gas plants — study." *E&E News*. March 26, 2019; Schmidt, Oliver et al. "Projecting the future levelized cost of electricity storage technologies." *Joule*. Vol. 3. January 16, 2019 at 85 and 86; Lazard (2019) at 7.

126 Makhijani, Arjun. Institute for Energy and Environmental Research. "Executive Summary. Carbon-Free and Nuclear Free: A Roadmap for U.S. Energy Policy." July 2007 at 6.

127 Cebulla and Jacobson (2018) at 890.

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