REPOWERING COAL

A BRIEF FOR COAL COMMUNITIES ON THE TRANSITION TO NUCLEAR POWER

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INTRODUCTION

Within living memory, the most powerful and organized environmentalists in America advocated for coal plants and nuclear power in order to save wild landscapes from hydroelectric dams. Then environmentalists turned against coal and nuclear, and although nuclear development slowed to a crawl, coal power expanded deep into the new millennium. But with the boom in unconventional natural gas production and restructured electricity markets, coal power plants have seen their market share halved.

Now, carbon emissions have become the biggest concern for policymakers and institutional investors. In an ironic twist, today's powerful and organized environmentalists see wild spaces as energy development opportunities to be exploited. The rise of wind and solar, combined with steady output from existing nuclear plants and a decade of cheap natural gas, have led the country's coal power fleet to the edge of closure.

This leads to a serious problem for communities dependent on coal power plants or the mines that feed them. Wind, solar, and gas plants provide almost no jobs once completed, and the construction jobs that wind and solar provide are transient in both time and geography.[1] Communities are built around stable employment and tax revenues, and as coal plants have closed, no other power sources have been able to come in and replace these losses.

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Fortunately, the jobs and tax revenues that communities have gotten from hosting coal plants
can be provided by nuclear energy. Better yet, many of the disadvantages of coal, like coal ash ponds and local air quality impacts — well-known and more-or-less tolerated by host communities — are solved. As many American towns have come to understand in the last half-century, there are rich advantages gained by being near a nuclear plant. In fact, surveys have shown that the strongest support for nuclear comes from those who live closest to nuclear plants.[2]

The purpose of this brief is to describe the opportunities and challenges in nuclear energy for coal communities facing plant closure. Section One outlines the losses facing coal communities. Section Two explains how nuclear may be able to address some or all of these needs. Section Three characterizes the U.S. coal power plant fleet by location, size, age, and utilization rates. Section Four discusses the implications for communities of hosting nuclear plants. Section Five discusses the implications for state-level policy-makers of a potential coal-to-nuclear transition. The report concludes with practical next steps for interested parties.

1. "U.S. Energy Employment Report." Department of Energy, 2021.
2. Ann Stouffer Bisconti, "Factors Affecting Public Opinion of Nuclear Energy in the United States." Bisconti Research, Inc., 2020.

THE NEED

America was built on coal. Cheap and abundant domestic coal powered the economic growth of the 20th century. It provides affordable electricity to households, businesses, industries, and services throughout our economy. And the unique advantage of on-site fuel storage at power plants contributes to reliability and resiliency, allowing coal to act as a hedge against volatile natural gas prices and the weather systems and seasonal energy variation in wind and solar power.

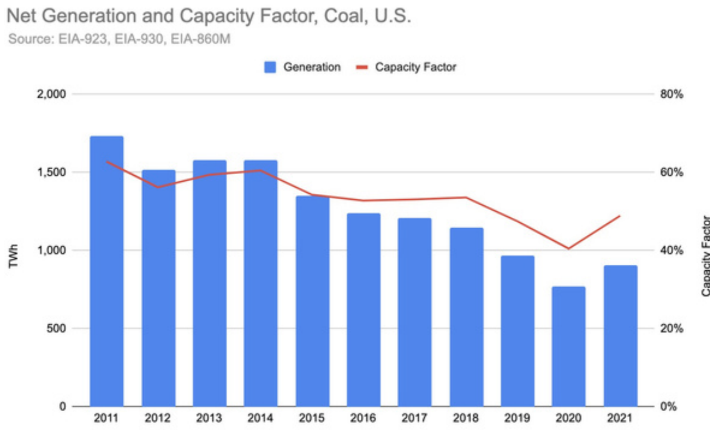


Figure 1. U.S. coal generation and capacity factor

Coal communities have had to tolerate environmental degradation, much of which does in fact stay local to the coal plant. Dust from coal trains and combustion products (depending on wind and atmospheric conditions) reduce local air quality and pose a typically small but real health hazard to the community. Coal ash, which is the waste left after coal is combusted, has to be stored on site and can leak or flood waterways.

In contrast to the environmental degradation that occurs during operation, the closure of coal plants has wreaked social devastation. Declining business in the coal industry have caused significant harm to the workforce and local communities.[3] Coal plant workers often have to make the difficult choice of either moving from their communities or taking jobs outside the energy sector that may not offer commensurate pay or benefits. Not only do communities lose jobs and neighbors: they also lose a significant portion of their tax base that funds local services.

Most energy experts believe that in order to lower carbon emissions, more and more energy has to be delivered through the electricity grid. Therefore, it is reasonable to expect that federal, state, and local policy and subsidies will continue to be oriented around electrification.

Fortunately, electricity provides an effective substitute for most local energy consumption, and it is easier to decarbonize than liquid and solid fuels burned on-site. Electrification recreates the higher growth in electricity demand that once drove the construction of America's coal plants. However, the desire to lower carbon emissions will limit the ability of existing coal plants to take advantage of higher load growth, while also eliminating new coal from consideration. So, what future awaits communities built around America's coal plants?

Coal with carbon capture, or so-called "advanced" or "clean" coal, has been almost completely unsuccessful despite billions of dollars spent in private capital, ratepayer funds, and public subsidies.[4] All major projects have been closed and further projects are not planned.

3. Emily Pontecorvo. "As coal dies, the US has no plan to help the communities left behind." Grist, March 3, 2021.
4. "Carbon Capture and Storage: Actions Needed to Improve DOE Management of Demonstration Projects." United States Government Accountability Office, December 2021.

Natural gas plants are very compact and produce relatively little local air pollution. However, they also produce carbon dioxide and are thus vulnerable to legislation or policies attacking carbon polluters. Perhaps more serious for communities built around coal, natural gas plants require just a fraction of the employment of coal plants in both the construction and operation phases. And, as gas prices go up and down, gas plant power output and profitability goes up and down.

Most attention from the energy policy and nonprofit sector on the topic of the fate of coal power plant towns is on how to help those towns benefit from renewable energy, like solar and wind. The problem is that wind and solar are not concentrated revenue sources for host communities as a whole, even if a few large landowners can collect some rent for allowing wind and solar facilities to be constructed on their land. Solar and wind facilities take hundreds of times more area than gas, coal, or nuclear plants to make similar amounts of energy, while offering a small fraction of the permanent employment in order to make the same amount of power.[5]

Large geothermal and hydroelectric facilities are constrained by geology and geography. Small geothermal and small hydro are not replacements for the scale of power generated by medium and large coal plants, while also not providing significant employment.

This leaves nuclear energy among the options that already exist for low-carbon power. Nuclear is the perfect community energy source from the perspectives of communities that either have to find new industries with tax revenue and employment or face decline followed by blight. It is the only energy technology that offers communities the same – or better – employment, revenue, and community benefits that coal does, but without the environmental costs.

5. “U.S. Energy Employment Report.” Department of Energy, 2021.

THE OPPORTUNITY

"Nuclear is an obvious choice for shuttered coal plants that are already connected to the grid, it just makes common sense."

Senator Manchin, March 1, 2022

Energy communities with retiring coal plants are facing the loss of tax revenues, jobs, and purpose. These communities could reverse these losses and more by replacing their coal generation with nuclear. By building small nuclear reactors on or near existing electricity generation sites, communities can "repower" their power plant.

Repowering coal plants with nuclear would maintain and expand the existing workforce. Nuclear plants need workers with skills and training that can overlap with work at fossil fuel facilities. For example, both plants require the operation and maintenance of plant equipment (pumps, valves, welding, etc.). In fact, trades workers at fossil fuel plants are often called up to help refuel nuclear plants during planned outages.

Across the U.S. nuclear fleet, plants require on average 0.7 workers per megawatt of capacity,[6] while U.S. coal plants employ an average of 0.15 workers per megawatt.[7] Although it is predicted smaller reactors will require fewer employees than gigawatt-scale, multi-unit nuclear sites, workforce estimates are still significantly higher than what already exists at coal plants. For coal plants located near active mining regions, the demand for more workers could potentially alleviate job loss from the mining sector.

Within the energy sector, nuclear plants are uniquely effective economic engines, as almost all the cost of operation goes into local labor. But communities also indirectly benefit from the plants. For every 100 power plant jobs, 66 more are created in the community on average.[8] And nuclear plants in the U.S. pay an average of $16 million annually in state and local taxes.[9] For most coal communities, this would be a significant increase in their tax base.

Nuclear plants built today are expected to last at least 80 years. Including construction time, this means communities can plan for nearly a century of steady income and employment. This makes it possible to get the best of everything on offer to small towns in America, from schools to roads, and from parks to hospitals for residents.

6. Dr. Robert Peltier, PE. "Benchmarking Nuclear Plant Staffing." Power, April 1, 2010.
7. "U.S. Energy Employment Report." Department of Energy, 2021.; U.S. coal capacity from U.S. Energy Information Agency
8. Mark Berkman & Dean Murphy. "The Nuclear Industry's Contribution to the U.S. Economy." The Brattle Group, July 7, 2015.
9. "Nuclear Energy Tax Issues: Tax Reform Position Paper." Nuclear Energy Institute, March 2015.

For nuclear plant builders and operators, the advantages of using existing power plant sites go beyond the existing workforces. Because existing power plants already have high voltage transmission lines built to take away coal-generated power, these lines would not have to be built from scratch or in some cases even upgraded to work with the newly added nuclear portion of the plant. A substantial but little-understood disadvantage of widely-dispersed new renewable energy is the need to expand transmission to connect widely dispersed installations, which is frequently blocked or delayed by residents along the path of the new wires.

Another reason nuclear is a good fit for former coal plants is that both energy sources require access to cooling water. Many coal plants are built with their own lakes, cooling towers, or river frontage perfectly suited to the needs of the new nuclear plant. In both cases, these plants consume some water or pass it over hot pipes to cool them down, but the river and lake water is not contaminated in the process. However, nuclear plants avoid the contamination potential of coal ash retention ponds that are required to hold the ashes from combusted coal, and are noted for the high quality of their local environments.

A significant cost for many new power plants is the planning and construction around intake and outflow of cooling water. Existing coal power plants will have intake structures on the banks of a natural or artificial lake, a river, and sometimes also cooling towers of various sizes. These structures will have been sized for the capacity of the plant, or even larger or more numerous units that were planned but never constructed. Their reuse should in many cases more than make up for any difficulties of undertaking nuclear construction within the confines of a preexisting site.

SURVEY OF U.S. COAL PLANTS

As of November 2021, 264 coal plants are in operation in the US, making power with 496 different boiler units.[10] Their average operation time and power output levels have fallen sharply in the face of cheap natural gas from the fracking revolution, increasingly costly environmental controls, and anti-carbon policies.

We believe that successfully building nuclear plants in former coal plant communities will happen when those communities do their own research and come together to attract a nuclear project. Therefore we have not included individual coal plant names. Instead we've grouped coal plants by basic suitability for nuclear plant repowering, according to a few simple metrics we chose for this purpose.

We used data from several US Energy Information Agency survey forms to sort coal plants and to check how much electricity they generated and how much coal they consumed. We've plotted the data on an interactive map that's available online to accompany this report.[11]

Our analysis sorts coal power plants into two classes based on a plant's total summed nameplate capacity across all coal boiler units. Plants in these two classes are categorized by the plant's usage rate ("capacity factor") from December of 2020 through November of 2021. We're calling large, high utilization plants Class 1, and small, high utilization plants Class 2. Within each class, plants are then grouped by utilization rate in the twelve months

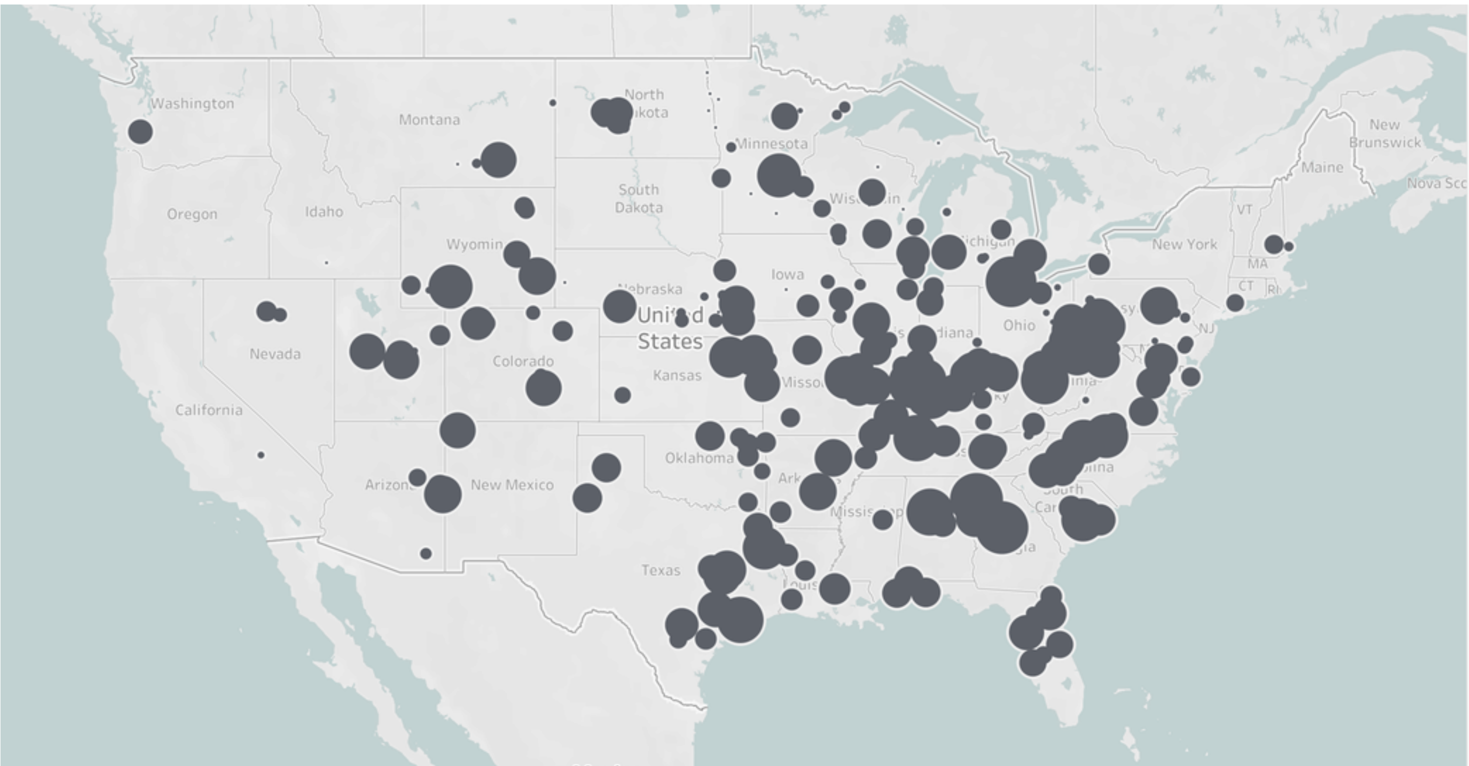


Figure 2. Map of U.S. coal plants; for interactive data, visit www.gndcampaign.org/repowering-coal

10. "Preliminary Monthly Electric Generator Inventory." U.S. Energy Information Administration, January 26, 2022.
11. Go to www.gndcampaign.org/repowering-coal

from January 2021 to December 2021, the most recent date with data available. Figure 3 provides a definition of each class.

Class 1 plants may be suitable for repowering with large reactors, or a larger number of smaller reactors, depending on the area required for nuclear plant facilities and construction operations. Class 2 plants may be more easily repowered with small reactors, if it is not possible to increase the plant boundary or access more cooling water.

Class 1A	Coal plants totalling over 1200 MW nameplate capacity, operating at a capacity factor of 50% or above
Class 1B	Coal plants totalling over 1200 MW nameplate capacity, operating at a capacity factor of 30-50%
Class 1C	Coal plants totalling over 1200 MW nameplate capacity, operating at a capacity factor below 30%
Class 2A	Coal plants totalling under 1200 MW nameplate capacity, operating at a capacity factor of 50% or above
Class 2B	Coal plants totalling under 1200 MW nameplate capacity, operating at a capacity factor of 30-50%
Class 2C	Coal plants totalling under 1200 MW nameplate capacity, operating at a capacity factor below 30%

Figure 3. Classification of U.S. coal plants

To illustrate the scale of the coal to nuclear repowering opportunity, Figure 5 shows the emissions impact of replacing all coal production from each class of plant with nuclear generation, assuming nuclear with the same total capacity of coal is installed; new nuclear runs at 90% capacity factor; and extra nuclear generation beyond replacing existing coal generation cuts into operation of natural gas power plants running at national average carbon intensity for power plants of that fuel type.

Coal plants with very low utilization factors are typically, though not always, in more economic distress than coal plants with higher utilization factors. Small plants are often owned and operated by electricity cooperatives which may have different economic considerations for continued operation than do Independent Power Producers (IPP), companies who own power plants to produce power for competitive electricity markets. In addition, some high usage coal plants may be under significant non-economic pressure to close from state legislatures or national clean energy policies.

Not all large plants will be well-suited for nuclear repowering, and not all small, low-usage coal plants are unsuited for nuclear repowering. Coal plants of all sizes running at low capacity factors may be suffering from disadvantages not connected to their location on the grid, such as declining access to cheap coal, inefficient equipment, or cheap local natural gas and electricity prices. Should nuclear plants directly replace low-utilization coal plants, they would be expected to operate not at the same low-utilization of the coal plants they are replacing, but rather at high rates (above 90%). This may be possible merely by undercutting other coal and gas plants in production cost. This may be even more likely in a future of technology-neutral subsidies for low-carbon generation, which would strongly favor nuclear power output.

In some cases, multiple small coal plants may end up closing in a region that could then host one nuclear plant, helping multiple nearby towns despite the loss of their own coal plant. Nuclear plants today typically draw their daily workforce from towns up to a few dozen miles away in every direction.

	Class 1A	Class 1B	Class 1C	Class 2A	Class 2B	Class 2C
Median plant operating year	1981	1974	1972	1980	1980	1977
Median plant nameplate capacity (MW)	1,503	1,662	1,531	448	465	459
Median capacity factor	66%	47%	23%	63%	53%	18%
Total generation, 2021 (TWh)	227	231	117	80	57	58
Share of total coal capacity, 2021	20%	29%	25%	7%	6%	13%
Share of total coal generation, 2021	29%	31%	15%	10%	8%	7%
Average carbon intensity (gCO_2/kWh)	974	1,000	1,017	1,056	1,035	1,068
Annual emissions (MMT CO_2eq)	221	233	119	84	59	62

Figure 4. America's remaining coal plants

	Class 1A	Class 1B	Class 1C	Class 2A	Class 2B	Class 2C
Replacement nuclear generation (TWh)	313	451	371	118	99	203
Generation above replacement (TWh)	86	220	254	38	42	145
Displaced emissions from nuclear (MMT)	256	321	221	99	76	120

Figure 5. Replacement by nuclear to illustrate carbon and production opportunity

COMMUNITY CONSIDERATIONS

Unlike the case of from-scratch ("greenfield") nuclear power plant construction, repowering existing coal plants which are close to or actually within towns means making temporary or permanent changes to the community. Many of these changes will be welcome, like attracting a wave of young families, sharply increasing local air quality, and adding a large local taxpayer.

Not all changes will be welcomed by everyone in the community. During years of construction, cars and heavy trucks will need to access the project site using local roads, which may need to be upgraded for the purpose. Especially during the delivery of heavy parts, roads may have reduced access. Even though nuclear plants in operation are extremely quiet and generally excellent neighbors, construction traffic is noisy and can produce dust.

Infrastructure development is difficult in America in part because of the ability of local communities to disrupt or reject projects near them, often to avoid these nuisances. This will also be true for new nuclear. Many coal plants are closing, and thus becoming candidates for repowering, so there will be more communities wanting a nuclear plant than available capacity to develop nuclear repowering projects. In such a market, communities that are not sufficiently united around the possibility of hosting a nuclear plant may find it difficult to secure serious developer interest.

There are of course potential concerns that are specific to nuclear power plants. Broadly, these concerns are about nuclear waste and power plant emergencies.

Nuclear waste concerns are overwhelmingly focused on "high-level waste", which is almost entirely spent nuclear fuel. Nuclear fuel is made up of metal tubes containing small pellets of uranium. These metal tubes are gathered into bundles for loading and unloading into the reactor. After nuclear fuel has spent about five years in a reactor making energy, it is placed into a pool of water to cool off for another five years. After that, several bundles are placed inside concrete and steel cylinders and placed in rows next to the reactor.

Although there has been discussion and planning for decades to gather up all the bundles from the country's nuclear plants and put them somewhere, the ease and safety of just having them sit next to the operating reactor has reduced the political urgency

The Netherlands's nuclear waste repository is open to the public and has Dutch art on display (COVRA N.V.)

to move them all to one spot in the country. There has never been a problem with the local storage, as each spent fuel storage cylinder weighs about one hundred tons and has no moving parts.

In some countries, the public is allowed and even encouraged to visit their radioactive nuclear waste. For example, the Netherlands stores its waste in a facility that is open to the public, contains an educational museum, and is decorated with large-scale art installations commissioned specifically for the facility. While awaiting a facility like this, American spent fuel remains on concrete pads at the power plant where it is produced.

The second major concern is nuclear plant emergencies.

Over nearly seventy years of commercial nuclear operation, the United States has had one voluntary evacuation: Three Mile Island in Pennsylvania in 1979. About half of the local population declined to evacuate and those that did returned within three weeks. There were no injuries and no discernible health impacts on the population.[12] Evacuations due to non-nuclear industrial plant accidents, wildfires, and floods similarly lead to the vast majority of residents returning, while being significantly more likely to occur than nuclear evacuations.

Most new reactor designs being proposed for repowering small coal plants are being intentionally designed to all but eliminate the need for temporary evacuations in the event of severe accidents. Broadly, these design changes involve lowering the reactor power compared to the amount of coolant available to remove heat from the reactor, while using gravity and natural flow of this coolant to allow the plant to stay undamaged even with the complete loss of power to the facility (from blackouts, such as those caused by earthquakes or major storms) or any breakage of equipment in the plant.

Although these changes typically lower the maximum power of individual reactors and will make it trickier to fit as much generating capacity in as small a plot of land as in the 1960s and 1970s, new reactors should allow for much smaller emergency planning zones.

Communities located near major industrial employers or located in known fire or flood zones have always had to make risk-versus-reward decisions. As nuclear energy combines unusually rich rewards with unusually small physical risk, communities accustomed to the tradeoffs of life near coal power plants are well-positioned to understand the situation and will be able to come to consensus about whether to host a nuclear plant.

Dry cask storage at the Palo Verde nuclear plant in Arizona

12. "Health Studies Find No Cancer Link to TMI." American Nuclear Society, July 11, 2012.

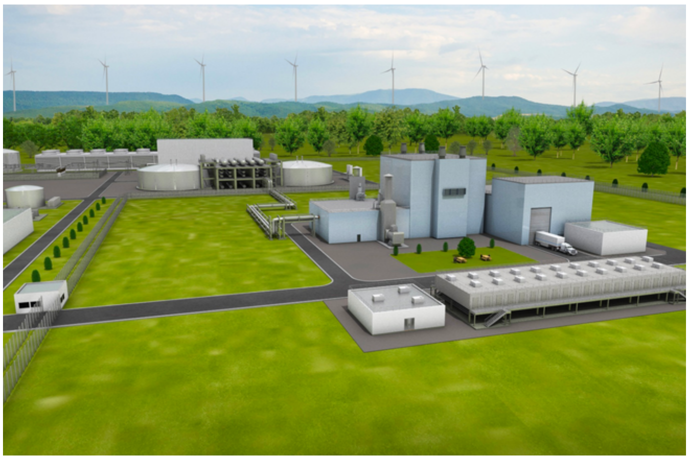
POLICY CONSIDERATIONS

Nuclear plants take a long time to get online. Communities that know their coal plant is closing are on the clock. Even if natural gas prices rebound, it is difficult to imagine a return of investment money sufficient to extend the life of many aging coal plants. The prospect of future carbon policy will suppress interest from investors even if a return of high wholesale prices supports newer coal plants for some time beyond 2022.

If communities take an interest in seeing their local coal plants evaluated for nuclear suitability, quick action is recommended. Not all sites will be suitable, but all coal plants require the major cooling infrastructure that would be required by similarly-sized nuclear plants, and certainly have the transmission capacity.

Newer reactor designs pursuing inherent safety over active safety (that is, safety through conservative margins and physical principles rather than with intervention and actively operated safety systems) may mitigate some site challenges that could stop previous nuclear reactor designs from being installed at existing facilities. But every site is different, and it will be necessary to request or sponsor an examination of the possibilities at each.

Many "advanced" nuclear reactor designs are being proposed by a wide variety of companies, from veteran nuclear industry firms to brand new startups. In general, the more a "new" design shares attributes or supply chains with "old" designs, the higher the chance for getting a Nuclear Regulatory Commission license in a reasonable amount of time, and the more



Rendering of the project in Kemmerer, WY (TerraPower)

lessons that should be transferable from the long and difficult "restart" of American reactor construction at Vogtle 3 and 4 in Georgia.

A number of countries around the world have serious plans coalescing around a 300-MW boiling water reactor concept in development in the U.S. For communities looking for a "safe" reactor concept to consider for site feasibility studies, the BWRX-300 reactor from GE-Hitachi is a solid starting point.[13] Another reactor startup, TerraPower, has chosen a retiring coal plant in Kemmerer, Wyoming as the site for demonstrating its first-of-a-kind, 345-MW Natrium reactor in collaboration with the Department of Energy.[14]

Communities interested in exploring nuclear energy must make sure their states do not ban nuclear construction. Nuclear moratoria were a popular political gesture in decades past when environmentalism had not yet considered carbon dioxide particularly concerning. This coincided with low demand for new plant orders, lengthening

13. "The BWRX-300 Small Modular Reactor." GE Hitachi Nuclear Energy. Accessed on March 1, 2022.
14. "TerraPower selects Kemmerer, Wyoming as the preferred site for advanced reactor demonstration plant." TerraPower, November 16, 2021.

construction times in an environment of rapidly multiplying regulations, and then poor operation and reduced uptime in the initial years of reactors entering service.

States can take a number of steps to put themselves in the best position possible to be courted by nuclear developers looking to demonstrate and deploy their reactors.

- **Repeal moratoria on new nuclear construction.** Currently, 12 states have bans on new nuclear power facilities. However, Wisconsin, Kentucky, Montana, and West Virginia have all recently repealed restrictions on nuclear power. A number of the states with prohibitive legislation have significant coal generation and therefore the most to lose or to gain from the transition away from fossil fuels.

- **Ensure nuclear is included in clean energy standards.** Policymakers should review their state's legal definition of clean energy to ensure it includes nuclear power. Companies looking to build nuclear will likely prioritize states that clearly value nuclear plants for their carbon-free electricity.

- **Commission a feasibility study.** In addition to relaxing restrictions on new nuclear last year, Montana created a legislative panel to study the feasibility of replacing the coal-fired units at the Colstrip power plant with small reactors. Nebraska policymakers held a nuclear information conference in 2021. Currently, Alaska, Colorado, Indiana, Nebraska, and Montana are all considering legislation that would initiate similar investigations. Determining the benefits, costs, and process of such projects will be important for policymakers and community members alike.

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