Gone with the Steam

How new nuclear power plants can re-energize communities when coal plants close

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Executive Summary

Retirement of a coal-fired generation plant can have significant economic implications for the host community—in particular, loss of jobs. In 2019, two coal plants closed on the same day in rural Adams County, Ohio. A Washington Post article drew attention to this issue:

> *The closing of those plants meant the loss of more than 700 jobs and devastation to the local economy.*[1]
>
> *"That money is never coming back," Ty Pell [president of the county commissioners] said of the millions of dollars in salaries and tax revenue that has vanished like wisps of steam from the coal stacks. The county commission has slashed the budget two years in a row in anticipation of lean times ahead.*
>
> *In the months since last year's closures, workers fled for jobs in Wyoming, Florida, Washington, Idaho, Wisconsin, Colorado, Oregon, and elsewhere. The local school system has seen enrollment plunge and has cut positions to make up for budget shortfalls.*

While coal plants face a challenging future, the announced closure of a coal plant does not have to mean "devastation to the local economy." There is an alternative—new nuclear power plants, including small modular reactors (SMRs). SMRs can replace the electricity production from a coal plant with:

- Economical, carbon-free electricity
- Jobs—more jobs and better-paying jobs
- Similar performance on the grid, leveraging existing site assets and workforce

All with benefits concentrated in the local community losing the coal plant.

Generation Type	Permanent Jobs on Site	Industry Wage Median	Carbon-free Energy?	Role on Grid- firm Energy?	Benefits Concentrated in Local Community?
Nuclear	237	$41.32	**Yes**	**Yes**	**Yes**
Coal	107	$33.64	No	**Yes**	**Yes**
Natural Gas	30	$34.02	No	**Yes**	**Yes**
Wind	80	$25.95	**Yes**	No	No
Solar	36	$24.48	**Yes**	No	No

Note: Comparison of alternatives producing annual electricity output equivalent to a typical 1,000-MWe coal plant.

However, SMR deployment is not certain. To achieve these benefits, some action will be needed:

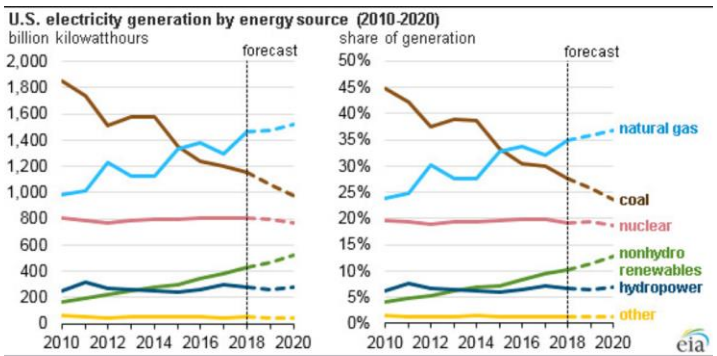
- Nuclear in general and SMRs specifically must be acknowledged as a zero-carbon solution.
- SMRs will need federal and state policy support to get beyond first-of-a-kind challenges.
- Clean energy incentives should be targeted to solutions that re-employ people.
- Local communities should receive support and funding to assess SMRs as an option.

[1] Washington Post, "In small towns across the nation, the death of a coal plant leaves an unmistakable void," 2019

Introduction

The percentage of U.S. electricity generated by coal plants has fallen from about 50% at the turn of the century to less than 20% today. While carbon capture, utilization, and storage (CCUS) technology offers hope that some coal-fired generation may remain viable, coal-fired plants—and the communities that host them—face an uncertain future. To date, the reality is that retiring coal plant electricity production has largely been replaced with another fossil fuel—natural gas.[2]

Exhibit 1



In an era of "net-zero" carbon commitments, the electricity industry is turning to identifying zero-carbon replacements for the remaining coal fleet. While wind and solar receive the lion's share of attention as clean energy, nuclear power has been the workhorse of zero-carbon electricity for decades.

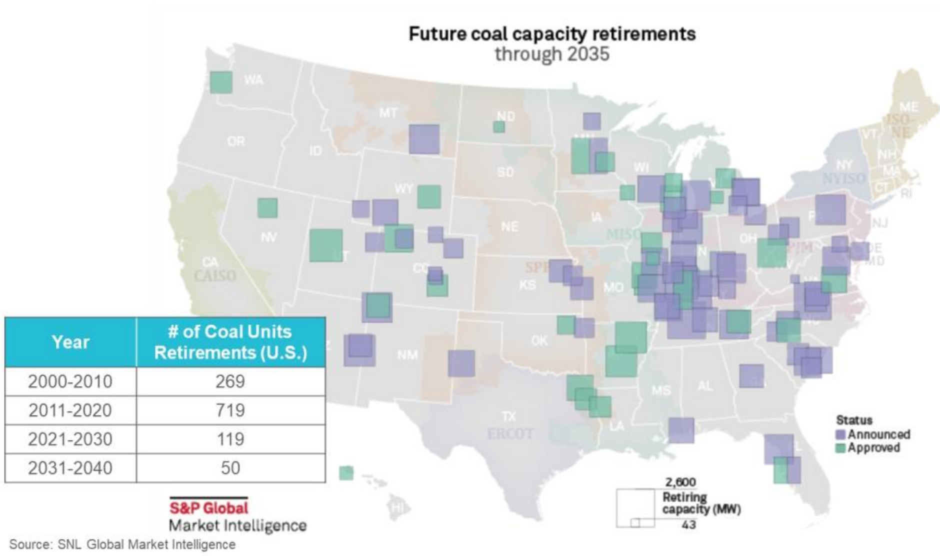
Which option provides cost-competitive, carbon-free electricity, while at the same time minimizing the negative impact to the local community that loses a coal plant? The answer may well be found in nuclear power's next generation of nuclear reactors, including SMRs. Like wind and solar, these SMRs provide affordable clean electricity—particularly when nuclear energy is valued for its firm capability (i.e., generating power 24 hours per day for 365 days a year). In addition, new nuclear reactor designs can replace the equivalent coal plant production on the very same site, leveraging the value of the existing workforce and site assets.

Converting to a next generation nuclear reactor is emerging as a preferred option that offers a lifeline for the local community losing the coal plant by providing ample well-paying jobs.

Coal Plant Closings Are Likely to Continue

For more than a decade, there has been a trend—coal plants are closing, and coal's contribution to U.S. electricity generation is falling. Absent a near-term CCUS breakthrough, this trend will continue as more and more utilities announce plans to retire coal plants. This phenomenon is not limited to a single region of the country, as shown by the distribution of coal plant retirements across the United States (Exhibit 2).

Exhibit 2



A major driver of the expected retirements of coal plants is the push toward decarbonizing the electric grid. Even without federal action on carbon, many states and utilities—driven in part by increasing consumer demand for carbon-free generation—have already moved forward on their own with commitments to a zero-carbon energy future.

With nearly 20% of U.S. generation still coming from coal plants, approximately 800 billion kWh of electricity will need to be replaced—a significant amount in a relatively short timeframe. But with what and at what cost?

The reality is that many coal plants are being replaced with natural gas plants.[3] While this has led to lower carbon emissions, without cost-effective CCUS, it will not achieve zero-carbon goals. Coal will need to be replaced with more zero-emitting resources. Wind and solar can fill a large part of this gap, but it will also be important to have a significant share of around-the-clock (or "firm") carbon-free generation to keep the grid both reliable and affordable. The leading technology to fill this essential role is nuclear. Further, if electrification of transportation and other parts of the economy (e.g., residential home heating) occurs as needed for decarbonization, there will be a need for even more carbon-free electric generation in very large amounts. We need all available clean energy options at our disposal to help achieve decarbonization goals, and nuclear is certainly one of those options.

Clean Energy Future

In June, South Carolina's regulators approved Dominion's 15-year integrated resource plan, which calls for shutting down the utility's coal-fired power plants within the next decade. Robert Blue [CEO of Dominion Energy] said the decision, which came after months of back and forth with advocates and regulators, "provides significant customer benefit" and "allows all parties to turn the page and focus on South Carolina's bright energy future." *Utility Dive Aug. 9, 2021*

A final consideration in replacing coal plants is ensuring that the valuable assets that exist in support of operating and managing those coal-fired plants are leveraged. With a coal plant comes a large, well-trained craft workforce. Coal plant sites also have land available with interconnections to the electricity grid and access to rivers and lakes for cooling water. This provides an excellent opportunity to use these assets for a SMR.

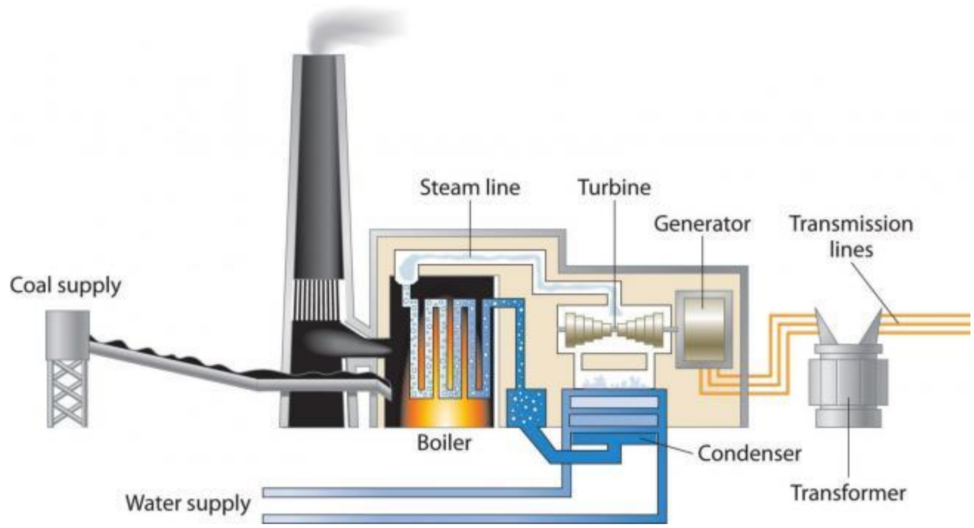
[3] U.S. Energy Information Administration

What Is a Coal Plant?

Should a coal plant be shut, it is important to know what it is, what role it serves, and what might be lost to the grid and the local community.

Coal Plant Technology – A coal-fired power plant is a "steam electric" plant. Coal is burned in a boiler to create steam. That steam flows through pipes (pumps and valves) to a turbine that spins a generator to create electricity. Electricity travels through transformers to high-voltage power lines and out to the electric grid. The steam is "condensed" back to water using cooling water from a lake, river, or tower.

Exhibit 3



Attributes – Coal plants tend to be very large. It is not uncommon for these plants to generate more than 900 MWe; according to the EIA, this is enough power to serve approximately 700,000 households annually.[4] These plants, sometimes referred to as "baseload," can run 24 hours a day, seven days a week, with very high reliability.

Workforce – The ongoing operation and maintenance of a coal power plant requires a well-trained and well-paid workforce. It is typical for there to be more than 100 jobs for a 1,000-MWe coal plant. Many of these jobs are well-paying (often represented) craft labor on the plant site. Exhibit 4 illustrates the jobs and wages for a typical 1,000-MWe coal plant. *Note: The "typical" coal plant used in this illustration and the remainder of this paper is based on a composite of select operating coal plants in the 1,000-MWe range.*

[4] U.S. Energy Information Administration

Exhibit 4

	Coal Site			
Job Type	**On-Site Coal FTEs**	**Total Hourly Wages**	**Median Hourly Wage**	**Total Hourly Wages per MWe**
Craft	34	$1,272.73	$37.36	$0.91
Operators	25	$976.85	$37.19	$0.70
Laborer	27	$681.25	$24.63	$0.49
O&M Support	3	$104.09	$36.53	$0.07
Supervisory	8	$403.20	$50.78	$0.29
Professional	6	$280.25	$49.74	$0.20
Senior Leadership	4	$263.42	$64.43	$0.19
Total	**107**	**$3,981.79**	**$37.19**	**$2.84**

To illustrate the specific types of jobs that are included in the numbers above, the following table lists a few examples of coal-fired power plant positions:

Exhibit 5

Coal Site		
Craft	**Operator**	**Laborer**
Mechanic	Control Room Operator	Coal Yard Specialist
I&C Technician	Field Operator	Material Handler
Electrician		Railroad Specialist
Tool Room Specialist		Railroad Train Operator
Plant Technician		Security Guard

Role on the Electricity Grid – The electricity grid was designed around the existing power plants and load centers to optimize generation and the way in which it is delivered to customers. Large "baseload" plants serve a key role in the current electric grid, ensuring reliability and dependability of power flows. When these baseload plants are shuttered, the overall electricity grid itself can be negatively impacted and force a need for adjusting measures. The grid can accommodate these changes, but it often requires a costly redesign.

One example of where there was a significant grid impact due to the closure of a large baseload plant was at the San Onofre Nuclear Generating Station (SONGS) in 2012. According to an article in Utility Dive, "…*the closure of this plant resulted in the need to invest millions of dollars in remediation to restore the stability of the electric grid. These measures included:*

- *Improving long-distance transmission to supply the San Diego-Los Angeles area*
- *Doubling major circuits to increase the volume of electricity moved*
- *Cranking out the capacitors to provide voltage support to the transmission grid by adding these to several substations*

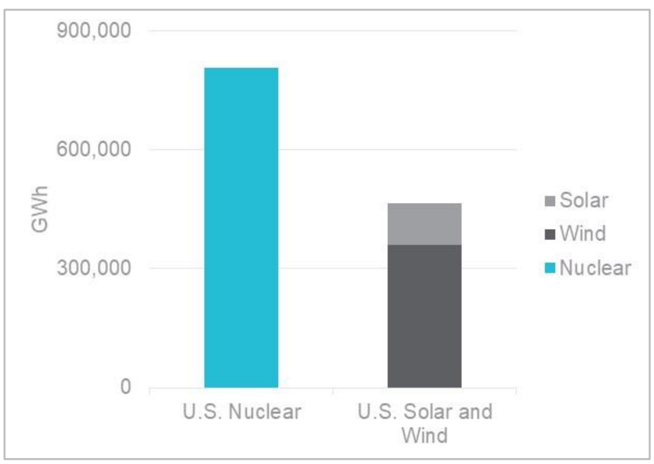
Additionally, the electric utility, Southern California Edison, needed to ramp up energy efficiency programs and decide if additional new plants needed to be built."[5]

Other Economic Benefits – A large baseload plant provides significant economic benefit to the local community in which it is located. These plants, often located in smaller communities, are the single-largest part of the tax base. For example, the closing of two coal plants in Adams County, Ohio, resulted in the loss of "several hundred million dollars" in taxable value.[6] In addition, indirect impacts on industries, such as restaurants and hospitals, will also occur. A joint 2019 study by researchers at Ohio University and the University of Maryland, focusing on coal-fired power plant closures in Appalachian Ohio, found that "the closure of these [coal] facilities will result in 1,131 lost jobs, more than $82 million in lost labor income, and a reduction in economic output of nearly $700 million" through both direct and indirect impacts.[7]

What Are SMRs?

SMRs are nuclear power plants. For decades, nuclear power plants have been the single-largest source of carbon-free electricity in the United States. As shown by Exhibit 6, in 2020, existing large nuclear power plants in the United States generated more than 1.7 times as much carbon-free energy as solar and wind combined.[8]

Exhibit 6



Nuclear plants can run 24 hours a day, seven days a week, and most run reliably with capacity factors above 90%. Existing nuclear plants can also be cost competitive—Lazard studies show ongoing operating costs of $26 per MWh, which compares favorably to new unsubsidized wind and solar.[9] Despite this track record, several nuclear plants are being shut down before the end of their operating licenses. Why? Because they are not cost competitive versus natural gas-fired electricity absent a price on carbon emissions. The United States is in real danger of losing additional "net-zero" generation if policymakers do not act to more fully value existing nuclear. (See ScottMadden's article How Nuclear Plant Closures Threaten to Offset Gains from Renewables.)

Conventional, large nuclear power plants have proven difficult and costly to construct in the United States and Europe (though the track record is much better in Asia and the Middle East). There is, however,

[5] Utility Dive (https://www.utilitydive.com/news/californias-grid-needs-these-3-upgrades-after-the-san-onofre-shutdown/139326)
[6] Washington Post, "In small towns across the nation, the death of a coal plant leaves an unmistakable void," 2019
[7] The economic, fiscal, and workforce impacts of coal-fired power plant closures in Appalachian Ohio. Ohio University and University of Maryland
[8] U.S. Energy Information Administration
[9] Lazard Levelized Cost of Electricity, v14, October 2020

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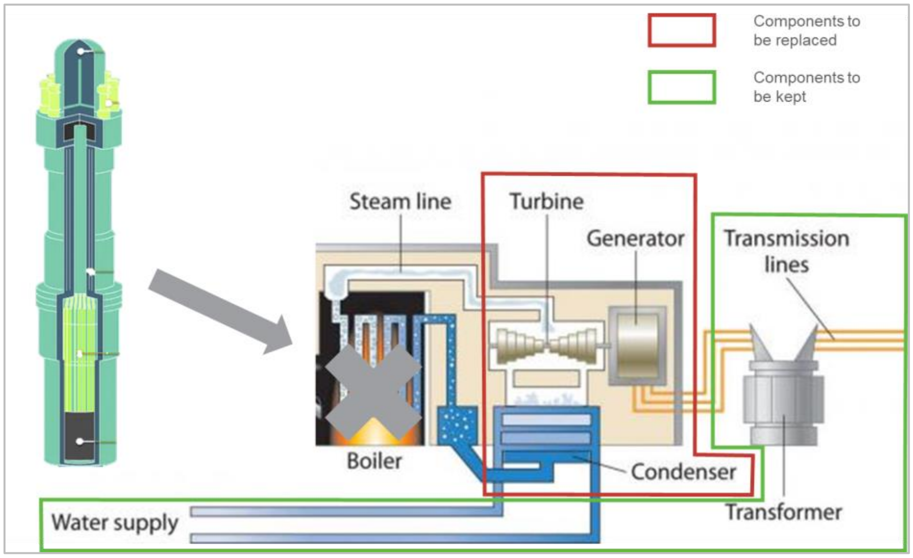
another hope for new nuclear in the United States. It comes in the form of SMRs. While definitions vary, a good synopsis is provided in a publication by the U.S. Office of Nuclear Energy:

> "Small Modular Reactors are nuclear power plants that are smaller in size (300 MWe or less) than most current generation baseload plants (1,000 MWe or higher). These smaller, compact designs are factory-fabricated reactors that can be transported by truck or rail to a nuclear power site".[10]

Like coal plants, SMRs are steam electric plants. Instead of burning coal, the steam is produced using the heat created through nuclear fission. Beyond a difference in how the steam is generated, a nuclear power plant is remarkably similar to a coal plant. The steam flows through pipes, pumps, and valves to a turbine that spins a generator to create electricity. Electricity travels through transformers to high-voltage power lines and out to the electric grid. The steam is "condensed" back to water using cooling water from a lake, river, or cooling tower. Exhibit 7 illustrates the assets and components of the coal plant that could be replaced (red) and those that could be kept (green) for a SMR.

Exhibit 7

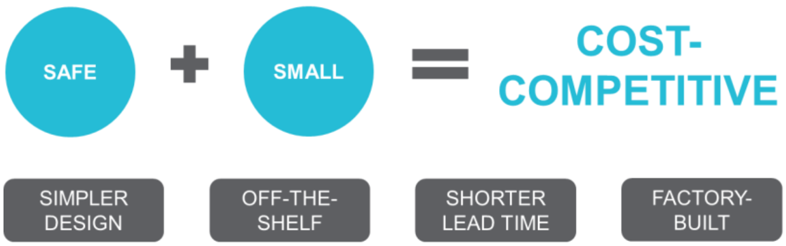


At the core of the case for SMRs is that these smaller, simpler, and more inherently safe designs provide improved safety and cost competitiveness. Conventional nuclear plant designs depend on an array of equipment that must function for both normal operations (e.g., reactor coolant pumps and steam generators) and shutdown safety (e.g., backup power and safety injection pumps). SMRs do not require many of the active shutdown and safety systems and actions characteristic of their conventional nuclear counterparts. Incorporating safety lessons from more than five decades of nuclear plant operations, SMR designs are expected to be safer than current plants. As a result, these smaller and simpler designs that leverage off-the-shelf equipment and factory-built modules are expected to be cheaper and more predictable to build than site-built mega-construction projects. Simpler designs with less equipment will also require lower cost for ongoing operations and maintenance.

The safety benefits of SMR designs will still need to be confirmed as part of the formal approval by the Nuclear Regulatory Commission. If approval is obtained in a way that satisfies stakeholder concerns, the inherent cost benefits can be realized, and construction should be able to occur with limited risk of regulatory delay.

[10] U.S. Department of Energy – Office of Nuclear Energy

Exhibit 8



There are many new nuclear plant designs currently in development, ranging from smaller versions of existing light water reactors (LWRs) to advanced reactors, such as molten salt designs. For purposes of illustration in the remainder of this paper, we have chosen the NuScale 12-module design (12 reactors for each 77 MWe on one site) as a comparison for coal plant replacement. This plant would provide 924 MWe of electric capacity. The NuScale design was used for comparison because it is well down the path to gaining regulatory approval and commercialization. This NuScale design was also selected due to the availability of data regarding estimates of costs and staffing of its proposed projects.

Why SMRs Are a Good Replacement?

SMRs are, in many ways, an ideal replacement for coal plants. SMRs can contribute to an increasingly clean electric grid by providing firm, reliable, carbon-free generation, while reducing the overall costs to consumers.[11] Most importantly, SMRs provide local economic benefits to the same community that would experience negative economic consequences associated with a coal plant closure. The local community and existing workforce would benefit from jobs created by the construction and operation of the SMR plant.

Good Jobs – Replacing the well-paying jobs of a coal plant is not easy. However, according to a recent report by USEER, median wage rates of nuclear jobs are the highest among power generation technologies (Exhibit 9). The nuclear median wage scale nationwide is 23% higher than coal and approximately 60% higher than renewables (wind and solar).[12] Nuclear jobs are also steady, having the highest level of represented workforce of any generation technology (Exhibit 10).

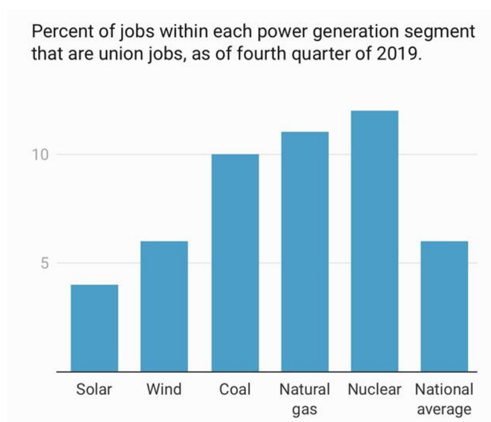
Exhibit 9

USEER Wage Report – EPG Wages by Sub-Sector

Energy Sub-Sector	Median Hourly Wages, 2019	Geographically Weighted Premium/Discount from Median Hourly Wages
Nuclear Generation	$41.32	114.6%
Coal Generation	$33.64	79.6%
Natural Gas Generation	$34.02	76.5%
Wind Generation	$25.95	34.9%
Oil Generation	$24.49	25.7%
Solar Generation	$24.48	20.9%
Other Renewable Generation	$17.98	-8.6%

Source: 2020 U.S. Energy and Employment Report (USEER)

Exhibit 10



Source: 2020 U.S. Energy and Employment Report (USEER)

Number of Jobs – According to NuScale, its 12-module configuration with 924 MWe would provide approximately 237 on-site jobs, well in excess of a typical 1,000-MWe coal plant. These jobs would exist

[11] The Role of Firm Low-Carbon Electricity Resources in Deep Decarbonization of Power Generation (https://www.sciencedirect.com/science/article/pii/S2542435118303866)
[12] USEER Wage Report 2020

throughout the life of the plant—more than 40 years. Focusing only on the on-site jobs (vs. industry-wide USEER data) and using U.S. Bureau of Labor Statistics (BLS) data, the median hourly wages for on-site SMR jobs would pay a premium of approximately 17% and, accounting for the greater number of jobs, yield more than double the annual labor spend of a comparable coal plant.

Exhibit 11

	Coal Site				NuScale SMR			
Job Type	On-Site Coal FTEs	Total Hourly Wages	Median Hourly Wage	Total Hourly Wages per MWe	On-Site SMR FTEs	Total Hourly Wages	Median Hourly Wage	Total Hourly Wages per MWe
Craft	34	$1,272.73	$37.36	$0.91	64	$2,810.65	$42.64	$3.04
Operators	25	$976.85	$37.19	$0.70	40	$1,846.60	$43.45	$2.00
Laborer	27	$681.25	$24.63	$0.49	55	$1,552.73	$25.35	$1.68
O&M Support	3	$104.09	$36.53	$0.07	49	$1,956.95	$41.74	$2.12
Supervisory	8	$403.20	$50.78	$0.29	10	$551.20	$55.12	$0.60
Professional	6	$280.25	$49.74	$0.20	14	$753.18	$52.96	$0.82
Senior Leadership	4	$263.42	$64.43	$0.19	5	$380.76	$75.62	$0.41
Total	**107**	**$3,981.79**	**$37.19**	**$2.84**	**237**	**$9,852.07**	**$43.45**	**$10.66**

Note: The wage rates in this analysis differ slightly from the national average USEER data in that it focuses only on jobs that are "on site." Coal FTEs are based on ScottMadden's analysis of a range of representative coal plant staffing. This analysis also relies on BLS job wage data for the equivalent SMR and coal positions.

Similar Jobs and Limited Retraining – Many of the SMR jobs, particularly craft jobs, require similar skills to those of typical coal plant staff. Like coal plants, SMRs require operation and maintenance of plant equipment (pumps, valves, welding, etc.). These jobs would require some retraining, but they would not require wholesale repurposing of the workforce to a totally different job type (e.g., information technology sector). Exhibit 12 shows the vast majority of jobs in a SMR have coal plant equivalents that would likely require low to medium levels of retraining.

Exhibit 12

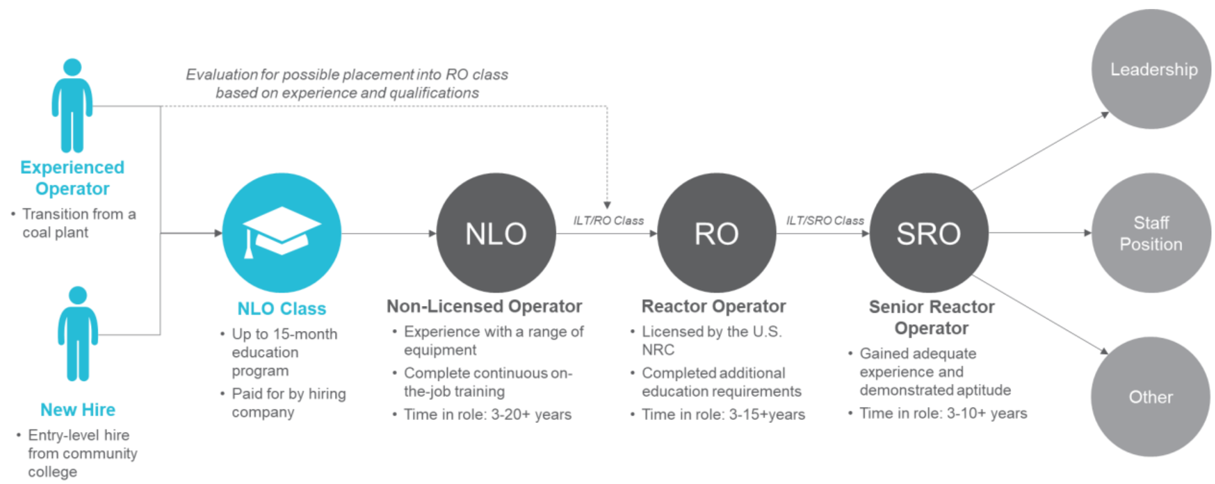
Coal Plant Position	# Dedicated Coal Positions	SMR Position	# Dedicated SMR Positions	Position Type	Degree of Retraining Required
Operations Supervisor	5	Senior Reactor Operator	5	Supervisor	High
Control Room Operator	10	Reactor Operator	15	Operator	High
Field Operator	15	Non-Licensed Operator	25	Operator	Low
Lab Operator/Chemistry/Scrubber	4	Chem Tech	14	Craft	Medium
Maintenance Supervisor	2	Maintenance Supervisor	3	Supervisor	Medium
Mechanical Craft	12	Mechanical Craft	21	Craft	Low
I&C Craft	9	I&C Craft	10	Craft	Medium
Electrician Craft	5	Electrician Craft	11	Craft	Low
Technician	11	Technician	13	Laborer	Low
Security Officer	20	Security Officer	48	Laborer	Low
Sub-Total	**93**		**165**		
All Other Positions	14		72	42 are O&M Support (Planners, Outage, etc.)	Medium
Total Positions	**107**		**237**		

Sources: NuScale; ScottMadden analysis

New Jobs and Promotional Opportunities – SMRs provide the opportunity to bring additional jobs to local communities. Engineering and professional jobs for which there are no coal plant equivalents would be new additions and provide a boost to the local community's economy. The 70+ jobs that have no coal plant equivalent ("All Other Positions" in Exhibit 12) offer new opportunities for workers in these communities.

Jobs, such as reactor operators or radiation protection technicians, do not have a coal plant equivalent, but they are in fact potential developmental paths for current coal workers. A typical career path for a nuclear reactor operator often starts with a plant laborer (see Exhibit 13).

Exhibit 13



This opens the door for the coal plant workforce to progress and develop into higher-paying jobs. In the nuclear job progression illustrated above, the nuclear worker is trained while on the job, and their salary and training are paid for by the nuclear operator, unlike many other retraining programs.

Construction Jobs – The discussion so far has focused on the ongoing jobs to operate and maintain a SMR through its expected 40+ year life. Estimates show that roughly 1,600 jobs would be created for a three-year period during the construction of a SMR.[13] It is also typical that some of these construction roles would transition into ongoing operating roles, providing the workforce a bridge needed until the plant is complete.

Economic Impacts on the Local Community – Because SMRs would be located on the same site as the retired coal plant, the local community would also benefit from the economic impact of the plant—both directly and indirectly. A study from SMR Start shows that in addition to the 237 on-site jobs, each permanent job at a SMR plant would result in 1.66 additional jobs in the local community.[14] The SMR would also prevent a major loss of tax base. In 2019, the Colleen Power Station contributed $2.3 million to the local government through property taxes.[15] According to a study conducted by NuScale, a 924-MWe capacity SMR facility will pay approximately $16 million in state and local taxes annually.[16]

Climate – Because they are nuclear plants, SMRs provide firm, zero-carbon electricity generation in support of climate goals.

[13] NuScale – An Ideal Solution for Repurposing U.S. Coal Plant Infrastructure and Revitalizing Communities
[14] SMR Start: The Economics of Small Modular Reactors (https://smrstart.org/wp-content/uploads/2021/03/SMR-Start-Economic-Analysis-2021-APPROVED-2021-03-22.pdf)
[15] The Journal-News (https://www.thejournal-news.net/stories/lights-out-for-coffeen-power-plant,66508)
[16] NuScale – An Ideal Solution for Repurposing U.S. Coal Plant Infrastructure and Revitalizing Communities

Like-for-Like Replacement – SMRs are close to a "drop-in replacement" providing a similar profile to the coal plant being replaced.

- ***Makes use of the current site location and assets*** – A SMR could leverage the existing infrastructure and site assets, ensuring they are not squandered. The interconnection to the electricity grid, switchyard, and access to river/lake as cooling water will be available for use by a SMR. Also, SMRs can pack a lot of MWs into a small site, meaning the existing land could easily host this type of plant. While light water SMRs will have very similar equipment like those used by the coal plant (pumps, turbine generators, etc.), these will likely not be salvageable for the SMR.
- ***Serves a similar role on the electricity grid*** – SMRs provide baseload, dispatchable power with a high-capacity factor. Like the NuScale 12-pack, a SMR would also be large enough (~1,000 MWe) to serve a role on the electricity grid similar to a large coal plant. Therefore, deployment of a SMR would not require a major reconfiguration of the electric grid.

Economic Impacts for the United States **–** In many ways, the United States missed an opportunity to lead in the solar and wind industries. Most solar panels are made in China, and much of the wind technology is dominated by European companies. Putting support behind SMRs as replacements for coal plants provides a broader economic opportunity to jump-start a clean energy industry and its robust supply chain in the United States.

Yeah, But This Sounds Too Good to Be True

Many of the benefits described in this paper may sound "too good to be true." Skeptics may point to the following concerns with SMRs:

Are SMRs Really Cost Competitive?

It is true that SMRs do not yet have a track record to use for comparison of their overall cost of production. However, there are good reasons to believe SMRs will be simpler to construct than large-scale nuclear, and studies indicate that their levelized cost of energy (LCOE) can be competitive. A recent study by the Breakthrough Institute estimated the cost of the NuScale plant across a range of differing costs of capital. At a 10% discount rate, the LCOE for a NuScale plant could be approximately $65 per MWh. Another SMR manufacturer, UAMPS, has stated a target of $55–$58 per MWh, similar to the NuScale estimate.

Levelized Cost of Energy

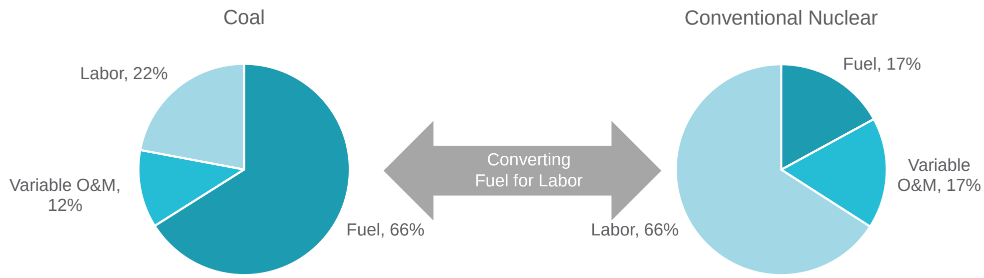
LCOE represents the average revenue per unit of electricity generated that would be required to recover the costs of building and operating a generating plant during an assumed financial life and duty cycle. It allows comparisons of plants with vastly different proportions of upfront fixed costs and ongoing variable costs.

As mentioned previously, many shuttered coal plants have been converted to natural gas. Combined-cycle gas turbine (CCGT) plants have been a cost-competitive option. According to Lazard, a new CCGT would have an LCOE between $44 and $75 per MWh. Adding an assumed cost of $20 per MWh (or less than $40 per ton CO_2) for carbon emissions or a similar requirement to add CCUS technology, the LCOE rises above the $55–$65 per MWh estimate for SMRs. This would make SMRs competitive against CCGT in a carbon-constrained world.

How Can a SMR Provide More Better-Paying Jobs than the Coal Plant It Replaced?

One might wonder how coal-fired generation can be replaced by SMRs and increase the number of jobs and overall labor cost, while at the same time remain cost competitive for customers. The answer to this question lies in the fact that fuel cost for the coal plant is the single-largest contributor to the overall cost of electricity, representing about 66% of total costs. By contrast, labor is the single-largest cost for a nuclear plant—the fuel cost is a mere 17% of total generation costs. A comparison of non-capital LCOE components can be seen below:

Exhibit 14



In a conventional nuclear plant, the fuel is not a major driver of the overall cost. Therefore, labor cost can be much higher for a SMR than for a coal plant because the fuel cost is less. In a sense, you can trade coal fuel cost for SMR labor cost and keep overall cost of electricity competitive.

Isn't Nuclear Too Costly and Risky to Build?

Many will say we have been down this road before.

It is true that one of the biggest drawbacks to a new conventional nuclear plant in the United States is the risk of a construction delay. The difficulty in building any mega-project, like a large nuclear plant, is the potential for significant schedule delays and cost overruns. A study by MIT professors[17] notes that conventional nuclear plant construction in the United States has not shown improvement through the experience curve. This is not a surprise since most nuclear plants in this country were constructed by a fragmented set of different utilities, each using different designs, over 20 years, with overlapping timelines. None of this contributes to efficient lessons learned. Where we do see this experience curve is in countries such as France and South Korea where a single utility constructs a standard design several times, becoming better and better at it.

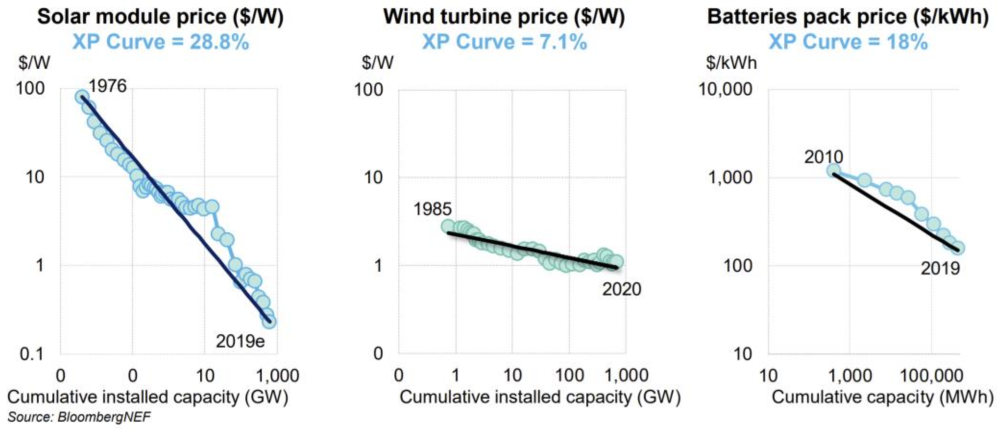
SMRs hold promise to solve the constructability problem. The approach of constructing factory-built modules with better control over the supply chain is expected to yield shorter (approximately three years) and more predictable construction. The size of the plants will also provide more construction control—it is easier to build small than large. Most importantly, there is a much greater ability to take advantage of the experience curve in SMRs than in conventional plants. Stamping out multiple factory-built, smaller reactors sequentially offers the potential for real learning curve benefits.

Solar, wind, and batteries have been able to drive down costs through the experience curve (as shown in Exhibit 15). Simply stated, as more total MWs are constructed, the cost per MW falls because of the

[17] Joule (https://www.cell.com/joule/fulltext/S2542-4351(20)30458-X?_returnURL=https%3A%2F%2Flinkinghub.elsevier.com%2Fretrieve%2Fpii%2FS254243512030458X%3Fshowall%3Dtrue)

experience gained. The charts below illustrate how the unit costs of solar, wind, and batteries have fallen as total installations have increased. Solar and wind benefited from early policy support (investment tax credits and production tax credits) when costs were high (and non-competitive) to gain the scale needed to drive down costs and become competitive. SMRs with their repeatable construction and standard designs could see similar experience and would therefore also benefit from similar policy support to gain scale and lower costs over time.

Exhibit 15



Shouldn't We Just Build Wind, Solar, and Batteries?

Wind and solar should be a significant part of a portfolio of carbon-free electricity generators. The LCOE for wind and solar, estimated by Lazard, ranges between $26 and $54 per MWh. However, they are not always the cheapest or most desirable option in every part of the country. Development of wind and solar will also come with a need for additional costs to build out transmission and distribution systems to deliver the electricity. There is also a risk in having an entire generation portfolio of intermittent, highly variable generation resources without the balance of baseload plants, such as nuclear. These "system integration" costs include wires, transformers, batteries, and backup generation sources. A 2019 OECD report estimated that systems with a high percentage of renewables would require upward of $35–$45 per MWh in additional system integration costs to handle this variability and ensure grid stability. At these levels, renewables could be more than $60 per MWh—in the range of a SMR.[18]

In terms of local jobs, wind and solar do not compare to SMRs. Solar generates mostly construction jobs with very few ongoing operations jobs. A comparison of different projects shows that SMRs provide the best option for the workforce (Exhibit 16).

Exhibit 16

Facility	Net Electrical Output	Capacity Factor	Electrical Capacity	Construction Jobs	Permanent Jobs
SMR	878 MWh	95%	924 MWe	1,600	270
Solar	975 MWh	25%	3,900 MWe	1,800	36
Wind	875 MWh	35%	2,498 MWe	688	80
Natural Gas	965 MWh	60%	1,485 MWe	800	30

[18] OECD (https://www.oecd-nea.org/upload/docs/application/pdf/2019-12/7299-system-costs.pdf)

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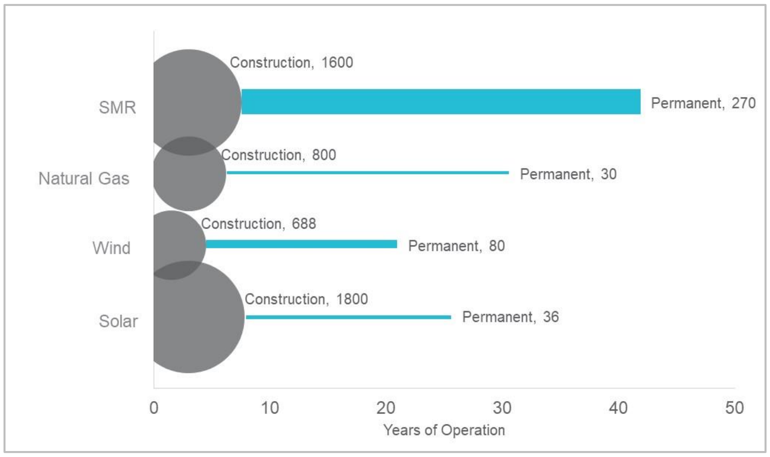
In the table above, the solar and wind generation projects are based on two recent new renewable projects: Samson Solar (2020) and Traverse Wind (2021). These projects and their associated jobs have been scaled up (3 times Samson Solar and 2.5 times Traverse Wind) to have a net electrical output comparable to the 1,000-MW coal plant.[19]

Note: Because solar and wind produce less electricity (MWh) relative to their capacity (MWe), more wind and solar capacity (MWe) would need to be constructed to produce an equivalent amount of MWh.

Exhibit 17



The job types and wage rates for wind and solar are on the lower end of the electricity production wage scale (see Exhibit 18). Retraining existing coal workers for these jobs may be straightforward, but the jobs would pay less and have less opportunity for advancement as compared to those in a SMR (e.g., non-licensed to licensed operator).

Exhibit 18

USEER Wage Report – EPG Wages by Sub-Sector		
Energy Sub-Sector	**Median Hourly Wages, 2019**	**Geographically Weighted Premium/Discount from Median Hourly Wages**
Nuclear Generation	$41.32	114.6%
Coal Generation	$33.64	79.6%
Natural Gas Generation	$34.02	76.5%
Wind Generation	$25.95	34.9%
Oil Generation	$24.49	25.7%
Solar Generation	$24.48	20.9%
Other Renewable Generation	$17.98	-8.6%

The jobs impact on the local community losing the coal plant would also be greater from a SMR, as wind and solar would likely be constructed in a more dispersed geography. Exhibit 19 illustrates how "spread out" 1,000 MWh are for various technologies in terms of leased land requirements. SMRs would be concentrated locally.

[19] Airswift (https://www.airswift.com/blog/wind-energy-projects-usa)

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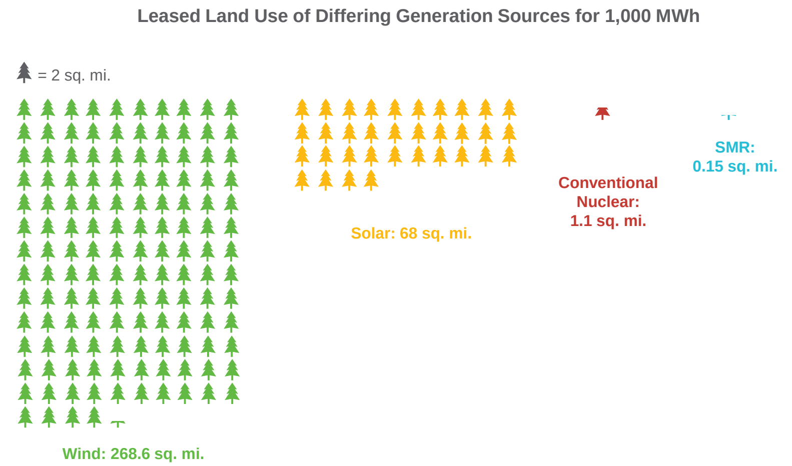
Exhibit 19



Source: NREL, NuScale Power – Environmental Footprint

Why Not Just Keep Building Natural Gas Plants?

One might ask, "why not continue to replace coal with natural gas plants?" They are cheap and easy to build and operate.

Climate – It is true that natural gas combined-cycle plants produce electricity at roughly half of the greenhouse gas emissions of a coal plant. The recent trend of conversion of coal to natural gas has helped significantly reduce carbon emissions from the U.S. electricity sector. However, natural gas-fired generation, absent CCUS, cannot be the centerpiece of a zero-carbon strategy. For zero-carbon emission scenarios, carbon-free generation sources—like nuclear energy—will need to play an increasingly significant role.

Jobs – Natural gas plants are like coal plants in that fuel is a large portion of the cost structure. There are even fewer jobs as compared to a nuclear plant, and they are not as well-paying as coal or nuclear plant jobs.

Cost Risk – Current natural gas prices have been historically low; however, one thing we have learned is that fuel prices are volatile, and increases are a real long-term risk. A rise in natural gas prices and/or an added price on carbon emissions could change the economics of a natural gas plant considerably and quickly.

Pipeline Infrastructure – Continued expansion of natural gas plants will require a significant addition of pipeline capacity to deliver natural gas to these generators. The ability to permit and build pipelines has proven difficult, in certain regions, and could limit the growth of natural gas electricity generation.

Won't This Take Too Long? Wind and Solar Are Here Now

One of the more common arguments against nuclear expansion is that it is too far off on the horizon. By the time we can get the new nuclear plant approved and built, it will be too late. We could have built other generation sources more quickly. One advantage of SMRs, such as the NuScale, GE-Hitachi BWRX-300, and Holtec SMR-160 designs, is that they are based on proven LWR technology. The LWR technology has been used successfully in small reactors to power the U.S. submarine fleet.

Because they are in the early stages of deployment, SMRs are experiencing issues, such as securing demonstration projects, building out supply chains, and shake outs in SMR companies. These are issues typical of developing technologies, not unlike the issues experienced by wind and solar in the past (and offshore wind currently). The wind and solar experience highlights that these hurdles can be overcome successfully with policy support.

Solar and wind are not without potential barriers to rapid deployment. Because they are more spread out, wind and solar will require transmission and distribution investments. These "wires" investments are difficult to accomplish and present potential barriers to rapid deployment.[20] In 2011, the Obama administration listed its top transmission investment priorities, many of which supported the growth of renewables. To date, a decade later, of the 3,208 miles of transmission proposed to be built, only 438 miles have been completed.[21] There are risks of delay in growing any zero-carbon technology, which means an "all of the above" approach, including nuclear as an appropriate balanced approach.

Others might argue that solar and wind could be added more quickly. It is true that solar and wind have and can be added very quickly, though often in smaller increments. SMRs by contrast can add a lot of MWs quickly on an existing coal site. To illustrate the importance of adding clean energy in large increments, it is important to see how the addition of clean energy in large amounts has happened. A recent study[22] by Nicholas Gilmore, et. al. attempted to do this by identifying the decade in which a country experienced the largest growth in clean generation capacity (per capita) and what generation type was responsible for that growth. Overwhelmingly, either hydropower or nuclear power was the engine of growth for a meaningful carbon-free generation increase. To illustrate this, France took a little more than a decade to build-out its nuclear program starting in the late 1970s. It can be done with nuclear, and it has been done with nuclear.

Exhibit 20

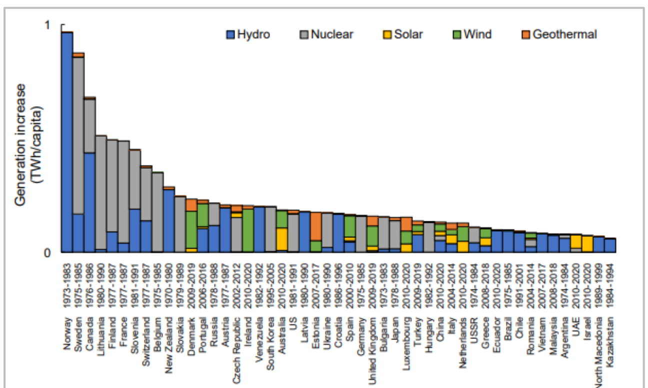
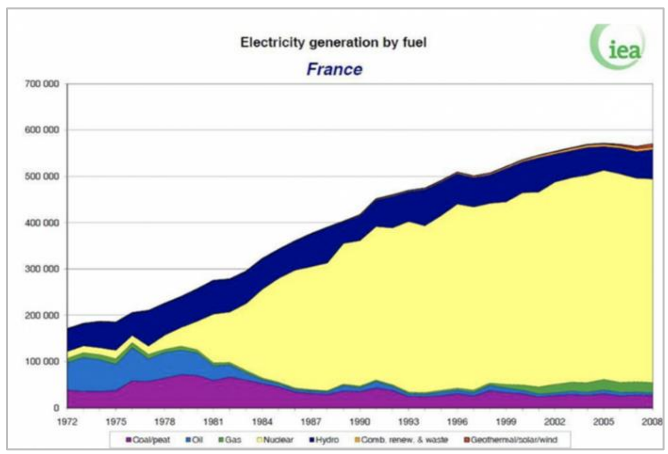


Fig. 11 Fifty largest increases in electrical generation per capita over ten years. Iceland 1998-2008 was omitted due to its small population but added 2.637 TWh/capita of hydro and 1.337 TWh/capita [6]



It is true that SMRs are a few years away from being fully "shovel ready," but coal plant closings will continue for decades. According to a well-known proverb, "the best time to plant a tree was 20 years ago. The second-best time is now."

[20] ScottMadden, Transmission in the United States, What Makes Developing Electric Transmission So Hard? https://www.scottmadden.com/insight/transmission-in-the-united-states-what-makes-developing-electric-transmission-so-hard/

[21] Transmission Hub (https://www.transmissionhub.com/articles/2011/10/obama-administration-to-accelerate-permitting-construction-of-7-projects-across-12-states.html)

[22] Nicholas Gilmore, et. al, Clean Energy Futures: An Australian based foresight study, https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3906061

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What Could Local Communities Actually Do?

There are three immediate steps that local communities with coal plants in their regions can undertake to explore this opportunity:

- **Commission a site feasibility study.** Commission a task force to investigate the benefits, costs, and risks of converting a coal plant to a SMR. A key aspect of this feasibility should be to understand if there are opportunities to streamline the permitting and construction of SMRs.
- **Revisit laws prohibiting nuclear development.** Thirteen U.S. states currently have restrictions on new nuclear power facilities.[23] Communities could look to influence state policy makers to change or revisit these laws to enable this opportunity.
- **Evaluate local community college curriculum and training practicum.** Educational institutions and boards of directors could evaluate if their current curriculum supports the jobs required to enable construction and operations of the next generation of nuclear power plants.

Summary

A retirement or even an announcement of a coal-fired generation plant closure will have significant economic implications for the host community, including:

- Loss of jobs as a direct result of the plant closing
- Loss of jobs as an indirect result of the plant closing, which may affect restaurants, supermarkets, and other service-oriented establishments
- Reduction in property tax revenue that support host community services (e.g., schools)
- Underutilized and undervalued land sites with access to the electricity grid and other resources (e.g., water)

SMRs provide an attractive alternative for replacing coal-powered generation plants:

- **Significant number of well-paying jobs** – SMRs provide more (237 vs. 107 on-site jobs) and better-paying jobs. SMRs provide similar jobs to those in coal plants, providing the existing workforce a much better opportunity to make the transition.
- **"Drop-in" replacement** – SMRs can provide similar operating characteristics on the same site, leveraging the existing assets and minimizing costs to redesign the grid.
- **Clean energy** – As a nuclear plant, SMRs provide a carbon-free replacement for coal which helps meet climate goals.
- **Cost competitive** – Constructability of SMRs provides a low-cost solution to replacing the electricity lost from a coal plant. Unlike conventional nuclear, SMRs with their modular construction offer real promise of leveraging the experience curve in construction.
- **Concentrated impact to the community losing the coal plant** – Being located on the same site, the community that loses the coal plant will benefit from the SMR's economic impact.

[23] National Conference of State Legislatures (https://www.ncsl.org/research/environment-and-natural-resources/states-restrictions-on-new-nuclear-power-facility.aspx), August 17, 2021

More decentralized solutions, such as solar and wind, would not provide the same concentrated benefit as a SMR.

- **Opportunity to create a growing industry** – Investing now provides the opportunity for the United States to become the industry leader in SMRs and the associated supply chain.

While SMRs hold the promise of significant benefits, there are near-term hurdles to achieving large-scale deployment. Realizing the benefits of SMRs will require action:

- First and foremost, nuclear in general and SMRs in particular must be acknowledged as a zero-carbon solution in federal and state climate change policies and by major energy consumers and the finance community.
- Like wind and solar, in the early days, SMRs will need federal and state policy support to get beyond its first-of-a-kind challenges.
- Congress and state legislatures should target clean energy incentives to solutions that not only provide zero-carbon electricity but also re-employ people.
- Federal and state programs should help local communities with the support and funding to assess SMRs as an option. It is critical to allow those most affected to be informed and have a say in what should happen in their communities.

As hundreds of coal plants are closed in the coming decades, there is a chance for some of the affected communities to avoid the fate of Adams County, Ohio. SMRs can provide zero-carbon electricity in support of climate priorities, while maintaining a vibrant economy for the affected local communities. Investment and support now can ease the transition for local communities, drive down costs over time, and build a vibrant, clean energy industry for the United States.

About ScottMadden's Energy Practice

We know energy from the ground up. Since 1983, we have served as energy consultants for hundreds of utilities, large and small, including all of the top 20. We focus on Transmission & Distribution, the Grid Edge, Generation, Energy Markets, Rates & Regulation, and Corporate Services. Our broad, deep utility expertise is not theoretical—it is experience based. We have helped our clients develop and implement strategies, improve critical operations, reorganize departments and entire companies, and implement myriad initiatives.

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