NuScale SMR Technology

An Ideal Solution for Repurposing U.S. Coal Plant Infrastructure and Revitalizing Communities

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Power for all humankind

Introduction

Over the past century, the power generator fleet in the U.S. has gone through many changes. New technologies, state and federal environmental regulations, and changing operating costs have all contributed to an increasingly diverse energy generation landscape.[1]

The early industrial successes of the world are credited to the affordability and abundance of electricity, particularly from coal-fired power plants. Historically, large-scale coal power plants in the U.S. offered a cost-effective power solution that satisfied growing energy demand, due to the wide availability of coal as fuel and the relative ease to which it could be delivered to a plant site. According to the U.S. Energy Information Administration (EIA)[2], over the last decade the United States has led the world with over 260 billion short-tons of recoverable coal reserves—translating to 28 percent of total global reserves—which is 50 percent more than Russia (the world's second largest reserves). Even as alternative generation sources emerged, America's continued use of coal as the primary fuel for electricity production was a direct result of the nation's wealth in it as a resource.

Coal's long reign over the energy sector, however, has rapidly declined throughout the 21st century as new clean energy technologies have emerged and climate change concerns across the globe have increased. Many U.S. electricity providers have announced the retirement of coal-generating assets due to both market and regulatory factors; coal infrastructure across the nation is also aging. The nation's coal consumption peaked in 2007 and in 2008, coal-fired electricity represented nearly half of U.S. generation. Since 2007, this capacity has declined by 39 percent.[3,4] The EIA's latest inventory of electric generators report[5] released in February 2021 states that a total of 48 gigawatts (GW) of coal-fired electric generating capacity has retired over the past five years. In 2021, 2.7 GW of coal-fired capacity is scheduled to retire, primarily from older coal units that are more than 51 years old.

Coal continues to face increasing competition from other generation sources, including natural gas, solar, wind, and hydro power. This purpose of this paper is to discuss the benefits of adding advanced small modular reactor (SMR) nuclear technology into this mix of competition.

NuScale SMR Technology: An Innovative and Economical Solution

With the first ever SMR to receive U.S. Nuclear Regulatory Commission (NRC) design approval, Oregon-based company NuScale Power is poised to usher in a new era of clean energy with advanced nuclear technology that builds on America's legacy of safe and reliable nuclear power.

NuScale has developed a new modular light water reactor nuclear power plant to supply energy for electrical generation, district heating, desalination, and other process heat applications.

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[1] Rode, D., Fischbeck, P., and A. Páez, (2017). The retirement cliff: Power plant lives and their policy implications. Energy Policy 106: 222–232.Retrieved from https://www.sciencedirect.com/science/article/abs/pii/S0301421517302136

[2] U.S. Energy Information Administration Independent Statistics & Analysis (2011). Today in Energy. Retrieved from https://www.eia.gov/todayinenergy/detail.php?id=2930#

[3] Congressional Research Service (2018). 21st Century U.S. Energy Sources: A Primer. Retrieved from https://crsreports.congress.gov/product/pdf/R/R44854

[4] Fleischman, L.et al. (2013). Ripe for Retirement: An Economic Analysis of the U.S. Coal Fleet. The Electricity Journal. 26(10), 51-63. Online at: http://dx.doi.org/10.1016/j.tej.2013.11.005

[5] U.S. Energy Information Administration (2021). Today in Energy. Retrieved from https://www.eia.gov/todayinenergy/detail.php?id=46436

The groundbreaking small modular reactor (SMR) design at the heart of the NuScale power plant is the fully factory fabricated NuScale Power Module™ (NPM) that generates a gross output of 77 megawatts of electricity (MWe) using a safer, smaller, and scalable version of pressurized water reactor technology. NuScale's scalable design—power plants that can house up to four, six, or 12 individual power modules—offers the benefits of carbon-free energy and reduces the financial commitments associated with gigawatt-sized nuclear facilities. NuScale builds on proven nuclear technology with a focus on integration and simplification. The result is an affordable clean energy solution that provides unparalleled safety, flexibility, reliability and resiliency.

	ELECTRIC CAPACITY MWe (gross)	ELECTRIC CAPACITY MWe (net)
NuScale Power Module™	77	N/A
4-module plant	308	293
6-module plant	462	441
12-module plant	924	884

NuScale's flagship power plant design can house up to 12 modules for a total gross output of 924 MWe. NuScale also offers smaller power plant designs in four-module (308 MWe) and six-module (462 MWe) configurations that are underpinned by the rigorous safety case of its NRC-approved 12-module flagship design. The scalable, multi-module features of the NuScale plant make it an ideal option to match to different coal power plant energy outputs, many of which are between 300 MWe and 600 MWe.

NuScale power plants can fit within the confines of an existing coal-fired power plant property. According to the Nuclear Energy Institute (NEI), "a nuclear energy facility has a small area footprint, requiring about 1.3 square miles per 1,000 megawatts of installed capacity. This figure is based on the median land area of the 59 nuclear plant sites in the United States."[6] The 12-module NuScale plant has a small physical footprint of 0.05 square miles, and the smaller four- and six-module NuScale plant designs have proportionally smaller physical footprints. By comparison, wind generation requires 94 square miles to generate the 924 MWe that a 12-module NuScale plant generates on just 0.05 square miles (to further illustrate, the city of San Francisco is 49 square miles), and solar photovoltaic (PV) requires at least 17 square miles.

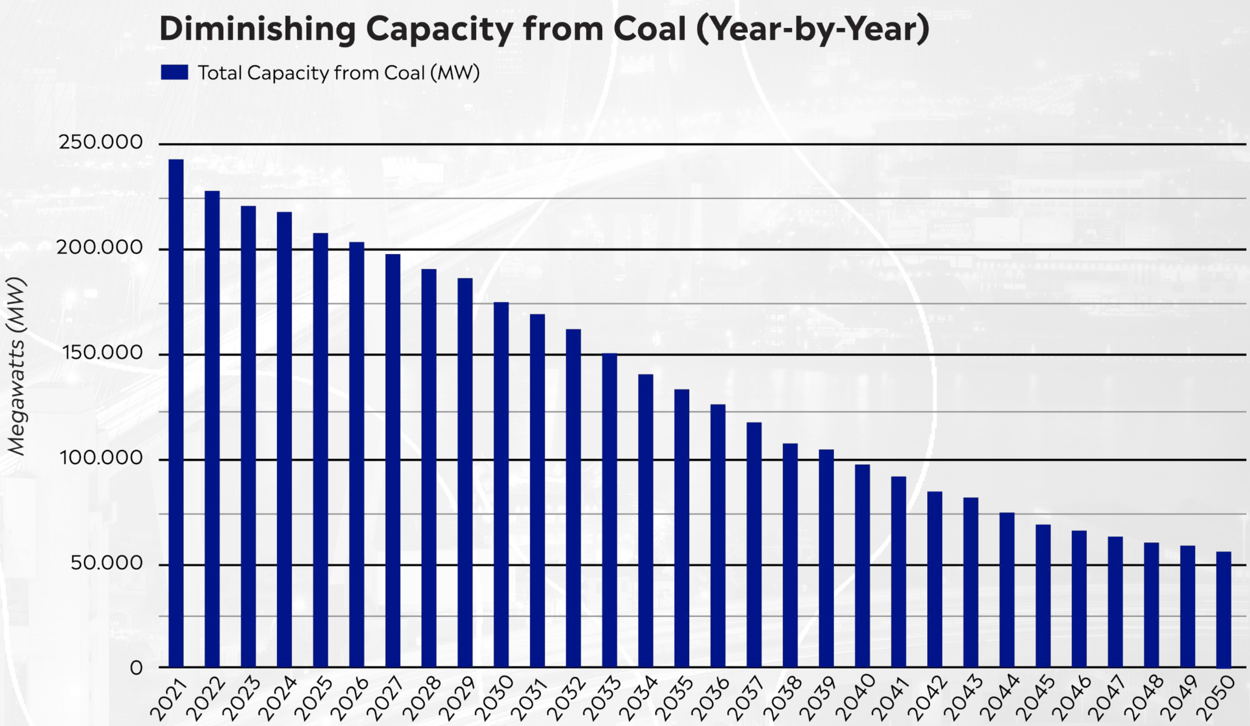
These scalable power plant solutions can support a variety of needs and geographic areas and can be located on retiring coal power plant sites. Some coal plant generation infrastructure can be repurposed and reused, such as cooling water delivery systems, demineralized water, potable water, site fire protection, and switchyard, as well as administrative, warehouse, and other existing buildings. These systems can be repurposed at significant savings: NuScale conducted a study which estimates that, on average, approximately $100M of existing coal plant infrastructure could be reused for a NuScale power plant. The NuScale plant can utilize existing energy infrastructure without the need to incur the cost of new major infrastructure, such as the installation of a transmission system connection.

[6] Nuclear Energy Institute webpage on land needs for energy generation https://www.nei.org/news/2015/land-needs-for-wind-solar-dwarf-nuclear-plants

America's Diminishing Capacity from Coal

Changes in federal regulations, such as those issued by the U.S. Environmental Protection Agency (EPA), have influenced a growing number of coal power plant retirements across the country. Analyses show that there are also other factors affecting the trend of coal plant retirements, including rising costs of coal[7], a sharp decline in natural gas prices, and flat demand for electricity.[8] A 2018 S&P Global Market Intelligence analysis of U.S. Energy Information Administration data highlights that based on current market conditions, it is unlikely that new coal plants will be built in the future.[9] Figure 1 illustrates the diminishing annual capacity from coal in the U.S. through 2050.

Figure 1: Diminishing Capacity of Coal in the U.S. Annually through 2050



Source: GlobalData 2020

NuScale's SMR power plants are timely solutions for the U.S. as coal power plant retirements progress and the cost of coal continues to increase. The retirement of aging coal-fired power plants, coupled with the unlikelihood of new coal plant construction, is already leading to changes in baseload generation and transmission infrastructure needs. While some retiring coal-fueled plants may be replaced with natural gas-fueled plants or new clean coal technology, many U.S. state energy efficiency and carbon reduction portfolios advocate for an increased integration of wind and solar energy generation.

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[7] See Table 15: Coal Supply, Disposition, and Prices in the U.S. Energy Information Administration Annual Energy Outlook 2020 report at https://www.eia.gov/outlooks/aeo/data/browser/#/?id=15-AEO2020&region=0-0&cases=ref2020&start=2018&end=2050&f=A&linechart=~~ref2020-d112119a.49-15-AEO2020~ref2020-d112119a.59-15-AEO2020&map=&ctype=linechart&sourcekey=0

[8] Tierney, S. (February 16, 2012). Why Coal Plants Retire: Power Market Fundamentals as of 2012. Analysis Group, Inc. Available at https://www.analysisgroup.com/Insights/publishing/why-coal-plants-retire--power-market-fundamentals-as-of-2012/

[9] S&P Global Market Intelligence. (January 30, 2018). Coal's 'aging out' problem: Most US customers operating older power plants. Available at https://www.spglobal.com/marketintelligence/en/news-insights/trending/c-mlubpv-fukfng57myl_za2

As previously discussed, wind and solar both require large tracts of land for siting and these generation sources are not capable of repurposing retired coal power plant infrastructure in the way that a NuScale SMR power plant can. Allowing coal-fueled plants to simply retire, without providing an alternative electrical generating source like a NuScale SMR power plant that offers reliable, safe, and flexible baseload power that can complement the intermittency of increasing wind and solar generation on an integrated grid, will significantly increase shifts in the reliability of power flows across the transmission system.[10] It also leads to the loss of jobs and can considerably impact the economic stability of many local communities.[11]

Features of the NuScale Power Plant

The NuScale power plant is designed to be smarter, safer, cleaner, and more cost competitive than large gigawatt nuclear power plants. The beauty of the NuScale plant design is in its simplicity, making it less expensive to build, operate, and maintain. The NuScale SMR uses the principles of buoyancy-driven natural circulation; no pumps are needed to circulate water through the reactor. Modules are fully factory-built with no in-field construction, erection, or fabrication, and they are transported to the power plant site—taking safety-related work out of the field.

NuScale plants are economical, as they reflect lower levelized and overnight costs on a per kilowatt basis when compared to large advanced nuclear plants. The simplified plant design results in greater use of "commercial off-the-shelf" items that need not be supplied under stringent and costly nuclear standards. NuScale plants offer streamlined construction and reduced construction schedules of less than 36 months from the first safety concrete—all features that lower costs to the customer. The overnight capital cost of the 924 MWe 12-module flagship plant on an Nth-of-a-kind, per kilowatt basis is lowered from the originally estimated $3,600 to $2,850—approaching a power output that makes it truly competitive within the gigawatt-size market, but with significantly better economics.

NuScale has undertaken detailed studies of capital, operating, and decommissioning costs for its 12-module, 924 MWe plant design. Results demonstrated that the total capitalized cost of the NuScale plant is approximately 38% of a reference 4-loop pressurized water reactor (PWR) of 1147 MWe net output, representing a reduction of nearly $4 billion. Accounting for differences in power output, the capitalized construction cost per kW for the NuScale plant is 62% of the 4-loop PWR ($3,466/kW versus $5,587/kW). Operating and maintenance costs for a NuScale plant will be lower than those of the top 25% of U.S. large nuclear power plants. In addition, a 2018 article by Black et. al in the journal Renewable and Sustainable Energy Reviews[12] detailed the economic advantages of modular approaches like NuScale's to the off-site manufacturing of nuclear energy technology. The study established that NuScale SMR factors such as design simplification, reduced componentry, modularity, and other features of the design result in significant savings in overall base costs. It also highlights that the NuScale design yields increased safety features, and reduced construction times and associated financing costs.

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[10] Quadrennial Energy Review: First Installment. (April 21, 2015). Available for download at https://www.energy.gov/quadrennial-technology-review-0

[11] For example, see USA Today coverage of the Navajo Generating Station shutdown and financial losses to Native American Tribes at https://www.usatoday.com/story/money/2019/11/18/navajo-generating-station-coal-plant-arizona-closes/4232386002/ and previous NPR coverage of the Navajo Generating Station https://www.npr.org/2018/11/11/660627883/looming-shutdown-of-the-navajo-generating-station-means-new-jobs-far-from-home

[12] Black, G.A., Aydogan, F., and Koerner, C.L. (2018). Economic Viability of light water small modular nuclear reactors: General methodology and vendor data. Available via ScienceDirect at https://www.sciencedirect.com/science/article/abs/pii/S1364032118308372

On January 30, 2020 Energy Northwest, a consortium of 27 public utility districts and municipalities across Washington State, released findings from a study titled "Pacific Northwest Zero Emitting Resources Study", prepared by Energy + Environmental Economics (E3). The E3 study highlights that firm zero-emitting capacity must be built into the Pacific Northwest region if it is to achieve deep decarbonization.[13] The report's findings demonstrate that SMRs, at NuScale costs, would reduce the cost of achieving a 100 percent electric sector greenhouse gas (GHG) reduction by nearly $8 billion per year, and that this reduction stems from NuScale's ability to provide firm capacity, thereby, avoiding a large overbuild of wind and solar generation. Through their findings, the E3 study offers further analysis that SMRs—including NuScale's SMR technology—provide an ideal mix of reliable carbon-free capacity able to seamlessly integrate with wind, solar, and hydropower generation.

In addition to baseload power, the multi-module NuScale plant offers operational flexibility for diverse applications. Electric and steam power outputs of modules can be tailored to different functions, such as desalination, oil refining, or hydrogen production. These applications are traditionally powered by fossil fuels; the NuScale plant provides a reliable, carbon-free power alternative. The NuScale plant can also extensively load follow to complement intermittent power generation from wind, solar, and hydropower and balance power supply on the grid, no matter the time of day, season, or weather forecast. The NuScale Power Module is capable of a ramp rate of 40% per hour in reactor power change, which aligns with specifications set by the Electric Power Research Institute (EPRI).[14] For even quicker responses to electricity demand, the NuScale SMR can rapidly lower its electric power output up to 10% per minute and return to full output at the same rate utilizing turbine bypass. This is significantly faster than conventional nuclear power.

The 924 MWe (gross) that a 12-module NuScale plant produces is enough to power nearly 700,000 homes in the U.S., while just one NuScale Power Module (77 MWe) can provide clean energy for 60,000 homes. Replacing a coal-fired power plant with a 924 MWe NuScale plant would avoid over eight million tons of CO2 emissions per year—the equivalent of taking 1.7 million cars off the road. Building a 12-module NuScale plant instead of a natural gas plant would avoid almost four million tons of CO2 emissions per year, or just over 800,000 cars off the road.

In terms of safety, NuScale's small modular reactor technology is second-to-none with features, capability, and performance not found in current nuclear power facilities. NuScale offers a fully passive safety system design, rigorously proven by our Triple Crown for Nuclear Plant Safety™ which ensures that reactors will safely shut down and self-cool, indefinitely, and do so with no need for operator or computer action, AC or DC power, or the addition of water—a first for LWR technology. Our strong safety case justifies an emergency planning zone in the U.S. that only extends as far as the site boundary (as opposed to 10 miles for current U.S. plants)—further reinforcing NuScale's ability to accommodate a variety of coal power plant sites.

The unparalleled safety of NuScale's SMR provides a new level of nuclear power plant resilience. Following a loss of offsite power or the loss of the transmission system grid, our plant can run in island mode, provide first responder power, and black start from cold conditions. The NuScale plant can be located at the "end of the line" or off-grid, without the requirement for offsite transmission source(s) to the station. The plant is resilient to natural events, with the modules and fuel pool located below grade in a Seismic Category 1

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[13] Energy + Environmental Economics (E3). (January 29, 2020). Pacific Northwest Zero-Emitting Resources Study: Executive Summary. Available for download at https://www.ethree.com/wp-content/uploads/2020/02/E3-Pacific-Northwest-Zero-Emitting-Resources-Study-Executive-Summary-Jan-2020.pdf
[14] Electric Power Research Institute (EPRI), Advanced Light Water Reactor Utility Requirements Document, Revision 13, Tier 2, Chapter 1. Login access only at https://www.epri.com/research/products/3002003129

building; it is designed to withstand an aircraft impact and is also resilient to electromagnetic pulse (EMP) and geomagnetic disturbance (GMD) events. Finally, our non-microprocessor-based module and plant protection systems use field programmable gate array technology that is invulnerable to cyber-attacks.

The NuScale plant can also provide exceptionally reliable power under a micro-grid arrangement to critical infrastructure so that your community can become part of a regional clean energy powerhouse. The 924 MWe 12-module NuScale power plant can provide 154 MWe of highly reliable power at 99.95% reliability to mission critical infrastructure without the need for more expensive backup battery or diesel-fueled power supplies, as well as 770 MWe of reliable baseload generation at over a 95% capacity factor. This level of reliability is appealing to hospitals, government installations, digital data storage centers, and other industrial facilities.

The Carbon Free Power Project: NuScale's First SMR Power Plant in the U.S.

The public power consortium Utah Associated Municipal Power Systems (UAMPS) is planning a NuScale power plant in Idaho as part of its Carbon-Free Power Project (CFPP). The CFPP is a power generation project involving NuScale's SMR technology that will replace retiring coal generation and serve as a key step toward decarbonizing UAMPS energy portfolios, while providing steady, resilient electricity to customers. UAMPS has stated that NuScale's SMR technology will support flexibility of dispatchable power output, allowing the CFPP to provide a reliable, yet adjustable supply of carbon-free electricity to both complement and enable large amounts of renewable energy, including wind and solar.

By the end of this decade, a NuScale SMR power plant will begin generating clean energy for the CFPP. This first NuScale power plant in Idaho will prompt additional deployment opportunities throughout the nation in the decades that follow; through the learning associated with each NuScale plant, subsequent deployments are expected to be lower in cost with even shorter construction durations. The planned deployment timelines of NuScale plants in the U.S. align with the timelines of diminishing coal power capacity (as highlighted previously in Figure 1), offering a viable and timely repowering solution, dependable supply of clean energy, and sustained regional and community economic development opportunities as coal plant retirements continue.

Energy Source Comparisons:
Life Cycle, Employment, and Environmental Impact

As shown in Table 1, for every 924 MWe of generating capacity, the NuScale plant employs more plant staff when compared to coal or natural gas plants. With respect to levelized cost of electricity (LCOE), NuScale maintains an internal LCOE financial model, which shows projected LCOE results for its technology in U.S. dollars per megawatt-hour ($/MWhr). Those LCOE figures can be compared to industry LCOE comparatives for other technologies, which are published the Annual Energy Outlook 2020 report from the U.S. Energy Information Administration (EIA) on Levelized Cost and Levelized Avoided Cost of New

[15] American Public Power Association. (July 24, 2019). "UAMPS members execute power sales contracts for SMR project." Available at https://www.publicpower.org/periodical/article/uamps-members-execute-power-sales-contracts-smr-project

[16] U.S. Energy Information Administration (EIA) Levelized Cost and Levelized Avoided Cost of New Generation Resources in the Annual Energy Outlook 2020. Available at https://www.eia.gov/outlooks/aeo/electricity_generation.php

Generation Resources . The LCOE varies considerably based on the financial modeling assumptions (e.g., project cost, financing assumptions, municipal or investor-owned utility (IOU), etc.) used in the analysis.

Table 1 compares the employment and life cycle costs of coal and natural gas combined cycle power plants with the NuScale SMR power plant while considering different environmental impacts and economic factors.

Table 1: Comparison of employment and life cycle cost and environmental impact of various power plants

	Coal Power Plant	Natural Gas Combined Cycle Power Plant	NuScale Power Plant
Plant Employees (per 924 MWe)[17]	143	29	270
Levelized Cost of Electricity ($/MWh)[18] [with CCS]	[$104]	$41 [$68]	$65
SOx (mg/kWh)	6700	300	11
NOx (mg/kWh)	3350	550	9
PM2.5 (mg/kWh)[19]	9210	100	~0
Greenhouse Gas Emissions (CO2-equivalent (g/kWh) [with CCS][20]	1025 [167]	492 [167]	15

Despite the higher plant staffing and average wage rates, the simplicity of NuScale's SMR design provides a competitive LCOE compared to other low carbon options, and the first U.S. plant target has an LCOE of $65/MWh. This cost estimate conforms to Association for the Advancement of Cost Engineering (AACE) 18R-97 – Class 4 cost estimate with over 14,000 line items priced using the current proprietary cost data or actual vendor quotes of the Fluor Corporation, a leader in the engineering, procurement, fabrication, and construction (EPFC) industry.[21] More stringent carbon reduction emissions regulations such as those occurring at the state level in the U.S. could further increase the levelized cost of generation of natural gas-fueled plants making implementation of NuScale SMR technology even more attractive.

The U.S. EIA projects that all new coal plants will need to be built with carbon capture and sequestration (CCS) technology to comply with federal regulations bringing the levelized cost of electricity (LCOE) to $104 per megawatt-hour (MWh) for new coal plants. By comparison, new advanced combined cycle natural gas plants, assuming the price of natural gas at $3.03/mmBTu, would have a base LCOE of $41/MWh, increasing to $68/MWh with CCS, as shown in Table 1.

Table 1 also shows the relative comparison of greenhouse gas (GHG) emissions and other air pollutants—sulfur dioxide (SO2), nitrogen oxides (NOX), and particulate matter (PM2.5)—emitted during the life cycle of coal, gas, and nuclear power plants per kilowatt-hour (kWh). In a nuclear plant like NuScale, all wastes are accounted for and managed during the entire life cycle of the plant and incorporated into the LCOE. Nuclear power plants also have a significantly smaller life cycle environmental impact than power plants

[17] Data received from various utility members of the NuScale Advisory Board.
[18] U.S. Energy Information Administration. Levelized Cost and Levelized Avoided Cost of New Generation Resources in the Annual Energy Outlook 2019, except NuScale (12-pack); NuScale LCOE Model.
[19] Masanet, E., et al. (2013). Life-Cycle Assessment of Electric Power Systems. Annual Review of Environment and Resources 38:107–36; Spath PL, Mann MK. (2000). Life cycle assessment of a natural gas combined-cycle power generation system, National Renewable Energy Laboratory.
[20] International Atomic Energy Agency. Nuclear Power and Climate Change 2016. Available at https://www.iaea.org/publications/11090/climate-change-and-nuclear-power-2016
[21] To learn more about the Fluor Corporation, see https://www.fluor.com/

fueled with coal or natural gas. Over their life cycle, coal plants produce an average of 1,025 grams of gas emissions (in terms of CO2-equivalent) per kWh that is directly emitted into the environment, and natural gas plants emit about 492 g/kWh. This amount is reduced to an average of 167 g/kWh with CCS for fossil-fueled plants, but nuclear plants still emit much less, only about 15 g/kWh.

When energy sources are evaluated over their entire life cycle—from mining of materials and fuel, to construction, and eventual decommissioning and waste storage—nuclear energy has one of the lowest carbon footprints that islower than solar photovoltaic (PV) and about the same as wind.

Community and Economic Benefits

By repurposing a current coal plant site with a NuScale plant for power generation, jobs and economic benefits stay within the community. NuScale's SMR power plant offers not only an opportunity to repurpose the infrastructure of the coal fueled power plant, but to also retain and retrain the current coal plant workforce. Many coal plant jobs are directly transferrable to the NuScale plant, and each NuScale plant deployed in the U.S. will employ about 270 people in high paying full-time jobs of high quality. A generic list of job positions broken down by category and number of jobs in each category are detailed in Appendix B. Examples of the types of jobs that are part of a NuScale power plant workforce include:

- Non-licensed operators
- Nuclear maintenance craftsmen
- Radiation protection technicians
- Training staff
- Non-nuclear craftsmen
- Security officers
- Department managers
- Technical supervisors
- Engineers

NuScale is committed to supporting workforce development and human capacity throughout its operations while providing unparalleled cost-competitive benefits for its customers. A study[22] prepared by the Idaho Policy Institute at Boise State University conducted a regional economic analysis to estimate the increased output (sales), employment, employee compensation, tax revenues, and gross regional product of the NuScale power plant in Idaho as part of the UAMPS Carbon Free Power Project. Some of the economic benefits a NuScale plant will provide as cited in the study include:

- Approximately 1,600 jobs will be created over the construction period of the plant.
- Economic impacts through indirect and induced effects will add a total of 667 jobs in the region each year over the estimated 40–to 60-year lifetime of the facility.
- The operations of the plant are estimated to increase labor income in the region by nearly $48 million, increase economic output in the region by an estimated $81.15 million, add $2.97 million to local and state tax revenues annually, and add $10.86 million to federal tax revenues annually.

Beyond the NuScale plant at UAMPS, the overall domestic supply chain for manufacturing 36 NuScale Power Modules (for three 12-module plants) is estimated to generate around 13,500 jobs. NuScale SMR exports to other countries will also further benefit the U.S. economy, as the U.S. International Trade Administration has stated that $1 billion of exports supports 5,080 U.S. jobs.[23]

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[22] Economic Impact Report: Construction and Operation of a Small Modular Reactor Electric Power Generation Facility at the Idaho National Laboratory Site, Butte County, Idaho. (January 29, 2019). Prepared for the Regional Economic Development for East Idaho (REDI) by Idaho Policy Institute, Boise State University McClure Center for Public Policy Research, University of Idaho. Researchers Dr. Geoffrey Black, Boise State University Mr. Steven Peterson, University of Idaho Final Copy. Available at https://easternidaho.org/wp-content/uploads/2019/02/SMR-Economic-Impact-Report-FINAL.pdf

As highlighted in Table 1 on Life Cycles of Power Plants, for every 924 MWe of generating capacity, the NuScale plant employs more plant staff and at a higher average annual wage when compared to coal or natural gas plants.[24] In other words, by repurposing a coal facility with a NuScale SMR plant, it would increase the number of available jobs while still being cost competitive with a natural gas-fueled plant. For comparison, a natural gas-fueled plant employs significantly fewer people on a per MW basis compared to the current coal-fueled facility, even when the gas plant has a higher output, creating a negative impact to the economy of local communities.

Building and operating a nuclear power plant brings direct economic benefits to the community it serves. Higher-paying jobs provide a means for citizens to invest more locally, creating a stimulus for the regional economy. On average per year, a nuclear power plant generates $470 million in sales of goods and services in the local community and pays about $16 million in state and local taxes, which can benefit schools and infrastructure.[25]

Training, Education, and Position Placement

The American National Standard, "Selection, Qualification, and Training of Personnel for Nuclear Power Plants," ANSI/ANS-3.1-2014, has been referenced as a standard that contains criteria for the selection, qualification, and training of personnel for the operating organization of nuclear power plants. The standard specifies minimum qualifications for levels of management and individuals for: (1) education; (2) minimum experience for the position; (3) nuclear power plant experience; and (4) related experience, which can include nuclear power plant, on-site, and supervisory or management experience. Definitions of these and other criteria by the ANSI/ANS-3.1-2014 are in Appendix A. Table 2 below summarizes the required education level and examples of associated job positions for the NuScale power plant.

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[23] International Trade Administration. Manufacturing and Services Economics Brief. (2012). Available at https://legacy.trade.gov/mas/ian/build/groups/public/@tg_ian/documents/webcontent/tg_ian_003978.pdf

[24] Economic Impact Report: Construction and Operation of a Small Modular Reactor Electric Power Generation Facility at the Idaho National Laboratory Site, Butte County, Idaho. (January 29, 2019). Prepared for the Regional Economic Development for East Idaho (REDI) by Idaho Policy Institute, Boise State University McClure Center for Public Policy Research, University of Idaho. Researchers Dr. Geoffrey Black, Boise State University Mr. Steven Peterson, University of Idaho Final Copy. Available at https://easternidaho.org/wp-content/uploads/2019/02/SMR-Economic-Impact-Report-FINAL.pdf and U.S. Bureau of Labor Statistics. (May 2018), National Industry-Specific Occupational Employment and Wage Estimates for Nuclear Electric Power Generation.

[25] Nuclear Energy Institute, Nuclear by the Numbers (2019). Available at https://www.nei.org/resources/fact-sheets/nuclear-by-the-numbers

Table 2. Education levels for NuScale job positions

Number of NuScale Job Positions	Required Education Level	Job Position Examples
45	Bachelor of Science	Department Managers Technical Supervisors System Engineers
162	Associates Degree, Vocational Education, and/or Nuclear Experience	Plant Operators Maintenance Craftsmen Radiation Protection Chemistry Technicians Training Staff
61	High School or GED	Site Support Craftsmen Security Officers Storekeeper
2	Entry Level	Administration Support

The NuScale Advisory Board (NuAB) is an advisory group that was established by NuScale in 2008. NuAB is comprised of power company executives including nuclear industry experts and heads of generation, system planning, engineering, and project development that have an interest in NuScale's SMR technology. NuAB evaluated the plant staffing data for eleven coal power plants and the results of the evaluation demonstrated that many job positions and their job requirements are similar to those found at most nuclear power plants. Differences do exist in typical coal-fueled plant operations, safety culture, programs and processes, procedures, systems, structures, and components (SSCs) that create a knowledge/ability (K/A) gap.[26] However, performing a K/A gap analysis can inform and support a training and position placement plan.

For instance, it is possible to retrain a coal power plant electrician to fulfill the role of a NuScale power plant electrician. The amount of retraining required for a coal power plant worker can be determined by performing a gap analysis of their K/A in their current role compared against the K/A required to perform the similar role at a NuScale power plant. In the K/A context, a systematic approach to training (SAT) program tests and gauges an individual's capability to do a job safely and successfully by measuring their knowledge and ability. To close the K/A gap, a detailed training program would be developed using the SAT process.[27] From the information collected from eleven U.S. coal power plants, Table 3 below captures the direct alignment of general coal power plant positions with equivalent or comparable roles at a NuScale power plant that can be attained with minimal, appropriate training. It is worth noting that coal-fueled power

[26] For knowledge/ability (K/A) we define knowledge as, "facts, information, and skills acquired by a person through experience or education; the theoretical or practical understanding of a subject" and ability as "possession of the means or skill to do something."
[27] According to the U.S. Department of Energy, the systematic approach to training (SAT) includes five distinct, yet interrelated, phases. These phases include analysis, design, development, implementation, and evaluation. SAT is consistent with other systematically based training systems such as performance-based training (PBT), training system development (TSD), instructional systems development (ISD), and other similar methods.

plants and nuclear power plants have similar systems and components, such as the steam turbine; main steam system; generator; main condenser; condensate pumps; feedwater pumps; feedwater heaters; cooling towers; circulating cooling water; electrical and control systems; and water treatment.

Table 3. Coal power plant roles and comparable NuScale equivalent roles

Department	Coal Power Plant Position	NuScale Equivalent Position
Senior Management	Plant Manager	Plant Manager[1]
	Operations Manager	Operations Manager[1,2]
	Maintenance Manager	Maintenance Manager[1]
	Engineering Manager	Technical Services Director[1,2]
	Common Facilities Manager	Site Support Services Supervisor
Operations	Assistant Ops Manager	Shift Manager[2]
	Shift Supervisor	Control Room Supervisor[2]
	Control Room Operator	Reactor Operator[3]
	Field Operator	Non-licensed Operator
Outage Planning	Outage Manager	Generation & Planning Manager[1]
	Planner	Planner
Maintenance Planning	Maintenance Supervisor	Maintenance Supervisor
	Foreman	Work Control Lead
	Planner	Planner
	Engineering Technician	Work Control Scheduler
Maintenance Planning	Boilermaker	Mechanic
	Steam Fitter	Mechanic
	Mechanic	Mechanic
	I&C Technician	I&C Technician
	Electrician	Electrician
	Heavy Equipment Operator	Site Support Craftsman
	Auto Mechanic	Mechanic
	Labor Foreman	Site Support Craftsman
	Laborers	Site Support Craftsman
	Metal Fabricator/Welder	Site Support Craftsman
	Tool Room Specialist	Tool Crib Attendant
Engineering	Thermal Station Engineer	Design Engineer
	System Engineer	System Engineer
	Site Project Engineer	Component Engineer
	Shift Engineer	Staff Technical Advisor
	Project Manager	Supply Chain Specialist
Environmental	Environmental Board Operator	Radwaste Operator
	Environmental Operator	Non-licensed Operator
	Plant Chemist	Chemistry Technician[4]
Coal Yard and Railroad	Coal Yard Specialist	Site Support Craftsman
	Coal Handler	Site Support Craftsman
	Railroad Specialist	Site Support Craftsman
	Railroad Train Operator	Site Support Craftsman
Security	Security Guard	Nuclear Security Officer

Notes for Table 3:

1. Nuclear power plant experience requirement of 4 years
2. Senior Reactor Operator License required
3. Reactor Operator License required
4. Limited to secondary and auxiliary water chemistry analyses

As seen above, comparable roles exist. However, for some roles, transfer from a coal plant to a NuScale nuclear plant position will require additional experience, training, or certification due to the additional requirements for nuclear power plant experience and/or special requirements specific to the job position. The roles listed below offer some examples for which this would be the case:

- **(7) Senior Management** job positions due to nuclear power plant experience requirement of four years
- **(14) Chemistry** job positions due to specific training/education course in radiochemistry (alpha/beta/gamma analysis) and two years of experience with gamma spectroscopy, to include three months of on-site experience with the site-specific Gamma Spectroscopy Instrumentation and Isotopic Reference Library
- **(17) Radiation Protection** job positions due to specific training/education course in radiation protection and participation in radiation protection activities at a nuclear power plant for six months
- **(5) Reactor Engineering** job positions due to two years of the four years of related experience in reactor engineering and an additional one year of nuclear power plant experience
- **(10) Senior Licensed Operator** job positions due to one and a half years of responsible nuclear power plant experience
- **Security** skills and duties are expected to remain comparable to that of a coal plant (e.g., weapon handling)

In most cases, the need for additional or new experience, education, or training can be addressed in a variety of ways. For example, senior managers from coal power plants can make the transition to a comparable position at a NuScale plant through a professional development and training plan that includes participation at an intensive Institute of Nuclear Power Operations (INPO) senior nuclear plant management (SNPM) training course and/or an external secondment to a nuclear power plant. INPO promotes the highest levels of safety and reliability to promote excellence in the operation of commercial nuclear power plants. Additionally, coal power plant chemists can start work at a NuScale power plant but must successfully complete an on-the-job training program in radiochemistry. Lastly, coal power plant field operators could commence work at a NuScale plant as a non-licensed operator and if so desired, pursue certification as a reactor operator after obtaining the required nuclear power plant experience.

Existing coal-fueled power plants have existing infrastructure that can be utilized in a NuScale plant. Our analysis shows that many of the workers at the coal-fueled plants could be easily transitioned to similar positions at a NuScale plant while other positions, requiring greater levels of experience or education, can be addressed in a transition plan. This is likely to be more cost effective since there would be a lesser need for new hires and provides for a positive impact on the local community.

The cost-effective approach of reutilizing existing plant equipment and retraining of current employees, along with zero emission power generation, makes replacing coal fueled plants with NuScale SMRs a viable and necessary solution.

Conclusion

By 2030, the U.S. will see 73 coal power plants enter into retirement, which translates to a loss of 38 GW of capacity. Changing regulatory requirements, a challenging economic environment, and uncertain long-term fossil fuel pricing means that a diverse energy mix is essential to meeting future energy needs. Today, the potential for a carbon-free power sector is moving closer to reality, in part due to the evolution of advanced nuclear technologies like the NuScale SMR; the need for reliable, carbon-free power has never been greater as the U.S. continues along the path of decarbonization of the energy, transportation, and industrial sectors. Many U.S. states have adopted laws requiring 100 percent zero-carbon electricity in the coming years, and many more have or are planning clean energy portfolios—further solidifying the key role that SMRs will have during this clean energy transition across our country.

NuScale's SMR technology development program is very mature and ready for commercialization. NuScale has the only SMR design that is approved by the U.S. Nuclear Regulatory Commission, and its SMR is the only advanced reactor design that has secured and signed an agreement with a U.S. customer, the Utah Associated Municipal Power System (UAMPS), that will bring its first NuScale SMR power plant online in Idaho in 2029. While there are potentially many promising advanced nuclear technologies under development, the majority of those are many years from commercialization. NuScale's SMR is the only near-term deployable economic commercial generation solution for repurposing retiring coal plants in the U.S.

With the UAMPS Carbon Free Power Project in Idaho and subsequent planned deployments, NuScale is ready to meet the diverse clean energy needs of states across the country that seek a reliable, safe, and carbon-free solution for retiring coal power plants while keeping jobs and economic benefits within communities. We have an historic opportunity to maintain the integrity of the coal plant workforce through training programs and an adoption of nuclear safety culture; NuScale's power plant is ideally suited to seamlessly repurpose and revitalize retiring U.S. coal plants and support job retention across America.

NuScale's ability to repurpose the infrastructure of retired coal plants provides an estimated savings in capital costs of $100 million. NuScale plants require cables, piping, steel, fuel assemblies, and other components—yielding economic benefits through a vast supply chain. The future domestic supply chain for manufacturing 36 NuScale Power Modules per year will generate around 13,500 manufacturing jobs and $2 billion in direct and indirect benefits from manufacturing and construction activities over the four-year plant construction period.

In addition to these significant economic benefits, environmental benefits naturally follow when shifting to a carbon-free nuclear energy source like NuScale's that also complements intermittent solar, wind, and hydropower generation. Advanced nuclear technology is revolutionizing our ability to meet carbon emissions reduction goals, mitigate climate change, and create a bright energy future for all. NuScale's groundbreaking SMR technology is redefining what is possible and leading the way into a new frontier of clean energy in the U.S. and beyond with its safe, reliable, and operationally flexible power plant solutions.

APPENDIX A

The American National Standard, "Selection, Qualification, and Training of Personnel for Nuclear Power Plants", ANSI/ANS-3.1-2014, has been referenced as a standard that contains criteria for the selection, qualification, and training of personnel for the operating organization of nuclear power plants.

Definitions

Nuclear power plant experience is defined as applicable work performed in a nuclear power plant (commercial or military) during preoperational, startup testing (which is part of commissioning), construction, or operational activities. With an estimated construction period of 37 months (first nuclear safety-related concrete to project mechanical completion) and an overlapping testing, start-up and commissioning period of 36 months (Commissioning Team training to initial fuel load), a coal power plant worker can gain the required nuclear power plant experience through a well-developed training program that includes coal plant workers in the construction, testing, startup and commissioning of a NuScale power plant to support their training and development.

On-site experience is defined as applicable work performed at the nuclear plant for which the individual seeks qualification. On-site experience is a requirement (per ANSI-ANS and INPO) in the U.S. that is applied to most job positions at any nuclear power plant. The Nuclear Energy Institute (NEI) 06-13A, Template for an Industry Training Program Description[28], provides "cold license guidance"[29] where a training program consisting of at least six months of practical work assignments on-site and successful completion of a site layout course can help meet the requirement. Prior to operation, plant experience requirements specified in Regulatory Guide 1.8 (Revision 3) and ANSI/ANS 3.1-1993 cannot be met. Additionally, other standard guidance for operator selection, training, and qualification cannot be met. Cold licensing of operators provides the method for operations personnel to acquire the knowledge and experience required for licensed operator duties during the unique conditions of new plant construction and initial operation.

Certain job positions also include special requirements (e.g., reactor operating license, weapon handling, radiochemistry sampling, etc.). Past experience can be considered on a case-by-case basis to meet the special requirements.

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[28] Nuclear Energy Institute. (2009). Template for an Industry Training Program Description. Available at https://www.nrc.gov/docs/ML0909/ML090910554.pdf

[29] Prior to operation, plant experience requirements specified in Regulatory Guide 1.8 (Revision 3) and ANSI/ANS 3.1-1993 cannot be met. Additionally, other standard guidance for operator selection, training, and qualification cannot be met. Cold licensing of operators provides the method for operations personnel to acquire the knowledge and experience required for licensed operator duties during the unique conditions of new plant construction and initial operation. Licensing process for operators can be viewed at https://www.nrc.gov/reactors/operator-licensing/licensing-process.html

APPENDIX B

In a NuScale 12-module 924 MWe power plant, an estimated 270 plant personnel will support operations, online maintenance, refueling, outage maintenance, security, and more.

Job Positions	Number
Plant Manager	1
Department Managers	6
Operations	45
Radiation Protection	17
Chemistry	14
Work Control	13
Outage Planning	21
Instrumentation & Controls (I&C)	10
Mechanics	8
Electricians	11
Systems Engineering	9
Reactor Engineering	5
Licensing	5
Emergency Preparedness	2
Training	19
Site Support/Facilities	13
Corrective Action Program (CAP)	2
Supply Chain	5
Fix It Now (FIN) Team	15
Backshift Supervisor	1
Security	48
Total number of positions:	270


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