Resources for Coal Repowering with Nuclear Energy

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NUCLEAR INNOVATION ALLIANCE

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This report is available online at:
https://nuclearinnovationalliance.org/resources

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Executive Summary

This document serves as a high-level introduction to coal repowering with nuclear energy (also known as coal repurposing, or coal-to-nuclear transitions) and a directory of useful resources for those looking to dive deeper into the topics discussed herein. It presents the key concepts, opportunities, and challenges associated with this energy transition, and provides readers with solid foundations and condensed information, facilitating a comprehensive understanding of this subject matter.

This document is intended for a diverse range of stakeholders interested in exploring coal repowering with nuclear energy, and is meant to foster informed decision-making, strategic planning, and meaningful discussions that contribute to coal repowering efforts. Policymakers, industry stakeholders, researchers, community leaders, potential customers, and interested individuals will find a concise overview of coal repowering to help navigate the multifaceted aspects of this energy transition and the extensive body of literature already available.

Each section presents a high-level overview of the topic at hand, and ends with a list of external, more detailed resources for further exploration. These sections cover the following topics:

1. Rising Coal Retirements and the Potential for Repowering with Nuclear
2. Communities in Transition
3. Opportunities and Challenges
4. Current Initiatives and Collaborative Efforts
5. Siting and Screening for Coal Repowering Projects
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9. Timelines: Building Bridges for a Workforce in Transition
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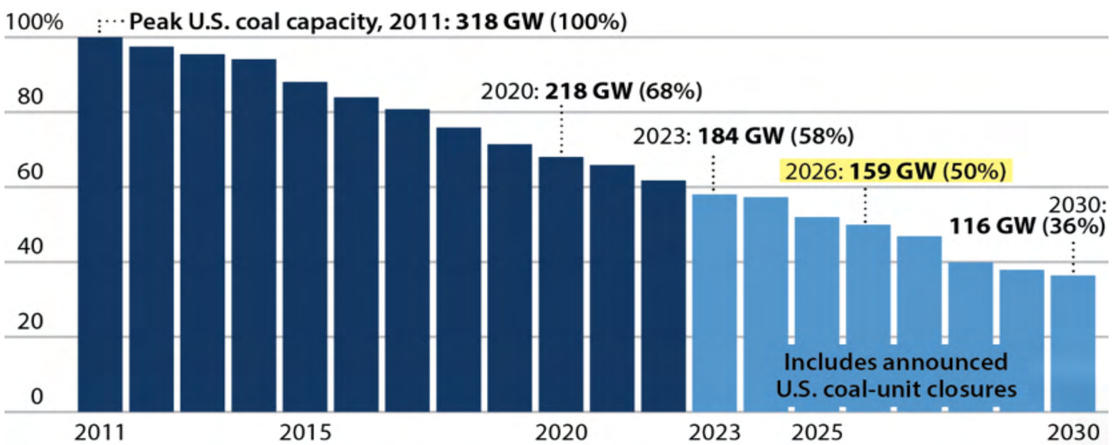
Rising Coal Retirements and the Potential for Repowering with Nuclear Energy

The retirement of coal-fired power plants in the United States has been on the rise in recent years and shows no signs of slowing down. This trend is driven by multiple factors, including federal and state commitments to clean energy, actions taken by utilities to meet clean energy targets, competition from affordable clean energy sources and natural gas, and the aging fleet of coal-fired plants. In recent years, the United States has consistently retired approximately 11 GW of coal capacity annually. This ongoing trend is expected to continue, with projections indicating that by 2026, the country's coal capacity will be reduced to half of its peak in 2011. Looking ahead, it is estimated that up to 80.6 GW of coal capacity will be retired between 2022 and the end of 2030.



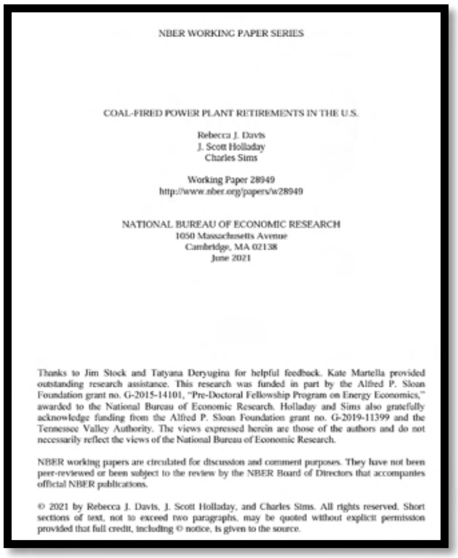
Source: *IEEFA*

Figure 1: Historic and projected coal retirements in the United States

In response to this wave of coal plant retirements, various stakeholders, including government agencies, utilities, private sector innovators, and local communities are actively exploring options to repurpose these retiring coal sites. Advanced nuclear technologies are especially attractive to all these stakeholders because they provide high-quality jobs, a reliable tax base, and clean, safe and resilient energy. Advanced nuclear energy technologies present a unique opportunity to transition from carbon-intensive power generation to low-carbon nuclear energy, addressing climate concerns and enhancing energy security. To fully harness this potential and drive a successful transition, it will be essential for stakeholders to understand advanced nuclear energy's potential and to collaborate, develop innovative repowering strategies, and navigate the regulatory landscape effectively. This period of transformation underscores the importance of proactive planning and policy support to ensure a sustainable and resilient energy future.

Moreover, the shift away from coal highlights the substantial economic impact on communities that have long depended on coal-related industries for jobs and essential benefits. Recognizing the profound implications of coal plant closures on these communities is crucial for achieving a just energy transition. It underscores the importance of implementing comprehensive measures to support affected workers and local economies during this transformation, and the opportunity to support these communities by repowering coal with nuclear energy.

Additional Resources on this Topic:



NBER WORKING PAPER SERIES

COAL-FIRED POWER PLANT RETIREMENTS IN THE U.S.

Rebecca J. Davis
J. Scott Holladay
Charles Sims

Working Paper 28949
http://www.nber.org/papers/w28949

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
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Davis et al. 2021. National Bureau of Economic Research. "Coal-fired Power Plant Retirements in the U.S."

This report summarizes the history of U.S. coal-fired plant retirements over the last decade, describes planned future retirements, and forecasts the remaining operating life for every operating coal-fired generator. It summarizes the technology and location trends that are correlated with the observed retirements, describes a theoretical model of the retirement decisions coal generator owners face, and predicts how much generation capacity will retire in the next twenty years.

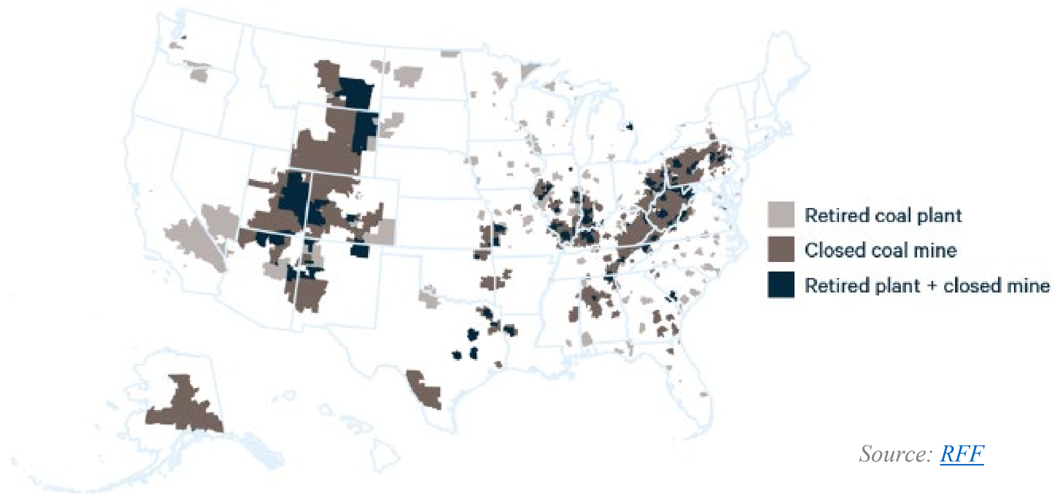
Nuclear Innovation Alliance. 2023. "Advanced Nuclear Reactor Technology: A Primer"

This primer provides basic information on advanced reactors to help the public and stakeholders understand the promise of innovative nuclear technologies. Dozens are under development around the world; this primer focuses on those in the United States and Canada. This document was last updated in July 2023

Communities in Transition

Many communities across the United States heavily rely on aging coal facilities, which have been closing down over the past two decades, leaving these communities vulnerable to economic decline during the transition to zero-carbon energy sources. The number of coal jobs in electric power generation fell by 8,300 positions in 2020, representing the highest annual rate of decline among energy sources. These closures have had a negative impact on local economies. While some coal plant workers find employment in other sectors in the same geographic area, other coal plant workers either relocate or face difficulty finding employment.

Retired coal facilities have a broad impact on communities across the nation, affecting not only the workers who lose their jobs at the power plants but also leading to a decline in coal demand and subsequent loss of mining jobs. These closures create ripple effects that reverberate through local economies, impacting both employment opportunities and the overall economic vitality of coal-dependent regions. The transition away from coal necessitates comprehensive strategies to mitigate these impacts and support affected communities during the shift to cleaner energy sources.



Source: RFF

Figure 2: Location of retired coal plants and closed coal mines in the United States

The emergence of renewable energy jobs in coal communities often falls short in terms of offering comparable salaries and union membership options. These communities seek solutions that can offer high-quality jobs and a reliable tax base while transitioning to new sources of clean and dependable electricity. Repowering fossil fuel facilities with advanced nuclear energy offers a viable solution for ensuring an equitable transition in these communities. By embracing advanced nuclear technologies, these communities can reap economic benefits and witness job creation, providing a promising pathway towards a sustainable and prosperous future. For instance, repowering a 924-MWe coal plant with nuclear energy has the potential to boost regional economic activity by $275 million and create a net gain of 650 new permanent jobs[1], including opportunities for former coal workers to transition to roles in advanced nuclear energy facilities, according to a report by the Department of Energy.

It's worth noting that in the meantime, prior to any possible deployment of an advanced nuclear reactor at a coal site, federal and state governments are making efforts to ensure these communities are not left behind. The U.S. Economic Development Administration's Coal Communities Commitment allocated $551.8M to communities across several programs and states.[2] Colorado has established an Office of Just Transition to aid coal communities in finding new employment opportunities. Similarly, New Mexico created funds for coal community assistance. These initiatives are a great start. In addition to these programs, the allocation of targeted government funding, specifically for coal repowering with nuclear energy, has the potential to provide significant support and momentum for these communities as they navigate the path towards a sustainable and prosperous future.

The loss of aging coal facilities in the United States presents economic challenges for affected communities, as job losses and economic decline can accompany the closure of coal plants. Repowering retired fossil fuel facilities with advanced nuclear energy offers a promising solution for these communities, providing clean and reliable electricity while generating economic benefits and creating new permanent jobs. By embracing advanced nuclear technologies, coal communities can achieve an equitable and sustainable transition to a cleaner energy future.

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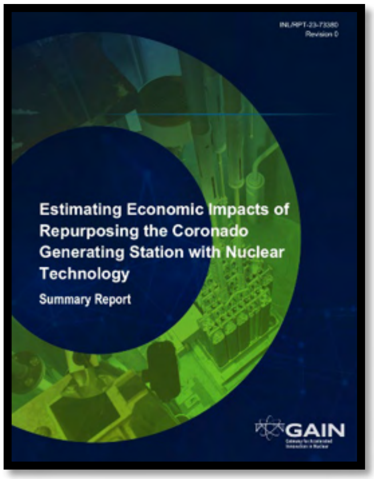
[1] Of these 650 jobs, two thirds are indirect and induced jobs. Indirect jobs are those created in related industries due to the economic activity of the nuclear project. Indirect jobs are those resulting from increased consumer spending by individuals who earn income from direct and indirect employment.

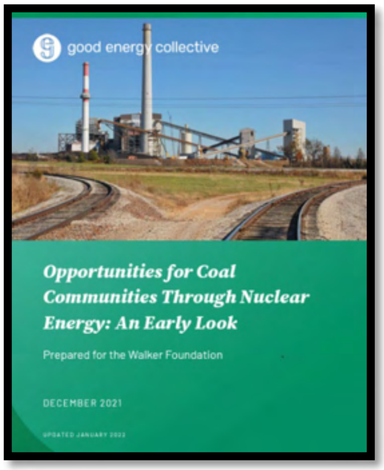
[2] States include: Alaska, New York, Oklahoma, Pennsylvania, and West Virginia. Programs include: the American Rescue Plan programs, Economic Adjustment Assistance program, and the Build Back Better Regional Challenge.

Additional Resources on this Topic:



Gateway for Accelerated Innovation in Nuclear. 2023. "Estimating Economic Impacts of Repurposing the Coronado Generating Station with Nuclear Technology"

This report describes the socioeconomic characteristics of these counties and then provides the results of a comparison between two states of the world: one where CGS runs as a coal power plant and one where it runs as a nuclear power plant. The analysis measures economic impacts to jobs, labor income in the region, value added (i.e., new economic activity) and economic output. These metrics are assessed at the level of the power plant (direct impacts), at the supply chain supporting the power plant (indirect impacts), and in the community surrounding the power plant (induced impacts).



Toth et al. 2021. Good Energy Collective. "Opportunities for Coal Communities Through Nuclear Energy: An Early Look"

This report discusses the need for economic revitalization in communities that have relied on coal plants for employment, tax revenue, and electricity. It highlights preexisting policy efforts to support coal communities' transition to nuclear energy and identifies suitable locations for coal repowering based on environmental, legal, technical, and social criteria.

ScottMadden Management Consultants. 2021. "Gone with the Steam: How new nuclear power plants can re-energize communities when coal plants close".

This report explores the economic implications of retiring coal-fired generation plants in local communities, and focuses on job impacts, wages, career opportunities, and other economic and workforce aspects of a coal repowering.

Delta Institute. 2014. "Transforming Coal Plants into Productive Community Assets"

Delta Institute conducted a national scan of coal plant redevelopment efforts across the country and developed this report, detailing how communities have redeveloped those sites. This report presents its results and discusses how to achieve a successful model for coal community redevelopment after a coal power plant closure, and the challenges associated with such closures and redevelopment.

Opportunities and Challenges

Coal repowering[3] can play a key role in meeting climate goals and providing benefits to coal communities. These transitions offer the potential to deploy advanced nuclear reactors[4] to create a sustainable future and breathe new life into local communities negatively affected by coal facility closures. By replacing coal-fired facilities with advanced nuclear energy, substantial reductions in greenhouse gas emissions can be achieved, while also unlocking numerous environmental, economic, and communal benefits. However, to fully realize these benefits, it is crucial to address and overcome the challenges that lie ahead.

These transitions involve repurposing retired or soon-to-be-retired coal power plants sites to deploy advanced nuclear reactors. This involves the decommissioning and remediation of the existing coal site, and construction and operation of advanced nuclear power plants. These transitions can offer several advantages to advanced reactor developers, local communities, and society as a whole, including:

- *Clean Energy Transition* – Increases the deployment of clean, safe, reliable nuclear energy, decreases the release of greenhouse gases, and helps to mitigate climate change.
- *Improved public health* – By reducing emissions of air pollutants, like particulate matter, associated with coal combustion, coal repowering has the potential to improve public health outcomes, leading to reduced respiratory diseases and other health-related issues.
- *Repurposing Existing Site Assets* – Retired coal sites still possess key assets including grid access and infrastructure needed to build and operate advanced nuclear power plants (e.g., transmission lines, substation equipment, water access, steam cycle components, auxiliary buildings, water supply, and transportation access). Reusing this infrastructure can reduce overall costs of the plant, making advanced nuclear energy more cost competitive.
- *Community Economic Revitalization* – When a coal-fired power plant is retired, it can leave a significant economic void in the local community. However, by building an advanced nuclear power plant at a former coal site, the community can experience economic revitalization. The advanced nuclear plant can serve as a new economic driver, providing an economic stimulus, supporting local businesses, and supporting supply chains.
- *Job Creation* – While some jobs are lost during a coal retirement, others can be saved, and new jobs can be created. Coal repowering can create direct job opportunities for certain positions that were previously held in the coal plant. These include highly skilled jobs such as pipe fitters and welders, who play crucial roles in the construction, operation, and maintenance of nuclear power plants. Additionally, this transition generates indirect job growth within the community. Moreover, the overall economic boost from job creation can lead to the emergence of additional employment opportunities in diverse industries, fostering a thriving and resilient community.
- *Commercialization of Advanced Nuclear Energy* – The first advanced reactors are expected to be operational in the late 2020s and early 2030s. It is essential to accelerate the large-scale deployment of advanced nuclear energy to meet midcentury climate goals. Utilizing the benefits of

[3] In this document, the phrase "coal repowering" refers specifically to "coal repowering with nuclear energy".
[4] The term "Advanced Nuclear Reactor", as defined in 42 U.S.C. 16271 and within the context of this document, means a nuclear fission reactor with significant improvements compared to reactors operating in December, 2020.

coal sites for deploying next-generation nuclear reactors offers a viable pathway to commercialization of these technologies and places communities that host advanced reactors at the forefront of a clean energy transition with numerous opportunities.

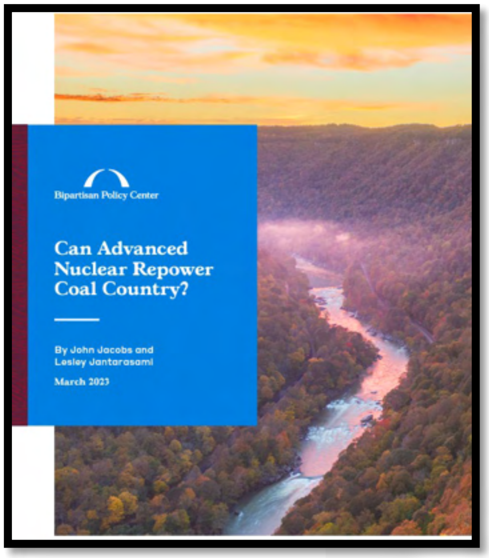
While these transitions offer numerous benefits, there are several obstacles that must be overcome to ensure their successful implementation. These challenges include:

- *Timing* – Ensuring smooth transitions requires careful coordination, aligning decommissioning of coal plants with construction of nuclear facilities. Delays may hinder skilled labor utilization, increase cost, and overall, negatively impact the success of the project.
- *Site Remediation* – This involves addressing environmental contamination, ensuring safe disposal of coal ash, and managing other former coal-site byproducts, to prepare for nuclear plant construction. This process could contribute to project delays and additional costs depending on the extent of remediation required. Additionally, it can shrink the pool of candidate sites that are able to be repowered with nuclear energy.
- *Licensing and Regulation* – Navigating the complex regulatory processes associated with licensing and permitting nuclear power plants can be time-consuming and resource-intensive. Licensing for coal repowering necessitates a comprehensive understanding of both the transition process and the regulatory frameworks applicable to advanced nuclear technologies. Licensing complexities unique to coal repowering projects involve regulations on repurposing existing coal sites, which may require different regulatory considerations and approvals for the transition. The regulatory processes for decommissioning and repurposing the coal infrastructure, as well as obtaining permits for the construction and operation of advanced nuclear reactors, may have unique requirements compared to traditional nuclear projects. However, legislative efforts are underway to help overcome these challenges, and certain regulatory burdens may be lessened. For example, coal sites may already have water usage and effluent permits that may streamline re-permitting for nuclear power plants.
- *Community Acceptance* – Gaining community acceptance and support for coal repowering is vital. Addressing concerns related to safety, environmental impacts, and economic considerations is essential for fostering trust and collaboration among stakeholders.
- *Workforce Transition* – Transitioning from a coal-based economy to a nuclear-centric one requires some degree of workforce retraining and reemployment strategies. Ensuring a smooth transition for coal plant workers by providing training programs and opportunities for employment in the nuclear industry is essential for minimizing the loss of skilled labor.
- *Financing and Investment* – Securing adequate financing and investment for the development and construction of advanced nuclear power plants is a significant challenge. Innovative financing mechanisms and incentives are needed to attract private investment and ensure the financial viability of coal repowering projects. This is especially challenging for First of a Kind (FOAK) projects.
- *Fuel Cycle Considerations* – Understanding the coal and nuclear fuel cycle is essential. The transition from coal-to-nuclear necessitates a shift in thinking about fuel supplies and considerations for safety, reliability, and resiliency.

- *Cost* – While site and equipment repurposing can reduce overall cost, care must be taken so complications associated with repurposing efforts don't escalate and lead to unanticipated cost overruns. Without proper project management, what was once a cost savings measure could balloon into a cost overrun. Additionally, site cleanup, and other costly activities might make a specific site not economically viable for a coal repowering. This is why care should be taken when selecting a site to ensure the maximum benefit, and cost factors including coal power plant removal and requalification, remediation, overnight capital, Nuclear Regulatory Commission (NRC) licensing costs, and more, should be well understood.

Addressing these challenges requires collaboration among policymakers, industry stakeholders, communities, and experts to develop effective strategies, policies, and frameworks that facilitate a successful transition. Coal repowering has garnered significant support at both the federal and state levels. However, to fully harness the benefits of coal repowering, it is imperative to reduce barriers associated with the use of advanced nuclear technologies at existing fossil fuel sites. By proactively addressing these barriers, the potential benefits of repurposing coal sites for advanced nuclear power plants can be realized.

Additional Resources on this Topic:

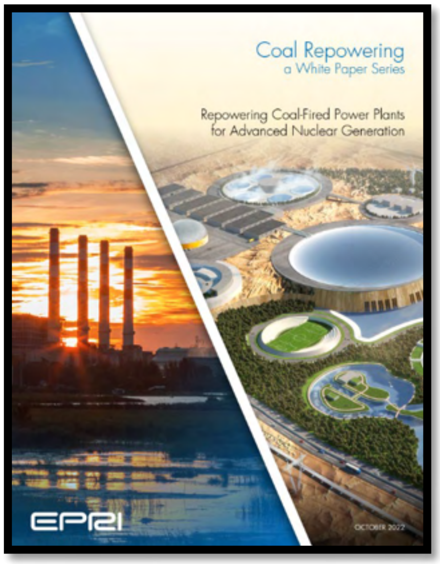


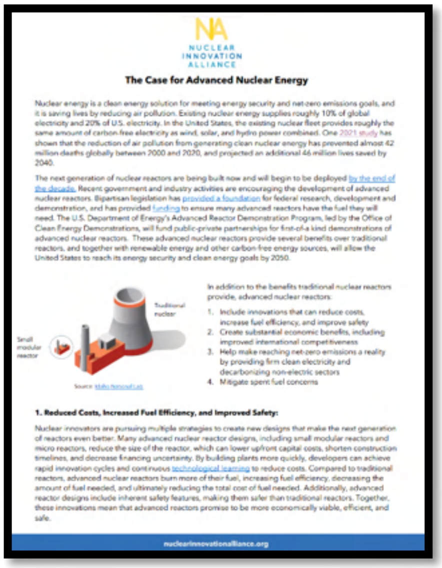
Jacobs, Jantarasami. 2023. Bipartisan Policy Center. "Can Advanced Nuclear Repower Coal Country?".

This report analyzes the benefits and challenges of coal repowering and highlights recent legislation that may hasten such a transition. Specifically, it addresses the benefits of advanced nuclear reactors, estimated savings of repurposing coal plant infrastructure for nuclear energy, transferring the skills of the coal power plant industry workers to nuclear energy, timing of a the transition, regional economic considerations, suitable locations for a transition, and recent congressional progress on enabling coal repowering.

Electric Power Research Institute. 2022. "Coal Repowering -- a White Paper Series: Repowering Coal-Fired Power Plants for Advanced Nuclear Generation".

In this white paper, EPRI explores the advantages of repowering coal plants into clean energy generators, and discusses numerous benefits of coal repowering, such as the opportunity to leverage existing site infrastructure, permits, equipment, and facilities for future clean power generation and energy storage projects. Additionally, this white paper discusses how repowering can lead to social and economic advantages for the local community by preserving jobs and tax revenue.

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The Case for Advanced Nuclear Energy

Nuclear energy is a clean energy solution for meeting energy security and net-zero emissions goals, and it is saving lives by reducing air pollution. Existing nuclear energy supplies roughly 10% of global electricity and 20% of U.S. electricity. In the United States, the existing nuclear fleet provides roughly the same amount of carbon-free electricity as wind, solar, and hydro power combined. One 2021 study has shown that the reduction of air pollution from generating clean nuclear energy has prevented almost 42 million deaths globally between 2000 and 2020, and projected an additional 46 million lives saved by 2040.

The next generation of nuclear reactors are being built now and will begin to be deployed by the end of the decade. Recent government and industry activities are encouraging the development of advanced nuclear reactors. Bipartisan legislation has provided a foundation for federal research, development and demonstration, and has provided funding to ensure many advanced reactors have the fuel they will need. The U.S. Department of Energy's Advanced Reactor Demonstration Program, led by the Office of Clean Energy Demonstrations, will fund public-private partnerships for first-of-a kind demonstrations of advanced nuclear reactors. These advanced nuclear reactors provide several benefits over traditional reactors, and together with renewable energy and other carbon-free energy sources, will allow the United States to reach its energy security and clean energy goals by 2050.

Traditional nuclear
Small modular reactor
Source: Idaho National Lab

In addition to the benefits traditional nuclear reactors provide, advanced nuclear reactors:

1. Include innovations that can reduce costs, increase fuel efficiency, and improve safety
2. Create substantial economic benefits, including improved international competitiveness
3. Help make reaching net-zero emissions a reality by providing firm clean electricity and decarbonizing non-electric sectors
4. Mitigate spent fuel concerns

1. Reduced Costs, Increased Fuel Efficiency, and Improved Safety:

Nuclear innovators are pursuing multiple strategies to create new designs that make the next generation of reactors even better. Many advanced nuclear reactor designs, including small modular reactors and micro reactors, reduce the size of the reactor, which can lower upfront capital costs, shorten construction timelines, and decrease financing uncertainty. By building plants more quickly, developers can achieve rapid innovation cycles and continuous technological learning to reduce costs. Compared to traditional reactors, advanced nuclear reactors burn more of their fuel, increasing fuel efficiency, decreasing the amount of fuel needed, and ultimately reducing the total cost of fuel needed. Additionally, advanced reactor designs include inherent safety features, making them safer than traditional reactors. Together, these innovations mean that advanced reactors promise to be more economically viable, efficient, and safe.

nuclearinnovationalliance.org

Nuclear Innovation Alliance. 2023. "The Case for Advanced Nuclear Energy"

This fact sheet gives the case for why we need advanced nuclear energy. It discusses the many benefits advanced nuclear energy has to offer and why we need them to meet our energy security and net-zero emissions goals.

Current Initiatives and Collaborative Efforts

The transition from coal to nuclear energy has gained significant attention as communities and utilities seek cleaner and more sustainable alternatives. Extensive efforts are underway to explore and advance coal repowering efforts and involve various stakeholders. Organizations, including advanced reactor developers, industry, states, government agencies, and research institutions are actively engaged in demonstrating the technical feasibility, economic viability, and regulatory aspects of repurposing coal sites for advanced nuclear power plants. These initiatives aim to provide valuable insights, gather data, and develop best practices to guide successful transitions.

By leveraging existing assets and collaborating on innovative solutions, these stakeholders aim to achieve cleaner, more reliable, and economically viable energy systems. A wide range of initiatives, including funding opportunities, analysis, tax incentives, and policy frameworks have been established to foster the development and implementation of advanced nuclear technologies for coal repowering. Although only one coal-to-nuclear project is currently underway in the United States, the ongoing efforts to evaluate, plan for, and accelerate these projects signify increasing commitment to a sustainable and low-carbon energy future that is supported by nuclear energy.

Advanced Reactor Developers:

Companies like X-energy and TerraPower, two prominent advanced reactor developers, are on the forefront of coal repowering. X-energy, in collaboration with the Maryland Energy Administration, published a feasibility assessment and economic evaluation for repurposing a coal-fired facility in Maryland with a Xe-100 small modular reactor. Meanwhile, TerraPower has already identified a site near the Naughton Power Plant in Kemmerer, Wyoming, as the location for their first Natrium sodium fast reactor. This site was selected after an extensive evaluation process involving multiple locations, and meetings with members from each community. When selecting this site, TerraPower evaluated a variety of factors, including community support, site characteristics, ability to obtain an NRC license, access to infrastructure, and the needs of the grid.

Utility Partnerships:

Utilities are also recognizing the potential of coal repowering with nuclear energy as a means to meet clean energy goals.

- PacifiCorp, a regulated utility that includes Rocky Mountain Power, has partnered with TerraPower to conduct a joint study to evaluate the feasibility of deploying up to five additional Natrium reactors near existing fossil-fueled generation sites in Wyoming and Utah. PacifiCorp's 2023 Integrated Resource Plan (IRP)[5] includes the addition of 1,500 MW of advanced nuclear energy by the end of 2032 to replace lost coal fired generation capacity.
- Duke Energy released an IRP that includes three potential energy portfolios for North Carolina and South Carolina. All three see coal-fired plants being phased out by 2035, and project nuclear energy to provide 68-70% of the total energy mix, as

[5] An IRP is a "road map" that identifies potential plans for a utility to meet future energy and demand requirements while considering the associated risks and benefits to customers. (Source: Duke Energy)

shown in the figure below. Additionally, Duke has proposed building new nuclear reactors at its Belews Creek site, a coal and natural-gas fired power plant site in North Carolina.

- Dominion is also looking to engage in coal to nuclear transitions and have stated they are looking at deploying nuclear energy at facilities that either have operating fossil fuel plants or fossil fuel plants that will soon retire.
- Salt River Project, a community-based not-for-profit organization that provides power to more than 2 million people in central Arizona, is considering converting its coal-fired Coronado Generation Station into an advanced nuclear generation site.
- The Tennessee Valley Authority is planning to phase out its coal generation by 2035, and will look to nuclear energy to fill in the gap. They have even established a new program to explore advanced nuclear energy options as an essential component of TVA's decarbonization efforts.

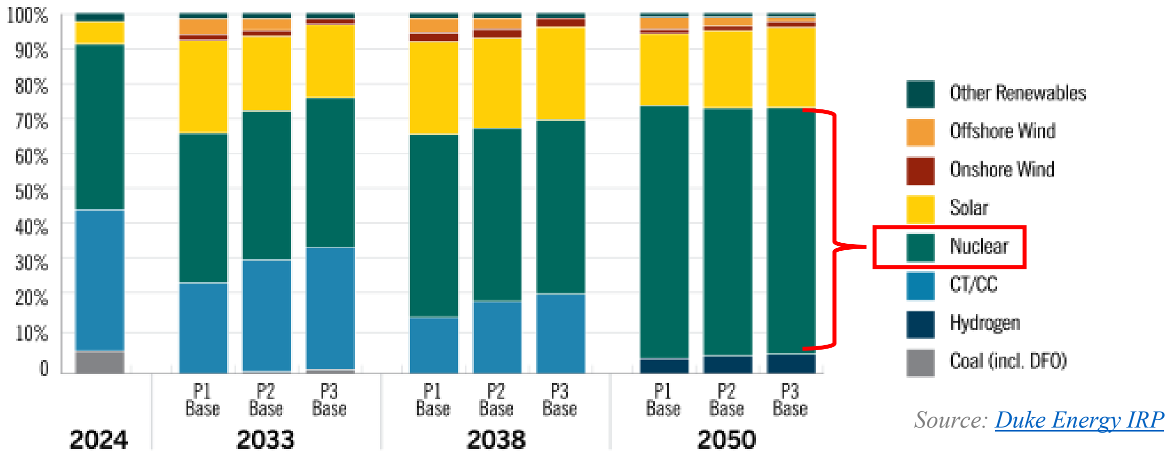


Figure 5: Modeled energy mix for each portfolio in the Duke Energy Carolinas IRP

Federal Support:

The U.S. Department of Energy, as well as DOE's national laboratories are playing a large role in performing research and providing information to help overcome challenges, and ensure the success, of coal repowering with nuclear energy. Congress has also recently enacted legislation that supports the development of coal repowering projects through a wide range of incentives. The Inflation Reduction Act (IRA) includes tax credits for advanced nuclear energy. Of note, the IRA includes a Clean Electricity Production Credit (PTC) and Investment Tax Credit, both of which get an additional 10% boost (referred to as the Energy Community Tax Credit Bonus), if projects are located within an energy community. The CHIPS and Science Act authorized $800 million to help to develop advanced nuclear reactors in coal communities. Additionally, the Infrastructure Investment and Jobs Act authorized assistance for identifying suitable locations for the deployment of advanced nuclear reactors in isolated communities.

DOE's Loan Program Office (LPO) can help finance coal repowering efforts. LPO's Title 17 Clean Energy Financing Program, which has $2.5 billion of loan guarantees available for financing projects that deploy new or significantly improved high-impact clean energy technology, includes advanced nuclear energy. This financing opportunity could be significant for developers looking for loan assistance when pursuing coal repowering, provided they can meet LPO's criteria.

Energy Communities Interagency Working Group:

President Biden signed an executive order creating the Interagency Working Group on Coal and Power Plant Communities and Economic Revitalization (i.e., the Energy Communities IWG). It was established to support communities affected by changes in the energy sector, particularly those impacted by the transition away from fossil fuels, and its primary goal is to help these communities diversify their economies, create new job opportunities, and support a just and equitable transition. The Energy Communities IWG has multiple resources meant to serve communities in the midst of energy transitions. The Energy Community Tax Credit Bonus Map helps identify where the 10% PTC and ITC bonus can be utilized to spur new investments in projects located in these communities. The Designated Energy Communities Map helps in identifying the communities that may qualify for the Advanced Energy Project Credit (i.e., the 48C tax credit). The Advanced Energy Project Credit was established by the American Recovery and Reinvestment act of 2009, and expanded with a $1.6 billion investment in the Inflation Reduction Act specifically for energy communities. The working group has also created a coal power plant redevelopment visualization tool that serves as a public database and map to enable state and local economic development officials, project developers, and power plant owners to identify and pursue opportunities for plant redevelopment and community reinvestment.

In April 2021, Energy Communities IWG published an initial report describing mechanisms for supporting and revitalizing the economies of coal power plant communities. It identified (1) a set of communities across the country hard-hit by coal mine and coal power plant closures, which should be prioritized for focused federal investment; (2) existing federal programs with potentially available funding totaling nearly $38 billion that could be used to provide immediate investments in energy communities; and (3) immediate steps the Energy Communities IWG should take within the next year to support energy communities. Additionally, in April 2023, the working group published a follow-up report that outlines the transformative activities the Biden Administration has taken since January 2021 to provide robust outreach and engagement with energy communities, and to ensure real investments continue flowing to those communities through strategic agency efforts and implementation of the major legislation signed in 2021 and 2022.

Finally, the Energy Communities IWG has a wide range of funding opportunities that could be applied to coal repowering activities, including the Area Development Program, which has $60 million of funding available for investing in critical infrastructure, business, and workforce development within the Appalachian Region. While this funding opportunity does not explicitly mention it is available for nuclear energy projects, it does not explicitly prohibit them, and coal repowering projects could fit within the Area Development Program project guidelines, depending on the individual project being considered. Similarly, the Rural Economic Development Loan & Grant Program has $1.5 million of funding available for projects that will create and retain employment in rural areas, and that may be applicable for the right coal repowering project. Additionally, the Capacity Building for Repurposing Energy Assets program has $3.5 million of funding available, and seeks to support local governments and communities in capacity building and workforce development planning within areas that host existing energy assets that have retired, or are slated for retirement, and that comprise or comprised a significant portion of local activities

State Interest:

Several states are considering coal repowering as a means to facilitate a clean energy transition and stimulate economic growth within their borders, including:

- Wyoming has provided funding and governor support, and local tribes and communities have worked with TerraPower and PacifiCorp throughout the development of the Natrium project. Wyoming also recently published their Wyoming nuclear energy strategic framework and roadmap.
- Maryland's Energy Administration, in collaboration with X-energy, MPR Associates, and Frostburg State University published a feasibility assessment and economic evaluation for repurposing a coal-fired facility in Maryland with a Xe-100 small modular reactor (SMR). In this assessment, the authors found that deploying a four-unit Xe-100 SMR may be feasible from an engineering and cost perspective, although several characteristics of the site, including the site boundary, electrical interconnection, and site emergency support, present challenges.
- Nebraska has a Nuclear Siting Feasibility Study Program, which awarded the a Nebraska Public power district a grant for conducting a feasibility study to assess siting options for new advanced nuclear reactors throughout Nebraska and existing electric generation facilities based on key compatibility assets for advanced nuclear reactors.
- Hawai'i established a "Powering Past Coal Task Force" in 2021 to track, coordinate, and facilitate the progress of projects intended to replace coal plants.

Other states are actively working to expedite the deployment of advanced nuclear energy more broadly and are taking proactive measures to support and promote these initiatives.

- Alaska, in August 2023, published permitting requirements for siting nuclear facilities within Alaskan borders, to help facilitate the US Air Force Microreactor Pilot Program's efforts to deploy a microreactor at Eielson Air Force Base in Alaska.
- Virginia has several initiatives that aim to help deploy advanced nuclear energy in the commonwealth, including the Virginia Nuclear Energy Consortium, the Nuclear Innovation Hub, and a SMR feasibility study that investigates coal repowering with nuclear energy.
- Kentucky has established a nuclear development workgroup focused on exploring the potential for advanced nuclear energy.
- Tennessee's governor appointed a 22-person council to promote nuclear power in the state, which will be made up of industry, policy, and academic members.

It is critical to ensure that efforts like these are driving the coal repowering conversation forward and successfully demonstrating projects that pave the way for more to come. However, it should be noted that twelve states currently have restrictions on constructing new nuclear power plants. Most recently, Illinois Governor J.B. Pritzker vetoed a bill that would have ended the state's moratorium on new nuclear construction, underscoring the need for continued efforts to advocate for policy changes and build momentum toward a more widespread embrace of advanced nuclear technologies.

Community Initiatives:

Communities heavily reliant on coal face economic challenges as aging coal facilities retire. These communities are increasingly looking to coal repowering as an opportunity for revitalization. As previously mentioned, the Energy Communities IWG supports communities affected by transitions away from fossil fuels. Additionally, the U.S. Economic Development Administration's Coal Communities Commitment and various state-level initiatives provide funding and support to aid in the transition of these communities. This demonstrates a recognition of the importance of ensuring a just and sustainable transition for coal plant workers and the economic well-being of affected regions.

Job training and retraining plans are being established for the Natrium Project in Kemmerer, Wyoming, by TerraPower and PacifiCorp in conjunction with the University of Wyoming and local community colleges.

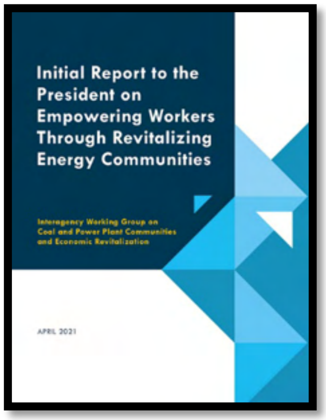
Research and Policy Studies:

Various agencies, research organizations, and think tanks are conducting studies, looking into community engagement and outreach, and providing policy recommendations to support coal repowering. This work contributes to the ongoing discussions and planning for successful transitions. These efforts include work performed by: Bipartisan Policy Center, Breakthrough Institute, Department of Energy National Labs, Gateway for Accelerated Innovation in Nuclear, Electric Power Research Institute, Good Energy Collective, Nuclear Energy Institute, and TerraPraxis.

International Efforts:

In addition to domestic initiatives, international efforts are also promoting coal repowering globally. Partnerships between American advanced reactor developers and international utilities highlight collaborative efforts to support this transition worldwide. For example, NuScale and RoPower Nuclear from Romania are actively involved in a feasibility study for the construction of NuScale's VOYGR-6 small modular reactor power plant at a former Romanian coal plant. Additionally, the International Atomic Energy Agency (IAEA) also coordinates webinars where researchers present coal repowering initiatives from partner nations.

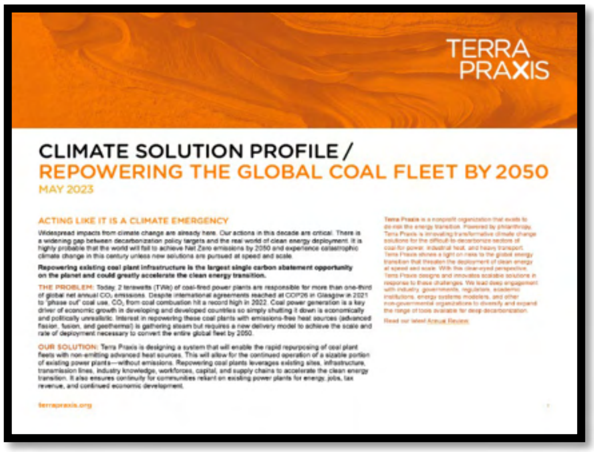
Additional Resources on this Topic:



The [Interagency Working Group on Coal and Power Plant Communities and Economic Revitalization]() supports communities affected by changes in the energy sector, particularly those impacted by the transition away from fossil fuels. Its primary goal is to help these communities diversify their economies, create new job opportunities, and support a just and equitable transition. The working group has multiple resources meant to serve communities in the midst of energy transitions, including an energy community tax credit bonus map, designated energy communities map, and coal power plant redevelopment visualization tool.

TerraPraxis. 2023. "[Repowering the Global Coal Fleet by 2050]()".

TerraPraxis is designing a system that will enable the rapid repurposing of coal plant fleets with non-emitting advanced heat sources. This will allow for the continued operation of a sizable portion of existing power plants—without emissions.


TERRA PRAXIS

CLIMATE SOLUTION PROFILE /
REPOWERING THE GLOBAL COAL FLEET BY 2050
MAY 2023

ACTING LIKE IT IS A CLIMATE EMERGENCY

Repowering existing coal plant infrastructure is the largest single carbon abatement opportunity on the planet and could greatly accelerate the clean energy transition.

THE PROBLEM:

OUR SOLUTION:

terrapraxis.org

American Nuclear Society. 2022. "[Powering our Future: The Coal to Nuclear Opportunity]()"

This hour-long webinar, moderated by Christine King (GAIN), includes presentations by Patrick Burke (Xcel Energy), Andrew Griffith (DOE), Carol Lane (X-energy), Jessica Lovering (Good Energy Collective), and Kenya Stump (Kentucky State Government), and discusses the challenges that still remain to unlock the full potential of a large-scale coal to nuclear transition in the U.S.

Siting and Screening for Coal Repowering Projects

While a large number of coal facilities are nearing retirement, not all are suitable for repurposing with nuclear energy. Numerous factors must be considered when assessing a coal site's potential for repowering with nuclear energy, and identifying viable candidates is a crucial initial step in any coal repowering project, as is recognizing opportunities and challenges for each site.

The process for siting a coal repowering site can generally be described using the steps shown below:

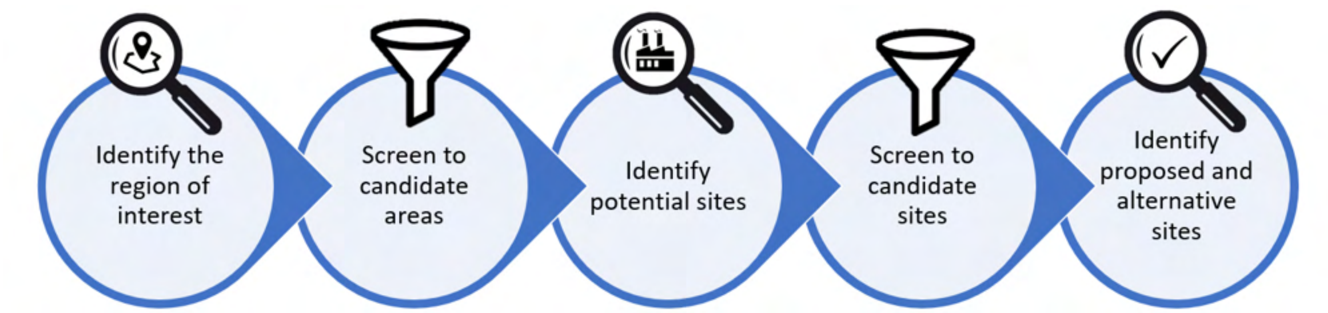
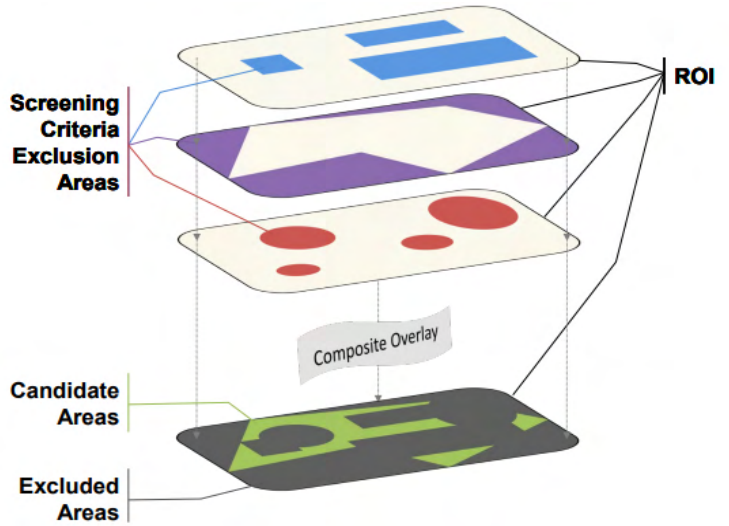


Figure 3: Steps in the siting process

Once a general region of interest is selected, the next step towards siting for coal repowering begins with screening, where specific criteria are applied to filter out areas that do not meet basic requirements. This initial, high-level assessment aims to create a shortlist of areas that are generally favorable for coal repowering. Screening criteria for this step in the siting process can include avoidance factors related to regulatory and environmental considerations. For example, geology/seismology data can be used to identify areas that exceed certain thresholds and make the area not favorable for new construction. A visual representation of three layers of screening criteria, and the resulting candidate areas, can be shown below.



Source: [Electric Power Research Institute]

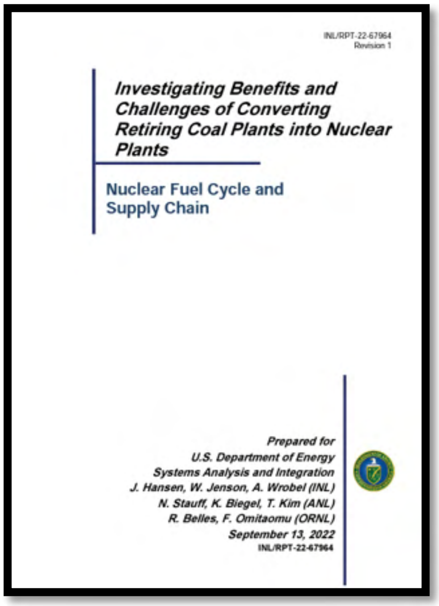
Figure 4: Visualization of the screening process

This initial round of screening can help effectively narrow down areas of interest to identify a smaller pool of potential sites, providing interested stakeholders with a more focused selection of coal facilities with the potential for a successful transition to nuclear energy. During the site selection process, owners and operators will carefully tailor potential sites to match their specific needs and preferences. However, the siting process up to this point is relatively high-level, lacking an in-depth exploration of site-specific nuances and a holistic look at the entire site and its surroundings.

Once potential sites have been identified, a more comprehensive siting analysis must be performed to evaluate site-specific details and ultimately determine a proposed site. This step involves a meticulous assessment of the sites that are found within the screened area. This assessment will apply another set of site-specific screening criteria to filter out coal repowering candidates at the site level and can include a thorough evaluation of each site's existing infrastructure, environmental conditions, and unique challenges. For example, siting will involve in-depth analysis of a site's population density, floodplain, fault lines, soil stability, and proximity of protected lands Additionally, coal plants older than a predefined number of years may be deemed not suitable due to the considerable aging of the site and the extensive restoration efforts required, and facilities that aren't owned and operated by a utility or independent power producer (e.g., coal facilities owned by universities) could be screened out given they aren't ideal first movers for such a project. Therefore, this step in the siting process is much more time-consuming and resource-intensive, as it pinpoints coal repowering sites with a higher degree of granularity using a detailed siting analysis.

Several entities have investigated the siting considerations for U.S. coal facilities to identify what sites are appropriate for coal repowering. Specifically, a U.S. Department of Energy report on the feasibility of coal repowering includes a siting analysis, which found that 80% of retired and operating coal power plant sites could host an advanced nuclear reactor, paving the way for 263.3 GW of coal-to-nuclear replacement projects across the United States. Similarly, a report from the Good Energy Collective identified 79 sites that would be suitable for coal-to-nuclear repowering.

Additional Resources on this Topic:

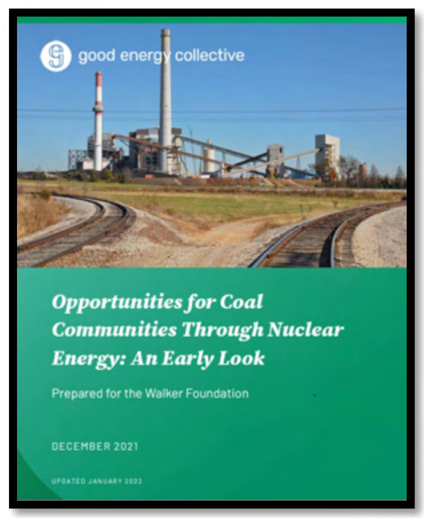


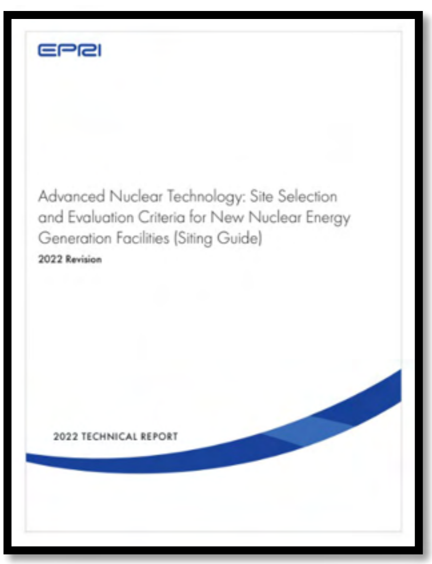
Department of Energy. 2022. "Investigating Benefits and Challenges of Converting Retiring Coal Plants into Nuclear Plants".

A comprehensive overview that aims to answer three questions: where in the United States are retired coal facilities located and what factors make a site feasible for transition; what factors of technology, cost, and project timeline drive investor economics over such a decision; and how will coal repowering with nuclear energy impact local communities. Of note, the study includes a siting analysis, and evaluates the siting characteristics of recently retired and operating coal plant sites.

Toth et al. 2021. Good Energy Collective. "Opportunities for Coal Communities Through Nuclear Energy: An Early Look"

This report discusses the need for economic revitalization in communities that have relied on coal plants for employment, tax revenue, and electricity. It highlights preexisting policy efforts to support coal communities' transition to nuclear energy and identifies suitable locations for coal repowering based on environmental, legal, technical, and social criteria.





Electric Power Research Institute. 2022. "Advanced Nuclear Technology: Site Selection and Evaluation Criteria for New Nuclear Energy Generation Facilities (Siting Guide)—2022 Revision".

This report provides guidance for organizations on conducting studies that will support both a sound business decision for their proposed site for a new nuclear plant and regulatory review of the application for a new nuclear plant. The primary audience for this report includes future owner-operators, technology developers and vendors, and engineering firms interested in or pursuing the siting of a new nuclear energy generation facility (nuclear plant) and developing associated licensing applications.

Costs of Coal Repowering with Nuclear Energy

Understanding the costs associated with coal repowering with nuclear energy is crucial for assessing the economic feasibility and viability of such a transition. Upfront capital costs and the levelized cost of electricity for advanced nuclear energy could be lowered by roughly 28-35%, and 9-28%, respectively, under the right conditions. Achieving this cost reduction and ensuring the successful implementation of a project rely on comprehensive cost assessments, accurate budgeting, and effective financial planning. By gaining a deeper understanding of the cost factors associated with these transitions, stakeholders can make informed decisions, develop realistic timelines, and allocate resources appropriately. Examining these factors will shed light on the financial implications and challenges associated with transitioning from coal to nuclear power, ultimately supporting the development of sustainable and economically viable energy strategies. By ensuring a robust understanding of costs, stakeholders can effectively manage financial risks, maximize cost-efficiency, and facilitate the successful implementation of coal repowering projects.

The major cost factors unique to coal repowering with nuclear energy fall into several categories. These include the following:

- *Coal Power Plant Removal* – If a nuclear power plant is built on a former coal plant site, the existing coal infrastructure that will not be reused must be decommissioned and removed. This process involves dismantling and disposing of the coal-fired boilers, generators, and other coal-related components.
- *Remediation* - The process of addressing and mitigating environmental contamination or damage at a site. Remediation involves various techniques and activities aimed at cleaning up polluted soil, water, or air and restoring the site to a safe and environmentally acceptable condition. For example, the costs associated with ash removal of certain elements can include transportation, storage, treatment (if required), and final disposal, adhering to environmental regulations.
- *Repurposing Infrastructure* – The process of repurposing the existing coal infrastructure for the nuclear power plant. It involves assessing and ensuring that certain elements of the coal site, such as transmission lines, substation equipment, auxiliary buildings, or water supply systems, can be safely and effectively reused for advanced nuclear reactors. To learn more about repurposing, see this document's chapter on "*Reusing Infrastructure*".
- *Transmission and Grid Upgrades* – Existing transmission lines may be used to connect the new powerplant to the grid, as building new transmission can be very costly. In fact, transmission access is often a key benefit of repurposing an existing coal site. However, transitioning from a coal plant to a nuclear facility may require upgrades to the electrical transmission infrastructure and grid connections. This can include expanding transmission capacity, installing new substations or transformers, improving grid stability, and maintaining transmission rights to accommodate the increased power

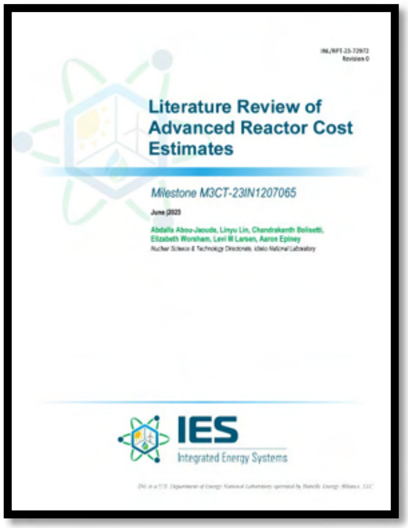
generation from the nuclear plant. The costs associated with these upgrades are, in a sense, repurposing costs. However, they are worth calling out specifically.

Like any large construction project, coal repowering projects will incur costs related to construction, operation, and licensing. These costs are discussed below, and while they are generally applicable to all nuclear power plant projects, the nuances of coal repowering can impact the total cost for each category depending on the specific site and the project. For example, receiving a license to construct and operate a nuclear power plant at a former coal site involves unique challenges that are specific to that site.

- *Overnight Capital Cost* - Expenses associated with designing, engineering, and constructing the nuclear power plant. These costs encompass site preparation, reactor components, safety systems, electrical infrastructure, and other necessary facilities. Overnight capital costs are a significant portion of the total project cost and play a crucial role in determining the feasibility and economic viability of a project. On top of these costs, finance charges like the loans, interest, and fees associated with borrowing capital to finance the overnight capital costs, contribute to the overall cost of a project.
- *Operating costs* - The ongoing expenses incurred to operate and maintain the nuclear power plant once it is operational. These costs include personnel salaries, maintenance, safety measures, security, fuel, and other day-to-day operational activities.
- *NRC Licensing* - The Nuclear Regulatory Commission (NRC) oversees the licensing process for nuclear power plants in the United States. The costs related to NRC licensing include application fees, technical evaluations, safety analyses, and compliance with regulatory requirements. Navigating the licensing process and meeting the necessary criteria can be time-consuming and costly, but it is a crucial step in ensuring the safe and legal operation of the nuclear facility.

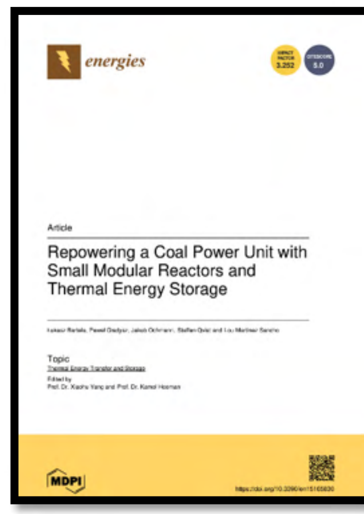
The costs of coal repowering encompass various factors that need to be carefully considered and managed. From pre-construction activities to licensing and final construction, each step in the process contributes to the economic feasibility and successful execution of a coal repowering project. By conducting thorough cost assessments, developing realistic budgets, and implementing effective project management strategies, the transition to nuclear power can be achieved in a financially responsible and sustainable manner

Additional Resources on this Topic:



Abou-Jaoude et al. 2023. Integrated Energy Systems - INL. "[Literature Review of Advanced Reactor Cost Estimates]"

This report provides a comprehensive review of existing literature on advanced reactor cost estimates in the form of a meta-study. Over 30 references are evaluated and considered as part of this effort. While not directly related to coal repurposing costs, this report provides an overview of advanced reactor cost estimates that broadly relate to advanced nuclear projects.



Bartela et al. Energies. 2022. "[Repowering a Coal Power Unit with Small Modular Reactors and Thermal Energy Storage]".

This paper presents the results of a technoeconomic analysis for three cases of nuclear repowering of a 460MW supercritical coal-fired unit in Poland. The economic analysis demonstrates that integration with thermal energy storage systems may be beneficial if the current levels of daily variation in electricity prices are maintained.

Licensing and Regulation of Coal and Nuclear Power Plants

Coal power plants and nuclear power plants are regulated differently due to their unique technologies and potential risks. Both must comply with environmental and safety regulation. Nuclear power plants have their own specific requirements established by the Nuclear Regulatory Commission (NRC) to ensure nuclear safety and proper radioactive waste management. Coal plant environmental impacts are primarily overseen by the U.S. Environmental Protection Agency (EPA) and state environmental agencies. Occupational safety and decommissioning processes also differ between coal and nuclear plants. Public perception and community engagement play significant roles in shaping the regulatory landscape for both energy sources. Understanding these regulatory differences is essential for maintaining safe, sustainable, and efficient energy generation while addressing public concerns and safeguarding the environment.

Environmental and Safety Regulations:

Environmental regulations play a vital role in ensuring that power plants minimize their impact on the environment. Coal power plants are subject to stringent air emissions permits and compliance requirements under the Clean Air Act (CAA). They must control and monitor their emissions of sulfur dioxide, nitrogen oxides, particulate matter, and air toxins to reduce air pollution. Water discharge permits are also essential for coal plants to comply with the Clean Water Act (CWA) by managing and monitoring their wastewater discharges.

While nuclear power plants must also comply with CAA and CWA, the Nuclear Regulatory Commission is the primary regulator of nuclear facilities, and they have their own nuclear-specific requirements and processes. The NRC oversees the licensing of nuclear facilities and establishes strict guidelines for nuclear safety and radioactive waste management. Nuclear plants are required to comply with NRC standards for the safe handling, storage, and disposal of radioactive materials. Coal plants have more immediate emissions than nuclear power plants. Both types of powerplants must prevent the release of pollutants that can cause long-term impacts. Nuclear plants must prevent the release of radioactive materials and coal plants must prevent the release of toxic emissions like heavy metals and chemical carcinogens.

Nuclear power plants can also receive Early Site Permits (ESPs), which are regulatory approvals issued by the NRC authorizing a specific location for the future construction of a nuclear power plant. An ESP provides assurance that the selected site meets rigorous safety and environmental criteria, which is valuable for prospective plant developers seeking to pursue coal repowering. Having an ESP streamlines the licensing process and reduces uncertainty, as it confirms the site's suitability upfront, facilitating more efficient and predictable deployment of nuclear power plants.

Occupational Safety and Health Regulations:

The safety of plant workers is another crucial aspect of regulation. Coal and nuclear power plants are subject to Occupational Safety and Health Administration (OSHA) standards, ensuring the well-being of employees involved in mining, transportation, and plant operations.

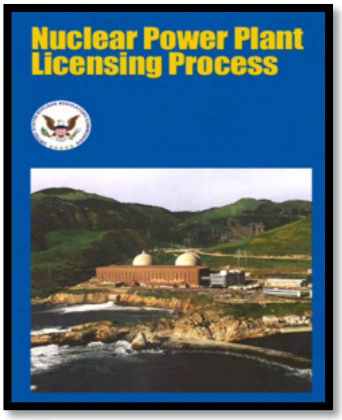
However, nuclear power plants have their own unique set of regulations pertaining to nuclear safety and security. These stringent standards are established to prevent radiation exposure to workers and ensure the physical protection of nuclear facilities against potential threats. Compared to coal plant workers, nuclear plant workers face different occupational risks, including potential exposure to radioactive materials, which requires rigorous training and strict adherence to safety protocols.

Decommissioning and Closure:

The end-of-life stage for both coal and nuclear plants includes a decommissioning process. For coal power plants, decommissioning involves dismantling and disposing of coal-fired boilers, generators, and other components. Any unused coal and hazardous materials within the coal facility or auxiliary buildings (e.g., process chemicals, lead, asbestos) are removed, and onsite coal ash ponds or solid waste landfills must follow the federal and state permit requirements for closure of these facilities. Additionally, all operating permits are terminated. (View this EPA fact sheet to learn more about the coal plant decommissioning process). Additionally, various funding mechanisms are needed for decommissioning coal power plants and include federal funding (see the 2019 Brownfields Federal Programs Guide), state and local incentives, and private source funding.

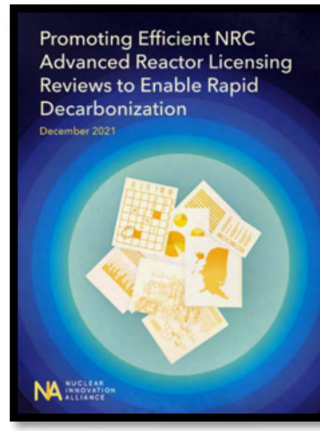
In contrast, nuclear power plants require decommissioning processes that are specialized to deal with the handling of radioactive materials. The NRC oversees nuclear plant decommissioning and requires thorough site restoration and waste management to ensure long-term safety. Additionally, the NRC requires financial assurance for decommissioning, meaning that the entity that receives the license for the construction and operation of the reactor must demonstrate they will have the funds for decommissioning before the license is issued.

Additional Resources on this Topic:



U.S. Nuclear Regulatory Commission. 2009. "Nuclear Power Plant Licensing Process (NUREG/BR-0298, Revision 2)".

This document, like the resource above, provides information on the NRC's process to license nuclear power plants, specifically on the different pathways to receive a license (10 CFR Part 50 and Part 52), early site permits, and design certifications. It also provides a deeper dive into parts 50 and 52, discussing construction permits, operating licenses, manufacturing licenses, duplicate plant licenses, standard design approvals, and site suitability reviews.



Nuclear Innovation Alliance. 2021. "Licensing Reviews to Enable Rapid Decarbonization"

Unnecessarily long licensing reviews raise significant barriers to investment, reduce customer interest in advanced reactors, and threaten successful long-term deployment of advanced nuclear reactors. In this report, the NIA explores how the Nuclear Regulatory Commission (NRC) and Industry can make advanced reactor licensing both more effective and more efficient.


Repowering Fossil Fuel Sites through Strategic Regulatory Innovation

Publication Forthcoming

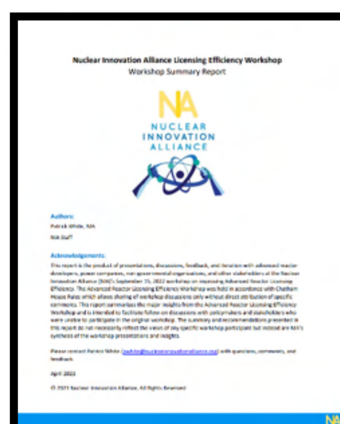
Charlyne Smith, PhD, Leigh Anne Llaveras, Guido Nuñez-Mujica, Adam Stein, PhD

Breakthrough Institute
Washington, DC 20005

Breakthrough Institute. *Publication Forthcoming*. "Repowering Fossil Fuel Sites through Strategic Regulatory Innovation"

This forthcoming report, which is scheduled to be released in October 2023, recommends establishing a DOE-led program that reduces regulatory uncertainty when siting new nuclear projects at retiring coal facilities, through the use of early site permits and strategic siting efforts.

Nuclear Innovation Alliance. 2021. "NIA Licensing Efficiency Workshop Summary Report"



This report summarizes NIA's 2022 Chatham House Rules workshop on Advanced Reactor Licensing Efficiency. The workshop convened stakeholders from both industry and public interest groups to share experiences and insights from prior licensing activities, best practices for licensing engagement and activities, and emerging best practices for new reactor licensing. This report synthesizes workshop presentations and discussions, and provides recommendations on how applicants, NRC staff and management, and the NRC Commission can work together to improve the efficiency and effectiveness of advanced reactor licensing reviews.

Remediation Efforts

Repowering coal plants with nuclear energy represents a significant step towards a cleaner and more sustainable future. However, this transformation necessitates careful planning and execution, especially when it comes to site remediation. Repowering site remediation involves restoring and repurposing retired coal power plant sites to accommodate nuclear facilities. This includes addressing the legacy environmental issues left behind by the coal power plant and preparing the site for the safe and efficient installation of the new nuclear facility.

When they retire, coal-fired power plants can leave behind contaminants and pollutants, such as heavy metals, ash, and coal combustion byproducts, that may lead to environmental degradation of the surrounding area. This impact on the environment can include soil and water contamination, or air pollution. Counterintuitively, coal ash and other combustion products may also contain radioactive elements that result in elevated background radiation levels at the site, surpassing the allowable limits for new nuclear construction. While it may be surprising, radiation exposure at properly regulated nuclear reactor sites is actually much lower than the background radiation doses received throughout the majority of the United States, due to the nuclear industry's rigorous safety guidelines and protocols. By remediating coal sites, we not only mitigate the environmental impact of coal but also pave the way for cleaner and more sustainable energy generation.

Key Steps in Coal Repowering Site Remediation:

- *Environmental Assessment* – Identifying and evaluating the extent of contamination and ecological damage caused by the coal plant's operations. This assessment guides subsequent remediation efforts and ensures compliance with environmental regulations. Early site permits may also play a critical role in assessing what remediation efforts are needed.
- *Site Clean Up and Soil Remediation* – Removal of pollutants, including heavy metals and toxic substances, from the site and soil. Techniques such as excavation, soil vapor extraction,[6] and bioremediation[7] could be employed to restore the site's soil quality and minimize contamination risks.
- *Water Remediation* – The use of water treatment systems to remove harmful substances and ensure the safe reuse of water resources. Technologies like filtration, ion exchange,[8] chemical

[6] Soil vapor extraction is a technique used to remove volatile contaminants from the soil by applying a vacuum to extraction wells, drawing vapors out of the soil for treatment, effectively reducing concentrations and preventing migration.
[7] Bioremediation employs microorganisms or plants to naturally degrade or transform contaminants in soil and groundwater.
[8] Ion exchange is a process that involves the exchange of ions between a solid resin and the water. This method is particularly effective for removing dissolved ions or heavy metals from water. The resin selectively binds to the target ions, allowing them to be removed from the water.

precipitation,[9] ultraviolet disinfection,[10] and oxidation[11] processes could be employed to purify wastewater.

- *Ash Removal* – Coal power plants generate significant amounts of ash as a byproduct of the combustion process. This ash is typically stored in a containment area known as an ash pond, or coal ash basin. This ash can contain various contaminants, including heavy metals and traces of radioactive elements, which must be safely removed and disposed of before the nuclear plant can be constructed.
- *Land Reclamation and Restoration* – Restoring the land to its desired state. This includes implementing erosion control measures.

These steps can have significant impacts on both the cost and timeline of repowering. The cost of site remediation can vary depending on the extent and complexity of contamination present at the site. Extensive contamination may require more extensive remediation measures, leading to higher costs. Additionally, the cost and complexity of complying with regulatory requirements and obtaining necessary permits for remediation activities can also contribute to the overall cost and timeline of a project

Coal site remediation plays a vital role in transforming the environmental legacy of fossil fuel power generation. Effectively remediating retired coal power plant sites not only addresses the environmental impact of coal but also paves the way for cleaner and more sustainable energy sources. Through comprehensive assessments, cleanup efforts, infrastructure removal, and land restoration, these sites can be repurposed to support nuclear energy generation, contributing to a greener future. Prioritizing and implementing effective site remediation strategies can ensure a smooth transition towards clean advanced nuclear energy.

[9] Chemical precipitation involves the addition of chemicals, known as precipitants, to the water to induce the formation of insoluble particles. These particles can then be separated from the water through sedimentation or filtration.
[10] UV disinfection utilizes ultraviolet light to destroy bacteria, viruses, and other microorganisms in water. It is a chemical-free method that effectively eliminates harmful pathogens.
[11] Oxidation processes involve the use of oxidizing agents, such as ozone or hydrogen peroxide, to chemically break down contaminants in water. These agents react with organic compounds, converting them into less harmful substances.

Additional Resources on this Topic:


Decommissioning Handbook for Coal-Fired Power Plants

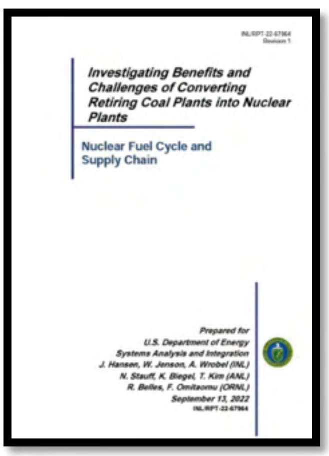
Electric Power Research Institute. 2004. "[Decommissioning Handbook for Coal-Fired Power Plants]"

This handbook lays out the steps necessary to fully decommission a coal-fired power plant. The handbook includes ways to handle permitting, environmental cleanup, site dismantlement, and site remediation. It also discusses overall decommissioning costs. It is based on three actual case studies of coal plants recently decommissioned: the Arkwright coal-fired plant of Georgia Power, the Watts Bar coal-fired plant of TVA, and the Port Washington coal-fired plant of Wisconsin Electric Power.


COAL PLANT DECOMMISSIONING
PLANT DECOMMISSIONING, REMEDIATION AND REDEVELOPMENT

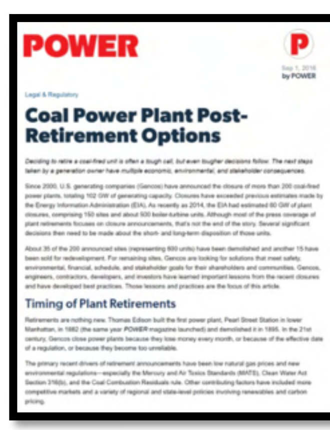
U.S. Environmental Protection Agency. "[Plant Decommissioning, Remediation, and Redevelopment]"

This document discusses the process of decommissioning, remediation, and redevelopment of coal power plants.


Investigating Benefits and Challenges of Converting Retiring Coal Plants into Nuclear Plants
Nuclear Fuel Cycle and Supply Chain
Prepared for
U.S. Department of Energy
Systems Analysis and Integration
J. Hansen, W. Jenson, A. Wrobel (INL)
N. Stauff, K. Biegel, T. Kim (ANL)
R. Belles, F. Omitaomu (ORNL)
September 13, 2022

Department of Energy. 2022. "[Investigating Benefits and Challenges of Converting Retiring Coal Plants into Nuclear Plants]".

A comprehensive overview that aims to answer three questions: where in the United States are retired coal facilities located and what factors make a site feasible for transition to nuclear power; what factors of technology, cost, and project timeline drive investor economics over such a decision; and how will coal repowering impact local communities. Of note, the study includes a discussion of coal power plant and ash removal, and remediation.

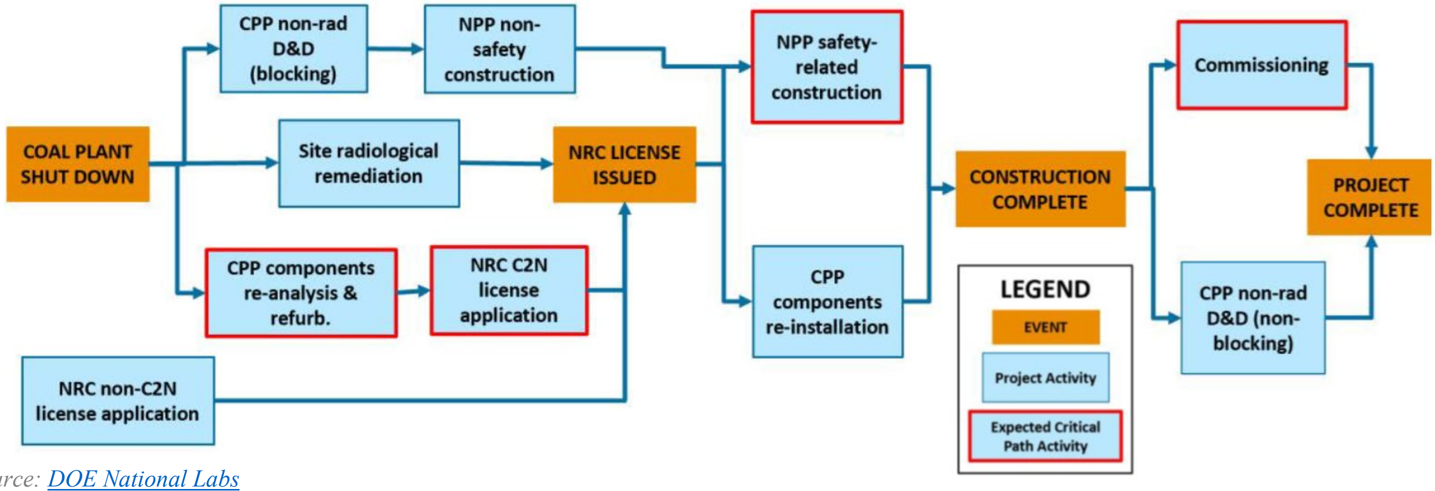

POWER
Coal Power Plant Post-Retirement Options
Timing of Plant Retirements

Power Magazine. 2016. "[Coal Power Plant Post-Retirement Options]"

This article gives a comprehensive overview of the different options coal power plants have when it comes to retirement.

Timelines: Building Bridges for a Workforce in Transition

A successful coal repowering project requires a tight timeline that encompasses various complex stages. From the decommissioning of coal infrastructure to site remediation and construction of nuclear facilities, each step in the process significantly impacts the overall timeline to operation. And timelines for each transition will be site specific and will depend on the reuse of the site. One example can be seen below.



Source: DOE National Labs

Figure 6: Example timeline of a coal repowering project

Depending on the advanced reactor being built (e.g., PWR, HTGR, or SFR[12]) and how conservative the assumptions are for the timeline in question, the total time needed to remove the coal power plant (CPP) and construct the nuclear power plant (NPP) can vary wildly. Below are estimates for how long each phase of construction and site preparation can take for several different projects and reactor types.

						NPP Construction Activities			CPP Removal and Requalification Activities		
Project Type	Example Reactor Type	Assumption set	Total NPP	Total Critical Path Duration	Required Revenue Gap	NPP Non-safety	NPP Safety	NPP Commis-sioning	CPP D&D	CPP Ash Removal	CPP NRC Licensing
				years		years	years	years	years	years	years
C2N#0	PWR	Baseline	5	5.5	0	1	3	1	1	1.5	0
C2N#1	PWR	Baseline	5.25	6.75	6.75	1	3	1.25	1	1.5	1
C2N#1	PWR	Conservative	6.25	8.75	8.75	1	4	1.25	1	2	1.5
C2N#0	HTGR	Baseline	5	5.5	0	1	3	1	1	1.5	0
C2N#2	HTGR	Baseline	5.5	6.5	6.5	1	3	1.5	1	2	2
C2N#2	HTGR	Conservative	6.5	8	8	1	4	1.5	1	2.5	2.5
C2N#0	SFR	Baseline	5	5.5	0	1	3	1	1	1.5	0
C2N#3	SFR	Baseline	5.25	5.5	2.75	1	3	1.25	1	1.5	1.5
C2N#3	SFR	Conservative	6.25	7	3.25	1	4	1.25	1	2	2

Source: DOE National Labs

Figure 7: Estimated duration during differ phases of a coal repowering project

[12] PWR = Pressurized Water Reactor; HTGR = High Temperature Gas Reactor; SFR = Sodium-cooled Fast Reactor, D&D = Decommissioning and Demolition

In this table the "Total NPP" column specifies the timeline for the nuclear project in isolation, excluding any contributions from coal removal activities. The "total critical path duration" represents the overall time needed to complete all coal repowering project activities, following the longest possible sequence in the project activity network. Meanwhile, the "Required revenue gap" column illustrates the necessary timeframe in which the utility does not generate income from either the CPP or the NPP. This period is primarily influenced by the timing of the retirement of the CPP for refurbishment and regulatory tasks.

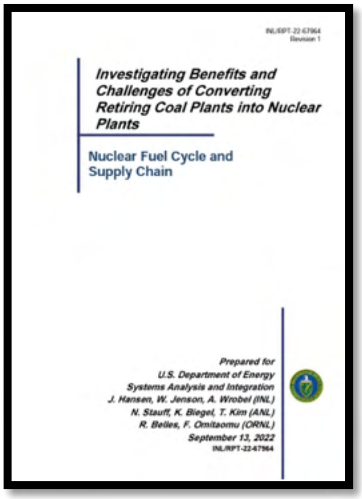
These lengthy timelines, and the potential delays, can significantly impact the coal plant's and the nuclear plant's workforce, specifically for those individuals who are looking to transition from working at a coal plant to working at the nuclear facility. These timelines may also be a reason to build next to, not on, an existing coal site to reduce the total time needed to build the nuclear power plant. Experienced coal plant workers possess valuable skills, but long and ever-changing timelines create uncertainty that can lead them to consider relocation or seek new job opportunities. Additionally, it's not realistic for a worker to stay in their community or hold off on taking another job while waiting years for the nuclear reactor to come online. Ideally, training programs can be implemented during the construction process, or much earlier, and workers can apply their skills during the various phases of construction. For example, the Natrium Project in Wyoming is seeing TerraPower and PacifiCorp establishing job training and retraining plans with the state, University of Wyoming, and local community colleges. But training programs will not be appropriate for all workers at all retiring coal plants. Therefore, it is important to note that such a timeline leaves little room for delays, emphasizing the need for careful planning and execution to ensure a successful transition.

Delays have the potential to arise at different stages, and can have subsequent ripple effects in construction, prolonging the transition and affecting its cost and community impacts. It is worth noting that nuclear construction has faced many delays in the past, making timeliness particularly critical in coal repowering. To ensure a smooth and successful transition, careful planning and mitigation strategies are essential.

To mitigate these challenges, it is crucial for project developers and stakeholders to prioritize timely construction, minimize delays, think about ways to integrate skilled workers into the construction efforts, and consider how to transition the workforce all the way from the retirement of the coal plant to the operation of the nuclear plant. For example, project developers and utilities can start engaging early with universities, labor unions, or other entities to ensure training programs are in place when they are needed the most to ensure a smoother transition. By adhering to realistic timelines and effectively managing the various aspects of nuclear plant construction, including regulatory approvals, supply chain logistics, and construction processes, the workforce can be better supported in their career transitions. Additionally, providing transparent communication and support to workers during construction can help maintain their confidence and commitment to the project.

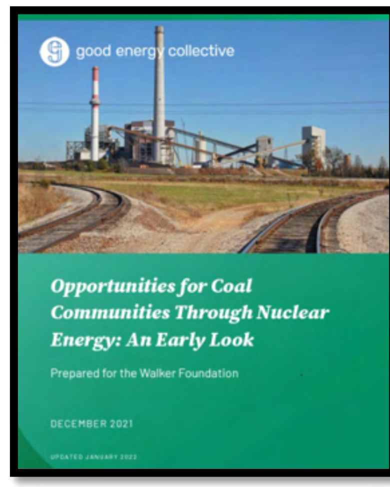
A successful coal repowering project requires careful planning and execution to manage the complex stages involved. Transition timelines and potential delays pose significant challenges for the nuclear plant's workforce, as experienced workers may face uncertainty and consider relocation or new job opportunities. By prioritizing timely construction, minimizing delays, and addressing the workforce's concerns and needs, a smoother and more sustainable transition can be achieved for both the reactor developer and the community.

Additional Resources on this Topic:



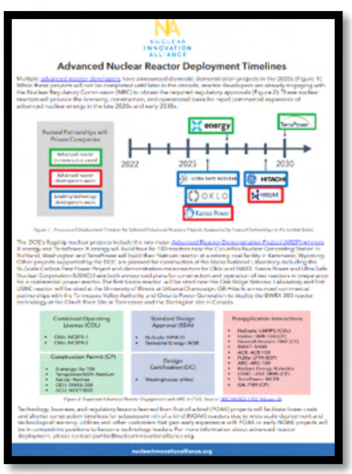
Department of Energy. 2022. "[Investigating Benefits and Challenges of Converting Retiring Coal Plants into Nuclear Plants]()".

A comprehensive overview that aims to answer three questions: where in the United States are retired coal facilities located and what factors make a site feasible for transition; what technology, cost, and project timeline factors drive project economics and investor decisions; and how will coal repowering impact local communities. Of note, this study evaluates the timeline of coal repowering projects.



Toth et al. 2021. Good Energy Collective. "[Opportunities for Coal Communities Through Nuclear Energy: An Early Look]()"

This report discusses the need for economic revitalization in communities that have relied on coal plants for employment, tax revenue, and electricity. The report highlights the analysis of possible locations for coal repowering, considering community support and environmental, legal, and technical constraints. Ongoing policy efforts to support coal communities and transition efforts are also discussed.



Nuclear Innovation Alliance. 2022. "[Advanced Reactor Deployment Timelines]()"

This NIA Fact Sheet highlights the deployment timeline of selected advanced reactors projects supported by federal partnerships in the United States and expected advanced reactor engagement with the Nuclear Regulatory Commission in FY2023

Reusing Infrastructure

The reuse of coal site infrastructure and components is a critical question that emerges when considering coal repowering. Understanding which assets can be reused is vital to assessing the economic and technical feasibility of such a conversion. It is important to recognize that the viability of reuse will vary from site to site, and factors such as the specific reactor design and compatibility with the existing coal steam cycle components will influence the feasibility. However, by acknowledging these key factors and thoroughly evaluating each site, we can make informed decisions regarding the suitability of a coal site for a nuclear transition. By doing so, we can proactively address potential issues associated with reusing components from the coal site and ensure a smoother and more successful transition to nuclear energy.

Viable Reuse Opportunities:

Determining the precise infrastructure that can be effectively reused, considering both technological and economic feasibility, remains a topic of ongoing exploration. Careful evaluation and decision-making are necessary to determine which infrastructure can be effectively repurposed, and which should be replaced to ensure a successful and efficient transition to nuclear power. Certain components, such as transmission lines, substation equipment, auxiliary buildings, water supply, and transportation access, lend themselves more easily to reuse, whereas components such as the coal-fired boiler, furnace, coal handling equipment (e.g., conveyors, crushers, loading systems storage facilities), flue gas systems, and ash handling and disposal systems (e.g., desulfurization equipment/scrubbers used to remove sulfur dioxide from flue gas) do not present viable opportunities for reuse.

Existing transmission lines present a significant opportunity for coal repowering. Pre-existing land zoned for industrial purposes and established transmission access are important advantages in avoiding the years of delays typically associated with building new transmission infrastructure. Constructing transmission lines for new nuclear projects can be a complex and time-consuming process, often taking several years due to regulatory approvals, environmental assessments, public consultations, and securing rights-of-way. However, by leveraging the already available transmission infrastructure, coal repowering can bypass these challenges and significantly expedite the process of connecting the nuclear facility to the power grid. This not only enhances the project's efficiency but also contributes to cost savings and a quicker realization of the benefits of nuclear power adoption.

One potential opportunity for reuse lies in the coal plant steam cycle, including the turbine, turbine generator, steam generator, condensing systems, and pumps. However, compatibility issues between coal and nuclear plant systems may present significant challenges. To reuse steam cycle equipment, the operating conditions (mainly temperature and pressure) of the nuclear power plant cannot be substantially different from the coal power plant conditions. As such, reuse of such components is technology-specific and site-dependent and affects how to approach the coupling of the coal and nuclear infrastructure.

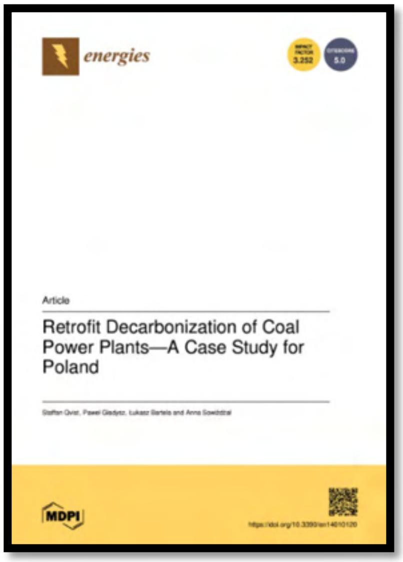
Mitigating Infrastructure Aging:

One issue that affects coal repowering with respect to timing is the rapid aging of the site and infrastructure, and the site's maintenance history. Assets at coal-fired power plants often undergo rapid degradation, including corrosion, structural deterioration, and mechanical failure, which accelerates over time, reduces the opportunity to reuse these systems, and at the very least increases cost associated with restoring them. To make matters worse, coal plants that have been retired for longer periods of time may not have undergone maintenance for years. Depending on the specific system and its components, the amount of recovery of the components that didn't receive maintenance will vary. Additionally, older coal sites could present more long-term negative consequences of aging, such as land subsidence, vegetation overgrowth, infestation and pest issues, and water and soil contamination, which can severely limit their suitability for future nuclear use and complicate site efforts. Therefore, the potential for integrating advanced nuclear technologies at coal power plant sites is generally more favorable for currently operating units that are scheduled to retire in the near future.

Similarly, when assets at a coal site are approaching the end of their operational lifespan, owners cannot always rely on their long-term reuse and must consider the cost of their replacement. For instance, if components of the site's steam cycle, such as the generator and turbine, are nearing the end of their service life within a few years, they may require replacement shortly after the operation of the nuclear power plant begins. In this scenario, initial replacement might be a more practical and cost-effective choice.

Efforts can be undertaken to enhance the reusability of components at a site by implementing measures to mitigate aging and system degradation before final retirement. This involves taking proactive steps, such as filling pipes with properly treated water to slow down corrosion, to prevent the site and components from degrading further. Therefore, parties interested in repurposing a coal plant for a nuclear energy transition should ensure such preparations are made during the decommissioning phase.

Additional Resources on this Topic:


energies

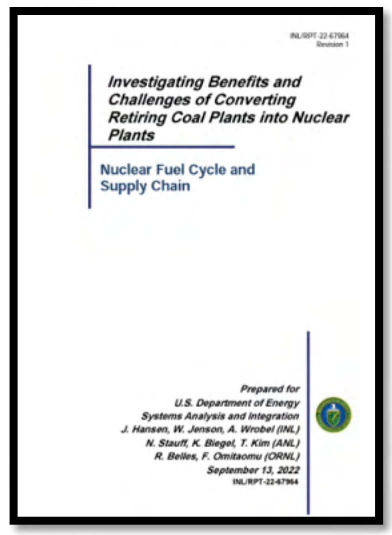
Article

Retrofit Decarbonization of Coal Power Plants—A Case Study for Poland

MDPI

Qvist et al. Energies. 2021. “Retrofit Decarbonization of Coal Power Plants—A Case Study for Poland”.

This study assesses the spectrum of available options for the future of equipment in the coal power sector by assessing the full scope of “retrofit decarbonization”. Retrofit decarbonization is an umbrella term that includes adding carbon capture, fuel conversion, and the replacement of coal boilers with new low-carbon energy sources like nuclear energy, in each case re-using as much of the existing equipment as economically practical while reducing or eliminating emissions. The study explores this idea using the Polish coal powerplant fleet as a cast study.


Investigating Benefits and Challenges of Converting Retiring Coal Plants into Nuclear Plants

Nuclear Fuel Cycle and Supply Chain

Prepared for U.S. Department of Energy Systems Analysis and Integration J. Hansen, W. Jenson, A. Wrobel (INL) N. Stauff, K. Biegel, T. Kim (ANL) R. Belles, F. Omitaomu (ORNL) September 13, 2022

Department of Energy. 2022. “Investigating Benefits and Challenges of Converting Retiring Coal Plants into Nuclear Plants”.

A comprehensive overview that aims to answer three questions: where in the United States are retired coal facilities located and what factors make a site feasible for transition; what technology, cost, and project timeline factors of drive project economics and investor decisions; and how will coal repowering impact local communities. Of note, this study evaluates the technological compatibility of infrastructure for coal repowering.

Conclusion

Coal repowering with nuclear energy has emerged as a pivotal strategy for advancing the next generation of nuclear energy, contributing to greenhouse gas emissions reduction, repurposing coal infrastructure, and supporting local communities. These transitions present a mutually advantageous opportunity for reactor developers and host communities, fostering sustainable economic growth, job creation, environmental enhancements, and lower capital costs for advanced nuclear technologies. This transformative shift holds the potential to rejuvenate communities and foster a sustainable economic future.

Nevertheless, challenges related to timing, site remediation, workforce transitions, and community acceptance must be met head-on. Addressing these challenges requires concerted efforts aimed at lowering barriers and fostering informed decision-making. By proactively tackling these issues, policymakers and other stakeholders can unlock the full potential of repurposing existing fossil fuel sites with advanced nuclear energy, yielding environmental advantages, empowering the workforce, and benefiting local communities at large.