From Coal to Nuclear

A Practical Guide for Developing Nuclear Energy Facilities in Coal Plant Communities

2023 TECHNICAL REPORT

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A Practical Guide for Developing Nuclear Energy Facilities in Coal Plant Communities

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ABSTRACT

Governments, utilities, and industries are looking to transition away from coal-based, electrical, and thermal generation to help meet carbon reduction and other emissions-related goals. Continued operation of coal assets may result in reduced economic and regulatory certainty. Many organizations are reviewing nuclear energy as an option due to its ability to provide carbon-free, dispatchable, and firm power.

Existing coal plants can provide benefits and opportunities that make consideration of deploying new nuclear generation on, or near, an existing coal site a compelling option. At the same time, however, utilities must consider the issues that come with reusing a previously industrialized site.

This report provides owner-operators and other stakeholders with practical guidance for the relatively near-term deployment of a nuclear energy facility on, or near, an existing coal plant site. The report provides a generalized, regulatory agnostic process for repurposing a coal plant with nuclear energy. It also reviews the many options and concerns that must be evaluated and resolved, including multidisciplinary engineering and technical considerations as well as workforce and community engagement issues.

Keywords

Advanced reactors
Coal plant repurposing
Community engagement
Nuclear plant siting
New nuclear deployment
Small modular reactors

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PRIMARY AUDIENCE: Coal plant owners, nuclear plant developers, nuclear owner-operators

SECONDARY AUDIENCE: Communities with coal plants, non-governmental organizations (NGOs)

KEY RESEARCH QUESTION

What are the necessary steps and considerations for redeveloping a nuclear energy facility on, or near, an existing coal facility in the near future?

RESEARCH OVERVIEW

The research is broken into three broad areas:

- Section 1– Given the varying levels of interest and perspectives, the first section gives readers foundational information about coal and nuclear power. This section addresses coal plant retirements in the coming years, benefits of nuclear deployment for replacing coal generation, and end user considerations.
- Section 2 – The second section provides a regulatory agnostic process for evaluating coal sites for the potential deployment of nuclear energy facilities on or near those sites.
- Section 3 – The third section discusses options and considerations recognizing that goals and objectives will be unique for every coal site.

KEY FINDINGS

- Water, land, and transmission availability are the greatest resources available from an existing coal plant for the development and deployment of a nuclear plant.
- Reuse of infrastructure, such as the balance of plant or the turbine cycle of the coal plant, should include a thorough review of all technical aspects of the system, structures, and components to understand their ability to meet all technical and licensing requirements for nuclear deployment.
- Project planning should consider the requirements for maintaining transmission rights to ensure that coal plant shutdown and nuclear plant startup are coordinated and timed as such.
- Legacy environmental aspects of the coal facility, such as coal combustion product (CCP) monitoring, must be evaluated considering nuclear environmental monitoring programs.
- The continuation or reuse of permits such as water, air, and land should be assessed early to determine the viability of the option.
- Community engagement and workforce development should occur as early as possible.

WHY THIS MATTERS

Coal facilities have been a deployable, baseload source of electricity around the world for decades. With coal plant retirement, nuclear offers the ability to provide that same deployable, baseload quality without carbon emissions. This research is intended to give a variety of stakeholders of differing perspectives common ground for discussion of nuclear deployment at coal sites or in the vicinity. This work is part of a broader EPRI research effort across the Generation and Nuclear sectors.

HOW TO APPLY RESULTS

This research can be applied by a wide variety of end users taking the following approach:

- Define the owner-operator's mission and business objectives.
- Identify the site.
- Characterize the site.
- Select technology and design.
- Evaluate site infrastructure and existing assets (for potential repurposing).
- Secure land, transmission, and water rights along with other permits.
- Perform cost and other economic evaluations.
- Obtain an early site permit (optional).
- Conduct community outreach.

LEARNING AND ENGAGEMENT OPPORTUNITIES

- Members of EPRI's Advanced Nuclear Technology program will host webcasts and one-on-one conversations. Please contact the project manager below for more information.
- This work is done in coordination with EPRI's Coal Decommissioning and Redevelopment Supplemental Program.

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ACRONYMS AND ABBREVIATIONS

ACC	Air-Cooled Condenser
ADEME	Agency for Ecological Transition (France)
AE	Architect Engineer
ALWR	Advanced Light Water Reactor
ANL	Argonne National Lab
ANS	American Nuclear Society
ANSES	Agency for Food, Environmental and Occupational Health & Safety (France)
ANT	EPRI Advanced Nuclear Technology Program
AR	Advanced Reactor
ARIS	IAEA Advanced Reactor Information System
ASME	American Society of Mechanical Engineers
BOP	Balance of Plant
BWR	Boiling Water Reactor
CA	Canada
CCP	Coal Combustion Product
CESifo	Munich Center of Economic Studies / ifo Institute
COL	Combined License
CP	Construction Permit
CPCN	Certificate of Public Convenience and Necessity
CWA	U.S. Clean Water Act
DC	Design Certification
DEQ	Department of Environmental Quality
DG	Draft NRC Regulatory Guide
EAB	Exclusion Area Boundary
EEA	European Environment Agency
EIS	Environmental Impact Statement

EPC	Engineering, Procurement, and Construction
ER	Environmental Report
EPRI	Electric Power Research Institute
EPZ	Emergency Planning Zone
EQ	Environmental Qualification
ESP	Early Site Permit
ETI	Energy Technologies Institute (UK)
FAA	U.S. Federal Aviation Administration
FHR	Fluoride Salt-Cooled High-Temperature Reactor
FWPCA	U.S. Federal Water Pollution Control Act
GEN	Reactor Generation
GCR	Gas Cooled Reactor
GIS	Geographic Information System
GW	Gigawatt
ha	hectare(s) (1 ha = 2.47 Acre)
HAZMAT	Hazardous Material
HTGR	High Temperature Gas Reactor
HWR	Heavy Water Reactor
I&C	Instrumentation and Control
IAEA	International Atomic Energy Agency
IEEE	Institute of Electrical and Electronics Engineering
INL	Idaho National Lab
IPCC	Intergovernmental Panel on Climate Change
IRP	Integrated Resource Plan
^{40}K	Potassium-40
km	kilometer(s) (1km = .62 mi)
km^2	square kilometer(s) (1 km^2 = .39 mi^2)
KY	Kentucky
LBNL	Lawrence Berkeley National Laboratory
LCOE	Levelized Cost of Electricity (Energy)
LFR	Lead-Cooled Fast Reactor

LLWR	Large Light Water Reactor
LR	Large Reactor
LWA	Limited Work Authorization
LWR	Light Water Reactor
lwSMR	Light Water Small Modular Reactor
m^3	Cubic meter(s) ($1m^3$ = 264.17 U.S. gal)
mi	Mile(s) (1 mi = 1.61 km)
mi^2	Square Miles(s) (1 mi^2 = 2.59 km^2)
MR	Microreactor
MSR	Molten Salt Reactor
MW	Megawatt
MWe	megawatt(s) electric (1 MWe ~ 2.94 MWt based on current efficiencies)
MWt	megawatts(s) thermal (1 MWt ~ .34 MWe based on current efficiencies)
NCSL	National Conference of State Legislature
NEI	Nuclear Energy Institute
NEPA	U.S. National Environmental Policy Act
NIA	Nuclear Innovation Alliance
NMAC	EPRI Nuclear Maintenance Applications Center
NPDES	U.S. National Pollutant Discharge Elimination System
NRIC	U.S. DOE National Reactor Innovation Center
NSSS	Nuclear Steam Supply System
O&M	Operations and Maintenance
OCC	Overnight Capital Cost
OEB	Ontario Energy Board
OEM	Original Equipment Manufacturer
Ofgem	Office of Gas and Electricity Markets (U.K.)
OL	Operating License
ORG	EPRI Owner-Operator Requirements Guide (ORG) for Advanced Reactors
ORNL	Oak Ridge National Lab
PE	EPRI Plant Engineering Program
PGA	Peak Ground Acceleration

PNNL	Pacific Northwest National Laboratory
PPE	Plant Parameter Envelope
PPS	Preferred Power Supply
PUC	Public Utility Commission
PWR	Pressurized Water Reactor
RAI	Request for Additional Information
RFF	Resources for the Future
ROI	Region of Interest, Return on Investment
SFR	Sodium-Cooled Fast Reactor
SMR	Small Modular Reactor
SPA	Standard Plant Approval
SPE	Site Parameter Envelope
SSC(s)	Systems, structures, and components
SCWR	Super Critical Water Reactor
T&D	Transmission and Distribution
TEA	Techno-Economic Assessment
U.S. ACE	U.S. Army Corps of Engineers
U.S. BLM	U.S. Bureau of Land Management
U.S. CEQ	U.S. Council on Environmental Quality
U.S. CRS	U.S. Congressional Research Service
U.S. DOE	U.S. Department of Energy
U.S. EIA	U.S. Energy Information Administration
U.S. EPA	U.S. Environmental Protection Agency
U.S. GAO	U.S. General Accounting Office
U.S. NRC	U.S. Nuclear Regulatory Commission
UNESCO	United Nations Educational, Scientific and Cultural Organization
URD	EPRI Advanced Light Water Reactor Utility Requirements Document
WNA	World Nuclear Association

CONTENTS

3 OPTIONS AND CONSIDERATIONS 3-1

LIST OF FIGURES

LIST OF TABLES

1
INTRODUCTION

In the United States (U.S.) and globally, governments, utilities, and other industries are looking to transition away from coal-based generation to help meet carbon reduction goals and reduce the economic and regulatory risk of operating coal plants. Today's coal plant is a firm, dispatchable resource for the grid operator that offers a range of services to the grid including electric power, primary and secondary reserves, and in some cases spinning reserves. In most locales, the retirement of coal plants will require replacement of the power and grid services in some form to meet grid reliability and end-user needs. Some of this need will be met with renewables such as wind and solar, but the firm baseload power typically supplied by coal plants will still be needed.

While there are many options available for providing this replacement power, one specifically being reviewed by many organizations is replacement with nuclear energy due to its ability to provide carbon-free, firm, dispatchable power. In addition to providing firm power, modern reactors can provide the types of grid services required to support significant penetration of intermittent renewables. As noted by the IAEA (IAEA, 2023):

> … the variable nature of renewables can be well compensated by coupling these technologies with nuclear energy to provide a more equitable and inclusive energy system that is also environmentally sustainable, safe, reliable and affordable, while supporting enhanced grid resilience.

While the design of the local transmission and distribution infrastructure, as well as the service territories and regulatory structure of various utilities, will help drive the location of any new generation, there is no specific requirement that new generation be located at, or even near the site of any retired generation. However, existing coal plants can provide key benefits and opportunities that make consideration of deploying new nuclear generation on, or near, an existing coal site a compelling option, but one that also requires consideration of the issues that come with reusing a previously industrialized site.

1.1 Purpose of this Document

The purpose of this document is to provide *practical* guidance for the *relatively near-term* deployment of a nuclear energy facility *on, or near,* an existing coal plant site. The italicized terms, *practical, relatively near-term,* and *on, or near*, are important terms for understanding the guidance in this report.

- *Practical* – There are many options, permutations, obstacles, and caveats, which can be considered when deploying a nuclear energy facility on, or near, an existing coal plant. There may be barriers that need to be overcome that could be alleviated with additional expenditure of time, money, and other resources. The goal of this document is to provide guidance that is pragmatic and sensible, particularly for earlier adopters, while also detailing the many issues and options that must be considered when doing so.

- *Relatively Near-Term* – Currently, there are a few nuclear technology options available, and more are in development. Also, there are many coals plants already retired with more planned to retire in the next 15 years (see Section 1.2 below). The goal of this document is to provide guidance on the most practical options for earlier adopters, i.e., those looking to have an operating nuclear facility in less than about 15 years.
- *On, or Near* – The concept of repowering coal sites with nuclear has been much discussed recently and a lot of this discussion has been about reuse of the specific coal plant site. While that is a viable option, this report will also discuss the concept of considering the region encompassed by the local coal plant community as a potentially available, practical, and timely, option.

This document provides an overview of the general process (see Figure 2-1) and discusses some of the opportunities and issues that may present themselves, and it also includes practical steps that make sense for a limited set of nuclear deployment scenarios. The specific circumstances of any locale, utility, plant site, or community may differ requiring choices or solutions not described herein. As noted above, there are other nuclear deployment alternatives available, but they may require additional time, money, or other resources.

While there are several potential new generation options available for repurposing a coal site, this document specifically addresses the deployment of new nuclear energy facilities, with a focus on electric power generation.

In addition to Section 1, which provides a background and foundational information, this document contains two primary technical sections:

- Section 2, Process Overview – This section describes the process one should follow to identify a potential site, determine if nuclear is an option for that site, and take the initial steps for nuclear deployment. Process steps include:
  - Define the Owner-Operator’s Mission and Business Objectives (Section 2.1)
  - Site Identification (Section 2.2)
  - Physical Site Characteristics and Technology Selection (Section 2.3)
  - Evaluate Site Infrastructure and Existing Assets (Section 2.4)
  - Securing Land, Transmission, and Water Rights and Other Permits (Section 2.5)
  - Cost and Other Economic Evaluations (Section 2.6)
  - Obtaining an Early Site Permit (optional. Section 2.7)
  - Community Outreach (Section 2.8)
- Section 3, Options and Considerations – This section describes a limited set of possible technical, environmental, and social issues and opportunities that may arise while performing the process in Section 2, and alternatives to address them.

1.2 Coal Plant Retirements

The potential need for power and the opportunity for deployment of nuclear on an existing coal site or within the community are both driven by the same circumstances in the U.S. and globally.

Evolving economic, regulatory, and carbon reduction goal conditions are changing the viability and desirability of operating coal-fueled generating assets. In the U.S., more than 90 gigawatts (GW) of older, smaller, and less economically efficient coal units have been retired since 2000 (2000 through 2021) due to environmental and economic changes (U.S. EIA, 2023). Global goals for managing climate change have put intense policy pressure on the coal fleet while driving significant financial change, including an increasing difficulty in financing coal related projects (CESifo, 2019). Pressures to retire and decommission the remaining coal fleet continue to mount as power generators worldwide transition to low-carbon or carbon-free energy sources.

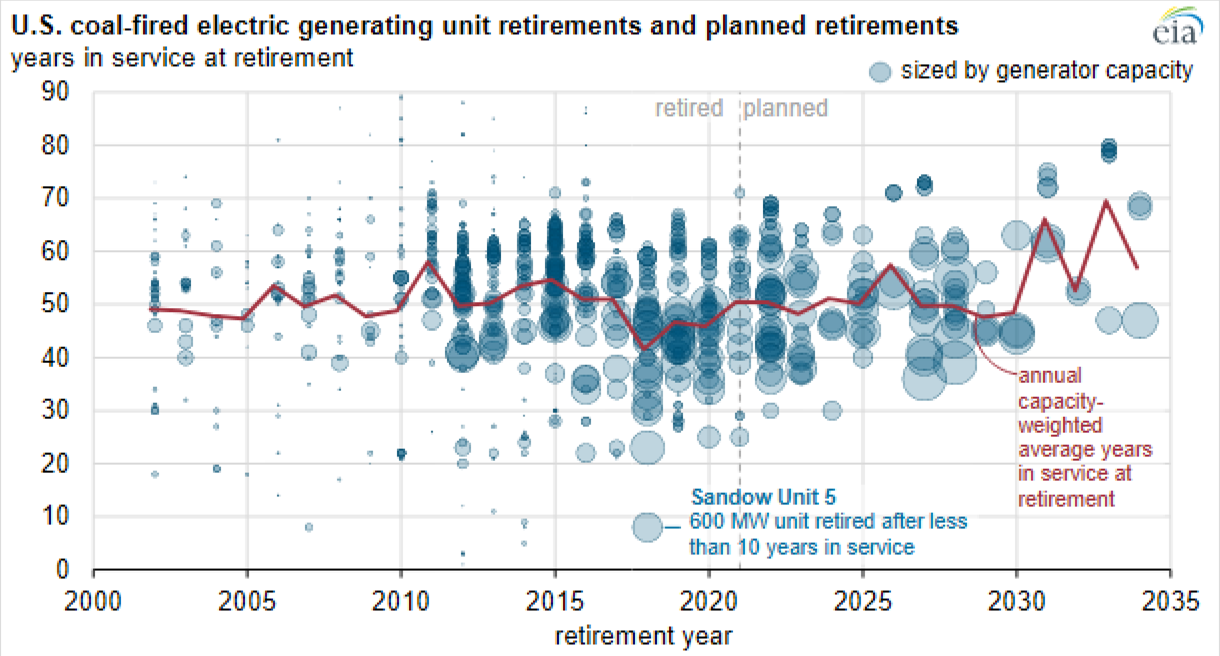

Figure 1-1
U.S. Coal Plant Retirements, Current and Planned (U.S. EIA, 2021)

Utilities across the United States have announced nearly 60 GW of coal plant retirements within the next 15 years (2023 through 2037) (U.S. EIA, 2023). This next round of plant retirements presents several new challenges. The average name-plate capacity for U.S. coal plants being retired in the next 15 years is approximately 450 MW per unit, compared to an average of 180 MW for units retired in the past 15 years (2008-2022) (see circle size increase in Figure 1-1).

Globally, including the U.S., the expected coal retirements over the next 15 years amount to about 280 GW (Global Energy Monitor, 2023). In fact, the World Economic Forum has noted that international coal plant retirements, preferably converted to cleaner energy, must be accelerated to meet International Panel on Climate Change (IPCC) goals by 2050 (World Economic Forum, 2020).

The plants slated for retirement now are technically more complex than older plants due to equipment such as air emission controls, and regulatory changes have resulted in more strict environmental limits, newly regulated materials, and more public scrutiny on the closure process. These new challenges are adding cost and risk to the decommissioning process for larger plants.

Utilities have typically addressed replacement of decommissioned firm baseload coal generation by constructing natural gas-fired units at existing facilities. For example, between 2011 and 2019, 103 U.S. coal plants were either converted to or replaced by natural gas power plants (U.S. EIA, 2020). However, the transition to low-carbon generation suggests this type of replacement may no longer be desirable or feasible. Rather, companies need to assess their coal-fired facilities to identify whether the power and grid services are needed, and if so, the assets of the site, limitations, and options for developing new clean energy generation in place of the existing facility.

Converting the existing challenges to opportunities can be addressed by systematically creating an inventory of the existing site infrastructure, characteristics, permits, and other attributes, and correlating it with the needs of the clean energy alternative that will fit both the retiring coal plant and the needs of the local community.

There are several advantages to repowering an existing coal site for new generation:

- Operating coal plant sites have existing transmission infrastructure and interconnection permits that may be able to be reused, modified, or extended.
- Many such sites have access to well-developed transportation infrastructure via road, rail, and waterways, as well as existing utility connections for buildings.
- The existing environmental permits for a coal facility may be modifiable for application to a new generating facility, thus streamlining an often-lengthy permitting processes and leveraging the community's knowledge in the collection of required public input.
- Many current sites offer the advantage of access to a large daily water withdrawal and water discharge allowance. In the United States, the right to withdraw water is under more scrutiny, and there are reputational and permitting advantages to modifying existing water withdrawal and discharge permits rather than undergoing the permitting process in a new area, if regulations permit doing so.
- Facilities with a land use permit, certificate of occupancy, and buffer property to provide a visual and physical barrier from neighbors provide siting advantages that may allow new plants to be constructed and commissioned more quickly than in a new location.
- Existing buildings, warehouses, and site equipment may offer opportunities to lower the cost of construction by repurposing those for the new generation option.

In addition to the benefits of existing land, infrastructure, permits and equipment, repowering a site for new generation may benefit the surrounding community. Local, state, and federal governments, municipalities, non-governmental organizations, development commissions, and environmental justice advocates increasingly call for fossil-fuel-based power generation facilities planning for, or undergoing, decommissioning to transition via site redevelopment to a new use for the property. The goal is to replace the taxes, jobs, and community goodwill that are lost when the coal plants retire, potentially providing retraining and continued employment for some, or all, of the coal plant workforce.

In the U.S., redevelopment of decommissioning coal plants became a federal priority in 2021, with the U.S. Congress and the U.S. Environmental Protection Agency (EPA) encouraging the transition of closed or closing coal power plants, and the industries that support coal-fired electricity generation, to adopt clean energy technologies. For example, in a 2021 report, the U.S. *Interagency Working Group on Coal and Power Plant Communities and Economic Revitalization* identifies the need to promote job-creating investments in communities, provide funding for local infrastructure, economic development, and training, by aligning twelve separate agencies to focus on the issues (U.S. Administration, 2021).

1.3 U.S. Coal Sites as Potential Nuclear Sites

A recent study by the U.S. Department of Energy (U.S. DOE, 2022) performed a preliminary evaluation of many U.S. coal sites, both retired and operating, for their potential viability to support a new nuclear plant. The study made use of manual techniques as well as automated Geographic Information System (GIS) software to perform an analysis like that described in Section 2.3.1 below. The study estimates that about 300 retired and operating coal sites *have the basic characteristics needed to be considered amenable to host an advanced nuclear reactor*. The report is extensive and contains several different breakdowns of the data, but two key takeaways are noted in the maps below. Figure 1-2 identifies the number of currently operating coal sites, by state, likely amenable to nuclear repowering[1] while Figure 1-3 identifies the number of coal sites retired in last six years, by region, likely amenable to siting an Advanced Reactor[2].

Two additional important considerations are identified in the report: The first is that population density is a key discriminator in determining viability for repowering with new nuclear (see Table 2-1, Population), and the second is that a crucial *factor favoring backfit of near-term nuclear technology at operating coal-fired utility and IPP generators is the existence of a dedicated cooling source*, a property exhibited by 43% of retired coal sites and 68% of operating coal sites.

Owner-operators can contact the DOE directly regarding the report and its results[3].

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[1] The data in Figure 1-2 is based on operating plant data and analysis found in Tables 3-15 through 3-19 of the DOE report and does not consider retirement dates.

[2] The data in Figure 1-3 is based on data and analysis found in Tables 3-1 and 3-7 of the DOE report.

[3] It is understood by EPRI that coal plant owner-operators can contact the DOE for the data specific to their plant, which the DOE will provide subject to potential restrictions. EPRI does not have the data, cannot provide it, and makes no warranty on the ability to obtain the data or on the results. To request the information, contact the team at the Gateway for Accelerated Innovation in Nuclear (GAIN).

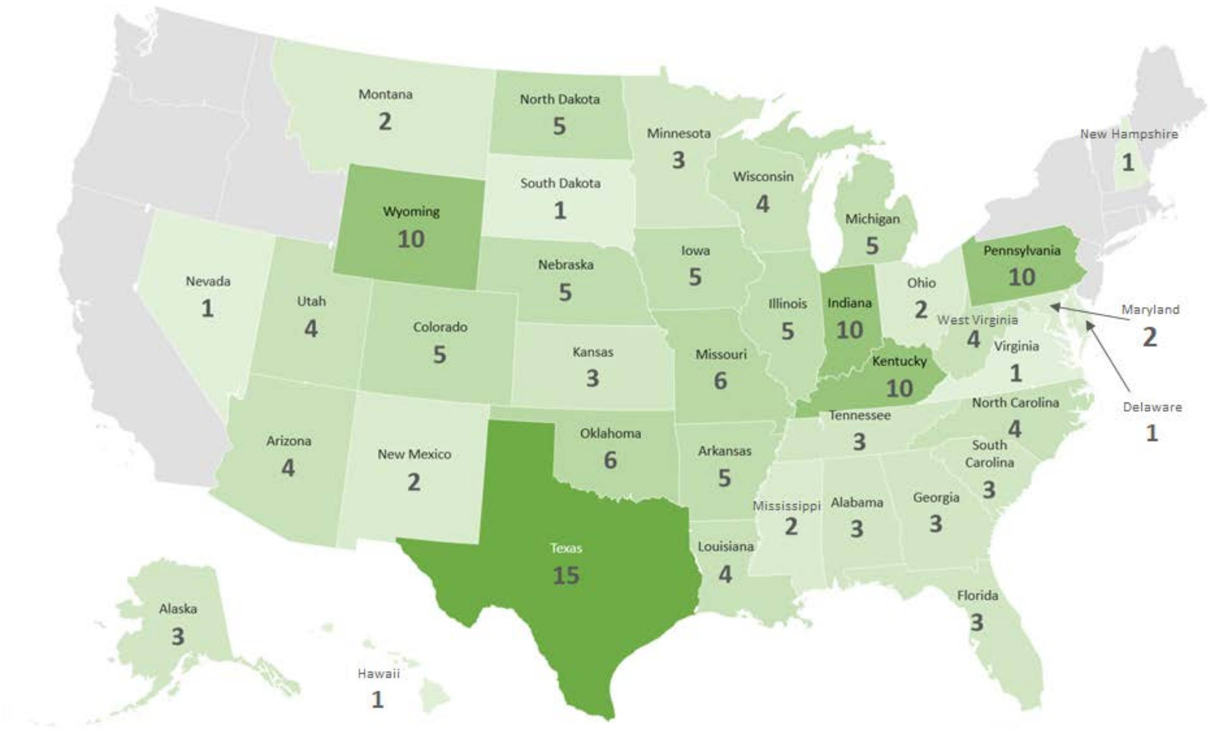

Figure 1-2
Map of Operating U.S. Coal Sites Potentially Viable for Advanced Nuclear

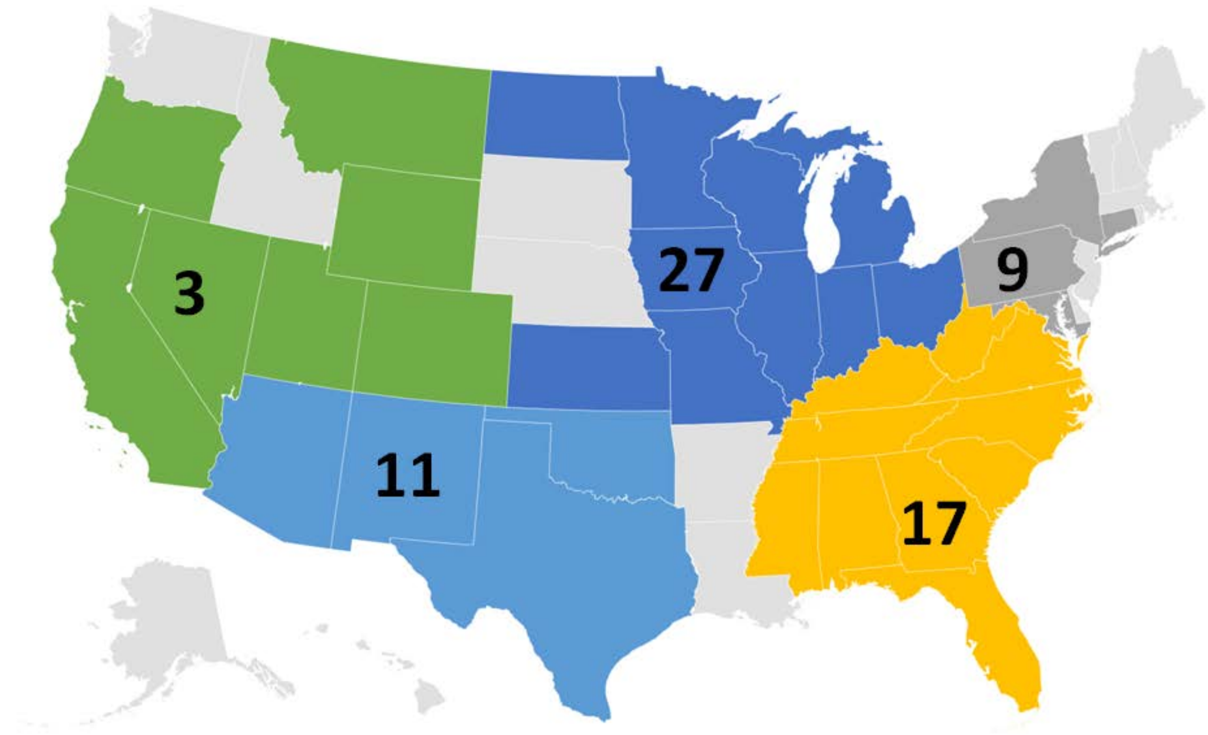

Figure 1-3
Number of U.S. Coal Sites Retired in Last 6 Years Likely Amenable to Siting an Advanced Reactor

1.4 Benefits of Nuclear for Repowering Coal Sites

The decision to deploy a nuclear plant on a retired coal site cannot be made in a vacuum and must be thoughtfully based on the owner-operator's business objectives in consideration of all other potential uses for the site, including energy-based solutions and those that are not, such as green fielding and re-sale for other development. For the purposes of this document, it is assumed that a decision to at least evaluate nuclear has been made, and that strict impediments such as a local moratorium on nuclear do not prevent deployment. With that understanding there are good reasons to include nuclear as a potential deployment option:

- **Clean** – While country, state, and local regulations may value it differently, nuclear power generation is non-carbon-emitting during its operating lifetime and, except for hydropower, emits less carbon over its entire lifecycle than any other generation source. (IPCC, 2015).
- **Reliable** – Nuclear plants have proven to have the highest capacity factors of any generation asset on the grid, routinely operating above 90% (WNA, 2022a).
- **Dispatchable** – Advanced Reactors will have the ability to operate flexibly on grids that include significant intermittent generation, such as solar and wind (EPRI, 2019b).
- **Scalable** – Nuclear plants can be sized to have generation parity with the original coal site, providing a similar electrical supply in the same location capable of servicing the same end users, and efficiently utilizing existing transmission capacity (Qvist, Gładysz, Bartela, & Sowizdzał, 2020).
- **Economical** – Although the capital cost of nuclear deployment can be higher than other generation, their long life and low fuel cost can make them economically attractive over the long term (WNA, 2022b).
- **Good Neighbor** – The long life of a nuclear plant is also an asset to the local community, providing much needed economic stability with an impact in terms of tax base and ancillary service businesses like the coal plant (Good Energy Collective, 2021). Nuclear plants can also provide both direct and indirect jobs to the local community in numbers like, or perhaps even greater than, the coal plant, with many jobs being transferable with reasonable training (ScottMadden, 2021; U.S. DOE, 2022).

As with other generation options there are also considerations that may make nuclear power unattractive. The most prominent issues center around community sentiment regarding perceived risk and nuclear waste management. From a technical perspective these issues can be overcome, and many forthcoming AR designs purposely address these concerns, but it is something that must be understood and evaluated when making the business decision to deploy nuclear. Since coal communities have had experience with power generation, this shared experience can be a good point for the owner-operator and local stakeholders to start a conversation.

From an international perspective, and as noted by international experts at a recent International Atomic Energy Agency event (IAEA, 2022a):

> Repurposing coal plants with SMRs would enable the continuation of power production for local customers. Their generation capacity, between 200 MWe and 400 MWe, is similar to that of a typical coal fired plant, therefore these SMRs would also be suited to existing grid connections…Cost saving factors could

> include avoiding land acquisition for the SMR plant, having an existing water source as well as rail and road connectivity, and a pool of trained human resources within commuting distance…Nuclear energy is uniquely positioned to redirect workers from the retired fossil fuel industry to the nuclear power plant, preserving steady power generation…

The repowering of coal plants to new nuclear can provide many advantages for electricity production, climate change, and communities.

1.5 End User Considerations

1.5.1 Getting Started

The following are recommended EPRI reports for those starting the process of evaluating nuclear power as a deployment option:

- *Site Selection and Evaluation Criteria for New Nuclear Energy Generation Facilities (Siting Guide),* EPRI 3002023910 (EPRI, 2022g) – The *Siting Guide* contains complete guidance on the criteria for siting a new nuclear plant. A primary goal of this document is to support the evaluation of whether an existing coal site can support development of a new nuclear facility, therefore much of this document refers to the EPRI *Siting Guide*.
- *Owner-Operator Reactor Technology Assessment Guide (Technology Assessment Guide),* (EPRI 3002025344) (EPRI, 2022a) – The *Technology Assessment Guide* describes the process for evaluating different reactor technologies and designs to find the best options for deployment. Having a specified Original Equipment Manufacturer (OEM) design is not required for early evaluation, but not having one or two designs identified will limit the evaluation without major assumptions because some decisions are design dependent.
- *New Build Nuclear Plant Development and Technical Assistance: Guide to EPRI Resources* (*NPTA*)*,* (EPRI 3002025692) (EPRI, 2022f) – The *NTPA* report provides a high-level discussion of the activities involved in a new build reactor project. It includes checklists regarding key information needed as the project moves forward from one phase to the next and includes a focused bibliography of resources that EPRI has available. This guide is intended for those new to nuclear plant development.
- *Coal Repowering White Paper Series: Repowering Coal-Fired Power Plants for Advanced Nuclear Generation,* (EPRI 3002025482) (EPRI, 2022b) – This white paper is a precursor to this report and provides a good summary of the opportunity for repowering a coal site with nuclear.

1.5.2 Energy Facilities, Plant, Sites, and Units

It is important to differentiate a coal site from a unit. Many coal sites have multiple units, and the retirement date of individual units on any one site may differ. Table 1-1 below shows some statistics on the planned retirements in the next 15 years based on the EIA data discussed above (U.S. EIA, 2023). Also note that not all coal sites will make for good nuclear candidates (see Section 1.3).

Table 1-1
Planned Coal Plant Retirements in U.S. Next 15 Years

Planned Coal Plant Retirements in U.S. Next 15 Years		
	Sites	**Units**
All Sizes		
Count	63	132
Minimum Size (MWe)	12	12
Maximum Size (MWe)	2,600	1,300
Median Size (MWe)	850	419
Average Size (MWe)	951	454
Plants and Units >= 250 MWe[4]		
Count	57	99
Median Size (MWe)	950	548
Average Size (MWe)	1,037	552

Unfortunately, in the cases of both coal-fired and nuclear generation, the terms *Energy Facilities, Plant, Sites, and Units* are not well defined or universally used in the same way. In this document, when used in specific contexts, they are typically intended to mean the following:

- *Energy Facility* – An industrial complex that produces energy for any purpose, such as electricity, steam, or hydrogen production.
- *Plant* – An industrial and organizational complex that houses a facility that generates electricity. It is often used synonymously with Site and Unit.
- *Site* – The specific land area that hosts the Plant, or Units.
- *Unit* – An individual complex that typically contains one heat source and one generator (but not always).

However, unless it is made clear in another context, readers can assume that the terms used in this document mean what they need them to mean for their own situation and business purposes. Consider the following two example statements:

- The owner-operator currently has a coal plant that sits on a site containing three units. They wish to decommission two units and replace them with three SMRs on a new site that is 70% the size of the land previously taken by the two retired units.
- The owner-operator has a single unit coal plant with a site size of 500 acres. They wish to decommission the plant and replace it with a single unit nuclear energy facility for hydrogen production.

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[4] Sizes of 250 MWe or more were selected because the economics of nuclear power, and trends in AR development, will tend to drive new nuclear plant sizes in this direction.

1.5.3 Reactor Size and Type Designations

The global nuclear industry has many classifications for defining the size and type of a nuclear plant. Unfortunately, these classifications are more generalizations than specifications which can lead to misunderstanding. Reactors are typically described by a subset of design attributes and features, which include:

- Coolant (water, gas, liquid metal, molten salt)
- Historical generation (I-IV)
- Mission (e.g., electricity, heat production)
- Thermal/electrical output (MWt/MWe) (also see Table 1-3)
- Neutron energy or speed (thermal or fast)
- Moderator (e.g., light water, heavy water, graphite)
- Fuel state (solid, liquid)

Classifications that are particularly relevant are detailed below.

1.5.3.1 Historical Generation

Generation (GEN) I, II, III, III+, and IV: These terms primarily refer to the historical development period of a nuclear reactor design. GEN I refers to the earliest prototype and demonstration reactors, of which there are none left operating today. Most reactors operating globally today are of the GEN II vintage, mostly light water reactors (LWRs), but also include other coolant designs (outside of the U.S).

GEN III and III+ reactors incorporate evolutionary improvements in design over GEN II, targeting standardization, efficiency improvements, and advances in safety. All GEN III and III+ designs are water-based, and many plants are operating globally, with more under construction or planned.

GEN IV specifically refers to a set of ARs currently under development and being studied by the Generation IV International Forum with expectations to start operations in the 2030’s. GEN IV reactors are expected to cover a broad range of plant sizes. Light water SMRs (lwSMR), while often included in GEN III/III+, offer attributes that bridge the GEN III/III+ and GEN IV classes. At the time of this revision, EPRI includes lwSMR technologies under the AR designation along with microreactors.

1.5.3.2 Size

Note: See Table 1-3 below for details on the relationship of size and thermal/electrical output.

Large Reactors (LR): Most commercial nuclear plants operating today are GEN II, III and III+ designs and would be considered Large Reactors (LRs). While there are some plants using different moderators and coolants, most are light water reactors, often referred to as Large Light Water Reactors (LLWRs), or Advanced Light Water Reactors (ALWRs) for later designs. Except for lwSMRs, GEN II, III and III+ designs have historically been large reactors, operating on the order of 600 - 1500 MWe.

Medium Reactors: The term medium reactor is not often used but is incorporated in this document to span the size gap between SMRs and LRs, about 300 MWe to 600 MWe. Historically, reactors in this size range have been avoided (except in the earlier years of nuclear development) due to economies of scale, being deemed too expensive to operate efficiently and leading to a proclivity for building ever larger designs. However, some new reactor designers are re-evaluating this size range on the assumption that modern construction and operations technology, combined with higher thermal efficiency, can make them economically attractive.

Small Reactors (SMR): Small reactors are often referred to as Small Modular Reactors (SMRs), however SMR is an ambiguous term that can easily cause confusion if not specified in more detail. At its simplest, this refers to a reactor generating a lower amount of electrical power as compared to more traditional large plants. SMRs are expected to be designed in a 'modular' fashion, but this is not a requirement and the definition of modular can vary from one design to another, including multiple small units deployed on a single site, multiple reactor modules deployed on a single site, or a more typical design but where the plant is constructed from factory-built modules.

In the U.S., the NRC considers light water designs of 300 MWe or less as SMRs (U.S. NRC, 2023c) while U.S. Code 42 USC §18751 defines an SMR as being less than 300 MWe ***and*** *that can be constructed and operated in combination with similar reactors at a single site* (U.S. House of Representatives, 2021), but those definitions are not globally standard and varied sizes and non-water designs may be considered SMRs in different countries. The U.S. DOE uses the term Advanced Small Modular Reactor (U.S. DOE, 2021) to mean both water and non-water-based designs, Canada uses the term Small Modular Reactor for the same thing (CA SMR Roadmap, 2018), and the IAEA defines SMRs as *advanced reactors with a power capacity of typically up to 300 MW(e) per unit, which is about one-third of the generating capacity of traditional nuclear power reactors and whose components and systems can be shop fabricated and then transported as modules to the sites for installation as demand arises* (IAEA, 2022b).

Microreactor (MR): Although there is no specific standard, this term typically refers to a small reactor generating a relatively low amount of power. A review of available literature will find the defining size of microreactors highly varied, ranging from about '10 MWe or less' up to '50 MWe or less'. The IAEA identifies microreactors as a subcategory of SMRs *with electrical power typically up to 10 MWe* (IAEA, 2022b). U.S. Code 42 USC §18751 defines a microreactor as being not greater than 50 MWe, while the U.S. GAO notes in a 2020 report that *Nuclear microreactors are very small reactors usually generating less than 50 megawatts electric (MWe)* (U.S. GAO, 2020), and as noted by the U.S. NRC in SECY-20-0093 (U.S. NRC, 2020f):

> There is not an agreed-upon definition for what constitutes a micro-reactor. Nevertheless, characteristics shared by the designs referred to as micro-reactors by stakeholders, industry, DOE, and DOD include low potential consequences in terms of radiological releases, small site footprints, and power levels generally on the order of tens of MWt or less, with increased reliance on passive systems and inherent characteristics used to control power and heat removal.

The low power levels, small site footprint, and high safety features available to microreactors open many opportunities for use cases and siting versus the considerations for much larger plants (EPRI, 2022e). For the purposes of this document, a plant operating at 50 MWe or less is considered a microreactor.

1.5.3.3 Technology Generation

After size, the native attributes of the specific reactor technology are important when evaluating them against other designs. The proposed designs for new reactors under development implement innovative technologies that impart many positive attributes, primarily for safety, but also for construction and operations, which can open opportunities for deployment. It can be useful to characterize reactor technology into two groups:

Current Generation: The current generation of nuclear plant technology encompasses all types of commercial nuclear reactors currently operating globally. As noted above, this includes GEN II, III and III+ designs (including developed LR designs not yet built and those under construction but excluding light water SMRs).

Advanced Reactor (AR): Much like SMR or MR, the term advanced reactor can be ambiguous, and many organizations have developed their own definitions. For example, the Nuclear Energy Institute (NEI) (NEI, 2023), the U.S. Congressional Research Service (U.S. CRS, 2019), and a recent U.S. DOE Funding Opportunity Announcement (U.S. DOE, 2020a) all identify slightly different definitions for advanced reactors (one including fusion), but a common theme is identified by the CRS as *a nuclear fission reactor with significant improvements over the most recent generation of nuclear fission reactors*. While the reactor types identified as GEN IV are typically considered ARs, the GEN IV designation is specific, so other reactors could be considered ARs as well.

The assessment process defined in this document is intended to be technology agnostic, however, and the following definition of AR is used by this document:

> ***An advanced reactor (AR) is any (fission) reactor concept or design beyond Generation (GEN) III/III+ technologies and includes non-light water designs, light water SMRs, and microreactors.***

1.5.3.4 Reactor Types and Designations

Since the beginning of the nuclear era there have been many proposed, tested, demonstrated, and deployed nuclear plant designs. Going into the details of all these designs is beyond the scope of this document, but the Nuclear Innovation Alliance has a detailed primer on some of the most current designs (NIA, 2023), the IAEA has additional references on *Advanced Large Water-Cooled Reactors* (IAEA, 2020) and *Advances in Small Modular Reactor Technology Developments* (IAEA, 2022b), and the organization Third Way manages a map of known AR OEMs and their designs (Third Way, 2022). Table 1-2 below contains a summary of the various reactor types and their common abbreviations which are often used in documentation and literature.

Table 1-2
Common Reactor Types

Type	Coolant	Abbreviation
Water	Light Water	PWR
		BWR
	Heavy Water	HWR
	Super Critical Water	SCWR
Gas	Carbon Dioxide	GCR
	Helium	HTGR
Molten Salt[5]	Molten Salt (Liquid Fueled)	MSR
	Fluoride Salt (Solid Fuel)	FHR
Liquid Metal	Lead	LFR
	Sodium	SFR

1.5.4 Land Area

When assessing various technologies and designs, the size of the nuclear plant can be an important attribute because under any scenario viable land space is a minimum requirement. It is best to have concrete knowledge of the land area needed for the chosen plant design, however, at early points in the evaluation process, design selection may not yet be complete enough for a rigorous assessment. Or, for example, in the case of an Early Site Permit (ESP) that makes use of a Plant Parameter Envelope (PPE, see Section 1.5.5), only general area size estimates may be known. At certain points in the various evaluation processes (EPRI *Siting Guide* Section 2), and criteria evaluation (EPRI *Siting Guide* Section 3) it is best if the land area is known, therefore, in the absence of exact known values, the values in Table 1-3 below can be used for guidance.

Note: There is some discussion globally about using marine-based technology for nuclear generation, which could then be used to replace lost generation from retired coal plants. The focus of this report is on land-based reactors and much of the discussion would not apply to marine-based reactors, which have vastly different considerations. For more information on marine-based nuclear power see the WNA's Nuclear-Powered Ships topic (WNA, 2023).

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[5] There are many different formulations of Molten Salts, and the choices depend on neutron energy design, solid or liquid fuel, and whether the salt is used as a primary or secondary coolant. See the World Nuclear Association's web page on Molten Salt Reactors (WNA, 2021).

Table 1-3
Typical Plant Land Area vs. Size

Size[6]	Operating (MWt)	Output[7] (MWe)	Typical Land Area Needed [acres (hectare)][8]		
			Plant Footprint[9]	Overall Site[10]	Additional Construction
Micro	≤150	≤50	0.1 to 4 (0.04 to 1.6)	1 to 8 (0.4 to 3.2)	2 to 10 (0.8 to 4)
Small (SMR)	150 ≤ 900	50 ≤ 300	25 to 200 (10 to 80)	50 to 500 (20 to 200)	50 to 100 (20 to 40)
Medium	900 ≤ 1800	300 ≤ 600	60 to 250 (25 to 100)	250 to 800 (100 to 325)	75 to 200 (30 to 80)
Large	> 1800	> 600	100 to 400 (40 to 160)	500 to 2000 (200 to 800)	100 to 500 (40 to 200)

Plant Footprint refers to all area needed to support the operating plant and includes items such as parking, offices, permanent support buildings and warehouses, waste storage, the power block, switchyard, cooling towers, laydown and storage, and the protected area (over and above any previous items). Note that this can vary significantly based on overall plant layout, including the compactness of the site (i.e., distance between buildings and other infrastructure).

The *Overall Site* includes the plant footprint plus any additional area technically declared as part of the site. As with the plant footprint, this can vary greatly. It could be just slightly larger than the plant footprint or could be significantly bigger depending on the overall characteristics of the site (e.g., orientation of existing property boundaries, location of water sources, environmental

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[6] The size and related values represent a single unit. Deployment of multiple units on a site is not necessarily a multiple of the numbers provided here and is dependent on reactor type, design, and layout. Consultation with an OEM and AE is recommended to obtain accurate values, however, in the absence of specific information, the unit sizes can be added together to estimate the land area.

[7] The MWe values are estimated based on MWt and standard Rankine efficiencies of 33%.

[8] The values in Table 1-3 are typical ranges based on consolidated values from several sources, including the EPRI *Siting Guide* (EPRI, 2022), NRIC's 2021 report on *Advanced Nuclear Reactor Plant Parameter Envelopes* (NRIC/PNNL, 2021), and select recent COL (U.S. NRC, 2020) and ESP (U.S. NRC, 2020c) licensing submittals. These values are for approximating land use, which is not 100% proportional to plant size in MWt or MWe and cannot be explicitly defined without discussion with an individual OEM and AE.

[9] As of publication time, the U.S. NRC has issued a draft *Generic Environmental Impact Statement for Advanced Nuclear Reactors* (U.S. NRC, 2021), which "…assumes that the proposed plant site would be no larger than 100 ac (40.5 ha), within which site disturbance would affect no more than 30 ac (12 ha) of land permanently and no more than 20 ac (8.1 ha) of additional land temporarily".

[10] If a cooling water reservoir is needed, the overall site could be as much as 4,000 acres (1,600 ha) larger, see Overall Site below. Some designs may be able to use air or hybrid cooling. While these systems can significantly reduce water needs, land space requirements can greatly increase.

consideration such as wetlands), the size of the NRC Exclusion Area Boundary (EAB)[11], other site planning considerations, and future site plans (e.g., future additional units).

The anticipated size of the Emergency Planning Zone (EPZ)[12] is a unique aspect of SMRs and ARs that should be considered when determining the land area needed for the proposed project. Because an EPZ for an SMR or AR could be much smaller an applicant siting a new nuclear plant may want to ensure the overall site footprint would encompass the anticipated EPZ size for the technology under consideration, or the bounding parameters contained in the PPE if a technology has not been selected.

When exact values are not known, there are a couple of criteria that can be useful for estimating at least the minimum site size. First, the plant footprint is the absolute minimum size for a site. Second, the size of the EAB can also be used as a reasonable proxy for at least a target lower end size. While it is not mandatory that the overall site proper be contained within the EAB, the requirement that "*…the reactor licensee has the authority to determine all activities including exclusion or removal of personnel and property from the area."* (U.S. NRC, 1998) indicates that containing the EAB within the site would provide the licensee with greater control of the activities within the EAB and potentially ease emergency management. These EAB requirements could limit the minimum land size needed, even for reactors with small facility footprints.

If a new plant or units are being constructed on or near an existing plant the overall size of the new site can be often significantly reduced because large sections of land have already been allocated, and some space can serve the existing and new plant. For example, the cooling water inlet and outfall, office and warehouse spaces, outage parking, etc., may be able to service the additional unit. On the other hand, if a new greenfield site is being developed and a cooling water reservoir is needed, the overall site could be significantly larger, and adding as much as 4,000 acres (1,600 ha) in additional area.

The *Additional Construction* area is an additional temporary area needed for construction. It may or may not end up being part of the site (e.g., nearby leased property), but it must be accounted for in an environmental review for U.S NRC licensing (U.S. NRC, 1996).

When evaluating land availability for a targeted site, such as an existing coal site, it is best to start with land area requirements on the higher end of the spectrum if actual requirements are not known (i.e., a specific design has not been selected). Assuming a viable cooling water source is available, there is typically no need to account for a cooling reservoir. If the available land space does not meet the higher-end requirements, then an evaluation will need to be made. If the available land size is close to the lower end requirements, then this could be problematic for deploying nuclear, at least at the size (i.e., MWe/MWt) desired. The best solution is to work with one or more OEMs to understand the actual land space needed (see section 2.3).

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[11] The Exclusion Area Boundary (EAB) is defined by the U.S. NRC as "area in which the licensee has the authority to determine all activities including exclusion or removal of personnel and property from the area" and is based on the potential radiation dose received by the public in the case of an accident (U.S. NRC, 1996).

[12] The U.S. NRC defines Emergency Planning Zones (EPZs) as the local areas around the nuclear plant for which it is required to have emergency plans (U.S. NRC, 2020). There are technically two EPZs, the Plume Exposure Pathway EPZ and the Ingestion Exposure Pathway EPZ (U.S. NRC, 1978). For existing reactors in the U.S., the Plume Exposure Pathway EPZ is 10 miles (16 km), and the Ingestion Exposure Pathway is 50 miles (80 km). The NRC is considering new regulations that could significantly reduce the size of the EPZ for ARs (U.S. NRC, 2020). Typically, the term EPZ (singular) is referring to the Plume Exposure Pathway EPZ.

1.5.5 Plant Parameter Envelope and Site Parameter Envelope

The terms *Plant Parameter Envelope* and *Site Parameter Envelope* are often used when siting a nuclear plant. While these terms sound similar, they are distinct in their definition and purpose. These concepts can be useful when assessing siting, as well as technologies and designs.

The purpose of a Plant Parameter Envelope (PPE) is to allow for the identification of potential sites when a specific plant design or technology has not yet been selected. In the U.S., this can be beneficial when developing an Early Site Permit (ESP) in accordance with 10 CFR 52 Subpart A (U.S. NRC, 2007d). A PPE is a detailed set of plant parameters reflecting bounding values for required site conditions. It is used when an applicant has identified one or more reactor designs for consideration and vendors have developed sufficiently detailed site requirements for their reactor designs. The PPE reflects bounding values across all designs being considered for each plant parameter and combines them into a single set of bounding conditions. Thus, potential sites meeting the bounding values could be considered suitable locations for any of the designs reflected in the PPE. The PPE then defines the envelope of the facility/site interface, conditions that if not satisfied by a potential site may preclude locating a nuclear plant there. Consider the following simple example:

Attribute	Plant A	Plant B	Bounding Condition	Bounding Plant
Min. Land Area	1000 acres (400 ha)	2000 acres (800 ha)	2000 acres (800 ha)	B
Cooling Water Flow Rate	700,000 gal/min (2,650 m^3/min)	600,000 gal/min (2,270 m^3/min)	700,000 gal/min (2,650 m^3/min)	A
Operating Staff	400 people	300 people	400 people	A

As individual parameters from each design are compared, the most bounding (nominally the most conservative value for siting purposes) is taken as the value used for the siting process, with the understanding that any site that meets all bounding conditions should then be able to support any of the reactor designs under consideration. In 2003, the NRC confirmed the PPE approach to be a valid methodology (U.S. NRC, 2003) and organizations developing an ESP can use NEI 10-01, *Industry Guideline for Developing a Plant Parameter Envelope in Support of an Early Site Permit, Revision 1* (NEI, 2012), for guidance on developing a PPE.

Note: At the time of publication, the NRC just issued a new Regulatory Guide (U.S. NRC, 2023d) on the use of a PPE, and NEI has issued a draft revision 2 of NEI 10-01 (NEI, 2021).

It is important that plant designs considered under the PPE approach be similar in most attributes, particularly in major attributes such as size, water usage, and ecosystem impact, or the overall bounding conditions may become overly conservative for some of the subject designs. Technically, if the bounding values meet the mission and purpose of the projects, the PPE approach would still work, but the resulting sites identified for consideration might be limited, possibly leading to a site selection that is not optimal for the final chosen design.

While the PPE is developed by the owner-operator during the siting process to identify potential sites that could support several designs, the Site Parameter Envelope (SPE) is developed by the reactor designer for their specific design. Like the PPE, it identifies bounding parameters, but for only one specific design. The purpose of the SPE is to allow the identification of a potential site of which the owner-operator can be reasonably assured that the plant under consideration can be sited with minimal changes to both the site and plant. Once a plant design is selected, a SPE can be a powerful tool to help screen potential sites during the siting process as defined in the EPRI *Siting Guide* (EPRI, 2022g). The SPE can also be used to bound environmental impacts, easing the effort to develop Environmental Reports (ERs) (U.S. NRC, 2007e)

These two concepts can play a part in the technology assessment process as defined in the EPRI *Technology Assessment Guide* (EPRI, 2022a). For example, if an ESP based on a PPE exists then several technologies or full designs will typically have been developed and the PPE parameters can be used as specific inputs into the assessment process. While it is likely that an owner-operator will already have put significant effort into understanding technologies and designs in the creation of a PPE for an ESP, the assessment process can still be used to select a final design. Additionally, if enough time has passed, innovative technologies may be available, or previously identified designs may no longer be available, necessitating additional evaluation.

If no PPE exists but a site has been identified, then the output of the technology assessment process (the selection of a primary design and alternatives), can be used to create one where the PPE bounds the primary design and one or more of the alternatives. On the other hand, upon selection of a primary design, that design's parameters (including any alternatives for bounding) can inform the creation of an SPE, which can provide input into the site selection process.

1.5.6 End User Applicability

This document is intended to be applicable to any owner-operator regardless of locale and is intended to be as regulatory neutral as possible. The actual process identified in Section 2 is regulatory agnostic and valid for almost any site or nuclear technology. Where reference to regulations is deemed needed, U.S. regulations are used for reference. Any noticed regulatory requirements will typically be necessary in any region because the activities themselves are needed to ensure nuclear, personal, and environmental safety. End users outside of the U.S. are encouraged to follow the process and use the references and examples provided to help guide them under their own regulatory requirements.

2

PROCESS OVERVIEW

Once both a specific site and nuclear plant design have been identified the process for new nuclear development and deployment is largely well established, typically following national regulatory requirements and recognized project management principles. There are many references an organization can use for this portion of the process, such as:

- *New Plant Deployment Program Model*, EPRI 1015113 (EPRI, 2008)
- New Build Nuclear Plant Development and Technical Assistance: Guide to EPRI Resources, EPRI 3002025692, (EPRI, 2022f)
- Project Management in Nuclear Power Plant Construction: Guidelines and Experience, NP-T-2.7 (IAEA, 2012b)
- *Construction for Nuclear Installations*, SSG-38 (IAEA, 2015)

And, of course there are locale specific regulations, such as that found in U.S. NRC 10 CFR 50 (U.S. NRC, 1998), 10 CFR 52 (U.S. NRC, 2007c), and associated guidance in relevant NUREGs and Regulatory Guides.

There is, however, limited guidance on the specific subject and process for redevelopment and deployment within coal communities. There is recent work that can be referenced on subjects such as:

- Coal Repowering White Paper Series: Repowering Coal-Fired Power Plants for Advanced Nuclear Generation, EPRI 3002025482 (EPRI, 2022b)
- Investigating Benefits and Challenges of Converting Retiring Coal Plants into Nuclear Plants, INL/RPT-22-67964 R1 (U.S. DOE, 2022)
- Idaho National Laboratory: Transitioning Coal Power Plants to Nuclear Power, INL/EXT-21-65372 (INL, 2021)
- *Retrofit Decarbonization of Coal Power Plants—A Case Study for Poland* (Qvist, Gładysz, Bartela, & Sowizdzał, 2020)
- Gone with the Steam: How new nuclear power plants can re-energize communities when coal plants close (ScottMadden, 2021)
- Opportunities for Coal Communities Through Nuclear Energy: An Early Look (Good Energy Collective, 2021)

However, this body of work provides little guidance on the specific steps one should take to decide to build in the first place, nor the evaluation of opportunities and challenges that will go into that decision making process.

This document provides a high-level process for determining whether a coal-fired power plant already retired, or slated for retirement, is suitable for repowering with nuclear generation. This includes determining if deployment nearby, or elsewhere within the coal plant community, is a viable option. This section covers the key issues and general process to consider when performing this evaluation, as shown in Figure 2-1.

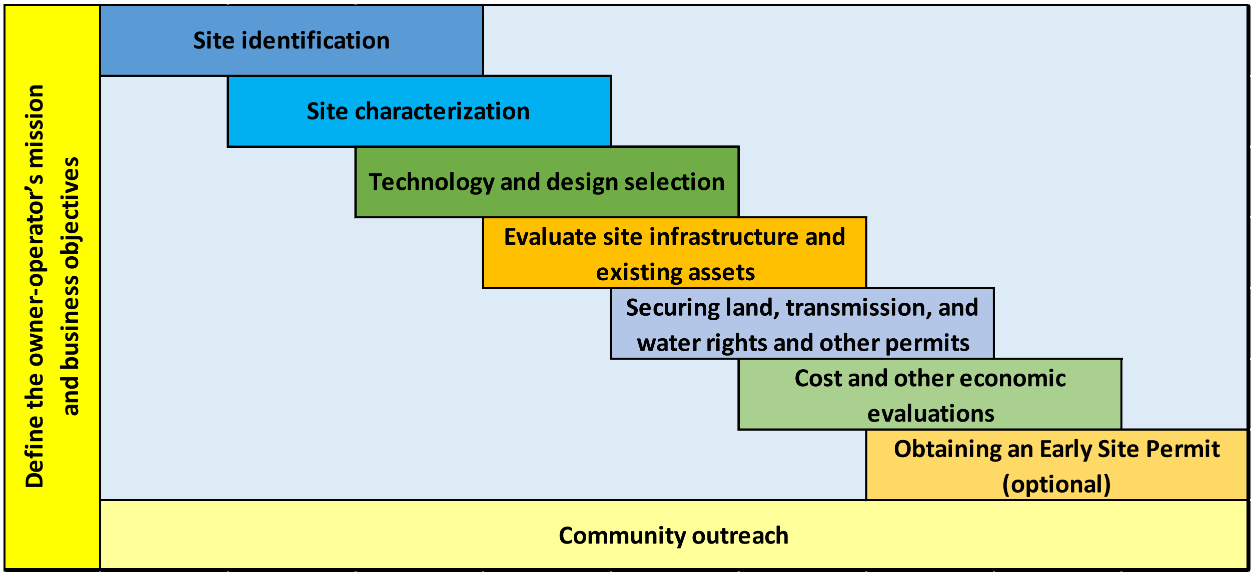

Figure 2-1
Early Process Steps for Repowering Coal Plant Sites to Nuclear

The deployment of a nuclear plant on the site of a retired coal plant requires significant planning. Due to the regulatory and licensing activities that must be completed there can be a gap in operations to account for decommissioning, remediation, and new construction. This time gap can be planned for, and details can be scheduled, but it is important that the planning activities begin early, preferably several years prior to scheduled retirement. Deployment of nuclear can take time, and an owner-operator will want to set themselves up for success.

Key activities that should be started as early as possible include:

- Define the owner-operator's mission and business objectives.
- Site identification
- Site characterization
- Technology and design selection
- Evaluate site infrastructure and existing assets (for potential repurposing)
- Securing land, transmission, and water rights and other permits
- Cost and other economic evaluations
- Obtaining an Early Site Permit (optional)
- Community outreach

The time to complete the above activities can vary and is dependent on the owner-operator's overall goals and timeline, as well as the level of effort applied and execution of activities in parallel, particularly in the preliminary stages. The original site suitability, decommissioning and remediation, the chosen design's readiness, and local regulations and regulator readiness, all contribute to the overall schedule. Time frames as low as three to five years and as high as ten or more years, excluding construction time, would not be unreasonable to assume.

The individual activities are discussed in more detail below.

2.1 Define the Owner-Operator's Mission and Business Objectives

Defining the mission and business objectives is the most crucial step and foundational to decision making. The EPRI *Technology Assessment Guide* (EPRI, 2022a) identifies a minimum set of criteria that should be developed by the owner-operator. They include items such as definition of the end-product (e.g., electricity or heat), required output (i.e., MWe or MWt), reasons for choosing the target coal site or other nearby location, plant service requirements (e.g.: priorities for flexible or firm generation, reliability, or weather resiliency), operating life expectancy, need dates and time frames, and budgets. This information is used for all remaining activities to ensure that the complex decisions are made according to the owner-operator's goals.

2.2 Site Identification

The EPRI report, *Site Selection and Evaluation Criteria for New Nuclear Energy Generation Facilities (Siting Guide)* (EPRI, 2022g) identifies a process for site identification and selection, including the identification of a primary site and alternative sites, which is a requirement of U.S. NRC regulations for obtaining a Construction Permit (CP) (U.S. NRC, 2016), Early Site Permit (ESP) (U.S. NRC, 2007d), or Combined License (COL) (U.S. NRC, 2007c). The identification of alternative sites may or may not be a requirement of regulators in other locales but is nonetheless identified as a best practice to ensure proper due diligence for site selection.

Typically, the process for selection of a primary site and any alternative sites is as described in Figure 2-2 and identified in the NRC review guidance for consideration of alternative sites, including Section 9.3 of NUREG-1555, (U.S. NRC, 2007e) and Section 9.3 of Regulatory Guide 4.2 (U.S. NRC, 2018). The first step in this process calls for identification of a *Region of Interest* (ROI). The definition of the ROI is based on the owner-operator's business objectives for the new nuclear plant, and NRC NUREG-1555 (U.S. NRC, 1999; U.S. NRC, 2007e) as well as Regulatory Guide 4.2 (U.S. NRC, 2018) and COL/ISG-27 (U.S. NRC, 2014b) all provide guidance for selection of the ROI in various circumstances.

Of key importance for deploying a nuclear plant at a specific location, such as a previously identified site or within an identified community, is the development of the ROI. For regulated electrical utilities the ROI is typically defined by the owner-operator's service territory or the combined service territory of participants in a jointly owned project. Owner-operators developing a merchant plant, or for other business objectives, must define their ROI based on the business objectives of the project. For example, if the objective is to supply power to a particular electric market, the ROI would allow for examination of sites in or near the boundaries of the selected regional transmission operator. A project to build on an identified target site or within an identified community could define a smaller ROI based on the mission and business objectives, which could include proximity to an existing grid connection and availability of water and other services. As stated in COL/ESP ISG-27 (U.S. NRC, 2014b) for lwSMRs:

> An applicant may request construction at a specific location to meet their purpose and need for a light water SMR facility. For example, an applicant may propose to use excess heat for industrial processes or station heating. A proposed light water SMR may be used to provide a secure energy source for military, government, or critical industrial facilities. In these cases, the applicant must still submit and the staff must review alternative sites. However, the region of interest used for the site selection process may be much smaller than is typical for LLWRs (e.g., within the confines of a military installation).

In any event, owner-operators should ensure that their ROI is large enough such that it does not exclude viable locations where the project objectives can be achieved.

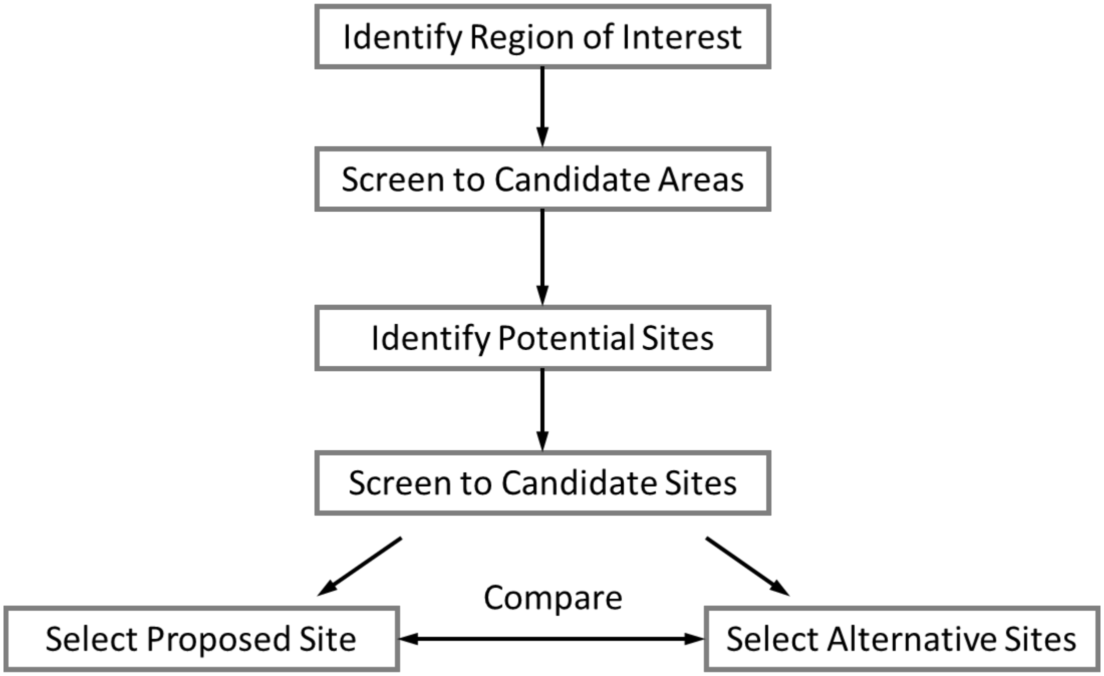

Figure 2-2
Site Selection Process Steps

If a specific site (i.e., the coal site) is identified, then that site would typically enter the site selection process as a 'potential site'. For alternative sites, a reasonable ROI around the targeted site would then be identified and the process in the EPRI *Siting Guide* followed. If only a community is identified, then a reasonable ROI including the community would be identified and the process followed.

A potential alternative could apply to a utility with multiple (typically at least 3) coal sites available as viable potential host sites (even if separated by great distance). It may be reasonable to identify all of them as potential sites, skipping a search for other alternative sites. However, potential owner-operators are reminded that the objective of the NRC's review of proposed and alternative sites, as stated in NUREG-1555 (U.S. NRC, 1999), is (emphasis added in italics)

> (1) to determine if the applicant has reasonably identified alternative sites, *predicted the environmental impacts of construction and operation at these sites*, and developed and used a logical, reproducible means of comparing sites that has led to the applicant's selection of the proposed site, and
>
> (2) to determine if any alternative site c*an be shown to be environmentally preferable, and if so, obviously superior* to the applicant's proposed site.

In practice, the NRC conducts an independent review of the applicant's analysis of impacts at the proposed and alternative sites, as provided by the applicant in Section 9.3 of the ER. NRC staff use this review to make the "environmentally preferable" determination (see "(2)" in the preceding excerpt).

Many considerations for the proposed/alterative site comparison are also reflected in guidance provided in NRC COL-ESP-ISG-026, *Interim Staff Guidance on Environmental Issues Associated with New Reactors, Attachment 6, Site Guidance for Alternative Review* (U.S. NRC, 2014a).

Formal identification of alternate sites is one of the last steps in the full siting process, and the actual identification of alternative sites should be completed through formal analysis as defined in the EPRI *Siting Guide*. The purpose of the alternative site discussion here is to function as a reminder for two early issues:

- The development of mission and business objective, and the corresponding ROI that meets those objectives, is a needed early step in the process.
- While a site may be targeted for new nuclear deployment, that site must be analyzed and demonstrated to be the best site available that meets the owner-operator's mission and business objectives.

Owner-operators taking an initial look at deploying nuclear on an existing coal site, or within a coal community, need **not** look at alternative sites much beyond the development of their mission and business objectives and ROI in the initial stages of evaluating nuclear as a potential option. However, moving beyond an initial review will require more in-depth analysis.

Note: See Section 4 of the EPRI *Siting Guide*, Special Considerations During Site Selection, for more information about potential siting on previously industrialized sites.

2.3 Physical Site Characteristics and Technology Selection

The deployment of nuclear is more tightly coupled to the physical site characteristics and technology selection than with other repowering options. This is because the regulatory and licensing processes for a nuclear plant are based on the plant's ability to operate safely and in an environmentally conscious manner *on a specific site*. The physical characteristics of the site must support the chosen nuclear plant's design and vice versa, often requiring an iterative process to identify the best site that supports a design that meets the owner-operator's business objectives. In the case of repowering a coal site, since a desired site location is known, the site must be well characterized to identify available technologies that will be a good fit. This process will still involve some iteration because the process of characterizing a site is normally completed in multiple stages, with the evolving information and data enlightening and evolving the technology and design selection process.

2.3.1 Preliminary Site Characterization

The EPRI *Siting Guide* (EPRI, 2022g) provides a regulatory neutral process for characterizing a potential nuclear site. The process and requirements are detailed and can take considerable time and effort; however, the process can be completed in stages, with the early work targeted at identifying the viability of the site to support a potential nuclear plant and the potential technologies and designs that could be deployed.

A factor that must be addressed first is the site's available land area. The EPRI *Siting Guide* identifies general land area requirements as noted in Table 1-3.

The size of any existing coal site will be dependent on several factors, often driven by the density of the surrounding local community development. Some sites may be large enough that a portion of the site may be cleaved off separately so nuclear development can start prior to shut down, decommissioning, and remediation of the coal units, others may be perfectly sized but need prior decommissioning to allow space for any new development.

Note: A recent case study feasibility assessment completed by X-energy for the Maryland Energy Administration (X-energy, 2022) provides insight on potential opportunities and challenges one might find when repowering a coal site. In this example case, it was determined that while the site had enough land area, the site geometry prevented deployment of a standard design plant. This will be discussed in more detail below, but at this point in the process it is important to understand that the final identification of land for nuclear development has impacts across the entire new plant development process.

Finally, from both a power generation need and community stakeholder perspective, one should not discount the concept of procuring land adjacent to (or near, within a few miles) an existing coal plant for nuclear development. This allows use of the grid connection and water supply (see Section 3.4), allows for nuclear construction prior to coal plant shut down with little to no remediation, and continues to provide opportunities for the local community.

The EPRI *Siting Guide* provides 42 technical criteria typically needed to characterize the site supporting these licensing purposes. However, a limited set of 13 criteria (with the inclusion of land area, which is not part of the 42 criteria, but rather a base requirement) can be evaluated to identify the potential for a coal site to support a nuclear plant (see Table 2-1).

This set of criteria is taken from Section 2, Table 2-4, of the EPRI *Siting Guide*, which identifies the pertinent criteria for each step of the process for Candidate Areas and Potential Sites, as noted in Figure 2-2. Evaluation of these criteria should be sufficient to provide early identification of a targeted site to determine if nuclear is a viable option.

Table 2-1
Initial Criteria for Evaluation of a Coal Site for Nuclear

#	Siting Guide Criteria	Description
1	1.4.2 Land Area	When assessing various technologies and designs, the size of the nuclear plant can be an important attribute because viable land space is a minimum requirement. It is best to have concrete knowledge of the land area needed for the chosen plant design, however, at early points in the assessment process only general area size estimates may be known. Therefore, in the absence of exact known values, the values in Table 1-3 can be used for guidance. While not specifically required for early review, an evaluation of the EAB and EPZ here may be prudent as there could be impact.
2	3.1.1.1 Geology/Seismology	Areas where regional hazard mapping shows that the Peak Ground Acceleration (PGA) exceeds the design requirement for a Safe Shutdown Earthquake is a common exclusionary factor. In the absence of specific design information, the value of 0.3g as noted in the EPRI URD (EPRI, 2014a) is recommended for large light water plants or other large designs, while a review of recent NRC license applications for ARs indicates that a value of 0.5g is likely a good value for smaller ARs.
3	3.1.1.2.1 Cooling Water Supply	Water sources that can always supply the identified cooling water demand (either singly or in combination, year-round, over the plant's lifetime, including potential drought conditions) should be identified and mapped. These sources may include surface waters (rivers, lakes, oceans), groundwater, and reclaimed water supplies (e.g., water treatment plant effluent).
4	3.1.1.3 Flooding	Flood potential should be qualitatively evaluated in the identification of potential sites. Using USGS topographic maps, major flood-prone areas should be avoided to the extent practical. Such areas would be characterized as locations near rivers and streams, marshy areas, and/or elevations at or slightly above the typical water level. If 100-year flood zone data is available, areas within the flood zone are typically excluded.
5	3.1.1.4 Nearby Hazardous Land Uses	Avoid land within 10 mi (16 km) of major airports and military installations. Evaluate airport takeoff and landing patterns. Maximize distances to other major industrial areas or potential hazards (such as active oil and gas well fields, chemical facilities, refineries, dams, etc.) Potentially hazardous facilities and activities within 5 mi (8km) of a proposed site should be identified. Note: If the business objective of the new nuclear plant is to service a facility that would be considered a 'nearby hazardous land use', thus requiring proximity, engineering evaluations may be needed to demonstrate safety.

#	Siting Guide Criteria	Description
6	3.1.2.1 Population	Regulations vary by country and can be complicated. Current U.S. NRC guidance requires a population density of 500 people per square mile or less over a 20-mile (32 km) radius. Under this guidance, a population center of about 25,000 or more residents should be no closer than 4 miles (6.4 km) from the reactor. The EPRI Siting Guide recommends excluding areas greater than 300 people per square mile to account for growth (with regulations requiring a maximum of 500). As of publication, development of U.S. regulations and guidance on population, particularly for ARs, is in flux. If completed as intended, new opportunities, such as being able to locate in slightly denser populations (and potential relaxation of criteria) could become available.
7	3.1.2.3 Atmospheric Dispersion	Atmospheric dispersion characteristics may be qualitatively evaluated. Using USGS topographic maps, areas where short-term atmospheric dispersion would be limited should be avoided to the extent practical. Such areas would be characterized as locations in valleys and/or surrounded by large hills.
8	3.1.3.2 Groundwater Radionuclide Pathway	Regions where U.S. EPA Class I groundwater resources and/or sole source aquifers have been identified should be excluded from further siting consideration.
9	3.2.1.1 Disruption of Important Species/Habitats – Aquatic	Exclude areas designated as ‘critical habitat’. Other protected ecological areas (e.g., marine sanctuaries) are also routinely excluded as part of the land use criterion evaluation. Effort should be made to avoid sites where threatened and endangered species (aquatic) are known to be present. It is important that up-to-date data on local species and habitats be developed and compared to up-to-date information on endangered species and critical habitat, which may have changed over the life of the original coal site.
10	3.2.2.1 Disruption of Important Species/Habitats – Terrestrial	Exclude areas designated as ‘critical habitat’. Other protected ecological areas (e.g., national wildlife refuges) are also routinely excluded as part of the land use evaluation. Effort should be made to avoid sites where threatened and endangered species (terrestrial flora and fauna) are known to be present. It is important that up-to-date data on local species and habitats be developed and compared to up-to-date information on endangered species and critical habitat, which may have changed over the life of the original coal site.
11	3.2.2.3 Disruption of Wetlands	Wetlands should be avoided. This is typically not an issue if confined to the coal-site proper, but generating stations are often adjacent to natural wetlands due to nearness to water, or manmade wetlands due to the station itself. The review should include construction and operations.
12	3.3.4 Land Use	Exclude established public amenity areas—those dedicated by federal, state, or local governments to scenic, recreational, or cultural purposes. As with wetlands, this is not likely an issue if confined to the coal-site proper, but these areas can spring up around generating stations over time. The review should include construction and operations and should include Indigenous cultural resources.

#	Siting Guide Criteria	Description
13	3.4.1.2 Pumping Distance	This is primarily a cost related issue and may not have any impact if locating on the original site and making use of the original intake location or reusing pumping infrastructure, but it could have an impact if locating near the original site, or new infrastructure is needed. Typically, 5 miles (8 km) is used for a quick evaluation.

The criteria above are intended to provide an early evaluation of the site's technical capability to support a nuclear plant. A site that meets these criteria will still need additional characterization for a final determination of adequacy. Also, these criteria do not account for cost related factors such as the cost to remediate the site, perform any topography grading, or install any needed transportation or transmission access. These items will need to be evaluated; however, the reuse of a coal site provides the potential to minimize these costs.

Failure to meet the guidance in Table 2-1 does not necessarily preclude the deployment of a nuclear plant on the site. If the site meets most requirements and would otherwise make for a viable candidate it may be possible to overcome challenges through site modification, plant design changes, or other engineering or regulatory activities. See Section 2.3.3 for additional guidance.

By default, the EPRI *Siting Guide* assumes that a specific site is not identified at the start, therefore, an additional step to evaluate the target site's land area is specifically needed. The process for performing this evaluation for an existing coal site is as follows:

1. Step 1 – Before evaluating the criteria in Table 2-1, an "Initial Candidate Site Land Area" should be identified.
    a. The owner-operator should evaluate the existing owner-operator controlled land to identify a contiguous parcel that meets the required land size based on Table 1-3. In general, available land should first be evaluated against the larger numbers (see d. below)
    b. The first pass for evaluation should include: any greenfield (or near greenfield land) and any developed land that is more easily decommissioned (contains low impact structures such as warehouses, office buildings, and service buildings). It should not include the physical coal plant proper, any cooling towers, or any Coal Combustion Product (CCP) storage (landfill, remediated ash pond, or ash pond).
    c. If the first pass does not meet the size requirements of (a.), then the owner-operator should consider: 1) adjacent non-owned land that could be procured, 2) space made available by decommissioning the plant, cooling towers, and/or full removal of CCPs.
    d. If the land space is still too small, then the owner-operator can evaluate against smaller sizes from the table, but not below the minimum size.
    e. Assuming the identified size is sufficient, this is now identified as the "Candidate Site Land Area".
2. Step 2 – Evaluate Criteria 8 through 11 from Table 2-1 against the defined "Candidate Site Land Area" and remove any land from consideration identified for exclusion.
3. Step 3 – Reverify against the land area requirements in Table 1-3.

a. If the identified size is sufficient, this is now identified as the “Potential Site Land Area”. Proceed with evaluation of the remining criteria from Table 2-1.

b. If the identified size is not sufficient, either return to Step 1 to identify additional land, or it must be determined that the target site is not viable, or additional remediation actions will be needed.

2.3.2 Final Site Characterization

The abbreviated review of site characteristics discussed above can be a great tool for quickly evaluating the viability of using a retired coal plant site for nuclear deployment, but eventually the site will need to be fully characterized as defined in the EPRI *Siting Guide* and local regulations. While this can technically wait until a design is fully identified and specific plans for deployment are made, doing so can significantly impact deployment schedule. Performing a more comprehensive analysis early and providing that information to potential developers can help identify development partners early. It is not uncommon, and preferred, that site characterization and technology and design selection take place using an iterative approach.

Existing site characterization data may have value, but the data used for licensing a nuclear plant must meet nuclear quality requirements. As defined in section 4.2 of the EPRI *Siting Guide*, a coal plant site would be considered to have *Limited Characterization*, and the following process can be used to evaluate existing data (see the EPRI *Siting Guide* for a detailed procedure):

- Collect all characterization data that is available.
- Evaluate the available characterization data for timeliness.
- Consider the quality control and assurance pedigree to determine if it can be used.
- Determine what new data must be collected.

When attempting to use characterization data from an existing site, the owner-operator should not only perform due diligence on the data itself, but also a cost-benefit analysis on the attempted reuse of any existing data. It may be more cost effective to reobtain the information instead of putting in the effort to find original data and dedicate it for re-use. When performing the detailed analysis, particularly for potential NRC licensing, owner-operators may want to consult EPRI’s *Early Site Permit Model Program Plan* (EPRI, 2002) along with the EPRI *Siting Guide*.

2.3.3 Using the EPRI Siting Guide to Evaluate a Single Site

The EPRI *Siting Guide* was developed specifically to find and evaluate a collection of potential sites, and determine which will be considered the primary site, and to identify alternative sites. The *Siting Guide* process was designed for the review and evaluation of a large Region of Interest (ROI), typically a utility’s service area, which may cover a size equivalent to several U.S. states. Because of this, the *Siting Guide* criteria and evaluation process uses the concepts of exclusionary and avoidance factors to quickly eliminate areas of land that do not meet the criteria to efficiently reduce the resources needed for detailed evaluations later in the process.

However, when evaluating a single site, one can find that many of the *Sting Guide* criteria would cause the site to be dismissed quickly in the process if the exclusionary or avoidance factors were taken verbatim. Therefore, it is important to understand that some criteria are more specifically exclusionary than others, and that the expenditure of additional resources may allow issues to be overcome. Also, failure to meet some criteria is not necessarily a problem, but it could mean that evaluation of alternative sites will take on more weight. Below are examples for illustration:

- *Failure to meet at least the seismic criterion of 0.5g PGA* – The only real criterion is that the plant design be able to meet the seismic spectra of the chosen site. If this cannot be met with the original design, the design could be modified with seismic isolation, but any added costs and schedule extension may be prohibitive.
- *Failure to Meet Population Criterion* – In the U.S., the NRC specifically notes in RG 4.7 (U.S. NRC, 2014c) that exceeding the 500 people per square mile criterion is not necessarily a problem, but, in this case, the NRC will add extra scrutiny to the Alternative Site review. Demonstrating that the targeted site is the best site will be required.
- *Failure to Meet Wetlands Criterion* – In the U.S., there are many possibilities for the management of wetlands that could allow a site with wetlands to be used. Options include moving the wetlands, restoring wetlands after construction, or exchanging wetlands credits.

A key point to understand is that the failure to meet a criterion does not automatically disqualify a potential site. However, the associated costs, schedule delays, and expenditure of other resources needed to mitigate any issues may be more than an owner-operator wishes to take on. Only the owner-operator, with a good grasp of their own mission and business objectives, can make the final decision. However, it is recommended that owner-operators consider keeping their options open early in the process to not foreclose on an opportunity too soon, but at the same time, ensure they understand their risks and monitor the overall evaluation process closely so that they do not spend resources on something that is likely to not move forward.

2.3.4 Preliminary Technology and Design Selection

The chosen nuclear plant technology and design to be deployed must be compatible with the business objectives of the owner-operator, local regulations, and the site itself. Before delving too deeply on the topic, readers are reminded of two important definitions identified in the EPRI *Technology Assessment Guide* (EPRI, 2022a).

- *Technology* can mean both the general technology (e.g., pressurized water reactor, PWR, gas cooled reactor, GCR), or a vendor specific design (e.g., Company A’s Model R-250). This is important because the EPRI Technology Assessment Guide process uses both instances, to settle on a general technology in the initial stages, and then refine selection to a specific procurable design.
- *Design* specifically means a procurable (or at least advertised) vendor specific reactor developed and marketed by an Original Equipment Manufacturer (OEM).

Today, nearly all operating nuclear plants are water-based technologies, with the majority being Pressurized Water Reactors (PWRs) or Boiling Water Reactors (BWRs). These plants are sized on the order of about 1GW and are often referred to as Large Light Water Reactors (LLWRs). Today there are a couple of more recent LLWR designs, often referred to as Advanced Light Water Reactors (ALWRs), that are available for deployment. These have the potential to be deployed on a retired coal site, but as noted above, the average size for a soon to retire coal plant is 450 MWe, therefore the siting options would be limited due to their need for larger land sizes, cooling water needs, and ability to make use of existing transmission.

Note: It is important to remember the difference between a coal site and a coal plant, while a single coal plant or unit may not have enough land area, the entire site might (see Table 1-1).

There are many innovative technologies under development from several plant designers (OEMs). These technologies include novel light water designs as well as other technologies, such as gas cooled or molten salt reactors. From a reactor technology perspective, these options are typically defined by a combination of their fuel form and primary coolant, and each has unique traits that should be considered. These reactors are often referred to as Advanced Reactors (ARs, see Section 1.5.3). Key features of these designs typically include:

- A smaller MWe output (often referred to as Small Modular Reactors, or SMRs).
- The ability to deploy multiple units to target a specific output.
- Potentially higher temperatures, increasing efficiency and enabling other product options.
- Increased flexibility options.
- Smaller land requirements.
- Lower cooling water requirements, including the potential for air cooling.
- The ability to deploy closer to populations.
- Reduced emergency planning zone sizes.

EPRI's *Technology Assessment Guide* (EPRI, 2022a), can be used to help an owner-operator select a technology and design that fits their mission and business objectives and the constraints of the site. Like the *Siting Guide*, Table 2-4 of the *Technology Assessment Guide* includes 31 specific criteria to be analyzed to first identify potential technologies and then finally settle on one or two specific designs to pursue. However, like the *Siting Guide*, a limited set of the criteria can be evaluated quickly to get an understanding of viable options (see Table 2-2).

Table 2-2
Initial Criteria for Technology Selection

#	TAG Criteria	Description
These items are evaluated in *significant* detail against the owner-operator’s business objectives		
1	3.1.1 Plant Energy Output	A measure of the output of the plant from an energy perspective but in a form that meets the mission and business objectives. At its simplest, for a firm power electricity mission this could be nothing more than size in MWe. For other missions, such as producing process heat, which could in turn be used for producing other products such as hydrogen, heat output in MWt may be the appropriate measure. Specific details include nominal energy (or product) output, number of units or modules, energy efficiency, minimum and maximum output, and ramp rates.
2	3.1.3.1 Fuel Selection	An evaluation of the type of fuel the plant will be using, including its mechanical design and license status, and its current or future availability. Fuel selection is evaluated against factors that affect the fuel’s availability, either through regulations or unsolved technical issues (e.g., HALEU), and the ability to be easily handled during operations. Typical fuel selection attributes would include enrichment, fuel form, license status, and availability.
3	3.1.3.2 Used Fuel Storage and Disposal	Preliminary evaluation is centered on physical protection and proliferation resistance: Does the fuel cycle involve the production of high-grade fissile materials at any stage? Are the nuclear materials in a form that provides inherent self-protection against theft or dispersal? And are the nuclear materials produced in the fuel cycle difficult to access?
4	3.2.1 Site Evaluation	An evaluation of a design’s ability to meet the site’s parameters as detailed in Section 2.3.1 above.
These items are evaluated in *limited* detail against the owner-operator’s business objectives. The evaluations are centered on technical maturity and ability to meet needed time frames, addressing primarily materials and novel concepts.		
5	3.3.1.1 Design Completion	Establish an understanding of the current design stage and evaluate its adequacy for the next activities that need to be completed. If it is not, what is needed to bring it into alignment, and finally what is the overall remaining effort to get to the desired level for the project.
6	3.3.1.2 Reactor Systems	All plants, regardless of technology or design, will have some type of reactor system that has the purpose of generating thermal power sufficient for the end-product needs, serve as a radioactive material boundary and possibly a pressure boundary, provide a flow path or other methods for coolant to remove heat generated under all operating conditions and removal of decay heat after shutdown, and provide for control of reactor core reactivity.

#	TAG Criteria	Description
7	3.3.1.3 Reactor Non-Safety Auxiliary Systems	Encompasses several sub-systems which may, or may not, be included in all technologies or designs. These include the heat exchanger system, coolant cleanup and volume control system, process sampling systems, and reactor (non-safety) shutdown cooling system.
8	3.3.1.4 Engineered Safety Systems	Engineered safety systems are typically technology and design specific with functions and systems that typically fall into two categories, Core Damage Prevention and Accident Mitigation. Evaluations would address materials and novel concepts.
9	3.3.1.5 Fueling, Refueling, and Fuel Handling Systems	Each reactor technology and design will have a different set of equipment, processes, and procedures for managing fuel, but typically the following functions must be included: receipt of new fuel, new fuel storage, fuel handling and inspection, spent fuel storage, reactor disassembly/assembly, cask handling, and spent fuel packaging and shipping (as applicable per local regulations and practices).
10	3.3.1.6 Other Systems or Critical Path Components	An evaluation of technology and design specific systems, typically including the power generation system, plant cooling system, waste processing systems, control rooms, instrumentation and control systems, shared systems, non-electric loads, other unique systems, structures, and components, and identified critical path components.
11	3.3.2 Regulatory and Licensing	This criterion addresses plant licensability, licensing engagement status, path to licensing, and the regulators capability to license a novel design. The evaluation would include the OEM’s interaction and progress with the regulator, the regulator’s ability to license the technology, the design against regulatory requirements, and formal licensing actions to date.
12	3.3.4 Supply Chain Maturity, Remaining Effort, Capability and Capacity	Evaluate the supply chain for the major (nominally large) components for the potential new construction project. For known technologies, an understanding of the supply chain’s capacity and capability may be sufficient. For novel components and manufacturing techniques, evaluate technical maturity and time frames.

Any detailed review of the above criteria will likely necessitate delving into EPRI’s reactor requirements guidance: the *Advanced Light Water Reactor Utility Requirements Document* (URD) (EPRI, 2014a) and the *Owner-Operator Requirements Guide (ORG) for Advanced Reactors* (ORG) (EPRI, 2019b). These documents are technically very deep, but an owner-operator can use them in conjunction with the *Technology Assessment Guide* to evaluate the potential designs offered by OEMs.

It is important to understand that many potential technologies, and the ultimate designs that will be offered by the various OEMs, are still largely in their infancy. Currently in the U.S., there is only one AR design, NuScale’s light water SMR, that has received U.S. NRC design certification (U.S. NRC, 2020e; U.S. NRC, 2023b), but there are several other ARs in various states of pre-application or licensing review (U.S. NRC, 2023a). Potential owner-operators considering ARs will need to perform due diligence to ensure they understand the capabilities, viability, and most importantly, the time frame for deployment, for these options.

2.3.5 Final Technology and Design Selection

Fully identifying a technology, and more importantly a specific design and related OEM partner (and potentially a lead Architect Engineer, AE), early is an important timing consideration. Since the AR technologies likely to be deployed on or near a coal site are still under development, partnering with an OEM will help move forward the site-specific engineering details that are necessary. At this time, it may be valuable to identify more than one design and OEM because the current state-of-the-art, and state-of-the-market, is in flux and having options can be valuable. While the reduced set of *EPRI Technology Assessment Guide* criteria can be used to develop a quick sense of technologies and designs that could both meet the owner-operator's goals and the site parameters, eventually a full evaluation of all criteria in the assessment guidance will be needed. Following the process in the *EPRI Technology Assessment Guide* will result in a well vetted primary design and a couple of optional designs.

2.4 Evaluate Site Infrastructure and Existing Assets

The EPRI *Siting Guide* (EPRI, 2022g) contains special guidance on the reuse of existing sites, be they retired coal plants, other generation or industrial facilities, or previous nuclear sites. As noted in the *Siting Guide*, as well as in several other reports that build upon each other (INL, 2021; Qvist, Gładysz, Bartela, & Sowizdzał, 2020; Orano, 2022; U.S. DOE, 2022), existing facilities can offer several valuable existing infrastructure elements that can make a site more attractive, particularly from economic and time frame perspectives. The infrastructure elements of most value for repowering with nuclear technology include:

- **Grid Interconnection** – Coal plants have existing high-voltage power connection infrastructure, interconnection studies, a site permitting evaluation, land-use rights, and off-taker agreements in place, to facilitate grid interconnection of future nuclear generation. Utilizing the existing structures and connections avoids the cost of new ones and saves time to secure the necessary authorizations from jurisdictional authorities. The carrying capacity of transmission and distribution (T&D) lines near the site can impact costs. For example, if the capacity of the nuclear plant is greater than the coal plant, existing substation equipment or utility lines may need to be upgraded to accommodate the increased generation capacity. Depending on the nuclear plant size, a feasibility study may be required to determine changes needed to the existing interconnection and the cost and timeline for upgrades (see Sections 2.5, 3.4.1 and 3.4.11.2).
- **Cooling Water Supply** – While some new nuclear designs are expected to be able to use air cooling, it is likely that designs with thermal output like the coal plant it is replacing will make use of cooling water. Coal and nuclear plants require the ability to remove the heat generated and typically use substantial amounts of water. This can be in the form of once-through cooling or via the use of cooling towers. In the U.S., the ability to use once-through cooling, even if it was the method previously used by the coal plant, is unlikely due to environmental protection rules (U.S. EPA, 2022a). The ability to use the existing plant's cooling systems is dependent on many factors, but of most value is the proximity to a

significant amount of water, and possibly more important, the availability of water use rights (see Sections 2.5, 3.4.2 and 3.4.11.3).

Note: Owner-operators should assess the ability of cooling water resources to support the nuclear plant year-round, over the lifetime of the plant, including in drought conditions, early in the process. Existing cooling water resources and systems could prove to be inadequate for a new nuclear plant due to its own cooling requirements, increasing local withdrawal, or climate change. For more information see the EPRI white paper *Nuclear Plant Resilience in the Face of Climate Change* (EPRI, 2021d).

- **Existing Land** – Existing land already owned by the owner-operator has potential to support development of a new nuclear plant depending on the space available and the ability for all nuclear plant siting concerns to be met (see the EPRI *Siting Guide*). Available land could include the land currently used by the coal plant itself after decommissioning is complete, or for larger sites, owner-operator property that is adjacent to the existing infrastructure (see Section 3.2.2).
- **Transportation Access** – Transportation access is a primary need for nuclear power, both during construction and over the life of the plant. Access for workers, heavy equipment, and components is needed for construction. Many OEMs are incorporating modular construction in their modern designs that is intended to reduce the need for heavy haul and barge access, sizing their modules to be easily delivered via highways and rail. Once construction is complete, there will still be a need for transportation access during operations for workers, nuclear fuel delivery, and typical industrial deliveries. Refueling and maintenance outages will typically see high traffic for temporary workers and equipment. (Section 3.4.7).
- **Utilities** – Existing utilities and easements, such as water, gas, and sewer, may be useful during new nuclear plant construction and operation (Section 3.4.9).

Other infrastructure elements that may be of value for nuclear deployment include:

- Switchyard (Section 3.4.1)
- Light cooling water and fire water systems (Section 3.4.3)
- Balance of Plant Systems (Section 3.4.4)
- High voltage power, emergency power, and off-site power (Section 3.4.5)
- Meteorological tower data collection (Section 3.4.6)
- Administrative buildings, warehousing, laboratories, machine shops (Section 3.4.8)
- Site emergency services, community outreach services (3.4.10)
- Existing environmental permits (see Section 3.4.11)

The ability to make use of any of these elements for a new nuclear plant is dependent on several factors including the selected nuclear technology, specific location and layout of the new plant, the planned output (e.g.: MWe), and the required amount of cooling water. The age and physical condition of the elements are also an issue that must be addressed. **Ultimately, the most valuable aspects of the coal site will be the land availability, an existing transmission**

corridor, and cooling water supply (including water rights, see Sections 3.4.2 and 3.4.11.3). The reuse of other infrastructure elements would typically be considered on a cost basis.

A key concern with reusing a coal site for a nuclear plant involves the level of decommissioning and remediation that will need to be completed prior to the start of nuclear deployment. The EPRI *Siting Guide* goes into some discussion on the decisions that will need to be made, but it must be understood that (EPRI, 2022g):

> [the] requirements and responsibilities for contamination cleanup at such sites are established as matters of law and regulatory requirements; they may also be affected by legal agreements reached in real estate transactions. The post-remediation cleanup goals depend on the nature and extent of contamination, regulations, and legal documents. Thus, even if legacy contamination exists, use of the site for [a new] industrial purpose may obviate or mitigate the need for some cleanup actions.

Depending on the overall size of the site, the amount of open space already available, and the extent of any existing environmental hazards, it may be possible to decommission and prepare a portion of the site for nuclear development without addressing the entire site. However, the nuclear plant's environmental analysis will need to be based not only on its specific site, but also nearby hazards, which could include portions of the coal site, for example, a CCP impoundment or coal ash pond if not dewatered.

2.5 Securing Land, Transmission, and Water Rights and Other Permits

A key value proposition for repurposing a coal plant with a new nuclear plant is that there are existing and available infrastructure elements already in place. Three of the key elements are:

- The site property, including additional adjacent utility owned land.
- Access to a transmission corridor and system.
- Access to water.

However, each of these infrastructure elements are usually accompanied by the need to have sufficient rights to access them. While these rights are in place for the operating coal plant, it is possible they could be lost and difficult to recover when the coal plant retires. The owner-operator should evaluate each of these rights and understand their ability to maintain them for new nuclear development. The rules, requirements, and regulations vary by locale, often nationally, and by state and county in the U.S. Several regulatory and permitting agencies may need to be involved. If possible, it is important to keep the land, transmission, and water rights active during the phases of decommissioning, new nuclear construction, and new plant operation. Other permit categories that should be reviewed include, but are not limited to:

- Air and water discharge
- Building codes and occupancy
- Fire protection systems
- Waste disposal
- Utility right-of-way

- Well water

Whether these permits can be extended, or their likelihood of being reissued, must be determined. Issues for which regulatory changes have been made but the coal site was not required to backfit must be investigated. The new nuclear plant may need to comply with the new requirements, even if on the same site (see Section 3.4.11 for more on typical permits).

Because the coal unit(s) to be replaced would have existing heat sink cooling systems and approvals for cooling water withdrawals, availability of that water could be an advantage in locating the replacement nuclear plant at the same site. However, the sizing and integrity of the cooling system will need to be evaluated, and more importantly, rights to water withdrawals may not automatically roll over to the new plant, even if the owner-operator is the same legal entity that operated the previous plant. To accept pre-existing water rights as an advantage in site selection, the NRC will require evidence that the previous plant's water supply will be approved by regulators for use in the new nuclear plant. In the U.S., many generation plants were constructed using once-through cooling, however updated fish protection rules (U.S. EPA, 2014) might disallow such use if the facility were repurposed[13]. Additionally, future water availability conditions under which the new nuclear unit will require water will need to be investigated, as they may be different than the coal unit.

Assuming the sizing of the nuclear plant is a like-for-like or smaller replacement, an existing switchyard and transmission line is potentially an asset; however, a larger capacity plant could require construction of added transmission capacity and any degradation from aging would need to be addressed. Nevertheless, an existing transmission corridor is of great benefit on its own due to already having a clear and valid right-of-way. As with water, the ability to make use of an existing transmission system will need to be verified and documented as required by the regulator. See sections 3.4.1 and 3.4.11.2 for additional information.

2.6 Cost and Other Economic Evaluations

As part of the decision-making process, the owner-operator should begin with a cost analysis. This includes an evaluation of internal development and project management costs, costs supporting an OEM or suppliers through development and licensing (if applicable), site characterization and licensing, construction and operating licensing, Engineering, Procurement, and Construction (EPC) costs, operations and maintenance (O&M) costs, fuel costs, and decommissioning costs. As noted in the EPRI *Technology Assessment Guide* (EPRI, 2022a):

> It is important to note that these cost estimates are more than just a measure of the two most common new nuclear plant costing calculations, Overnight Capital Cost (OCC) and Levelized Cost of Energy (LCOE). The owner-operator must ensure that risk, in particular schedule risk, is included. OCC and LCOE work well when comparing two things of equal risk, but they fail when the risks diverge. This is especially pertinent when working with novel designs because much of the early upfront work may be outside those costs due to lower maturity and will therefore

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[13] Current U.S. 316(b) fish protection rules apply to 'New Facilities', which are defined in 40 CFR 125.83. It might be possible to retrofit a coal plant into a nuclear plant in a manner that does not result in designating it as a 'new facility' by managing the plant and cooling system design, and cooling water usage, but this is untested.

require more effort in a Techno-Economic Assessment (TEA) approach versus just a cost estimating exercise.

There are several TEA methods available (see the EPRI *Technology Assessment Guide)*, but all address key concepts: Understanding and evaluating the economic status, understanding maturity and remaining effort, and understanding uncertainty and risk.

Any organization will need to ensure that they evaluate all costs associated with the project. For an organization planning to build on an existing coal site, the costs for decommissioning the coal facility and maintaining the CCP impoundment, if applicable, will be pertinent along with the cost for new construction. This may be different for a third party developing on new land in a coal community looking to access just the water and transmission lines. How these different items will be financed is also a factor. It is beyond the scope of this document to describe all the scenarios for new development costs and financing, but the need for all costs that will affect the organization to be addressed is important. In an early evaluation it will not be possible to accurately assess the actual costs, rather wide-ranging estimates will need to suffice, but it is possible with enough due diligence to assemble a good list (i.e., Work Breakdown Structure, WBS) of the cost account items. Effort should be made to understand the range (+/-) of those estimates.

Note: Economic evaluations typically include a comparison of cost against revenue. It is beyond the scope of this document to discuss potential revenue from a new nuclear plant, and any utility would understand how this would be calculated for their situation (e.g., regulated or not). But owner-operators are reminded that nuclear plants can open opportunities for additional revenue due to typically higher capacity factors, or in some locales, credits for reliability and resiliency.

2.7 Obtaining an Early Site Permit (optional)

Completing the actions above will put the owner-operator into a great situation if there is a decision to develop a nuclear plant at the retired coal site. However, in the U.S., there is one more thing that should be considered by the coal plant owner-operator; development of an Early Site Permit (ESP). The process of obtaining an ESP is like that described in the activities above, where the collected data and information is packaged into an ESP licensing application with the U.S. NRC. The development of an application and resulting review with the NRC can be time and resource intensive, but the resultant ESP from the regulator is a significant asset that can last for up to 40 years[14] (U.S. NRC, 2007d). The primary value is that with an ESP, decisions about deployment can be made later. It provides the owner-operator with a valuable asset, one that could even be sold to another organization, such as another utility with a greater nuclear operating background that has more interest in developing a nuclear plant.

In the U.S., the primary ESP regulations are governed by 10 CFR 52 Subpart A - *Early Site Permits* (U.S. NRC, 2007d). There are many more regulations, requirements, and guidance documents that need to be followed, but these are beyond the scope of this report. Owner-operators interested in developing an ESP, should start by reviewing the EPRI *Siting Guide* (EPRI, 2022g) and *Early Site Permit Model Program Plan* (EPRI, 2002), the INL report,

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[14] Per 10 CFR 52, Subpart A, Early Site Permits, an initial ESP is valid for 10-20 years, with the ability to be renewed for an additional 10-20 years.

Summary Overview of Content Guidance for Early Site Permit Applications (U.S. DOE, 2020b), and the several ESP applications that can be found on the NRC's web site. (U.S. NRC, 2020c).

2.8 Community Outreach

As noted above, retired coal plants can make attractive options for advanced nuclear. Aside from the technical advantages of repurposing the coal plant, its loss can negatively impact the local community making the transition a favorable option. Coal plants are often in smaller communities and may be the largest local employer. The loss of jobs, related services, and tax revenue can be detrimental to the community. Thus, many coal communities are actively looking for businesses to fill the gap, and nuclear is sometimes being considered (TerraPower, 2021).

Therefore, it is important that the owner-operator works in concert with the local community, but at the same time, the owner-operator should not assume the degree for which the local community does, or does not, embrace nuclear. The experience of the local community with the previous operating organization and whether they were considered a good neighbor or not can impact public acceptance. Also, while the community specifically hosting the coal site may embrace a new nuclear plant, surrounding communities, potentially including nearby Indigenous communities, may have different opinions.

The EPRI *Siting Guide* contains information about managing public involvement and acceptance and provides guidance on developing an integral engagement and communications organization for this point in the nuclear development process. Also, in the U.S., there are several federal and state programs and policies supporting coal communities (Good Energy Collective, 2021; U.S. Admin, 2023). Owner-operators should take the initiative to understand the available options, including those available from local business councils and economic development agencies, and use them as applicable, or guide the stakeholder communities to their availability for their own use.

Note: Section 3.4.10 briefly discusses Outreach Services as available organizational infrastructure and Section 3.8 provides additional consideration on Community Engagement. The X-energy report (X-energy, 2022) also provides an example strategic communication plan.

One of the most important aspects of engaging the community is listening to all stakeholders and addressing their concerns in a positive manner. An engaged and accepting community is a great asset for deploying new nuclear. For maximum benefit, community outreach should be a partnership between the owner-operator and state and local leadership, working in concert to understand and address community concerns, while also clarifying the potential benefits to the community. When discussing potential benefits, it is important that the owner-operator understand the goals and needs of the community. Simply stating statistics, like the number of new jobs, may or may not address the benefits the community is seeking. Community outreach is needed across the entire timeline of the nuclear development process, but a first step is to identify and engage with local and state leadership.

2.9 Quicker Evaluation for Potential of Nuclear Deployment

To get a more rapid assessment on the viability of a coal site to support a nuclear plant, some organizations are looking to perform a review more quickly. The criteria identified in Table 2-1 is already a limited set and was chosen to best reflect a reasonable due diligence process that balanced a solid review against reasonable effort for a preliminary evaluation. However, the review can be completed using significantly fewer criteria. Care should be taken because this review will be extremely limited. The criteria to review are:

- *Geology/Seismology* – Virtually all nuclear plants receive some type of design modification to support the local site situation, but these changes are limited to minimize cost and schedule impact. While it is possible to modify a nuclear plant to meet about any geology or seismology situation, for example through the addition of seismic isolation, the cost to do so can be high and, potentially more importantly, could impact deployment schedule. Therefore, a site that cannot meet the seismic requirements noted in the EPRI *Siting Guide* and Table 2-1 should be excluded.
- *Cooling Water Supply and Pumping Distance* – If an existing coal site is being evaluated, access to the required amount of cooling water is likely not a concern at this stage of an evaluation (however, see Cooling Water in section 2.4). However, if sites other than an existing coal site, such as elsewhere in a coal community, are being evaluated, this could be a concern if a reasonable source cannot be located, or the infrastructure requirements are too large. In the U.S., even if a site is currently using once through cooling, any new nuclear deployment will most certainly require the use of cooling towers, significantly decreasing the withdraw requirement (but potentially increasing the consumption). While cooling water is typically available, its unavailability is considered exclusionary unless dry cooling is a clearly viable alternative (see Section 3.4.11.3.3).
- *Nearby Hazardous Land Uses* – It should be noted that any nearby hazardous land use, as defined in the EPRI *Siting Guide*, is considered an exclusionary attribute. However, the specific regulatory requirement is that these hazards be evaluated and mitigated, so they do not specifically have to be considered exclusionary. By default, the EPRI *Siting Guide* is designed to consider large ROIs versus targeted sites, and excluding areas impacted by such hazards is prudent from a resource perspective. This may be different for a singularly identified site for which other value is deemed present. For an early evaluation, it is recommended that areas subject to Nearby Hazardous Land Use criteria be excluded, but owner-operators are reminded that they can be addressed.
- *Population* – The DOE study (U.S. DOE, 2022) points out that population density is a key discriminator in determining viability for repowering with new nuclear. Current U.S. regulations identify a population density of 500 people per square mile over a 20-mile (32 km) radius as the (preferred) maximum. The EPRI *Siting Guide* recommends excluding areas greater than 300 people per square mile to account for population growth. The exclusion of sites with more than about 300 people per square mile is recommended at this early stage, unless the site is in an area that is known to have a shrinking population, and sites greater than 500 people per square mile should normally be excluded.
- *Land Use* – Areas that have known land use issues should be excluded. In general, an operating coal site is likely to have few concerns with the site proper or its owner-controlled property, but changes over time since the original coal plant deployment could bring new impacts. Land use issues are of particular concern for new potential sites within a coal community. Some examples include the new identification of Indigenous people’s landmarks, newly developed wildlife refuges or national/state parks, or newly developed

recreational or scenic areas. While land use issues can sometimes be mitigated, at this early evaluation stage, excluding areas with impacts is recommended.

- *Land Size* – As noted in Section 2.3.1, ensuring enough land area is also a requirement. Because this reduced assessment does not fully address all the issues associated with ensuring adequate land area (i.e., habitats and wetlands are not addressed), an evaluation of the estimated easily available land area (Section 2.3.1, Step 1) against the general land sizes in Table 1-3 should be completed. If the site cannot meet at least the minimum land area noted in the table, it should be excluded.

Performing this shorter, but limited, evaluation can provide a quick assessment of the ability of any target site to support a nuclear plant. But owner-operators are reminded that this evaluation can provide sub-optimal results.

2.10 Documenting the Review

The EPRI *Siting Guide* (EPRI, 2022g) specifies that land not meeting any one of the criteria identified in Table 2-1 based on either exclusionary or avoidance factors be excluded from further review. As noted in Section 2.3.3 this immediate exclusion assumes searching for a site within a large ROI. In the case of evaluating a single site this could mean the exclusion of a potentially valid location without assessing relaxation of avoidance factors, or potential mitigations or evaluation for exclusionary factors.

During an initial review, issues found with criteria that would normally result in exclusion should instead be documented, with the following noted as a minimum for each criterion:

- Criteria Name and Siting Guide Section Number
- Short Description
- Overview of Site-Specific Data and Information
- Evaluation of Relevant Criteria for Early Review
- Comparison of Site-Specific Data and Information against Criteria Requirements
- Gap Identification
  - Technical criteria not met via exclusionary or avoidance factors, if not meeting the criteria is an explicit no-go attribute, or if it can be overcome through some level of mitigation activity.
  - Identified regulatory concerns revealed during the review.
  - Areas where more information is needed to make a full decision.
  - Item identified during the review that are not an issue now but could be as the process progresses.
  - This last item is important. During the early evaluation, the number of criteria and the criteria scope subject for review is purposefully limited. However, while performing the review information and data needed for later in-depth evaluation will be collected. It is important to collect the data and information and flag potential opportunities and

  challenges but avoid the temptation to analyze more than necessary now to avoid unnecessary expenditure of resources.

- Gap Resolution, Mitigation, or Evaluation
  - For each gap identified above, the criteria should be evaluated for the effort needed to overcome any challenges and the associated risk to meeting those challenges. Challenges may be overcome by technical mitigation, technical evaluation, or regulatory action. The collection of more information and data may also be required.

Below are a couple of scenarios, provided as hypothetical examples only, to illustrate potential gaps and how they might be addressed:

- The potential site, while large enough in total area, is restricted by a small river that impacts its overall shape. This means that the layout of a potential new plant may need to be redesigned to fit into the available footprint.
- There is potential for the local seismic activity to exceed that specified under the Geology/Seismology criteria. One OEM has identified that their design can meet the technical need but would require licensing activity to demonstrate that. Another OEM has indicated they could add seismic isolation to their design, but that would require both engineering and licensing activities.
- The existing coal plant will no longer be taking water, and the planned nuclear plant will take less than the coal plant did, so there is plenty of water available nearby. However, if the plant is in a region where water is scarce and there is a long waiting list for water use permits, significant communication and negotiation with water regulators and local communities will be needed to demonstrate value and obtain a permit.
- A local industrial business within five miles (8 km) of the potential site may need to be considered as a ‘nearby hazardous land use’. However, more information is needed about the business, the products produced, and the potential risk to the plant.
- A review of the site and local area indicates that the current population meets minimum U.S. regulatory requirements at about 450 people per square mile. While the area has been rural for decades, it is known to be an up-and-coming location for families. While not required at this time in the review, it should be noted that a long-term population growth evaluation will be needed and there is some risk.

The X-energy report (X-energy, 2022) provides some real-world examples of similar considerations.

3
OPTIONS AND CONSIDERATIONS

The deployment of a nuclear energy facility on an existing coal plant site, or within a coal community, can be met with many different permutations, options, considerations, and caveats that can impact the decision-making process. While there are a few hardline issues that would prevent development of nuclear, most can be overcome with enough time, money, or other resources.

For those considering nearer term nuclear deployment among other energy or site use options, early decision making can be a key factor. In this section, several options are addressed. There are effectively an infinite number, so only the most probable are reviewed. The intent is to address the most likely scenarios and provide practical guidance for decision making that can enlighten owner-operators as they encounter their own scenarios.

3.1 Mission and Business Objectives

Section 2.2 of the EPRI *Technology Assessment Guide* (EPRI, 2022a) provides guidance for the development of Mission and Business Objectives for technology and design selection. While these objectives are not specific to siting, they should be adequate, particularly early in the evaluation process.

While owner-operators should be sure to address all the objectives noted in the EPRI *Technology Assessment Guide*, there are several issues they should be sure to consider in detail:

- *Required Output* – Identification of the required output of the new facility is of utmost importance as it drives many other issues. In general, it is assumed that the new facility will provide roughly as much power as the coal site, but there are several considerations:
  - With the advent of SMRs and microreactors, it may be possible to meet the required output through deployment of multiple units at the same time, or over time.
  - A coal site consisting of multiple smaller units could house a single large reactor.
  - The maximum capacity of the transmission line(s) will limit the maximum output of any new electrical generation unless upgrades are made.
  - Cooling water availability, either physical or due to permitting, could limit the maximum output of new generation (unless dry cooling is a possibility)
  - Unlike other generation options, the output of a nuclear plant is typically fixed by the OEM design. This can result in mismatched plant output and transmission line capacity and limit potential reuse of other assets.
- *Need Dates and Time Frames* – This will be a key driver in decision making, particularly for nearer term repowering projects.

  - Earlier need-dates will effectively constrain choices, limiting technology and design options for deployment.
  - Later need-dates will allow for more technology and design choices, but timing against other issues, such as ensuing water, transmission, and land use rights and permits are still available, and ensuring employment opportunities of the local workforce are maximized, could be impacted.
- Both the EPRI *Siting Guide* and *Technology Assessment Guide* consider the concepts of *Exclusionary* and *Avoidance* factors regarding the criteria identified in Table 2-1 and Table 2-2. Section 2.1 of the EPRI *Technology Assessment Guide* provides a good definition of these terms and how they relate to mission and business objectives but remember that these will drive the results of the criteria evaluations. This is most crucial when addressing avoidance factors because these are under full control of the owner-operator and can be changed as desired, but doing so can impart risk to the project.

3.2 Siting

Siting a new nuclear plant on a coal site, next to a coal site, or on new land within a community, can each bring a series of issues and options. A non-exclusive set is discussed below.

3.2.1 Owner vs. Operator

In general, this document assumes that the owner-operator of the existing coal site is an electrical utility and that the same organization will be the owner-operator of the new nuclear facility. This is done for simplicity in the document, but there is no requirement that this be the case. There are many possible owner-operator scenarios and not all can be discussed, but below are two primary options for consideration:

- The owner-operator of the coal plant is a utility and will also be the owner-operator of the nuclear plant. This is the default case assumed herein and the most straightforward, except when the organization has no nuclear operating experience. An organization with no nuclear operating experience might find the effort to evaluate and deploy nuclear an arduous task and engagement with trusted partners is recommended. Affiliating with a nuclear operating company that could take on the role of nuclear plant operator should be considered, and has been utilized in multiple scenarios with the operating nuclear fleet.
- The owner-operator of the coal plant will not be the owner-operator of the nuclear plant, i.e., the site will be sold to another organization. This can make sense, for example, if an existing utility with nuclear experience wishes to deploy a nuclear plant and finds value in the coal site as a deployment option. Points of consideration in this scenario are usually financial or legal liability related. For example, how much liability will the new owner-operator take on if potential ground water contamination is found in the future (see Sections 3.2.5 and 3.2.6)?

There are several other options, for example a non-utility industrial organization may have interest in becoming an owner to gain access to process heat but will then partner with a nuclear operating company, or an existing nuclear operating company may find value in nearby land within the community and only want access to water and transmission. While there are many permutations, the crucial point to understand is how these decisions can affect cost, financing, liability, and schedule, especially critical path activities such as decommissioning and remediation of the existing coal site as well as nuclear site and plant licensing with the regulator.

3.2.2 Identifying Land for Use

A three-step process for identifying available land on a coal site is noted in Section 2.3.1. Owner-operators should follow the steps in this process, but below are some important considerations.

Care should be taken to ensure there is a clear understanding of what is meant by the terms *coal plant*, *coal site*, and *owner-operator controlled land* (see Section 1.5.2). For a small single unit coal plant all of these may effectively be the same, but for a large multi-unit coal station built on a large swath of owner-operator controlled land (e.g., in the western U.S.) these may be entirely different things. Regardless, the owner-operator will need appropriate land for siting.

From a practical perspective, land that is the easiest to develop should be targeted for a new nuclear plant and the three-step process in Section 2.3.1 identifies such land. This opens issues for different scenarios:

- For a large site with significant amounts of open or easily remediated land, there may be few issues finding appropriate space for new development without significant decommissioning or remediation activities needed beforehand.
- For smaller sites, significant decommissioning and remediation of the land may be required to find enough space. Section 4.1 of the EPRI Siting Guide (EPRI, 2022g) discusses many of the issues associated with nuclear development on brownfield or previously industrialized sites and Section 3.2.5 of this report discusses decommissioning specifically. The two most prominent issues are:
    - The decommissioning and remediation process that will take place, including the degree to which it is completed, who will perform these actions, who will fund, and who retains any liability (see Sections 3.2.5 and 3.2.6).
    - The schedule for decommissioning and remediation and its impact on the new nuclear development project.

There has been consideration by some to include the decommissioning and remediation activities as part of the new nuclear development process. This is based on the concept that a nuclear site could be considered an environmental improvement over a coal plant, thus imparting a favorable attribute to the overall environmental rating of the proposed site. At this time, this direction would not be recommended for nearer term deployment as there are many unresolved regulatory, liability, cost (including financing), and schedule implications. See section 4.1.2 of the EPRI *Siting Guide* (EPRI, 2022g) for more information on this.

The controlling factor is likely to be the schedule. On one hand, if there is currently available open land, new plant deployment may be able to begin as soon as allowed by the local regulatory process, on the other hand, if land is not immediately available, decommissioning and remediation activities will be critical path to deployment. The X-energy report (X-energy, 2022) contains a good example of the potential tradeoffs one may need to evaluate before reusing a coal site. As the report notes:

> While the site may be large enough to accommodate the [standard] facility (with significant deviations from the standard…configuration), there could be significant cost and schedule implications of modifying the standard design four-unit plant to accommodate siting constraints. Further, development adjacent to the site in combination with the constrained site may make establishing appropriate construction, security, and radiation boundaries challenging. The existing grid interconnection will require upgrades to the current electrical interconnection facilities. Consideration of a two-module unit for the site would mitigate these principal siting and interconnection risks due to the smaller footprint and lesser electrical output. Further consideration of a two-module facility is recommended.

This is not to say one option is better than the other, but rather the owner-operator must evaluate the options against their mission and business objectives to determine the best course of action.

Any industrial activities taking place next to a new nuclear plant must also be addressed from a safety perspective based on being a potential Hazardous Land Use, and its impact on the local Population and Emergency Planning. This could be a concern if operation of other coal units, or coal plant decommissioning activities, were to take place near an operating nuclear plant.

Use of land that is nearby, but not specifically part of the coal site may be a viable option. Nearby land can still provide some of the same benefits as the coal site (but not all), but also has some additional limitations. Three key benefits are:

- Proximity to a water source
- Proximity to a transmission corridor and lines
- A viable local workforce

Another benefit is logistical separation from the coal site itself, which opens other opportunities, for example, new construction can begin independently of coal plant shut down and decommissioning. However, new land will need to be procured, not only for the nuclear plant itself, but potentially for development of short right-of-way corridors for water and transmission now located a few miles away.

3.2.3 Using a Previously Industrialized Site

Section 4.1 of the EPRI *Siting Guide* contains useful information on potential nuclear development at a previously industrialized site, with Section 4.1.2.4 specifically addressing non-nuclear generation options, such as a coal site.

The most important points to note regarding previously industrialized sites are:

- They may contain existing infrastructure that could potentially provide value.
- They may contain hazards or other challenges to new nuclear deployment.

Owner-operators considering new nuclear will need to fully understand and balance the opportunities and challenges. There may be potential upfront cost savings, but these could come at the expense of deployment schedule or O&M costs in the future. See Section 3.4 below for more information in potential infrastructure reuse.

A previously industrialized site can provide potential value due to the availability of previous site characterization data. Section 4.2 of the EPRI *Siting Guide* discusses several states of previous site characterization. An existing coal site would usually be considered to have *Limited* characterization data as defined in Section 4.2.2 of the EPRI *Siting Guide*, and as noted below:

> Sites with limited characterization data would typically include brownfield locations: larger industrial sites, non-nuclear generation facilities, and nuclear non-generating facilities, particularly non-civilian. These types of development projects can require copious amounts of characterization data for their own engineering, construction, licensing and permitting, much of it remarkably like that needed for civilian nuclear projects, but because these endeavors are regulated by organizations other than a civilian nuclear regulator, the data and information collected may be only a subset of what is needed or may not have the quality control and assurance pedigree needed.

In short, this means that while characterization data may be available, work will be needed to validate that data, and new data will still likely need to be collected. Section 4.2.2 of the EPRI *Siting Guide* defines a process that can be used for performing due diligence on available data and information. There are two characterization options for perspective new development:

- *Option 1* – Start with and maintain site characterization data and information that meets regulatory requirements for quality control and validation. This option requires a greater up-front investment but may prevent the need for rework if the project is carried forward. This does not mean that all data must be collected, only the most relevant data to de-risk the project. An alternative method to executing this work would be to carry it out under another company’s established nuclear quality assurance program, and later accept it under the licensee’s quality program.
- *Option 2* – Collect the same data and information, but not under a quality program recognizing that if the project moves forward a significant amount of rework may be required to bring the site characterization data and information into alignment with regulatory quality standards. While this will cost less up front, it imparts risk to both cost and schedule.

As identified in the EPRI *Siting Guide*, review of NRC licensing applications and associated Requests for Additional Information (RAIs) indicate that quality control and assurance related to site characterization is of key importance to regulators. For the above reasons (and others, see the following references), EPRI recommends configuration management activities begin as early in the process as possible, regardless of the above option chosen. For perspective see the EPRI report, *Data-Centric Configuration Management for Efficiency and Cost Reduction: An Economic Basis for Implementation* (EPRI, 2014d). It should also be noted that information turnover must be accounted for early in the design and construction plan for effective turnover after construction, as discussed in EPRI’s *New Nuclear Power Plant Information Turnover Guide (Revision 1)* (EPRI, 2016b).

Note that the NRC RG 1.28, R5, *Quality Assurance Program Criteria (Design and Construction)* (U.S. NRC, 2017) defines the appropriate quality assurance requirements for new plant development, which endorses several more recent revisions of NQA-1, *Quality Assurance Requirements for Nuclear Facility Applications* (ASME, 2008-2015), meeting the requirements of 10 CFR 50 Appendix B (U.S. NRC, 2019a). EPRI’s *Early Site Permit Model Program Plan*

(EPRI, 2002) recommends starting quality assurance activities early if there are plans to pursue an ESP (and would be the case for a CP or COL).

3.2.4 Construction Land

In Section 1.5.4, Land Area, Table 1-3 identifies temporary land area that needs to be reserved for construction. It is important to point out that this land is not required to be specifically adjacent to the actual plant site if there is an adequate transportation corridor that can support any needs for heavy haul and oversized loads. Nor is it required that construction land be owned by the owner operator, leasing is an option.

Land identified for construction will still need to be reviewed against the criteria in the EPRI *Siting Guide* for environmental purposes, particularly for licensing. Also, the regulator will typically require affirmative demonstration that land can be leased, or is otherwise available, before issuing any licenses or permits.

3.2.5 Decommissioning of the Existing Coal Site

Assuming that the coal site will be decommissioned to make room for the new nuclear plant, there are a few things to keep in mind.

EPRI's *Roadmap to Plant Retirement, Decommissioning, and Site Redevelopment* (EPRI, 2021a) contains a good overview of the process steps needed to plan for, and decommission, a coal site. As pointed out in the report, the period before decommissioning is an important one that requires significant planning, even without a plan for repurposing to nuclear. There must be a plan for safe operations with limited resources, generation risk must be managed to ensure operation when needed, and overall resource planning for end-of-life assets will need modification. When a plan to repurpose is added, this period, and the activities included, can become even more complex, and timing can become more critical to ensure alignment with the planned nuclear deployment schedule[15].

Based on the EPRI report the basic process steps for decommissioning are noted below, with additional notes useful when planning repowering with nuclear:

- *Frame the Project* – Establish the basic project management functions and planning. This can be complex with decommissioning alone, but adding nuclear repowering can add complexity. If schedule were not an issue, the least complex plan would consider decommissioning separate from nuclear deployment, i.e., decommissioning to greenfield, then starting a nuclear development project. However, this could result in a much longer schedule than is needed. This means that the decommissioning plan may need to include elements of the nuclear development project (that can be included based on regulatory rules and requirements).
- *Characterize the Site* – This should begin as soon as retirement is announced. For decommissioning, site characterization will include a review of the following:
  - Buildings (purpose, size, furniture, records)

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[15] Readers should review EPRI's Plant Decommissioning and Site Redevelopment Supplemental Program (Program 255) for more information.

  - Equipment (type, size, age, condition, records)
  - Operations (permits, contracts, workforce, records)
  - Underground Infrastructure (tanks, CCPs, gas, water, sewer, electrical, records)
  - Environmental (soil and groundwater contamination, asbestos, landfills, records)

  When considering nuclear deployment, all the above will be required, but their potential impact (including opportunities) must also be evaluated. For example, building and equipment can be assessed for reuse, not just disposal or aftermarket sale. Also, environmental assessment may require more diligence for understanding potentially radioactive contaminants to ensure liability is not passed on to the nuclear plant.

- *Planning for Remediation and Reclamation* – Use the information gained from site characterization to build a plan and schedule. This could be different when considering nuclear development versus decommissioning alone. It is possible that planning and scheduling for the two could be intermingled to some extent. Note that most regulators require some type of specification and permits before 'nuclear construction' begins, for example, in the U.S. a 10 CFR 50 Construction Permit (CP) (U.S. NRC, 1998), 10 CFR 52 Combined License (COL) (U.S. NRC, 2007c), or 10 CFR 50 Limited Work Authorization (LWA) (U.S. NRC, 2019b), is typically needed, but there is usually work that can be done beforehand, but what can, and cannot be done, must be fully understood.

  Once a nuclear power plant is constructed and in operation it will be subject to strict groundwater monitoring programs over its lifetime. It is important that the site be appropriately characterized, and if necessary remediated, to ensure that any contaminants that will be monitored during nuclear operations are well baselined before operations begin to ensure anything found later can be appropriately attributed to it source. While not specifically required for coal plant decontamination and remediation per se, knowledge of what will be required by the nuclear plant in the future could be helpful for planning. For example, in the U.S., the NRC Regulatory Guide 1.21, *Measuring, Evaluating, and Reporting Radioactive Material in Liquid and Gaseous Effluents and Solid Waste* (U.S. NRC, 2021d), identifies regulator expectations and the following EPRI reports as guidance:

  - *Groundwater Protection Guidelines for Nuclear Power Plants*, Rev. 1, EPRI 3002000546 (EPRI, 2013b)[16]
  - *Groundwater Monitoring Guidance for Nuclear Power Plants*, EPRI 1011730 (EPRI, 2005)
  - *Groundwater and Soil Remediation Guidelines for Nuclear Power Plants*, EPRI 1023464 (EPRI, 2010)[17]

- *Implementation* – In a typical coal plant decommissioning project, decommissioning, remediation, and restoration will happen in a staggered, overlapping manner. Typical activities include:

  - Contractor Selection (bids, due diligence, evaluation, award, finalize schedule)

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[16] A previous 2008 reversion is publicly available as EPRI 1016099.

[17] A public version of this revision is available as EPRI 1023464.

  - Project Management (permitting, community and regulatory notifications, document review and management)
  - Buildings and Infrastructure (remove fuels, sell applicable assets, disconnect utilities, building demolition, remove slabs and foundations)
  - Environmental Remediation (Execute remediation activities, verify, obtain regulatory approval)
  - Site Restoration (bring to final grade, restore vegetation, prepare for future development)

  When considering nuclear development, the above steps are similar, but there may be differences. For example, contractors with nuclear experience may be considered for site restoration, the plan for building, infrastructure, and utility demolition may differ because items are being kept, underground infrastructure that would have been left may need to be removed, and the site restoration plan may differ, for example, vegetation may not be restored where the new nuclear development will take place.

- *Project Closure* – This includes verification that all remediation and relocation activities are complete as planned. Under any decommissioning project, project closure is important, but it may be more so when moving on to nuclear development. Formal identification of project closure may be required by the public utility commission (PUC) for financial reasons, and clear closure and turnover will be important for liability issues as the site transitions to nuclear.

Note: The report *Decommissioning US Power Plants: Decisions, Costs, and Key Issues* from Resources for the Future (RFF, 2017) contains a good primer on coal plant decommissioning costs and challenges, including those related to Coal Combustion Products (CCP). Also, Qvist (Qvist, Gładysz, Bartela, & Sowizdzał, 2020) notes a complete decommissioning can take between 18 and 30 months.

As noted by Orano in a report for the U.S. DOE (Orano, 2022), for plants that undergo decommissioning, building basements, buried piping, and other commodities at depths greater than 1 to 2 meters are routinely left in place. This can make sense for facility decommissioning and return to a greenfield state, but this can pose difficulties for future nuclear plant construction:

- Many advanced reactor designs include placing all or a substantial portion of the reactor block below grade.
- The physical presence of below grade material simply has the potential to impact general new construction activities.

Careful consideration should be given to leaving below-grade structures in place. An inventory of below grade structures left in place should be developed and evaluated against the nuclear plant construction plans. The inventory should minimally include the location, physical dimensions, depth relative to grade, maximum depth, and material(s) of construction.

3.2.6 Coal Combustion Products (CCPs) and Other Environmental Issues

There are several environmental concerns that must be addressed when decommissioning a coal plant (whether all the plant or just part of it). Some of the most significant issues are related to the final management of CCP units (i.e., landfills and surface impoundments containing coal ash, bottom ash, FGD solid residuals, and boiler slag, which can also be referred to as Coal Combustion Residuals, CCRs). Apart from being one of the costliest aspects of decommissioning, the final state of the CCP units, how they will be managed in the future, and their proximity to the new nuclear plant can have significant impact.

Note: The above-mentioned Resources for the Future report (RFF, 2017) provides succinct information on CCPs and a recent white paper from the NEI (NEI, 2022b) helps explain the regulatory and legal landscape associated with CCPs and potential legal and financial liability.

Coal plants designated for 'repowering' are often remediated to a brownfield condition (see EPRI *Siting Guide*, Section 4.1.2). Brownfield sites are property that *may be complicated by the presence or potential presence of a hazardous substance, pollutant, or contaminant* (U.S. EPA, 2022f). Typical contamination issues *include soil contamination from leaks of petroleum or other liquids, CCR-related soil or groundwater contamination, and the presence of asbestos, PCBs, lead, or other regulated materials* (RFF, 2017).

In general, soil and groundwater contamination issues, chemical or radionuclide, could be of concern for a new nuclear plant as potential sources of future contamination on the nuclear site, especially for groundwater. Also, any radionuclides from the nuclear plant that make their way back to CCPs or other contaminated areas could affect their waste classification.

Typically, when a coal plant is decommissioned, a site characterization is performed to identify all environmental hazards, such as asbestos, PCBs, lead paint, hydrocarbons, and other regulated materials, which must be removed or remediated to within regulatory limits, but CCPs can remain on site in some form if properly addressed. As part of developing the application information for a site license application with the regulator, significant characterization of the planned nuclear site will also be completed. These characterization exercises will provide valuable sets of baseline data, although additional chemical sampling of groundwater and soil over and above what might be done for a greenfield site is likely in order.

With this baseline data in hand, the primary concern is some type of future cross contamination between 'nuclear' and 'non-nuclear' areas. For example, coal ash contains low levels of uranium, thorium, radium, and potassium-40 (^{40}K). As noted in the EPRI report, *Assessment of Radioactive Elements in Coal Combustion Products* (EPRI, 2014b), the levels of radioactivity are not a safety concern and transport in groundwater is usually limited under typical groundwater conditions. Also, it is important to consider that groundwater will not always be contaminated by CCP management. In particular, landfills with composite liners and leachate collection systems can prevent releases to groundwater. However, any detection of new radionuclides in the nuclear site's ground water monitoring program will require verification that the source is not from the nuclear plant itself. For consideration in the other direction, the presence of a radionuclide from the nuclear plant in the coal ash or other groundwater or soil could complicate how it needs to be managed in the future.

CCP units may also need to be considered as 'Hazardous Land Use', depending on their design, proximity to the plant, and how they are remediated. If there is a potential for a CCP unit to fail and spill ash onto the nuclear plant site, either on its own or due to an external hazard such as flooding or an earthquake, the CCP unit should potentially be considered a 'Hazardous Land Use' as defined in the EPRI *Siting Guide* (EPRI, 2022g).

The EPRI *Siting Guide* specifically calls for land within 5 miles (8 km) of a 'hazard' to be excluded. This is based on the concept of looking for greenfield sites in a large ROI, with the assumption that the extra cost of remediation, mitigation, or evaluation is not practical, especially if the ROI is large enough. However, remediation, mitigation, and evaluation are options. For example, while a wet ash pond can fail and spill, the terrain and total volume could limit CCP transport to a short distance, much less than 5 miles.

Also, in the U.S., under the Coal Combustion Residuals Rule (U.S. EPA, 2015), most CCPs will need to meet specific standards. Per the NEI white paper:

> … the performance standards address restrictions on the location and siting of CCR units, design and operating criteria, groundwater monitoring and corrective action, and closure and post-closure care requirements (see below for more details). Subject CCR units that, as a technical matter, cannot meet the performance standards specified in the rule must retrofit or close by certain deadlines.

This means that, in the U.S., most CCP units will be mitigated as part of decommissioning (or going *cold and dark*[18]). Ash ponds will be dewatered, and the contents transferred to a landfill, or closed-in-place, and dry-ash impoundments will be either removed or closed in place. Those left in place but closed[19] will be subject to meeting safety standards for environmental hazards and be inspected and monitored for many years in the future. The result is that, while CCP units are something that needs to be managed, they can be.

The purpose of this document is to help with early evaluation of the viability of a coal plant, or coal community, for new nuclear plant development. For those taking an early look, there are two things to keep in mind:

- As the new nuclear site land area is being developed, consider the location of CCP landfills and impoundments, their status, and whether impoundments have been dewatered and closed or still contain ponds, and whether site investigations have been performed to assess groundwater quality impacts.
- Be sure to understand the short- and long-term plans for CCPs. The time and cost of removal and remediation can be significant and could impact the schedule for new deployment.

The technical evaluation of CCPs and their relationship to any new nuclear construction is something that will need to be managed and evaluated before new construction can begin.

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[18] *Cold and Dark* - Limited decommissioning and remediation are completed and the site secured and left as-is, like SAFSTOR for nuclear plants.

[19] Under the EPA CCR Part B Final Rule, (U.S. EPA, 2020) some CCR units that would have been closed per the Coal Combustion Residuals Rule could potentially stay open. To date no applicants have been approved.

3.3 Technology Selection

The EPRI *Technology Assessment Guide* (EPRI, 2022a) provides a detailed process for choosing a technology followed by a specific design for nuclear plant deployment. In the early evaluation stages identification of a specific technology or design is not a requirement, but some level of evaluation must be completed to make informed decisions.

Section 2.3.4 above provides a limited set of criteria that can be evaluated to get an early understanding of technology and design options (Table 2-2). Once one or more candidate designs have been identified, the needed land size and other criteria related to siting can be better identified. Regardless of whether there are plans to pursue an ESP (Section 2.7), development of a PPE (Section 1.5.5) early in the evaluation, even if limited in detail, can support the siting criteria evaluations as defined in Section 2.3.1 and Table 2-1.

In the end, all criteria will need to be evaluated, but the most essential information to extract from the technology selection evaluation is:

- The number of units for any candidate design needed to meet the energy output goals as defined in the mission and business objectives.
- The land size (and potential layout) required to support the number of units.
- The cooling water needed to support the number of units.
- Cost and schedule information (to be evaluated against the need dates and budgets identified in the mission and business objectives).

The first three bullets, number of units, land size, and cooling water needs, directly affect whether a specific site can support the chosen design for new nuclear development as defined in the mission and business objectives. The fourth bullet is linked to the site itself but cost and schedule are of foremost importance. A design that is not ready to be deployed when needed, or costs more than the owner-operator can justify, is not really a viable option.

Failure to satisfy any of the criteria outlined does not necessarily disqualify the site or design for new nuclear development, depending on the owner-operator’s willingness to change mission and business objectives. Therefore, technology and design selection are best completed as an iterative process with site selection, so that decisions can be refined at each iteration.

3.4 Reuse of Site Infrastructure

The reuse of an existing coal site can provide options to reuse existing infrastructure, thus avoiding cost, and possibly reducing schedule. Section 4.1 of the EPRI *Siting Guide* provides some discussion on reuse of site infrastructure as do three recent studies (INL, 2021; Qvist, Gładysz, Bartela, & Sowizdzał, 2020; U.S. DOE, 2022).

A decision to reuse any existing infrastructure comes down to understanding the cost of replacement versus the value of reuse. The Qvist study correctly points out that the value of any reused infrastructure is based on its remaining service life, but this can be misleading if it has already gone through previous repair and refurbishment, so this must be based on more than just a review of calendar time but include an evaluation of history.

Even if infrastructure is reused, there may still be costs to bring them to a needed quality or performance level. This includes all costs for the following categories:

- *Repair* – Maintenance to fix degraded items.
- *Refurbishment* – Preventative maintenance to ensure a desired operating life.
- *Remediation* – Removal and disposal of any hazardous materials
- *Code Compliance* – Upgrades or changes to meet current codes and standards, including programmatic requirements, such as seismic or environmental qualification (EQ).
- *Quality Control and Assurance* – Inspection, testing, and maintenance to verify operating and quality requirements,
- *Process upgrades* – Upgrades or changes required by new systems and processes.

These six categories can be organized into two groups for early evaluation: those that can be completed without a defined nuclear plant design, and those that cannot.

An early evaluation of the need for repair, refurbishment, and remediation can typically take place without having a defined design or input from an OEM. The owner-operator can take an inventory of structures, systems, and components (SSCs) and review them against existing inspection and maintenance status or perform inspections to understand their state. However, results depend on the comprehensiveness of procurement, maintenance, and inspection records.

EPRI has hundreds of reports and supporting information that can aid in these evaluations. There are too many to call out here but pertinent report types to examine are maintenance guides, inspection and preventative maintenance guides, end-of-life guides, condition assessment guides, and reports on degradation and failure modes. Some example EPRI (and other) reports are noted in the sections below, but these are not the only valid references and are provided as starting sources for investigation. Relevant EPRI program areas are noted in Table 3-1.

Table 3-1
Relevant EPRI Programs

Nuclear Programs[20]		Generation Programs	
41.05.01	Nuclear Maint. Appl. Center (NMAC)	219	Steam Turbines and Auxiliary Systems
41.05.02	Plant Engineering (PE)	220	Generators and Auxiliary Systems
41.05.03	Instrumentation and Control (I&C)	224	Integrated Asset Management
41.08.01	Advanced Nuclear Technology (ANT)	226	Boiler and Turbine Steam and Cycle Chem.
41.09.03	Water Chemistry	229	Materials and Repair
Power Delivery & Utilization Programs		241	Coal Combustion Products Management
35	Overhead Transmission	255	Plant Decom. and Site Redevelopment
37	Substations		

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[20] As of this writing, there is a plan to merge NMAC, PE, and I&C into a single new program, Plant Reliability and Resilience (PRR, 41.05.04) on or around the beginning of 2024.

An evaluation of the last three items, code compliance, quality control and assurance, and process upgrades will require the input of an OEM to provide the necessary information regarding what will be needed for their specific design. Specifically, the latter of the three, which may involve an iterative process where the OEM design is modified in conjunction with changes to the SSCs to meet the goals of the project.

The impact of keeping pieces of infrastructure must also be evaluated against decommissioning and new plant construction logistics and schedules. For example, an available warehouse that is in good condition and could be used as-is with little additional costs might find itself located right where the primary construction crane will need to sit, requiring removal in any case. Or it might be in a location that significantly impedes truck traffic on site, potentially causing delays to critical path delivery schedules.

The X-energy report (X-energy, 2022) provides some insight into a real-world evaluation for reusing site infrastructure. As identified in the report and provided here only as examples:

- Due to differences in operating conditions (e.g., pressure and temperature), the existing steam plant cannot be repurposed.
- The age and location of the existing cooling towers can limit reuse.
- The targeted output of the new nuclear plant exceeds that of the current switchyard limiting potential reuse, but some electrical systems could be used for construction.
- The high voltage transmission corridor and structures could be reused, but additional lines will be needed to support the increased plant output.
- The existing stormwater collection system (supporting local wetlands management) could be reused, but rerouting of buried piping will be necessary.
- Wastewater discharge facilities and piping could be reused, but with modification.
- Existing municipal utilities can be used for construction and operations.
- Existing rail and access roads could be reused, but maintenance and upgrades may be necessary.

The examples above are only valid for the site and design selected and evaluated, so inferences about other sites and designs cannot be made, but the examples clearly illustrate the thought process.

As noted above, the decision to reuse any existing infrastructure requires an understanding of replacement cost versus the value of reuse. However, owner-operators are also reminded that there can be value in certainty. The reuse of any infrastructure brings risk to the project that can manifest during licensing, construction, or operations. Owner-operators should perform proper due diligence before reusing any existing infrastructure.

The following sections expand on some specific opportunities and challenges for selected site infrastructure elements. For additional information on the consideration of existing infrastructure see *Generic Design Support Activities for Advanced Reactors: Site Reuse Deployment Guidance Project - Final Infrastructure Assessment and Modern D&D Methods* (Orano, 2022). While this report specifically considered the reuse of a non-generation nuclear facility, there are parallels relevant to a coal plant.

3.4.1 Grid Interconnection, Including Switchyard

One of the most valuable assets available to an existing coal plant is its connection to the grid. This includes its switchyard and the lines connecting to the local transmission corridor. While specific circumstances can vary, the order of importance for these assets is typically as follows:

- The transmission corridor itself (i.e., the actual right-of-way land that has already been cleared and developed leading from the plant to the primary connection to the grid) – The process to site a transmission line is like siting a nuclear plant, with many of the same criteria found in the EPRI Siting Guide needing evaluation. In addition, land will need to be procured, regulatory approvals are needed, and the public will have an opportunity to weigh in. The costs are not insignificant, but more importantly, the schedule for completion can be long. EPRI's Guide for Successful Transmission Line Siting (EPRI, 2013c) contains a good overview of the transmission line siting process.
- *The towers and poles along the corridor* – The ability to reuse these as-is will provide significant savings. These components can generally last for a long time with proper maintenance, but an evaluation will need to be done to ensure they can support the new development (EPRI, 2017a; EPRI, 2004).
- *The wires (and related equipment) along the corridor* – Assuming they have been well maintained, and that they can support the new energy load, these may be reused. However, if the expected energy load exceeds that originally provided by the original coal plant, replacement or additional wires may be needed. See the X-energy report, (X-energy, 2022) for a real-world example of this situation. In this last case, the towers and poles will need to be evaluated on their ability to support additional wires.
- *The plant switchyard* – This may be able to be reused but is going to be dependent on the final load of the new plant, the health of the equipment (EPRI, 2012), and the final location of the new plant. As noted in the X-energy report (X-energy, 2022):

> The electrical output from the [design] does not align with the existing switchyard components and capacities. Relocating these components would also be necessary to support the footprint requirements of the [design], and further limits potential use to support the new plant. However, the existing electrical distribution yard could be used to provide construction power needs during much of the power island construction.

The transmission network at the point of interconnection to the nuclear plant needs to have adequate capacity to transmit the power to meet demand, with some redundancy to allow for planned and unplanned outages of transmission circuits. If the new nuclear plant has similar capacity as the coal plant being replaced, no major reinforcements of the transmission grid would be needed. In some cases, it may be possible to use various technologies to increase the transmission capability of the surrounding transmission grid without resorting to the construction of new transmission infrastructure. See EPRI reports *Increased Power Flow Guidebook – 2022: Increasing Power Flow in Lines, Cables, and Substations* (EPRI, 2022c) and *Grid-Enhancing Technologies: Use Cases and Solutions Design* (EPRI, 2022d) for more information on increasing power flow. See Section 3.4.5 for additional discussion on the reliability and power quality requirements at the point of interconnection.

Depending on the final location of the new development, some distance of new grid corridor may need to be developed. For example, if the new nuclear plant is located elsewhere in the community, a new corridor to the grid will need to be developed, perhaps requiring the procurement of new land for the right-of-way. This should be factored into the costs and schedule.

The ability to use the grid interconnect is also dependent on the ability to obtain the permits to connect. For example, as noted in the X-energy report for the location, *there is a moratorium on consideration of new interconnection applications due to the high backlog of applications to be processed and the need to resolve process issues*. See more on this Section 3.4.11.2.

3.4.2 Cooling Water Supply, Including Intakes, Piping, and Cooling Towers

Much like the transmission connection, the ability to reuse the existing water supply is dependent on the equipment capacity and health as well as the final location of the new development in relation to the supply.

Whether or not the existing supply has the capacity is dependent on the needs of the new plant. While not globally true, new plants, especially in the U.S., are expected to require the use of cooling towers. For a coal plant that used once-through cooling, the system's capacity may be more than sufficient, but in fact may be so overdesigned that it could cause efficiency problems (e.g., flow rates too high, overcooling, wear on equipment). For a plant that previously used cooling towers, the capacity may be fine, but if the new plant's electrical output is greater the capacity could be too low. Also, while *total withdraw* is less, cooling towers *consume* two to three times the water of once through cooling, which could be a concern in areas with limited water resources (see Section 3.4.11.3).

For the proper thermal efficiency of the new plant, it is best if the cooling system is properly sized to match the design, which may require a significant amount of infrastructure replacement. If the new plant is not located exactly where the original plant was, significant new piping may be needed as well. The material used in most cooling systems, particularly concrete piping and cooling towers, are also prone to long-term degradation (EPRI, 2016a; EPRI, 2011; EPRI, 2018), and their current health may be such that refurbishment and reuse is not prudent. While the most pressing concern is the cooling water intake, the discharge system may also have similar concerns. The SSCs are typically the same materials as the intake system and, if the new plant produces more thermal power, outlet temperatures may be a new concern. Environmental and permitting concerns may also result from these higher temperatures. See Section 3.4.11.3.

Structures such as intakes and transfer canals may offer some of the best opportunities for reuse, but again this depends on the final location of the new plant and the needs for water withdrawal. If withdraw is higher than that of the coal plant, intakes may need to be bigger, and if the new nuclear plant is located farther way from the original location, new piping may be needed, which may require the procurement of additional land for a right-of-way.

Additionally, changing conditions due to climate change could require other changes, such as lowering intakes to account for reduced water levels during drought conditions. Also, it is important to note that a nuclear plant always requires cooling availability, even during shutdown, so unless alternative cooling is available the ability to always withdraw cooling water is necessary and more conservative assumptions may be required for analysis (see section 3.4.11.3.3 for information on alternative cooling systems).

What is of most value is simply the volume of cooling water available from the source. Assuming the new plant will be taking the same or less water from the source as the existing plant, and assuming the sources can be considered relatively the same (i.e., same river or reservoir as the original and the withdrawal location located such that it can be considered the same), the ability to provide cooling water may be sufficient. If the new plant requires more withdraw, or consumption is greater than can be replenished, then an evaluation will be needed.

The EPRI *Siting Guide* criterion, 3.4.1.2, Pumping Distance, is identified in Table 2-1 for early review. This criterion is evaluated to understand the cost and effort needed to obtain cooling water. This is used as either an avoidance factor (i.e., cost related), or as a comparison against other potential sites. When evaluating a large ROI, pumping distance can be a relative proxy for cost, however, when evaluating a single site on its own, and without comparison, it would be treated as an avoidance factor based on cost, therefore an estimated cost should be established. Cost would include upfront capital for pumps and piping, as well as long-term operating costs.

The ability to reuse any of the cooling system SSCs is very design dependent and the owner-operator will need to work closely with an OEM and AE to determine what can be reused with their individual design. Those that are making an early evaluation and have not identified a design will need to assume little reuse in their planning.

As with the transmission corridor, the rights to withdraw the water may be another issue. See more on this in Section 3.4.11.3. Also see Section 3.4.11.3.3 on alternate cooling systems.

3.4.3 Light Cooling Water and Fire Water Systems

Light cooling water systems, including fire water systems, may have potential value. As with other SSCs, this is dependent on their capability to support the new plant, the health of the various SSCs (EPRI, 2017b), the final design of the new plant, and the location of the new plant.

For most new nuclear plant designs there are likely few plant-specific SSCs that can be reused, but external systems such as pumphouses and storage tanks may be viable for reuse. These systems are often fed by local wells and well capacity and location may also need to be evaluated (see Section 3.4.11.3).

The ability to reuse any of the light cooling water systems, including fire water systems, is very design dependent and the owner-operator will need to work closely with an OEM to determine what can be reused with their individual design. Those that are making an early evaluation and have not identified a design will need to assume little reuse in their planning.

3.4.4 Reuse of Balance of Plant Systems

There have been previous cases where the boiler of a coal plant was replaced by a combined cycle gas plant and connected to the existing balance of plant (BOP) systems, including the turbine and generator (Modern Power Systems, 2020). A few studies have been completed on the potential reuse of the balance of plant systems for nuclear (INL, 2021) (Qvist, Gładysz, Bartela, & Sowizdzał, 2020) (TerraPraxis, 2023), and there are historical examples of this being done in the early days of nuclear (ANS, 2013). One study estimated that the potential overnight capital cost (OCC) savings for new construction could be as much as 28% - 35% versus greenfield construction (Qvist, Gładysz, Bartela, & Sowizdzał, 2020) and the recent DOE report (U.S. DOE, 2022) identifies potential savings of 15%-35%.

Two key considerations for reuse of the BOP are that the nuclear steam supply system (NSSS) must provide a steam supply that meets the steam temperature, pressure, throughput, and quality, for which the BOP systems were originally designed, and that under typical nuclear designs the BOP can have systems, structures, and components (SSCs) that are considered *safety significant*, meaning that their design, materials, and construction must be considered in the overall safety of the nuclear plant. Due to the regulatory process in most locales, a nuclear plant is typically designed and licensed to very particular specifications, which may or may not be in line with the BOP's current state, potentially requiring significant modification.

A study by TerraPraxis (TerraPraxis, 2023) and a design proposed by TerraPower (TerraPower, 2022) consider the concept of including an intermediate heat storage system which offers the opportunity to decouple the steam supply from the balance of plant, which could alleviate these concerns. While these studies and potential designs indicate that reuse of the BOP is a technical possibility and could provide cost savings, this is currently an untested scenario, and the technology is not yet commercially available.

As another example for illustration only, it may be possible to install one or more ARs upstream of an existing BOP in a configuration that will work. In this case, two SMRs tied to a common steam line may be able to meet the mass and thermal balances needed by the existing BOP. For this example, the OEM will need to slightly redesign the SMRs to meet the required steam mass, and additional superheating will need to be installed to meet the needed temperatures, pressures, and steam quality. This redesign will require additional design and licensing activity.

The choice to reuse any BOP systems comes down to cost and schedule and this can only be achieved through a rigorous analysis, taking into consideration the factors identified in Section 3.4. The significant effort and potential impact to schedule impart a level of risk that earlier adopters should be sure to consider.

3.4.5 High Voltage Power, Emergency Power, and Off-Site Power

The need for incoming routine-use high voltage power, emergency power, and off-site power will be design dependent. Some new AR designs are expected to not need safety related electrical systems and the systems used by the existing coal plant may offer the potential for reuse. As with previous systems discussed, key considerations are capacity, SSC health, and final location of the plant (EPRI, 2019a).

Of primary value to a new nuclear plant is the lines up to the existing property as specific changes to the property will need to be made for the final design. As with the transmission system, if the new plant is located farther away, right-of-way land corridors may need to be obtained and developed.

The ability to reuse any of these systems is very design dependent and the owner-operator will need to work closely with an OEM to determine what can be reused with their individual design. Those that are making an early evaluation and have not identified a design will need to assume little reuse in their planning.

Many modern ARs under development will not require safety related (i.e., Class 1E) AC power, and some may even be designed for black start capabilities. However, ARs will typically expect incoming power for when the plant is off-line, and these off-line loads will typically be higher than the coal plant required due to added requirements for fuel and fuel pool cooling, and in the case of MSRs and SFRs, resistive heating and electromagnetic pumps needed to prevent salt solidification. If the design does require safety related AC power, the incoming lines and system will need to meet regulatory requirements. In the U.S. this means meeting the requirements of Criterion 17, the Electric Power System, of the *General Design Criteria for Nuclear Power Plants* (U.S. NRC, 2007a), NRC RG 1.32, *Criteria for Power Systems for Nuclear Power Plants* (U.S. NRC, 2004), and IEEE 765-1995, *Standard for Preferred Power Supply (PPS) for Nuclear Power Generating Stations* (IEEE, 1995).

Regardless of a plant's need for safety related power or the plant's ability to maintain safety without offsite power, the availability, reliability, and quality of offsite power, and the overall interrelated nature of the grid to nuclear plant interface, is still important. The IAEA's *Electric Grid Reliability and Interface with Nuclear Power Plants* (IAEA, 2012a) discusses the basic requirements for connecting a nuclear plant to the grid as well as off-site power reliability and abnormal events. Also, as noted in *Grid Reliability Using Risk and Safety Management Tools: Phase I: Zone of Vulnerability Analysis for Nuclear Power Plants* (EPRI, 2014c):

> When a large generator trips, there is an impact to the transmission grid from the loss of real and reactive power support. If a nuclear plant is forced to trip off-line during periods of transmission grid instability, this will further destabilize the transmission grid. Nuclear plant risk and grid instability are interrelated—indeed the tripping of a plant can cause grid instability, and grid instability can result in the tripping of a plant.

Even if nuclear safety is not a concern, a plant trip still causes loss of generation, wear and tear, on equipment, and could result in wider losses across a region, and therefore should usually be avoided. A review of the coal plant's historical trips due to loss of off-site power, or interconnection quality issues, including those caused by weather, can provide insight into the need for any additional interconnection upgrades that may be required or warranted.

3.4.6 Meteorological Data Collection Towers

If they are installed and available, Meteorological Data Collection Towers, or MET towers, offer two separate opportunities. Any existing towers could be used for data collection (including historical data) for site characterization purposes, however, the data (i.e., tower height, tower location, data collection equipment, and data collected) will need to be qualified to use the data for licensing purposes. The existing data should certainly be viable for initial decision making, but qualification should be completed before extended characterization is completed.

An existing tower may be able to be reused for the new nuclear plant, however, a new nuclear plant is likely to require at least two towers, so unless the coal plant already has two, another may be needed. Also, the final full qualification of the site may require additional towers to be installed (potentially including alternative sites). If the new site is located farther away from the existing site, new towers may need to be erected, however, there is potential that an existing tower could still be reused for early evaluation or as the second tower if needed.

The ability to reuse a MET tower for a new nuclear plant depends on the health of the tower and its equipment. The tower and data collection equipment must meet certain quality requirements for full site characterization and ongoing operation of the new nuclear plant. In the U.S., this currently means meeting the requirements of NRC RG 1.23, *Meteorological Monitoring Programs for Nuclear Power Plants* (U.S. NRC, 2007b), and this includes appropriate management for cyber security concerns (NEI, 2017), as well as collecting two years of data.

3.4.7 Transportation Access (Road, Rail and Barge)

Existing transportation access is an asset for an existing coal plant. There are two general types of transportation access that must be considered: Access that goes up to the site boundary and what is specifically on the site itself.

Roads, rail service, and barge access that leads up to the site perimeter is of significant value and with some exceptions should be available for reuse:

- Access roads and local highways will need to be able to manage expected traffic and loads for decommissioning and new construction. These roads were adequate when the coal plant was commissioned but over time their capacity and load handing ability may have been reduced as traffic and the need for heavy loads for the plant were reduced. In addition, a build out of local infrastructure over time may make once easy transportation routes more complex, requiring transport through city streets or under overpasses that were not there at the time of original construction. The Orano report (Orano, 2022) provides a good list of criteria that can be used to understand the state of local access roads and highways.
- Like access roads, existing rail access may need evaluation for capacity and loads for decommissioning and new construction. Some coal plants receive coal by train and these lines may be quite serviceable, but it is common for spurs once used for new construction to be closed and paved over during operations. The Orano report provides a good list of criteria that can be used to understand the state of the site and local rail access.
- Barge access may or may not exist depending on where the plant was located (e.g., on a river vs. a lake or reservoir). As with rail lines, barge access once used for construction may no longer exist or be usable. Barge access may also be available from other nearby locations, not just on the site. In this case, the condition of local roads or railways will also need to be considered. The Orano report provides a good list of criteria that can be used to understand the state of the site and local barge access.

Depending on the final design chosen, only one or two of the transportation access methods may be needed, as some designers are using modular construction techniques to reduce the need for heavy haul access.

Beyond access up to the site property, road and rail spurs within the plant proper may have value to new nuclear plant deployment. The final site layout may require moving internal throughfares and the ability to support heavy loads will need evaluation. The decommissioning process may also require removal of roads to support removal of underground SSCs.

3.4.8 Non-Power-Block Buildings

Non-power-block buildings include structures such as administrative buildings, warehouses, analytical laboratories, machine shops, and site emergency facilities. The ability to reuse any of these structures is dependent on the final site layout and the capability of those buildings to support the new need (e.g., number of people that an administration building can support or capacity of the machine shop or warehouse). The amount of refurbishment that needs to be completed, meeting current codes and standards, and the need for hazardous material abatement may also affect decision making.

While some existing structures may have potential for reuse, their existing location may interfere with efficient decommissioning or new construction activities. Regardless of their ability to be used for the final development, these structures can sometimes be temporarily used during decommissioning and new construction activities until new facilities are built.

3.4.9 Utilities

Existing utilities and easements, such as water, gas, and sewer, may be useful during new nuclear plant construction and operation. Like transportation access, previously existing utilities are potentially reusable, depending of course on their condition and capacity. Even if utility lines need to be replaced, existing easements can provide real value.

The ability to reuse utility infrastructure on the new plant site will be very dependent on the final layout of the new site and any impact its existing location may have on new construction. For example, below ground utility lines may need to be removed to make room for below grade construction of the new nuclear plant.

Care must also be taken to not damage existing lines during decommissioning and new construction. Evidence exists that the actual locations of older utility lines can be lost to history. Prior to decommissioning and new construction, the owner-operator should endeavor to ensure they have mapped all existing utilities (and other underground structures such as tanks, piping, and cable runs). Even if the existing utilities are not intended for reuse, inadvertent damage can be a safety issue.

As with other infrastructure, condition assessments should be made on any existing utilities to ensure they are safe for continued operation for an extended period. While specifically intended for maintaining buried piping at operating fossil and nuclear plants, EPRI reports *Underground and Buried Piping Fossil Power Plant Equipment Guideline* (EPRI, 2017c) and *The Buried and Underground Piping and Tank Reference Guide: Revision 2* (EPRI, 2021b) may provide insight into locating and managing underground utilities and other buried structures.

The value of existing utilities for a site located elsewhere in the coal community will be limited.

3.4.10 Services

The Orano report (Orano, 2022) identifies two existing services that may be available for use: Community Outreach Services and Site Emergency Services. As identified in the report, the subject services were already set up for the needs of the subject nuclear facility, so in that specific case much of the service infrastructure for a new nuclear generation plant will already be in place. However, these services are likely to exist in some form for the coal plant as well.

- *Community Outreach Services* – As a function of infrastructure, this refers to the organizational structure that may already exist.

  Note: Community Outreach as a process is described briefly in Section 2.8 and in the EPRI *Siting Guide* (EPRI, 2022), and Community Engagement considerations are discussed in Section 3.8.

  Whether or not a coal site has its own local community outreach services organization will depend on factors such as the overall plant size, the size and organizational structure of the owner-operator, the plant's location, and its relationship with the local community. Regardless, there should already be a functional organization structure with responsibility for local community outreach and this can be leveraged for future outreach on coal to nuclear transition planning.

  Development of a new nuclear plant is a community intensive endeavor, and the more local the outreach organization is the better they will be able to provide needed services. Therefore, while initial services can be provided by a corporate organization during early evaluation, transitioning to a local organization early in the process, particularly if the project will move forward, is prudent.

- *Site Emergency Services* – As noted in the Orano report, a typical nuclear facility will require emergency services that include (Orano, 2022):

  > … emergency preparedness; emergency medical, fire, and hazardous material (HAZMAT) responders; an existing onsite fire station and supporting equipment; agreements with other area responders; onsite health services building; and emergency response centers.

  As with community outreach services, the level of services already available at the coal site may differ, but as a minimum there will be some functional organization responsible for managing various emergency issues. Even if the coal plant has limited services of its own, it should have response agreements and procedures in place with local police, fire, and medical emergency responders.

  Early in an evaluation the existing organization can interface with the community to identify future needs and set expectations if, or for when, the new nuclear plant becomes operational. As with community outreach, as the project moves from evaluation to actual deployment a more defined local emergency services organization may be needed.

  It should be noted that many proposed AR designs are expected to have the nuclear plant's Emergency Planning Zone (EPZ) limited to the site boundary, reducing the complexity for emergency planning with local community, but this will not negate the need for planning and continued communications. Also, there is a goal for these new ARs to require fewer security forces by making use of innovative designs to reduce the overall security footprint. While this would result in fewer security forces on site, it could increase the need for planning and communication with local emergency responders.

While not physical infrastructure, these functional organizations that already exist can be leveraged during the coal to nuclear transition. And, because these are not physical infrastructure, they can be leveraged to some extent whether the final site is on the coal site proper or elsewhere in the community.

3.4.11 Permits

As described in the EPRI *NPTA* (EPRI, 2022f), in addition to authorizations from the nuclear regulator, many additional permits are required as new nuclear plant development begins and progresses. In some cases, these permits apply to construction activities and in others to plant operations. In the U.S., these permits are obtained from federal, state, and local authorities and may include agencies as diverse as the Federal Aviation Administration, U.S. Army Corps of Engineers, and state departments for environmental quality and for historic sites.

If permits are not obtained at the appropriate time or compliance is lax, the responsible regulators may stop work, issue fines, or require remediation actions. The importance and complexity of this area typically requires establishing a dedicated permitting group within the project team to manage permitting and to build relationships with the various regulators (note that the U.S. NRC expects, and will verify, that communications with these other agencies takes place).

3.4.11.1 General

Table 3-2 below is a non-exhaustive list of the types of permits that will be needed for nuclear plant construction and deployment, particularly in the U.S (EPRI, 2022f). Many of these permits may already be in place for the existing coal plant. When evaluating new nuclear, the most important consideration is to have an inventory of existing permits, understand what they cover, and the process and schedule to update and maintain them without unintended schedule delay.

Table 3-2
Typical Permits Required for Nuclear Plant Construction and Operation

Federal Aviation Administration (FAA) – Construction Notice, aircraft hazards (i.e., for tall structures)
State Public Utilities Commission – Certificate of Public Convenience and Necessity
U.S. Army Corps of Engineers (U.S. ACE) – Federal Water Pollution Control Act (FWPCA) Section 404 Permit for protection of wetlands
U.S. Coast Guard – private aids to navigation (if project affects a navigable waterway)
USACE/State regulator – Rivers and Harbors Act
US Fish and Wildlife Service – Endangered Species Act, Migratory Bird Treaty Act
State Department of Environmental Quality (DEQ)
Hazardous Waste and Mixed Waste in accordance with Resource Conservation and Recovery Act
Clean Air Act, operating permit, air pollution control and abatement, construction equipment air emissions
Drinking water
Withdrawal of groundwater
General permit to discharge storm water during construction and after completion
National Pollutant Discharge Elimination System (NPDES)
Permit for liquid discharges to surface waters
Solid waste
State Department of Historic Resources – cultural survey, etc.
State Department of Transportation
Transport of hazardous material
Transport of radioactive material
Equipment transport routes for oversize or overweight loads
State/DOE permit – water supply, wetlands
Local agencies – certificate of occupancy for buildings.

Organizations outside the U.S. will have different rules, regulations, and requirements, but they will fall into similar areas.

While the table above itemizes several typical authorizations and permits that may be required, there are a few that need more detailed discussion.

3.4.11.2 Grid Interconnection

The specifics of grid interconnection requirements vary by locale and the full details are beyond the scope of this document. A recent report by NEI, *Generator Replacement Survey: A Review of Generator Replacement Tariff Reforms by Transmission Providers* (NEI, 2022a), provides a good primer on the subject, Also, the IAEA report, *Electric Grid Reliability and Interface with Nuclear Power Plants*, explains the basic needs for connecting a nuclear plant to an electric grid in a safe and secure manner and provides a breakdown of the typical activities performed by a grid operator and the nuclear plant owner-operator (IAEA, 2012a).

As noted above, the policies and procedures for making a grid connection will vary by locale, but in the U.S. the process has historically been that those wishing to connect new generation to the grid must have their request queued up with the system operator along with all other requests, largely on a first come first served basis. As identified by the Lawrence Berkeley National Laboratory (LBNL, 2022), the process is typically as follows:

- An interconnect request is made.
- A series of interconnection studies on feasibility, system impact, and facilities are completed. If there are concerns, it is typically withdrawn.
- An interconnection agreement is granted.
- The new generator enters commercial operation.

As identified in the LBNL report and expanded upon by ClearPath (ClearPath, 2022), this backlog results in a significant amount of time for a request to move through the process to a final agreement. Currently it takes an average of nearly four years to move through the process and less than around 25% of the requests make it through to commercial operation.

As noted in the NEI report, this process has typically been applied to ‘new generation’, and as a policy matter, based on ensuring fair competition among providers. ‘New generation’ has typically included new facilities or new fuel types deployed at existing sites. From NEI (NEI, 2022a):

> A facility owner that intends to use such a new facility to replace a retiring facility—including, e.g., replacing a coal-fired plant with a new gas or nuclear facility at the same location—must still submit a new interconnection request…

Recent changes in U.S. policy have opened opportunities for existing generators to expedite their request through the process, but there are caveats. Currently, these policy changes are administered on a somewhat ad hoc basis by different service provides, but in addition to several ownership and procedural requirements, the following typically applies (NEI, 2022a):

- The replacement facility must utilize the same point of interconnection as the existing facility.
- The replacement facility will require up to the same level (MW capacity) of interconnection service as the existing facility.
- The replacement facility will utilize the same type of interconnection service as the existing facility.
- The interconnection request must be submitted at least one year before the existing facility will cease operation.
- The replacement facility must achieve commercial operation within three years following the retirement of the existing facility.

For those considering the deployment of new nuclear as a replacement for a retiring coal plant a key point here is to understand the specific requirements for the local transmission and distribution service provider, and more importantly, to understand the timing and schedule implications. For example, waiting for full decommissioning of the coal plant or spending time attempting to reuse portions of the coal plant followed by new construction could render the new policies moot and force the generator into the existing queue.

3.4.11.3 Water Rights and Permits

3.4.11.3.1 Water Withdraw

How water rights and permitting are managed varies significantly by locale. In the U.S., they are primarily managed by individual states. As an example only, water withdraw in the State of Kentucky is managed by the Department for Environmental Protection and withdraws from either ground or surface water greater than 10,000 GPD (38 m^3/day) require permitting, *except* for *production of steam generating plants of companies whose retail rates are regulated by the Kentucky Public Service Commission,* which do not require department permits (KY Energy and Envionment, 2022). Excluding any unusual circumstances Kentucky has a straightforward process that can take less than a year from application to permit. However, as another example, the State of California's process is significantly more involved and includes state environmental review, public notice, and protest resolution (CA WRCB, 2020).

The federal government also has a role, for example with the *Boulder Canyon Project Act* (U.S. Congress, 1928) allocating waters of the Colorado River to several western states, or the U.S. Bureau of Land Management's administration of water for federal lands (U.S. BLM, 2013).

Outside the U.S., regulations, policies, and procedures can also vary. For example, in Canada federal, provincial, and municipal governments all share responsibility, along with Aboriginal governments as applicable (Government of Canada, 2016).

In the U.S., there are two primary types of water rights, *riparian* and *appropriative*, typically defined as follows (Water Education Foundation, 2023):

- *Riparian* – Water, typically surface water, is allocated to those whose property abuts the water's path, and the rights remain with the property and cannot be normally sold separate from the property. Usually, riparian rights are based on reasonable use because all those along the path must share the water.
- *Appropriative* –Surface water and groundwater withdraw rights are assigned to those who are 'first in time of use', and the water may usually be used for any beneficial purpose and the rights may also be sold on the open market.

The use of either type of rights varies by state, however, riparian rights are common in the eastern U.S. and appropriative in the western states. California for example, uses a mixture of both forms for water permitting and management. Typically, state agencies take responsibility for overseeing allocations under either regime, attempting to ensure all users get a fair share. Organizations permitted under riparian rights *may* find it easier to keep their water rights while transitioning to a nuclear plant, while those with appropriative rights *could* find that extended lack of use results in the loss of rights and requiring new permitting. Due to the nature and history of these types of rights, obtaining new or increased water rights can result in extended times for permitting, which sometimes requires litigation due to others making claims.

Water usage can be a critical issue, particularly when supply is limited such as in drought-stricken areas and areas of increasing development, and especially when the water source crosses jurisdictional boundaries such as state or country lines. As of publication there are critical conversations about water availability in the western U.S. and how to allocate water rights. There is controversy regarding allocations along the Colorado River (The Associated Press, 2023; U.S. CRS, 2023), where a city in Arizona cut off water supply to a neighboring community (Washington Post, 2023) and the state may need to limit development (New York Times, 2023).

This is not only a U.S. concern. The European Union's European Environment Agency issued a report in 2021, *Water resources across Europe — confronting water stress: an updated assessment* (EEA, 2021) noting that southern Europe faces severe water stress problems, like those in the western U.S., and for generally the same reasons. Water shortages are not only an issue with surface waters. The United Nations *World Water Development Report 2022* (UNESCO, 2022) documents the ongoing stress to global groundwater supplies which particularly affects regions impacted by increasing drought and continued development.

While processes vary by locale, stresses on the water supply, and potential extended processes for obtaining water rights, mean that the owner-operator should ensure they understand the regulations, policies, and procedures for their locale and organization, and clearly understand the time it will take to obtain the necessary permits and be prepared to manage uncertainty.

3.4.11.3.2 Water and Effluent Discharge

Globally, many locales have regulations regarding the discharge of water back into the environment. The local regulations, requirements, and procedures should be well known to any existing coal plant owner-operator; therefore, the purpose of this section is not to explain them in detail, but just to note a few important points.

In the U.S., The National Pollutant Discharge Elimination System (NPDES) was created in 1972 as part of the *Clean Water Act* (CWA) (U.S. EPA, 2022b) to control pollution from discharges into 'Navigable Waters of the U.S.' (U.S. EPA, 2023) from point sources, which specifically include the discharges from industrial facilities. The issuance of permits is currently managed by the individual states (excepting Massachusetts, New Hampshire, New Mexico, District of Columbia, and U.S. territories other than the Virgin Islands). An NPDES permit is typically a license for a facility to discharge a specified amount of a pollutant into receiving water under certain conditions. Per the CWA, permits can only be issued for a maximum of five-year terms but can be extended it they are re-applied for at least 180 days before expiration (U.S. EPA, 2022e). Section 316(a) of the CWA regulates thermal discharges which can add requirements to NPDES permits addressing thermal effluent limitations, which can affect the allowable temperature and rate of discharge.

Provided as an example only, discharge within a province of Canada, like Ontario, may be covered by national and provincial regulations, such as the national *Canadian Fisheries Act* and Wastewater Systems Effluent Regulations (Government of Canada, 2017), and the *Ontario Water Resources Act* and the *Ontario Environmental Protection Act*, including regulations for Effluent Monitoring and Effluent Limits specifically for the Electric Power Generation Sector. Organizations must have one or more environmental permission from the Ministry of the Environment, Conservation and Parks, including Environmental Compliance, Environmental Activity and Sector Registry, and Environmental Assessments (Government of Ontario, 2021).

When a U.S. owner-operator transitions from an operating coal plant to a new nuclear plant, the ability to extend their NPDES permit comes into question. While there may be some scenarios where the permit may be extended, since the licensing of a nuclear plant is a major federal action which includes U.S. NEPA (U.S. CEQ, 2023a) requirements and different effluent discharges, new NPDES permits will likely be required.

The NPDES process, when started new, includes the following steps (U.S. EPA, 2022d):

- Permit Application
- Notice and Comment of Proposed Permit Action
- Potential Public Hearings
- Permit Review, Approval, and Issuance

NPDES permitting will be a part of the NEPA review for the final ER submitted with a nuclear licensing application and including documented compliance with Section 401 of the CWA. The new permitting requirements will add time and uncertainty to the process. Therefore, the owner-operator will need to ensure that they understand the regulations, policies, and procedures for their locale and organization, and have a clear understating of the time it will take to obtain the necessary permits and be prepared to manage uncertainty.

3.4.11.3.3 Alternate Cooling Systems

One potential option for sites located where water sources or water use are limited (see 3.4.11.3.1) is using alternate cooling options that can reduce the water use needed for power plant cooling. As noted in EPRI's report, *Advanced Cooling Options for Nuclear Power Plants* (EPRI, 2013a), typical alternate cooling options include:

- Direct dry cooling using air-cooled condensers (ACCs).
- Indirect dry cooling using air-cooled heat exchangers paired with water-cooled surface condensers.
- Hybrid systems that incorporate both dry and wet cooling elements.

However, as noted in the EPRI report, the water savings comes at a price in the form of more expensive equipment, higher cooling system power requirements, reduced plant efficiency and limited plant capacity on hot days. And there are issues specific to nuclear power that have limited their use in nuclear applications to date.

A 2018 update by the U.S. Energy Information Administration (U.S. EIA, 2018) noted that 83 U.S. power plants, accounting for about 20 GWe of capacity, were using dry or hybrid cooling. Most of that capacity is from natural gas combined cycle plants due to efficiency, and currently no nuclear plants in the U.S. are using any of these systems.

A report from U.S. DOE, *Cooling Water Issues and Opportunities at U.S. Nuclear Power Plants*, (U.S. DOE, 2010) notes:

- Dry cooling systems are extremely inefficient in comparison to water cooling and require substantial amounts of open land directly adjacent to the plant to install. For example, EPRI's

Advanced Heat Sink Options for Thermoelectric Power Plants (EPRI, 2021c), notes that a 45 cell ACC for 420 MWe coal plant in Wyoming requires two acres of land.

- Due to inefficiency, dry cooling systems exact a significant energy penalty, typically 2% to 4%, but as high as 20%, on an intermittent basis, relative to wet cooling systems.
- Plant reliability and grid stability problems can be caused by dry cooling on hot days or with high wind gusts.
- Dry cooling is expensive, with about three to five times higher capital costs than closed-cycle cooling. Dry cooling brings with it other environmental issues, including air pollution and noise.

Direct dry ACC systems take the steam directly from the plant turbine. In the case of boiling water reactors this would lead to a direct path from the reactor to the condenser, which is outside the plant and therefore an unfavorable scenario. While there is not a direct path for a pressurized water reactor, the same concerns may still apply because under normal design, cooling water is a tertiary system. This will tend to drive nuclear towards indirect or hybrid systems.

To date there have been only two dry cooled nuclear plants built world-wide. Both used ACC systems and only one, which is quite small, is currently operating. However, AR designers are considering the use of dry cooling systems. For example, NuScale is proposing the use of air cooling for its reactors (NuScale, 2020) and Dominion Energy proposed using hybrid cooling towers for its North Anna Unit 3 (Dominion Energy, 2016; EPRI, 2021c).

3.5 Building Elsewhere in the Community

One option to consider is not building the new nuclear plant on the existing coal site but rather nearby, within the community. In this sense, nearby could mean next to the coal site or up to a few miles away.

As noted in Section 2.4, some of the key assets available from an existing coal site are the grid interconnection, the cooling water supply, and transportation access, which to some extent could still be considered assets for building nearby.

A grid interconnection or cooling water supply within about five miles are viable for use with any new nuclear plant. Additional land may need to be purchased, rights-of-way established, and new infrastructure built, but at about five miles or less these are generally feasible distances for new nuclear construction. The sheer existence of a nearby cooling water supply and transmission corridor is tremendously valuable.

Transportation access would be a localized issue, and a primary access road may need to be built, but access into the community would already exist.

There are other assets that can be leveraged as well:

- *Local Workforce*: One reason that coal communities may be interested in new nuclear is to support employment upon the coal plant's retirement. The local coal plant operators and maintenance staff can be retrained for nuclear operations and potentially support new nuclear construction. The new nuclear plant is also likely to require more staff for O&M than the coal plant, thus opening additional employment opportunities (ScottMadden, 2021; U.S. DOE, 2022). See Section 3.7 for more on workforce development.

- *Local Services*: Any industrial operation makes use of local services for everyday operations, and those commonly used by the coal plant would still be available. This would include local services such as maintenance and machine shops, automobile maintenance, printing and office supplies, and food service. The nuclear plant is also likely to have an increased need for local services, and thus a corresponding increase in indirect local jobs (U.S. DOE, 2022).
- *Local Utilities*: While new line easements may be necessary and physical lines may need to be run, basic electrical, natural gas, portable water, and sewage may be available and have the needed capacity, and communications lines (voice and broadband) may already exist. In many cases, the coal plant may make use of well water, and the local aquifer may still be accessible.

In addition, the assets and infrastructure of the coal plant itself could still be potentially reused, especially if the owner-operators are the same for both plants. This could particularly apply to new construction activities.

- *Barge or Rail Access*: Existing barge or railroad access might be able to be used for delivery of the nuclear plant's components, limiting truck hauling to the final few miles. This would be particularly attractive to construction of smaller ARs, since these are expected to have smaller components.
- *Office Space*: At least early in development, office space will be needed before it is available on the new site. Initial engineering staff may be able to be housed there until new space is available.
- *Equipment Storage and Laydown*: If space is available, the coal site may be able to be used for temporary equipment storage and laydown (however, care should be taken to protect materials from particulates that may be detrimental from a foreign material or corrosion perspective).
- *Repurposing*: Upon final decommissioning, the coal site may be able to be repurposed for other activities. A central office building could be transformed into a training center or remain in use for general administration activities that do not require being always on site, such as accounting, payroll, and communications.

Building elsewhere in the community can also provide additional benefits. One key issue is the overall schedule. If the new nuclear plant construction cannot begin on the site until after coal plant decommissioning, there would be a significant delay before power can be generated with decommissioning and new construction being critical path activities. Although OEMs with modern designs are promoting shorter construction times, there will still be several years before new power can be generated. If the new plant is built in parallel a near seamless transition can take place. The importance of this issue is dependent on the overall need for power in the owner-operator's service territory and may require reevaluation of the retirement schedule: it may be prudent to extend the life of the coal plant to support parallel nuclear construction.

Another issue is retaining the local workforce. If there is too much time between the coal plant shutdown and new plant startup there is a risk that the local workforce will move on. Some coal plant communities are small and significantly dependent on the coal plant for employment. If operators or maintenance staff cannot find work with the new construction activities, they may find other employment away from the area, which is likely to be perceived adversely by the local community. Balance will be needed, however. If the coal plant remains operational, then additional actions will be needed to ensure the existing staff is trained and prepared to operate a nuclear plant while the coal plant is also operated reliably and safely. This may include a need to bring in additional staff from outside the community, to either operate the coal plant temporarily or to train for operating the nuclear plant. The latter is likely to be required in any case due to the need for more people and some very specifically trained staff. If local employment is a primary incentive for the local community, then care should be taken to fully understand and evaluate these issues (see Section 3.7).

Being a distance away from the coal site can alleviate potential cross contamination between the coal and nuclear site or other safety issues and can also potentially reduce the costs of decommissioning. For example, any CCP units left on site would not pose a hazard. Also, it is common to greenfield a decommissioned site by leaving below ground piping and structures in place. To build a new nuclear plant on the same site, below ground piping and structures will typically need to be removed.

The value of building elsewhere in the community can also be driven by the results of an evaluation on reusing existing site infrastructure (see Section 3.4). If the results indicate that there is value in reusing site infrastructure and the schedule is not a concern, then building on the existing site may be the best choice. However, if the evaluation demonstrates little or no reuse potential, building elsewhere becomes a more compelling option.

As noted above, having an engaged and supportive community is an asset to new nuclear development. While communities may be open to the development of a new nuclear plant, it is unlikely that their interest is based on the specific existence of the plant, but rather the benefits the plant can bring to the community. Beyond potential tax revenue, another key benefit most communities expect is an increase in jobs.

A report by Idaho National Lab (INL), done in collaboration with Argonne National Lab (ANL) and Oak Ridge National Lab (ORNL) for the DOE (U.S. DOE, 2022), takes an in depth look at potential community benefit, and specifically looks at three different kinds of jobs and the impact of a nuclear plant compared to the existing coal plant:

- *Direct Jobs* – Jobs that come from working at the coal or nuclear plant.
- *Indirect Jobs* – Jobs that come from those servicing the coal or nuclear plant.
- *Induced Jobs* – Jobs that come about from the influx of people and disposable income.

The INL report demonstrates that there would be an expected increase in all three types of jobs for the cases studied. While the cases studied are specific and there is a range of results, the net change from coal to nuclear shows roughly a doubling of each type of job (see Section 3.7).

3.6 Regulatory Engagement

3.6.1 Nuclear

The development of a new nuclear facility will require significant interaction with the local nuclear regulator. The EPRI *NTPA* report (EPRI, 2022f) contains more detailed information on nuclear regulator engagement, but there are a few takeaways that need to be understood at the beginning of the process.

- The process of developing licensing documents, having them reviewed, and responding to questions can take several years. Understanding the regulator's process and schedule is important to know up front so that the schedule can be accommodated with the owner-operator's need date for the facility to be on-line and generating power.
- The development of a nuclear plant on a coal site, or other specifically targeted site, can introduce novel issues for the regulator. Early interactions with the regulator can be helpful, even if those interactions are informal. It is important to identify the regulator's concerns with the plan as early as possible in the process.
- Globally, the regulatory environment for advanced reactors is much less mature than for large light water reactors. This can impart risk to schedule and cost. If possible, engagement should be three ways, between the owner-operator, potential OEMs, and the regulator, due to the relationship between the design and siting.

In the U.S., there are currently two specific paths that can be followed for new plant licensing:

- The 10 CFR (Part) 50 Process (U.S. NRC, 1998)
- The 10 CFR (Part) 52 Process (U.S. NRC, 2007c)

Each of these processes comes with its own set of opportunities and challenges. In addition, the U.S. NRC is also working on a new 10 CFR Part 53 (U.S. NRC, 2021b) process specifically intended for advanced reactors, but it is still a work in progress and will not be discussed further.

In general, the 10 CFR 50 process includes the separate development of a Construction Permit (CP) followed by an Operating License (OL) after construction is complete. This process can be useful for deployment of novel technologies still being designed and is being considered by several advanced reactor developers. The 10 CFR 52 process includes only a single Combined License (COL) but is based on an essentially complete OEM design that has obtained either a Design Certification (DC), or partial design that has received a Standard Plant Approval (SPA). As an example, a NuScale design has recently received a DC (U.S. NRC, 2023b), and thus could be a suitable candidate for the 10 CFR 52 process.

As noted above, a coal site considering nuclear should also consider the development of an Early Site Permit (ESP) (U.S. NRC, 2007d). The ESP is technically part of the 10 CFR 52 regulations, but can support both a 10 CFR 50 CP and a 10 CFR 52 COL. Nuclear site development cannot begin without an ESP, COL, or a Limited Work Authorization (LWA) (U.S. NRC, 2019b), (which can be issued to ESP, COL, or CP applicants). The development of an ESP is a significant undertaking, can cost more than US$10 million and take several years to complete (Bechtel, 2002), however, it is an asset that can be held for many years, providing future options.

The key takeaways from this section are that the licensing process and interactions with the nuclear regulator must be accounted for in the overall development schedule, which must be aligned with the owner-operator's business objectives. The path to licensing is highly dependent on the final OEM design chosen, so any engagement must include the OEM as well. This may include multiple OEMs if a final design is not yet chosen, which may be especially pertinent in the development of a PPE for an ESP.

3.6.2 Utility Commission Engagement

In the U.S., it will be necessary to engage with the local state Public Utility Commission (PUC). Globally, different countries generally have their own analogs to the PUC, for example, in Canada, the Ontario Energy Board (OEB, 2023) is the independent regulator of the province's electricity and natural gas industry and Ofgem (the Office of Gas and Electricity Markets) is the independent energy regulator in the United Kingdom (Ofgem, 2023). Typically, these commissions have the responsibility and authority to approve or deny applications for new power plants, set rates and tariffs, enforce safety and environmental standards, and resolve disputes between utilities and customers. In the U.S., there can be differentiation between regulated and unregulated states, which can affect pricing and how development costs are recovered.

Typically, an operating coal plant would already have a relationship with their local commission and understand the basic rules, requirements, and regulations required for generating electricity and putting it on the local grid. However, this does not lessen the need to begin engagement early in the process when considering the development of new nuclear.

In regulated states, the owner-operator will need to work with the local PUC to understand how the costs of new plant development will be recovered. Issues that need to be addressed include:

- Can, or should, any decommissioning costs be recovered as new development costs?
- When can site related development work be considered as new development?
- How will construction and O&M costs over the lifetime of the plant be recovered?

The local commission will also want to understand the need for power as identified by the owner-operator, changes to power generated (i.e., will the new facility generate more or less power than the coal plant), timing for power generation, and the need for new or upgraded transmission lines.

The local commission will also need to issue a Certificate of Public Convenience and Necessity (CPCN). Some U.S. states, 12 as of August 2021 (NCSL, 2021)[21], have moratoriums against new nuclear development, and some of these moratoriums are based on laws that prevent the issuance of a CPCN. Often these moratoriums are based on the need for a defined, and often federally funded and managed, waste repository. Potential nuclear owner-operators in these states will not only need to engage with their PUC, but also their state legislatures before embarking on a new nuclear development program.

A key need for engagement with most PUCs (and other regulators) will be the owner-operator's (assuming a utility) Integrated Resource Plan (IRP). As of 2021, 35 U.S. states require the development of an IRP (PNNL, 2021). IRPs are typically updated every 2 to 5 years and have planning horizons between 10 and 20 years. IRPs identify the plans for a utility to meet future energy demand while considering energy growth combined with conservation and efficiency measures, in a manner that best meets the functional and financial needs of its customers.

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[21] As of August 2023, two U.S. States are working to end moratoriums, Illinois (SB0076) and Connecticut (HB5202). The Illinois governor has recently vetoed SB0076, however the legislature intends to address in the fall.

The IRP would need to identify the time frames for retiring the coal plant and options for new generation. The owner-operator would need to identify in their plan how new nuclear development fits, and makes sense, within their plan. Different utility commissions will have different requirements for their jurisdictions, but typically the owner-operator will need to demonstrate a positive value for the new nuclear plant in their plan. Eventual costs to the consumer are a major consideration, but not always the only factor. For example, having a diverse energy mix (and hence a diverse fuel supply), the ability to operate in inclement weather, a mix of firm, intermittent, and flexible generation, goals for carbon reduction, and the effect on local economics can all play a part in the development of an IRP.

Because costs to the consumer are often a primary concern in development of an IRP, the costs to deploy and operate a nuclear plant must be well developed. Globally, recent history has indicated that nuclear development costs have well exceeded original estimates in some cases (Eash-Gates, et al., 2020). Additionally, many advanced reactor designs are still in a state of development such that the confidence in their costs to deploy and operate is low (ETI, 2020). The owner-operator will want to ensure that due diligence is performed with potential OEMs to get the best estimate for costs. Refer to the *Technology Assessment Guide* (EPRI, 2022f) for more information on evaluating OEM designs and costs.

U.S. states and other locales that do not generate formal IRPs will typically develop similar information to their regulators, or at least internally for their own, or their investors', needs.

3.6.3 Environmental Protection

In the U.S., the U.S. Environmental Protection Agency (EPA) is the lead regulator for environmental protection, but other federal agencies, as well as many state and local governments also have responsibility for providing rules and requirements. Some of those responsibilities may be delegated to them from the EPA, or they may be self-contained to the state or local governments. Similar examples outside the U.S. are U.K.'s Environment Agency (Environment Agency, 2023) or both the Agency for Ecological Transition (ADEME) and the Agency for Food, Environmental and Occupational Health & Safety (ANSES) in France (ADEME, 2023; ANSES, 2023).

Some of the issues regarding environmental protection, particularly permitting, are discussed in Section 3.4.11. Many of the noted issues will be relevant and well understood by any coal plant owner-operator and any coal plant going through the decommissioning process will have substantial engagements with environmental protection agencies.

Of key importance for transitioning a coal plant to new nuclear is the relationship and engagement with environmental protection regulators during the licensing process. This will be different in each locale, but in the U.S., the process is effectuated though the development of the ER for an ESP, CP, or COL application, and the corresponding Environmental Impact Statement (EIS) developed by the NRC.

In the U.S., the issuance of a nuclear plant license is considered a major federal action, and thus requires following the *National Environmental Policy Act* (NEPA) (U.S. EPA, 2022c) which requires federal agencies to assess the environmental effects of their proposed actions prior to making decisions. Title II of NEPA established the President's Council on Environmental Quality (U.S. CEQ), which has issued regulations (U.S. CEQ, 2023a) to implement NEPA.

These regulations are binding on all federal agencies and many of them have developed their own NEPA procedures that supplement the CEQ NEPA regulations. These NEPA procedures vary from agency to agency since they are tailored for the specific mission and activities of the agency. Per the CEQ, lead agencies are identified for various activities and the U.S. NRC has this role for commercial nuclear plants (U.S. CEQ, 2023b). The NRC administers its responsibility through 10 CFR 51, *Environmental Protection Regulations for Domestic Licensing and Related Regulatory Functions* (U.S. NRC, 2021a). The CEQ also identifies cooperating agencies, which includes any other federal agency with special expertise with respect to any environmental issue. For example, the NRC has a memorandum of understanding with the U.S. Army Corps of Engineers (U.S. ACE/NRC, 2008) as a cooperating agency to review environmental issues related to 'Waters of the Unites States' (U.S. EPA, 2023).

To support the NRC in development of the Environmental Impact Statement, as part of the licensing process the prospective owner-operator will need to develop an ER. The guidelines and requirements for this report are covered in several NRC documents:

- NUREG 1555 - Standard Review Plans for Environmental Reviews for Nuclear Power Plants: Environmental Standard Review Plan (U.S. NRC, 2007e; U.S. NRC, 1999)
- Reg. Guide 4.2 Revision 3, 2018 - *Preparation of Environmental Reports for Nuclear Power Stations* (U.S. NRC, 2018)
- Reg. Guide 4.7, Revision 3, 2014 - *General Site Suitability Criteria for Nuclear Power Stations* (U.S. NRC, 2014c)
- COL/ESP-ISG-026 - Interim Staff Guidance on Environmental Issues Associated with New Reactors (U.S. NRC, 2014a)
- COL/ESP-ISG-027 - Interim Staff Guidance on Specific Environmental Guidance for Light Water Small Modular Reactor (U.S. NRC, 2014b)

As pointed out in Section 2.2, this guidance also requires the development, and evaluation of alternatives, which includes alternative generation options and identification and evaluation of alternate sites.

These NRC requirements are comprehensive and detailed and need to be addressed in the licensing process. What prospective nuclear plant owner-operators must keep in mind early on is that the NRC will be reviewing the ER for documented evidence that the applicant has affirmatively engaged all pertinent agencies, including cooperating federal agencies as well as appropriate state and local agencies and local Tribal governments in its development. The owner-operator should engage these agencies early to determine if there are specific impediments to their plans and what actions need to be taken to ensure a successful project.

3.7 Workforce Development

There are likely two competing workforce needs that should be covered when transitioning from coal to nuclear. The first is to ensure that a qualified workforce is available to operate the new nuclear plant, and the second is managing a viable transition for the local workforce and the community.

3.7.1 Ensuring a Qualified Nuclear Workforce

A primary goal for AR developers is to design and build nuclear plants that cost less to build and operate than today's large reactors. Therefore, operating the plant with fewer staff is a targeted goal[22]. However, the number of staff required for operating an AR is not clearly known at this time. The DOE report, *Investigating Benefits and Challenges of Converting Retiring Coal Plants into Nuclear Plants* (U.S. DOE, 2022) looks at several other studies and scenarios, and roughly estimates about a 2 to 1 increase in staffing at a nuclear plant compared to the staffing at a 'retiring' coal plant of the same size. This means that even if 100% of the existing coal plant staff could be used to operate the nuclear plant, additional staff will be needed.

To use existing coal plant staff for the new nuclear plant they must be qualified. Both the ScottMadden report (ScottMadden, 2021) and the DOE's *Investigating Benefits and Challenges of Converting Retiring Coal Plants into Nuclear Plants* report (U.S. DOE, 2022) consider the types of job functions at both coal and nuclear plants and the number of staff in each. As can be seen in both reports, while there are many functions that overlap, there are some that do not, and the numbers within each function differ. For example, the ScottMadden report notes that about 30% of the jobs have no coal plant equivalent. There are also functions that require specific qualifications that may not be readily available by existing coal plant staff, particularly those related to nuclear power itself. In many cases, the coal plant staff may have the underlying qualifications to be retrained, but in other cases they may not. The retraining needs fall into three categories:

- *Minimum* –Security, Technicians, Maintenance, Laboratory, Emergency Services
- *Advanced* – Field Operators, General Supervision and Management, Training
- *Specialty* – Nuclear Engineers, Control Room Operators, Licensing, Plant and Engineering Management

It would be incorrect to say that all coal plant staff cannot be retrained, but the ability to do so is dependent on the existing qualifications of the existing staff, the time available to get them qualified, and their own desire to move into the nuclear workforce. While nuclear jobs typically pay higher wages, the time and effort needed to go through retraining and the need to work within the 'nuclear safety culture' can be drivers for some to find work elsewhere.

Beyond the coal plant staff, a sizable number of additional staff is also likely needed. Like the coal plant staff, some of these additional staff can come from the local community with additional training and qualifications. Examples include people currently employed by local emergency services, such as police, fire, and medical, maintenance technicians, and office workers. There is no reason that local people could not be easily trained as field operators, general supervision, and management. And local colleges and universities can be sources of engineering talent.

It is not atypical to staff a new nuclear plant with several non-local, but highly qualified personnel, typically staff with experience in nuclear plant operations. This serves two purposes.

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[22] As noted by the WNA (WNA, 2022), the total cost for a nuclear plant is a function of several parameters, essentially the cost to construct, fixed operating costs, variable operating costs, and cost of financing. Most developers are looking to optimize all functions, however, significantly reducing one or two could make a difference, especially in certain revenue markets and when considering potentially much higher capacity factors.

It brings in a critical mass of experienced staff to help ensure safe and efficient operations from the beginning and provides a level of mentoring to staff new to nuclear. Typically, these will be a subset of nuclear engineers, control rooms operators, licensing, and management, but could also include people in all other areas.

To adequately staff the new nuclear plant, the owner-operator will need to bring in staff from all available sources, the existing coal plant, the local community, local, nearby, and farther off colleges and universities, ex-military, and staff from other operating nuclear plants. When planning for the transition, the owner-operator will need to factor these staffing needs into their planning and scheduling.

3.7.2 Local Community Workforce Considerations

As noted in Section 2.8 a community's willingness to support the development of a new nuclear plant is a great asset, and conversely, to ensure an efficient successful project, it is imperative that a plan for truly engaging the local community is developed to provide a forum for concerns to be voiced and discussed (and not explained or educated away, see Section 3.8). If a project is facing an unwilling community, local, state, and utility leaders should weigh the communities' input carefully and the potential impact on the project. The local community will want to understand the effects of any new nuclear plant on their way of life. Some concerns are going to be based on safety, some on explicit community impacts, such as traffic and housing, and direct community economics, such as the tax base. These are all straightforward to define and explain. But the community is also going to be concerned with local jobs, and this can become much more complicated to define and explain.

As noted in Section 3.5, the development of a new nuclear plant is likely to lead to an increase in direct, indirect, and induced jobs. Many communities will be amiable to such growth (but depending on circumstances some may not). But, assuming the owner-operator can show overall job growth, and that statistically lost jobs will be replaced, those that could potentially lose their jobs, or have their job status or function significantly changed, may still have negative opinions. It will be important that the owner-operator manage the planning, schedule, and transition carefully, and communicate plans and status continuously and consistently. Even if the existing coal plant staff could be guaranteed a position with the new nuclear plant, there will still be concerns about potential time off or reduced pay during certain activities, such as during training, decommissioning, and construction.

There will be a level of churn within the community. Some coal plant staff will continue working at the nuclear plant, some will not. Some of the local community will begin working at the new nuclear plant, and their current jobs will need to be replaced, either by those no longer working at the coal plant, by others within the community, or by people moving in for the opportunity. The community will see an influx of new people, which will require more services, opening more job opportunities. And some people will leave for a variety of reasons.

Due to safety and quality requirements, working at a nuclear plant requires a way of working that can be unappealing for some, resulting in their leaving for other opportunities. Those with ties to the community, or those that feel invested in the organization, tend to stay longer resulting in less turnover, so it is of value to the owner-operator to work with the existing coal plant staff, and the community, to ensure residents can work in the new nuclear plant.

Two examples on opposite ends of the spectrum are discussed below to illustrate scenarios. Each will look at general staffing issues for the existing coal plant staff, the immediate local community, and the influx of new people. For these scenarios, decommissioning is expected to take two years, and construction three (some AR vendors are targeting construction times of three years using modular and advanced construction techniques).

3.7.2.1 Fully Decommissioning the Coal Plant Before Beginning Construction

In this hypothetical example, upon coal plant retirement, the coal plant will be decommissioned to the level necessary to begin construction of the new nuclear plant. The new plant will be constructed, and then begin operations.

Existing Coal Plant Staff

Some existing staff could easily move to the decommissioning project. This could include many of the existing job functions: technicians and maintenance workers will be needed, laboratory analysis will need to be done, and supervision and management duties will be required. Their historical knowledge about the plant will also be of help during the decommissioning process. However, not all existing staff will be able to transition to decommissioning.

Some existing staff could become part of the new nuclear plant construction planning and management team, which would need to be working at full capacity. However, nuclear construction does require much more specialization. Some of the existing staff could be trained in this area, using the time during decommissioning to go through training and qualification.

Temporary Decommissioning and Construction Staff

During decommissioning and construction there will be an influx of temporary staff. Some of these staff will have general industrial or business operations experience, but others will have specialized decommissioning or construction experience. Some temporary staff for decommissioning could have qualifications that allow them to transition to the new construction team, and of those working on the construction project, some will be able to transition to the operating plant, which is not uncommon. It is quite possible that people from the local community could fulfill many of these temporary roles with limited training.

This decommissioning and construction work can provide well playing jobs for many people, but most of the jobs, potentially in the thousands, are temporary. After the work is complete the jobs will cease to exist. This influx of people can significantly impact the local community. The need to house, feed, and service these temporary workers and their families can provide value to the community with an influx of money and customers for restaurants, hotels, and services, but they can also increase crowding and traffic, and once the work is complete, the extra revenue will drop significantly, and a community can find that they have overbuilt to support the influx.

New Nuclear Plant Staff

Some of the existing coal plant staff will be able to move to the new nuclear plant for operations, as will some of the decommissioning and construction staff. But additional nuclear plant operating staff will also be needed. Planning for operations will take place during plant construction, and new people can be brought in from the local community and from outside. The jobs for the new plant will typically be permanent, and with the lifetime of the nuclear plant typically 40 years or more, this should be a significant asset for the community.

Timing

Timing is an issue for the owner-operator interested in protecting as many of the original coal plant jobs as possible (which will be a concern for the community). Unfortunately, this can lead to a Catch-22 situation which cannot always be solved but can be managed with proper planning.

Many of the jobs, including those for decommissioning, construction, and especially new nuclear plant operations, require some level of training and qualification, which depending on the job function can be as short as a few weeks to as long as several years. Planning will be necessary to identify people for future roles, identify their training needs, and configure a schedule that meets everyone's needs. But, even if well planned, there are likely to be complications.

For example, assume an individual from the coal plant is identified as a future nuclear plant control room operator. That training can take between 18 and 24 months and requires previous nuclear experience or specialized education[23]. To facilitate this transition, the owner-operator could provide additional education and work experience, typically at another nuclear facility, and then specific training on the new nuclear plant. And during this time, there may be downtime, of which if the individual is not earning some type of income, they may move on to something else.

The key points here are that specific planning is needed, the plan must be well communicated, and that workers not employed, even temporarily, may move on and no longer be available.

3.7.2.2 Constructing the New Nuclear Plant in Parallel

Under this scenario, on the opposite end of the spectrum as the previous one, it is assumed that the new nuclear plant is constructed elsewhere in the community, or if room is available on the coal site itself, while the coal plant is still operational, and the nuclear plant is ready to start power generation immediately after the coal site shuts down. This scenario could be immensely beneficial to the owner-operator. The construction of the new nuclear plant is not impacted by the coal site in any way, and there is no loss of generation capacity.

Existing Coal Plant Staff

This scenario represents a problem for those intent on protecting the jobs of the existing coal plant staff. Those needed to operate the coal plant will have little time and availability to train for nuclear plant jobs. As noted above, some staff could make the transition quickly with minimal training, but for other job functions non-coal plant staff will need to be trained in parallel to be ready when the nuclear plant starts.

It is typical that a coal plant will reduce staff as it "coasts down" towards retirement, and some staff can be moved off early for training and qualification. Larger owner-operators with a fleet could potentially bring in temporary workers from other sites to cover the plant as it shuts down, staffing services may be able to provide temporary coverage, and recently retired workers could be brought back temporarily.

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[23] Some Advanced Reactor developers are designing their plants to be simpler to operate, and thus require less training for many tasks, however, these are untested scenarios and local regulatory requirements may limit results.

Temporary Decommissioning and Construction Staff

Under this scenario, new construction will take place before coal plant decommissioning. As noted above, some coal plant staff could transition to construction activities as the plant nears retirement. As also noted in the previous example, once the coal plant enters the decommissioning phase, some workers will be valuable assets to stay on for decommissioning. Since decommissioning will take place after the new nuclear plant is constructed, there is an opportunity for some of the construction staff to move over to decommissioning.

Since new nuclear plant construction is expected to start three years before the coal plant shuts down, and detailed planning will need to start a few years before that, there will be limited opportunities for coal plant staff to participate in construction activities. This does not mean there are no opportunities, but the owner-operator will need to be selective to ensure safe and efficient operations at the coal plant.

There will be an opportunity for other residents to take on roles in both construction and decommissioning activities, and a substantial number of outside people will need to be employed as well. As with the previous scenario, the impact of decommissioning and construction workers within the community cannot be ignored.

New Nuclear Plant Staff

In this scenario, careful planning and scheduling of training will be necessary to ensure some staff are able to make the transition to the new nuclear plant. However, it is likely that many positions will need to be filled by others from within the community or from outside.

Timing

The timing of this scenario could be the least beneficial to the current coal plant operators directly, but since there will be churn in the community, it does not mean it needs to be detrimental to the project. While important in all cases, it is especially important here that the owner-operator provides employment services in support of the existing coal plant staff. Other jobs in the owner-operator’s organization may be available, and by collaborating with leaders in the community, other opportunities can be found.

Additionally, while the jobs at the nuclear plant are typically fixed, as with all companies, people will come and go, and new opportunities will open. The owner-operator can provide existing coal plant staff with additional training and education that can qualify them to apply for open positions later, either at the new nuclear plant, or at any other nuclear plant. Some workers will find this of tremendous value because nuclear jobs tend to offer particularly good wages.

3.7.3 Finding Future Nuclear Staff

In almost any scenario, the owner-operator will need to find new nuclear workers at all levels of the organization, from craft labor, to technicians, to operators, and management.

As noted above, looking local is a great place to start. Some areas to begin are:

- Within your own organization
- Local trade associations
- Local industrial companies

- Local trade schools and community colleges
- Local four-year colleges and universities
- Colleges and universities out of the area that local people often attend
- Returning military, especially nuclear navy

When looking less locally, the areas are similar, but recruiting from existing nuclear plants would certainly be a consideration, especially any nuclear plant that has its own plans for retirement. But it is important that any outside candidates show a desire to live in the local community. While not always true, coal plants can tend to be in more rural areas with a lifestyle that does not appeal to all. To minimize turnover, ensure candidates are a good fit for the culture of the organization as well as that of the local community.

Offering early training and education opportunities are also important. Providing college and university scholarships for residents, particularly for nuclear and other engineering fields, and including summer internships can be of value to ensure a pool of qualified candidates. Also, providing specialty training for craft workers, for example on nuclear welding, or to quality control personnel on nuclear requirements can also be of value.

3.8 Community Engagement

The process step of Community Outreach is discussed in Section 2.8 and Community Outreach Services (as functional infrastructure) are discussed in Section 3.4.10. But it is important to understand that these topics are explicitly discussing a process and an organizational function, not the concept of engagement. Many organizations confuse the process and function of engagement for what is essentially ‘a practice’. This often manifests itself as the owner-operator, OEM, or other nuclear proponents talking ‘at’ the community, telling the community what they want to say, and not really listening or engaging.

A recent report by the National Academy of Engineering, *Laying the Foundation for New and Advanced Nuclear Reactors in the United States* (National Academy of Engineering, 2023) notes that:

> The developers and future owners that represent the advanced nuclear industry must adopt a consent-based approach to designing, siting, and operating new facilities. The siting approach will have to be adjusted for a particular place, time, and culture. Following best practices will require additional time and financial resources to be allotted to successfully site and construct new nuclear power facilities, and the industry must account for these costs in their plans. The industry should be willing to fully engage with a community, hear their concerns and needs and be ready to address them, including adjusting plans. While this would raise the likelihood of successful deployment, it is not a guarantee of success. Additionally, the industry, guided by experts in consent-based processes, should capture best siting practices in guidance documents or standards. (Recommendation 8-5 as printed in the Public Briefing Slides.)

The report goes on to note seven best practices:

- An overriding commitment to honesty, transparency, and consistency of communication.

- A consent-based, participatory, and long-term process of site selection.
- The right for communities to veto or opt out until an agreed-upon milestone.
- Some form of socially acceptable compensation granted for affected communities.
- Partial funding for communities and public interest groups to conduct independent analyses.
- Retention of some control over a facility, perhaps through partnerships.
- There are no guarantees in siting: owners should be prepared to walk away.

There are other important considerations regarding engagement that must be noted:

- *Defining the Local Community* – The term local community is used throughout this document. In most cases, it is intended to represent the specific town, or other population center, in which the coal plant currently resides. But in terms of engagement, that definition is insufficient. In practice, the local community consists of all stakeholders that will be impacted by the closing of the coal plant and development of the nuclear plant. From a logistical perspective this will typically include much of the surrounding area, including surrounding towns and counties, including Indigenous communities. Distance may play a factor, but there may be people farther away that are (or at least feel they are) stakeholders, for example a town farther away through which fuel or waste will be transported, or communities that are farther way but have citizens that commute into the area for work at a large local business.
- *Understanding Stakeholders* – It is easy to define stakeholders as those that will be clearly impacted by the closing of the coal plant or the new nuclear plant. But, any person, or organization, that has a concern, or an opinion, should be considered as a stakeholder. Obviously, balance must be maintained. One cannot respond to every person or organization that chooses to involve themselves, but with today's modern communications, many people can have an impact on the opinions of others.
- *Goals, Priorities, Concerns, and Opinions will Vary Greatly* – No group of stakeholders has the same overall goals, concerns, or opinions. Government leaders, business leaders, workers, commuters, parents, teachers, students, etc., will all have different priorities. And no one person can be confined to any one group, for example, a government leader may own a local business to which they commute to on the highway that runs past where the new nuclear plant will be constructed, and they may have a spouse that is a teacher at the local nearby high school, where their children are students.
- *Engaging with Local Regulators* – Working with local regulators will be mandatory to construct and operate a *new* nuclear plant, and in the U.S., the NRC requires proof that such engagement has taken place to obtain a license. This engagement should begin as early as possible in the new plant development process. But it is often the case that owner-operators hold off on this engagement until more firm plans are in place because commitments cannot yet be made. This can result in local regulators feeling like they have been surprised and that the owner-operator is not being transparent, which can lead to a lack of trust that can permeate the community.
- *Don't Lead with the Science* – The National Academy of Engineering report contains good insight on why discussions on the risk and safety of nuclear plants often fail to lead to desired

results. Instead of leading conversations in what has been the ‘traditional way’, communications strategies should be grounded in social science and *include respect for community apprehensions and desires*.

Another important concept that is gaining global attention is *Equity and Environmental Justice*. As noted in EPRI’s *Equity and Environmental Justice Considerations for Coal-Fired Plant Repowering* white paper (EPRI, 2023):

> Many coal communities are heavily reliant on the coal plant as a source of economic stability, jobs for residents, and related social structures that depend on the plant’s presence. U.S. coal plants that have recently been retired and those projected for retirement in the near term are often—although not exclusively—located in regions where poverty rates are already high, so that the jobs and other benefits provided by the coal plant may be critical to the community … Plant decommissioning and repowering may remove or lessen environmental concerns, but may simultaneously raise economic and social issues in the community.

Equally important for the owner-operator to remember is that not everyone sees these concepts through the same lens. Again, as noted by EPRI’s white paper:

> Equity and justice terminology is complex and layered, and it may be applied differently depending on the speaker, situation, or focus of attention. In the context of a major change to a community, equity is concerned with fairness and ensuring that individuals and communities—especially those who are under-resourced—are protected from carrying unfair burdens in the course of a change. Justice adds the need to ensure support and provide paths forward for those emerging from unfair past burdens.

The white paper goes on to note that EPRI has developed a definition for a just transition: ***Providing equitable access to the benefits and protection from the risks associated with the shift to a low carbon economy for workers and communities***. Furthermore, to help ensure a just transition, owner-operators should always consider the following:

- Community Engagement
- Workforce Impacts
- Financial Impacts
- Social Impacts
- Environmental Impacts

Readers should review the EPRI white paper for more information and additional references on the subject.

A last point to consider when engaging the community is to ensure the owner-operator fully understands the community’s infrastructure, and how their project will be affected. And in turn, the owner-operator and community must both understand how the infrastructure will also be affected, both short and long term, and how that aligns with the community's goals. For example:

- Coal plants are often sited in rural communities with limited communication infrastructure, such as high-speed broadband or mobile wireless service. Will the new development bring in new infrastructure, and if so, in a way that supports the community as a whole and not just the plant?

- New construction will require many temporary workers. Are there hotels available, or will new ones be built, and if so, who will pay for them and what will happen to them after construction is over? Could a temporary RV park be developed for construction, and then be turned over to the community?
- A new nuclear plant may need services from the community that don't already exist. Can the owner-operator provide incentives and support to help build out those businesses and infrastructure?

The primary takeaway on engagement is that the owner-operator should *listen* first, then engage the community on *their* issues and concerns.

3.9 Reusing an Already Retired Site

As discussed in Section 1.3, there are several already retired coal sites that might be amenable to nuclear development, and it is quite possible that existing coal plants will be retired without specific plans for immediate new power generation. Therefore, it is feasible that at some point one might want to consider deploying new nuclear on an already retired coal site.

Use of an already retired site can provide many of the benefits of an existing site: available land, proximity to water and a transmission corridor, and a local community looking for growth.

Fortunately, the process and related considerations for reusing an already retired site is like what has been discussed in the sections above, however, there are a few issues that must be managed based on the state of the retired site, of which there are typically two possibilities:

- The site has had limited decommissioning and remediation and has been left essentially intact (i.e., going *cold and dark*, see Section 3.2.6).
- The site has been fully decommissioned and remediated to a greenfield state.

In the case that the site has gone *cold and dark* there is still a large amount of infrastructure on site, therefore the process and considerations as described above generally stand, but there are additional considerations, the most important being the current state of the remining site infrastructure. Additional review to understand the current state and ability for any reuse will be required. With planning, it is possible for a coal plant to be laid up in a manner that preserves the infrastructure, but if this is not done properly the ability to reuse anything may be lost due to lack of monitoring and maintenance, and exposure to the elements. Additionally, if enough time has passed, previous maintenance records may have been lost.

If the site has been decommissioned and remediated to a greenfield state, the exact specifics of the site's overall state must still be known. It is common to leave below ground equipment in place, the exact location of which may have been lost to time, and a concerted effort to identify such items will be needed. It is very possible that one or more CCPs have been left standing for long-term monitoring which will need to be accounted for in some way. And, some infrastructure may have been left, particularly transmission towers and lines, which may be usable, but as noted above, all remaining infrastructure is suspect due to lack of monitoring and maintenance, and exposure to the elements.

Finally, in both cases, permits and other rights are likely to have been lost, and potential operating staff have gone separate ways. However, these issues, and those noted above, are minor when compared to other values gained through site reuse.

4

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