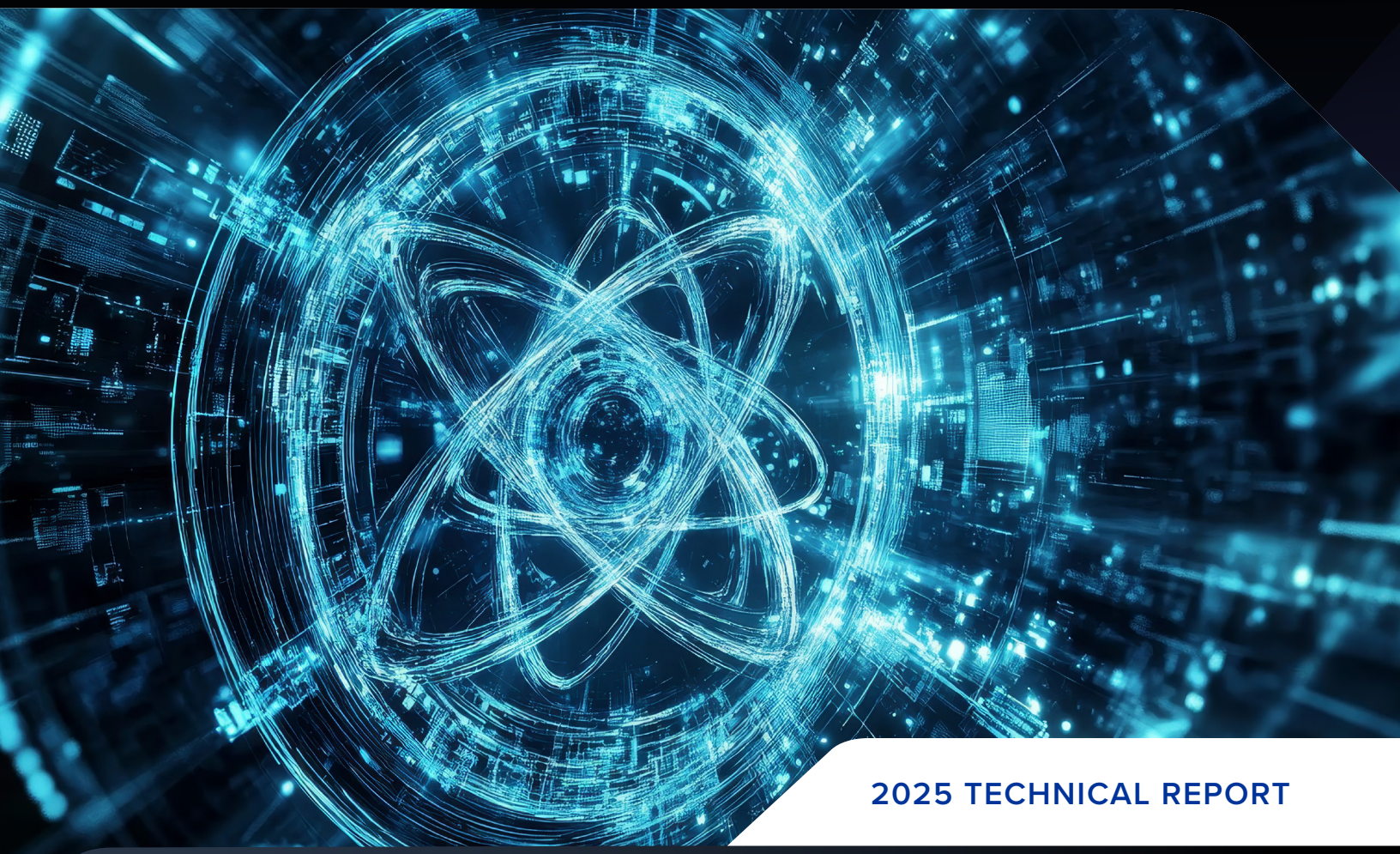
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2025 TECHNICAL REPORT

Advanced Nuclear Technology: A Guide for Co-locating Data Centers with Nuclear Power

Advanced Nuclear Technology: A Guide for Co-locating Data Centers with Nuclear Plants

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ABSTRACT

The International Energy Agency projects that global electricity consumption by data centers could nearly double by 2026, growing by about 340–540 TWh globally and about 60 TWh in the United States. This corresponds to a minimum need of about 45 GW of new generation capacity globally, with about 7 GW of that in the United States. Other studies by McKinsey and the Boston Consulting Group estimate that U.S. data center growth will require a minimum of an additional 30–35 GW of generation by 2030. Much of this growth is driven by hyperscale data centers processing artificial intelligence applications.

Data center organizations are also looking to decrease their carbon footprint and be more sustainable, increasing the need for clean, carbon-free power. Typically, data center organizations have used grid power, some local generation and storage, and contractual purchases of carbon-free power to match their annual power demands. However, the intermittency of renewable sources, their limited growth rates, and regional variation in their economic viability have caused data centers to look for other non-carbon emitting sources.

These drivers have led data center organizations to explore the use of nuclear power as an energy source. Nuclear power is carbon free, highly reliable, and resilient, all qualities desired by data centers. New nuclear technologies, such as microreactors, small modular reactors, and other advanced reactor technologies, offer new possibilities for powering data centers. However, the nature of nuclear power raises technical considerations, primarily related to ensuring the safety of the nuclear plant and the public.

The purpose of this report is to provide *practical* guidance for data center organizations considering nuclear power as a generation option. This report primarily addresses the deployment of a new nuclear plant to provide power for a data center facility, either directly or via a behind-the-meter connection. It also addresses other options through which data centers may be able to take advantage of nuclear power, such as typical grid connections and behind-the-meter connections to existing nuclear plants.

Keywords

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Artificial intelligence (AI)

Data centers

New nuclear deployment

Nuclear integration

Small modular reactors

EXECUTIVE SUMMARY

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Primary Audience: Data center organizations (owners, operators, co-locators, developers), nuclear plant developers, nuclear owner-operators

Secondary Audience: Communities interested in new nuclear, non-governmental organizations (NGOs)

KEY RESEARCH QUESTION

What are the practical, logistical, and safety issues that must be considered when developing new nuclear assets or using existing nuclear assets to power a data center through a typical grid connection, a behind-the-meter connection, or a direct connection?

RESEARCH OVERVIEW

This research is broken into two broad areas:

- Section 1 gives readers foundational information about data centers, nuclear power, and nuclear plant siting. This section addresses the fundamentals of nuclear deployment and end user considerations.
- Section 2 discusses the opportunities and challenges of using nuclear energy to power data centers. These include the benefits of nuclear, the data center organization's business objectives with respect to nuclear, and selection of the best options for making use of nuclear. Further detail is provided on topics such as technology and design selection, siting, and regulatory and community engagement.

KEY FINDINGS

- A clear understanding of the data center organization's mission and business objectives with respect to nuclear is needed at the start of the project to make informed decisions.
- An understanding of the total data center load, considering both periodic variations and long-term trends, is critically important.
- Simply connecting to the grid where there is high nuclear generation capacity can bring many of the benefits of nuclear power to the data center.
- Careful consideration of nuclear licensing and nuclear safety requirements is necessary for integration options other than simply connecting the data center to the grid.

- New nuclear plant development can take time. Data center organizations should begin working with utilities and new plant developers early in their decision-making process.
- Both nuclear safety and grid regulations will need to be addressed. Early and frequent engagement will help the project to move more smoothly and efficiently.
- As with all nuclear development projects, community engagement and workforce development should occur as early as possible.

WHY THIS MATTERS

The advent of small modular reactors and advanced reactors has opened opportunities for powering data centers that go beyond use of existing nuclear power plants. In addition, changes in electricity and energy infrastructure and markets, including anticipated load growth and continued addition of variable renewable energy to the grid, have opened new possibilities and challenges for end users. This research is intended to give stakeholders common ground for evaluating new nuclear as a deployment option. This is part of a broader EPRI Advanced Nuclear Technology (ANT) and Nuclear Beyond Electricity (NBE) research effort to address new nuclear deployment options and considerations. This report can be used by data center developers, existing nuclear owner-operators, and nuclear plant developers to understand key technical considerations for co-locating data centers with existing and new nuclear power plants.

HOW TO APPLY RESULTS

- Define the data center organization's mission and business objectives with respect to nuclear power.
- Understand the options available for using nuclear power generation.
- Choose the best option that aligns with the organization's objectives.
- If choosing to develop new nuclear power: Select a technology and design, select a site, engage with the regulator, and conduct community outreach.

LEARNING AND ENGAGEMENT OPPORTUNITIES

- EPRI maintains public- and member-facing advisory groups under the ANT program that focus on advanced reactor R&D, demonstration, and commercialization topics. These forums provide opportunities to exchange information and obtain input on the direction and nature of EPRI's ANT and NBE opportunities for the development of nuclear-data center integration and its application to support commercialization of advanced nuclear technology and global decarbonization goals.
- Data center organizations may want to consider EPRI's DCFlex initiative, a living laboratory demonstrating innovative strategies for integrating data centers with the grid under various conditions to facilitate widespread adoption and replication of those strategies.

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ACRONYMS AND ABBREVIATIONS

acre	1 acre = 0.405 hectare
ADEME	Agency for Ecological Transition (France)
AE	architect engineer
AI	artificial intelligence
ALWR	advanced light water reactor
ANL	Argonne National Lab
ANSES	Agency for Food, Environmental and Occupational Health & Safety (France)
AOO	anticipated operational occurrence
APAC	Asia-Pacific countries
AR	advanced reactor
AWS	Amazon Web Services
BWR	boiling water reactor
CFR	U.S. Code of Federal Regulations
CNSC	Canadian Nuclear Safety Commission
COL	combined license
CP	construction permit
CPCN	Certificate of Public Convenience and Necessity
CSR	corporate social responsibility
CTT	Clean Transition Tariff
dBA	A-weighted decibel
DC	design certification
DCIE	data center infrastructure efficiency
DCIM	data center infrastructure management
DG	Draft NRC Regulatory Guide
EA	environmental assessment
EAB	exclusion area boundary

EIS	environmental impact statement
EPC	engineering, procurement, and construction
EPZ	emergency planning zone
ER	environmental report
ESG	environmental, social, and governance
ESP	early site permit
ETI	Energy Technologies Institute (U.K.)
FHR	fluoride high-temperature reactor
ft2	square feet (1 ft2 = 0.093 m2)
GCP	Google Cloud Platform
GCR	gas-cooled reactor
GEN	reactor generation
GPU	graphic processing unit
GW	gigawatt(s) (1 GW generation ~ 8.76 TWh/year)
GWe	gigawatts electric
ha	hectare(s) (1 ha = 2.47 acre)
hectare	1 hectare = 2.471 acre
HTGR	high-temperature gas-cooled reactor
HWR	heavy water reactor
IAEA	International Atomic Energy Agency
INL	Idaho National Lab
IRP	integrated resource plan
ISO	independent system operator
km	kilometer(s) (1km = 0.62 mi)
LBNL	Lawrence Berkeley National Laboratory
LCOE	levelized cost of electricity (energy)
LFR	lead-cooled fast reactor

LLWR	large light water reactor
LOOP	loss of offsite power
LPZ	low population zone
LR	large reactor
LWA	limited work authorization
LWR	light water reactor—uses normal water as both its coolant and neutron moderator
lwSMR	light water small modular reactor
M	million
m2	square meter(s) (1 m2 = 10.764 ft2)
mi	mile(s) (1 mi = 1.61 km)
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 Legislatures
NEI	Nuclear Energy Institute
NEPA	U.S. National Environmental Policy Act
NERC	North American Electric Reliability Corporation
NIA	Nuclear Innovation Alliance
NREL	National Renewable Energy Laboratory
NUREG	U.S. NRC Technical Report
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
ONR	U.K. Office of Nuclear Regulation
ORG	EPRI Owner-Operator Requirements Guide (ORG) for Advanced Reactors
ORNL	Oak Ridge National Lab
PNNL	Pacific Northwest National Laboratory
PPA	power purchase agreement
PPE	plant parameter envelope
PUC	public utility commission
PUE	power usage effectiveness
PWR	pressurized water reactor
REC	renewable energy certificate
RG	U.S. NRC Regulatory Guide
ROI	region of interest
RTO	regional transmission organization
SAAS	software as a service
SCWR	super critical water reactor
SFR	sodium-cooled fast reactor
SMR	small modular reactor
SPA	standard plant approval
SPE	site parameter envelope
TEA	techno-economic assessment
TWh	terawatt-hour(s) (1 TWh/year ~ 0.114 GW generation)
UPS	uninterruptible power supply
URD	EPRI Advanced Light Water Reactor Utility Requirements Document
U.S.	United States
U.S. CEQ	U.S. Council on Environmental Quality
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. FERC	U.S. Federal Energy Regulatory Commission
U.S. NRC	U.S. Nuclear Regulatory Commission
U.S. SEC	U.S. Securities and Exchange Commission
VDR	CNSC vendor design review
VPPA	virtual power purchase agreement
WBS	work breakdown structure
WNA	World Nuclear Association

DEFINITIONS

Topic[1]	Definition
Capacity	The maximum generating capacity of a generating station, often referred to as its rated, nominal, installed, gross, or nameplate capacity.
Capacity factor	The ratio of the electricity generated, for the time considered, to the energy that could have been generated at continuous full-power operation (nameplate capacity) during the same period.[2]
DCIE	Data center infrastructure efficiency, the measure of a data center's energy efficiency calculated as the percentage of energy used directly by IT equipment out of the total energy consumption (DCIE = IT Equipment Power / Total Facility Power, or 1/PUE). Higher DCIE values signify greater efficiency in non-computational functions.
Energy	The quantity of electricity generated by a station or consumed by an end user in one hour, typically measured in MWh or TWh and referred to on a per year basis.
Inertia	The energy stored in large rotating generators and some industrial motors, which gives them the tendency to remain rotating. This stored energy can be valuable when a large plant fails, as it can temporarily make up for the power lost. This temporary response allows the systems that control most power plants time to detect and respond to the failure. Grid frequency can drop if a large power plant or transmission fails. Inertia resists this drop in frequency, giving the grid time to rebalance supply and demand.
IT equipment power	The amount of energy needed to supply IT-related equipment in a data center, including servers, switches, storage, and networking.
Physical PPA	A contract in which a buyer agrees to purchase electricity (electrons) directly from a specific power generator, receiving the physical delivery of that electricity through the grid or direct connection.
Power	A generating station's capacity to produce electricity in each moment, typically measured in MWe or GWe.
PUE	Power usage effectiveness, the ratio of total facility power to IT equipment power (PUE = Total Facility Power / IT Equipment Power). The optimum value is 1.0; however, typical centers fall in the range of 1.2 to 1.4. Microsoft noted in its most recent annual report that its data centers achieved a PUE of 1.12 (Microsoft, 2024).
RECs	Renewable energy certificates, also known as *green tags* and *green certificates.* These are tradable instruments that can be used to meet voluntary renewable energy targets as well as compliance requirements under renewable energy policies.

[1] From NREL (NREL, 2020a), U.S. NRC (U.S. NRC, 2024f), Data Center Knowledge (Data Center Knowledge, 2023b), TechTarget (TechTarget, 2024), Rocky Mountain Institute (RMI, 2019), and World Resources Institute (WRI, 2008)

[2] The U.S. average capacity factors (2014–2023) range from ~11% for gas turbines to ~93% for nuclear. Solar, wind, and combined cycle gas plants sit in between at ~23%, ~34%, and ~55%, respectively (U.S. EIA, 2024a).

Topic[3]	Definition
Total facility energy	The amount of electricity needed to supply the data center with all the energy needed at maximum load. For a grid-only connection, this would be the electricity that must be supplied to the data center by the grid. Total facility energy includes IT equipment power plus the power needed for cooling, lighting, other miscellaneous equipment, and any losses from uninterruptible power supplies and power distribution.
Virtual PPA	A PPA in which the buyer does not own and is not responsible for the physical electricity (electrons) generated by the project. This is purely a financial transaction, exchanging a fixed-price cash flow for a variable-priced cash flow, and often for renewable energy certificates. The buyer still needs to meet its electricity load through traditional channels.

[3] From NREL (NREL, 2020a), U.S. NRC (U.S. NRC, 2024f), Data Center Knowledge (Data Center Knowledge, 2023b), TechTarget (TechTarget, 2024), Rocky Mountain Institute (RMI, 2019), and World Resources Institute (WRI, 2008)

CONTENTS

1 Introduction 1

1.1 Purpose of This Report 2

1.2 Data Center Electricity Needs 3

1.3 Getting Started 11

1.4 Energy Facilities, Plant, Sites, and Units 12

1.5 Reactor Size and Type Designations 12

1.6 Plant Parameter Envelope and Site Parameter Envelope 14

1.7 Owners, Operators, Data Centers, and Organizations 15

1.8 End User Applicability 15

2 Data Centers and Nuclear Power 16

2.1 Benefits of Nuclear for Powering Data Centers 17

2.2 Defining the Mission and Business Objectives 18

2.3 Choosing the Best Option 19

2.3.1 Concepts 19

2.3.2 For Existing Data Centers 28

2.3.3 For New Data Centers 29

2.4 Developing New Nuclear for Powering Data Centers 30

2.4.1 Technology and Design Selection 31

2.4.2 Siting 40

2.4.3 Regulatory Engagement 48

2.4.4 Cost and Other Economic Evaluations 53

2.4.5 Public Perception and Acceptance 54

3 References 56

LIST OF FIGURES

Figure 1. Example of a typical grid connection 20
Figure 2. Example of a behind-the-meter connection 22
Figure 3. Example of a direct connection 24
Figure 4. Early process steps for deploying nuclear on a targeted site 31

LIST OF TABLES

Table 1. Data center sizes and power capacity 8
Table 2. Largest hyperscale data center operators 9
Table 3. Common reactor types 14
Table 4. Data center load and multiple reactor units 35
Table 5. Nuclear plant distances from population centers for early evaluation 38
Table 6. Typical plant land area vs. size 42

1 INTRODUCTION

For a variety of reasons, such as growing energy needs, energy diversification, and carbon reduction, many organizations in the United States (U.S.) and globally are considering deployment of new nuclear energy facilities. Due to data center growth and desire for carbon-free, reliable, firm power, one area of increasing interest is the use of nuclear energy for powering data centers.

As noted in a 2024 report by the International Energy Agency (IEA, 2024a), global electricity consumption by data centers is expected to nearly double by 2026, growing by about 340–540 TWh[4] globally and about 60 TWh in the U.S. This corresponds to a minimum need of about 45 GW of new generation capacity globally, with about 7 GW of that in the U.S.[5] Other reports from McKinsey (McKinsey, 2023) and the Boston Consulting Group (BCG, 2023) estimate U.S. data center growth will require a minimum of an additional 30–35 GW of generation by 2030. Much of this growth is being driven by hyperscale data centers processing artificial intelligence (AI) applications.

As data center deployments and corresponding needs for electricity grow, the ability of utilities to keep up with the demand for both generation and transmission is being challenged (U.S. News, 2024; LBNL, 2024). This has data center organizations considering distributed, or co-located, generation options (Data Center Dynamics, 2023e).

To further confound the situation, data centers seek to decrease their carbon footprint and be more sustainable (McKinsey, 2023), increasing the need for clean, carbon-free power. Typically, data center organizations have used grid power, some local generation and storage, and contractual purchases of carbon-free power to match their annual power demands. However, the intermittency of renewable sources, their limited growth rates, and their regional nature (i.e., their limitation to places where the sun shines, the wind blows, or hydrothermal power is available) have caused data centers to look for other non-carbon emitting sources.

[4] Unless noted otherwise, all references to TWh are per year.

[5] The generation capacity values here assume a capacity factor (CF) of 100%, which is not accurate. For example, if the capacity is based on 100% nuclear with a CF of 93%, the values would need to be increased by about 7.5%. For combined cycle gas with a CF of 55%, the values would need to be increased by about 82%, nearly doubling the capacity that needs to be deployed. Capacity requirements become even more complicated when intermittent generation, such as wind and solar, is added to the mix due to the need to add spinning reserve capacity (Energy Systems Integration Group, 2022). Additional non-spinning and supplemental reserve capacity is also needed for both planned and unplanned outages (NREL, 2011).

These drivers have led data center organizations to explore nuclear power as an energy source. Nuclear power is carbon free, highly reliable, firm, and resilient, all qualities desired by data centers. New nuclear technologies, such as microreactors (MRs), small modular reactors (SMRs), and other advanced reactor (AR) technologies, offer new possibilities for powering data centers. However, the nature of nuclear power raises technical considerations, primarily related to ensuring the safety of the nuclear plant and the public. In addition, the uncertainty of new plant development timing and deployment costs impacts decision making.

1.1 Purpose of This Report

The purpose of this report is to provide *practical* guidance for data center organizations considering nuclear power as a generation option. This report primarily addresses the deployment of a new nuclear plant to provide power for a data center facility, either directly or via a behind-the-meter connection (see Sections 2.3.1.3 and 2.3.1.4). It also addresses other options through which data centers may be able to take advantage of nuclear power, such as typical grid connections and behind-the-meter connections to existing nuclear plants.

This report provides an overview of the typical business model and technical options available and the considerations that must be addressed for each option, including opportunities and challenges.

- Section 1 of this report provides background and foundational information.
- Section 2, Data Centers and Nuclear Power, covers the following technical topics:
  - Section 2.1, Benefits of Nuclear for Powering Data Centers—Nuclear power can provide benefits, whether the connection is through the grid or more direct.
  - Section 2.2, Defining the Mission and Business Objectives—Understanding the goals of the data center organization, as a whole and with respect to nuclear, is a key first step in the evaluation of nuclear power.
  - Section 2.3, Choosing the Best Option—There are multiple options available; selecting the right one requires an understanding of the choices and the opportunities and challenges presented by each.
  - Section 2.4, Developing New Nuclear for Powering Data Centers—If a decision is made to evaluate the deployment of new nuclear power, there are considerations that must be understood, and actions that must be taken, to move the concept forward.

The development of nuclear power in support of a data center is a significant effort. This report does not cover every aspect but should instead be considered as a first step in the overall process. It will help a data center organization understand the basic concepts and provide pointers to other documents and resources that support such an endeavor.

1.2 Data Center Electricity Needs

As noted in a 2024 report by the IEA (IEA, 2024a), there are currently about 8,000 data centers globally, with about 33% of them in the U.S. As of the date of this publication, the Data Center Map (Data Center Map, 2024), a voluntary online resource for researching data centers, identifies more than 6000 global data centers, with more than 2200 in the U.S. Per the IEA report, these data centers consume about 460 TWh[4] of electricity worldwide and about 200 TWh in the U.S. (as of 2022). This corresponds to a minimum of about 52 GW of generation capacity globally and 22 GW in the U.S.[5]

The IEA report also notes that the global demand for energy for data centers is expected to nearly double by 2026 to 800–1000 TWh (from 460 TWh in 2022), while U.S. data center electricity demand is expected to increase to about 260 TWh (compared to 200 TWh in 2022) over the same period. Notwithstanding electricity growth from other sectors or energy savings through efficiency efforts, this amounts to a need for a minimum of about 45 GW of new generation capacity globally, with about 7 GW of that in the U.S. The IEA estimates that nearly one-third of the U.S. demand growth through 2026 will come from data centers.

Looking further into the future, a 2023 report by McKinsey (McKinsey, 2023) notes U.S. electrical demand for data centers is expected to increase from about 17 GW in 2022 to about 35 GW in 2030 (with an increase of about 4 GW by 2024).[6] Additionally, a 2023 article by the Boston Consulting Group (BCG, 2023) estimates the U.S. growth to be about 260 TWh by 2030, or about 30 GW.

In a recently released white paper, *Powering Intelligence: Analyzing Artificial Intelligence and Data Center Energy Consumption* (EPRI, 2024c), EPRI modeled and analyzed several load growth scenarios for data center energy consumption across the U.S. from 2023 through 2030. EPRI's analysis indicates that data centers could consume from 4.6% to 9.1% of U.S. electricity generation annually by 2030 (versus an estimated 4% today).[7]

The EPRI white paper also points out that data center loads are not uniform across geography, creating economic opportunity but also localized grid stress. Fifteen U.S. states account for 80% of national data center load, with Virginia, Texas, and California leading. Globally, data centers use 1.2% of electricity, but in Ireland, they use 20% and may use 33% by 2026, per the IEA.

[6] More recently, McKinsey noted that globally, the electricity demand for data centers could increase from about 55 GW in 2023 to 171–219 GW by 2030. However, as with the IEA projections (see below), there is much uncertainty in those estimates (McKinsey, 2024).

[7] Also see EPRI's *Powering Data Centers: U.S. Energy System and Emissions Impacts of Growing Loads* (EPRI, 2024e).

The IEA report indicates that most electricity use is for traditional data centers (all use cases other than cryptocurrency and AI), followed by cryptocurrency and then AI applications. Electricity demand for AI applications was relatively insignificant in 2022 but is expected to increase exponentially, about 10 times, by 2026 (as compared to 2023). While a significant increase in electricity demand is expected from forthcoming dedicated AI data centers, the most overall growth over the next few years will be from traditional data centers, followed by cryptocurrency.

While estimates of historic electricity usage and projections of growth vary by source, a review of the relevant industry literature indicates that growth estimates tend to increase over time, indicative of the rapid change in the data center industry. As an example of this growth, PJM, a regional transmission organization in the U.S., recently updated its long-term load forecast, noting, "Rising energy demand … is increasingly driven by the development of data centers throughout the PJM footprint" (PJM, 2024). A report by Grid Strategies (Grid Strategies, 2023) notes that other U.S. regions (e.g., ERCOT, NYISO, CAISO) also see increasing demand growth from data centers and that current load forecasts may understate data center load growth.

Additionally, due to the nascency of AI applications and lack of trend data, future growth is difficult to estimate, but these applications require significant amounts of electricity. For example, as noted in the IEA report and by MIT (MIT, 2023), OpenAI's ChatGPT training required about 10 TWh of electricity, which is equivalent to about 1 GW of generating capacity. In addition, as noted in the IEA report, queries on generative AI models can use about 10 times more energy than typical web search engine queries. It is beyond the scope of this report to delve too deeply into U.S. and global load growth projections, but the trend is clear: data center loads are likely to increase significantly.

On the other hand, data center operators are also working diligently to reduce their energy usage through operational and cooling efficiency, attempting to minimize their power usage effectiveness (PUE) and increase their data center infrastructure efficiency (DCIE). It is important to note that about 60% of data center electricity use is for data processing activities and 40% for cooling; the amount of electricity needed for other ancillary operations is negligible. An article by Data Center Dynamics (Data Center Dynamics, 2023f) highlights the steps that data centers are taking to reduce energy use in cooling systems by 20% to 40%. Whether those values can be achieved will depend on future cooling technologies and heat produced by the server racks. Also, as noted in the MIT report, AI applications are becoming more energy efficient as the vendors refine how the models are trained and used.

Note: The significant need for cooling, particularly cooling water, is an important consideration when co-locating with nuclear. This will be discussed more in Section 2.4.1.4.

The race to build new data centers while simultaneously taking steps to increase efficiency adds uncertainty to any load growth projections.[8] As noted in the EPRI white paper:

> *A fundamental uncertainty in projecting data center load growth comes from the broad emergence of artificial intelligence (AI) technologies in business and daily life—punctuated by the explosion into public consciousness of generative AI models, such as OpenAI's Chat GPT.…*

But this growth can be offset by efficiency gains, as also mentioned in the EPRI white paper:

> *Although gains in data center operational efficiency have plateaued in recent years, there are clear opportunities for further improvement, including more efficient IT hardware; lower electricity use for cooling, lighting, and security; and more efficient AI development and deployment strategies.*

While data center deployment growth and the corresponding need for electricity are growing rapidly, the ability of utilities to keep up with the demand is facing challenges. A 2024 article in *U.S. News and World Report* notes the difficulties utilities are having:

> *The rapid growth has raised concerns that the U.S. electric utility industry, historically known for slow and steady returns, will be unable to respond quickly to the rise in power demand because of a swelling backlog of power generation and transmission projects in line to connect to the grid (U.S. News, 2024).*

This backlog is largely due to data centers but also includes other competing end uses, particularly transportation (i.e., electric vehicles) and new manufacturing and industrial electrification efforts (Grid Strategies, 2023; IEA, 2024a). However, the development of new generation is not the only concern; new transmission and distribution lines are also needed.

While the policies and procedures vary by locale, 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 or local utility along with all other requests, largely on a first-come-first-served basis. As identified by the Lawrence Berkeley National Laboratory (LBNL, 2024) and also discussed by ClearPath (ClearPath, 2022), it takes significant time for a request to move

[8] As noted in the IEA's World Energy Outlook 2024 (IEA, 2024b), there is significant uncertainty in expected data center growth. As noted by the IEA, "Our assessment of uncertainties indicates that demand growth to 2030 could vary … by as much as 170 TWh. It also suggests that, while data centre electricity demand will grow, it is likely to account for a relatively small share of total global electricity demand growth to 2030, although the sector will be **more significant at the national or regional level in major data centre markets"** (emphasis added).

through the process to a final agreement.[9,10] Currently this takes an average of nearly five years, and less than around 19% of the requests make it through to commercial operation. (Note that, compared to just a few years before, these permit processing times are longer, and fewer requests make it through the process.) Because of these issues, data centers are looking for other ways to meet their electricity needs without limiting their growth (also see Section 2.4.3.2).

Data center companies are also being pressured to decrease their carbon footprint and be more sustainable. As noted in the McKinsey report, "some regulators and governments are imposing sustainability standards on newly built data centers." In the U.S., the Securities and Exchange Commission (U.S. SEC) recently adopted final rules for the standardization and reporting of climate-related disclosures (U.S. SEC, 2024), which will significantly increase the transparency of an organization's carbon emissions. As an example, Microsoft recently released its *2024 Environmental Sustainability Report* (Microsoft, 2024), in which it noted a slight reduction in carbon emissions from energy use (due to clean energy procurement, green tariff programs, and use of unbundled renewable energy certificates (RECs). Energy use generates only a small proportion of its overall carbon emissions, however, with emissions from its supply chain being significantly greater and actually increasing.

This transparency is important because investors, and hence boards of directors, often consider environmental, social, and governance (ESG) and corporate social responsibility (CSR) as part of a company's overall performance goals (Oxford Sustainable Finance Programme, 2021). ESG refers to a "set of standards used to measure an organization's environmental and social impact" (IBM, 2024b), while CSR is "the idea that businesses should operate according to principles and policies that make a positive impact on society and the environment" (IBM, 2023).

As noted in the McKinsey report, data centers are often signing power purchase agreements (PPAs) with renewable energy providers to meet carbon reduction goals, while large hyperscalers such as Amazon are starting to fund the building of grid-scale renewable power generation. However, a key problem with renewable generation is that it is intermittent, with solar power only generated in the daytime, wind power typically generated at night, and neither being particularly guaranteed at any time. Data centers will often complement PPAs by adding requirements for stored renewable energy, typically from grid-scale battery installations, or by trading renewable energy credits, but these types of PPAs can add considerable cost.

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[9] As of May 2024, the U.S. Federal Energy Regulatory Commission (FERC) has passed a new rule (U.S. FERC, 2024a) intended to speed transmission development. The rule provides for long-term planning and right-sizing of transmission and specifies the role of states in planning. Also, to reduce backlog, grid operators and utilities must change planning procedures, will be subject to firm deadlines, and may be subject to penalties if connection requests are not processed on time.

[10] Many new interconnection requests are for solar and wind generation. Due to reduced capacity factors, solar and wind require more generation capacity; however, they also require larger land areas and therefore may be difficult to site in a single place, which can result in multiple generation projects, each with its own request.

From a functional perspective, data centers may be added to the grid in areas with sufficient baseload capacity. In areas with insufficient capacity, new baseload generation might be required to avoid taking available electricity generation away from existing end users. This new generation can be driven by virtual PPAs that include solar or wind, leading to the addition of intermittent generation that can impact the resiliency and reliability of the grid and possibly result in more carbon-based generation (i.e., natural gas) to compensate for times when solar or wind is not available.[7,11]

Due to the uptime requirements to support customers' needs, and for their own revenue generation, data centers are 24/7 operations. Therefore, they also need backup power in case grid power is lost. Backup power is typically supplied by carbon-emitting diesel generators. While frequently tested to assure reliable operation, these can have additional maintenance requirements. For this reason, many data centers are looking at other generation options, such as fuel cell systems[12] and Li-ion battery storage, for either primary or backup generation (Data Center Dynamics, 2023a; McKinsey, 2023; Data Center Dynamics, 2023b).

Some organizations are also looking to natural gas generation for backup power. This can result in lower emissions than some other generation sources and can potentially be more economical and reliable. However, natural gas systems are not carbon free and are "highly dependent upon regional energy costs, pipeline access[13], regulations and ability to recoup costs through revenues" (Black and Veatch, 2020). A white paper from Schneider Electric even proposes the use of on-site distributed natural gas generation as the main power supply (Schneider Electric, 2020). Another option under development is use of hydrogen or other low-carbon fuels for backup generators.

Note: There is some discussion on using nuclear as backup power for data centers (TechRadar, 2023; Data Center Frontier, 2023). While this could be done, it requires thought. Nuclear plants must shut down periodically, typically for refueling and maintenance, and they can have unplanned outages that can last for extended periods, depending on circumstances. Because data centers typically require constant 24/7 operations, additional backup generation would

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[11] One option to address this last problem is the relatively new concept of clean transition tariffs (CTTs), which is being explored by Google and NV Energy in Nevada and Duke Energy in North and South Carolina (C2ES, 2024). CTTs can be used to procure clean, firm power from sources such as nuclear or geothermal, while helping to manage financial risks associated with such large projects.

[12] Today's fuel cells are best used for firm generation and do not make for good emergency backup generation because they are slow to start and don't load follow well. However, they could be a good option for non-emergency outages, such as extended nuclear plant outages. This is a scenario one might see with a behind-the-meter connection, where the fuel cells, not the grid, cover the difference in generation when the nuclear plant goes offline. For extended fuel cell operation, sufficient hydrogen needs to be stored locally, which can lead to additional combustible fluid hazards that must be considered.

[13] If direct pipeline access is not available, then keeping enough fuel on site for backup situations can be difficult. The Uptime Institute has specified 12 hours of fuel on site as a minimum for its Tier Standard defined data centers (i.e., Tiers 1–4) (Uptime Institute, 2014). The Telecommunications Industry Association standard TIA-942 specifies a value for each tier, with up to 96 hours for Tier 4 (Caplitoline, 2021).

still be desirable, and the nuclear plant would still require its own backup power. In addition, the nuclear plant would need to be run in standby, which would make for expensive backup power. Rather than dedicated nuclear backup, another option could be diversion of power from a nuclear plant that is connected to the electrical grid for normal operation through a behind-the-meter connection (see Section 2.3.1.3). In this scenario, electrical grid stability and nuclear plant operational impacts require careful evaluation due to the fast demand transient, typically less than a minute. The impact of such a transient would be dependent on the amount of electricity diverted, but the sudden loss of a large generation source diverted from the grid to a data center could be problematic for grid stability.

Data centers come in all sizes, each with its own energy needs. As identified in an article by Dgtl Infra (Dgtl Infra, 2024b), data centers are typically categorized into three size bins, as noted in Table 1 below.

Table 1. Data center sizes and power capacity [based on (Dgtl Infra, 2024b)]

Size[14]	Small	Medium (Average)	Large[15] (Hyperscale)
Building Size	5,000–20,000 ft^2 (460–1,860 m^2)	20,000–100,000 ft^2 (1,860–9,200 m^2)	100,000 ft^2–1M+ ft^2 (9,200–92,900+ m^2)
Server Count	500–2,000	2,000–10,000	10,000–100,000+
Power Capacity	1–5 MW (~0.01–0.05 TWh)	5–20 MW (~0.05–0.2 TWh)	20–1000+ MW (~0.2–10 TWh)
Example	Equinix	Digital Realty	Amazon Web Services

While all data centers need significant amounts of electricity, hyperscale data centers, which represent about 10% of all data centers by number, have tremendous needs. Hyperscale data centers are typically divided into two tiers (Data Center Frontier, 2019):

- Tier 1—mega-hyperscale operators. Examples include Google, Microsoft, Amazon Web Services, Meta (Facebook), and Apple, as well as co-location providers such as QTS and Vantage.
- Tier 2—software as a service, platform companies, and cloudlets. Examples include Oracle, Salesforce, SAP, Workday, PayPal, Dropbox, Uber, and Lyft.

Table 2 shows some statistics for the largest hyperscale data center operators.

[14] A fourth size is the micro data center, which is typically very small and consumes less than 150 kW (IBM, 2024a).

[15] The IEA noted in 2019 that hyperscale data centers can consume as much as 150 MWe (1.3 TWh) (IEA, 2019); however, much larger gigawatt-scale data centers are being planned (Data Center Frontier, 2024).

Table 2. Largest hyperscale data center operators (as of 2024) (Dgtl Infra, 2024b)

Company/Service	Notes and Statistics
Amazon Web Services (AWS)	• The largest hyperscale cloud provider globally • 32 cloud regions and 102 availability zones[16] • 33.5 million ft^2 (3M m^2) total
Microsoft Azure	• Second largest hyperscale cloud provider globally • Data center portfolio totals over 200 facilities • 62 cloud regions and 120 availability zones
Google Cloud Platform (GCP)	• Third largest hyperscale cloud provider globally • 39 cloud regions and 118 availability zones
Oracle Cloud	• 46 cloud regions and 56 availability zones
Meta Platforms (Facebook)	• 21 hyperscale data center campuses globally • Over 50 million ft2 (4.6M m^2) total
Apple	• Eight hyperscale data centers located in the U.S., Denmark, and China, with two in development in the U.S. and Europe

Per the Data Center Frontier report, as of 2019, there were about 430 hyperscale data centers worldwide. These accounted for a small percentage of total data centers, but they processed more than half the world's data and consumed an outsized amount of electricity. In comparison, in 2017, there were 320 hyperscale data centers; in 2021, there were 728; in 2023, there were 992; and 1200 or more are expected by the end of 2026 (ComputerWeekly, 2022; Synergy Reserch Group, 2024). As of 2019, the U.S. had about 40% of the hyperscale data centers, followed by China, Japan, the U.K., Australia, and Germany, with about 30% combined. As of April 2024, the U.S. data center capacity was 51%, followed by 43% combined in China, the rest of the Asia-Pacific countries, and Europe. The rate of growth indicates that deployment of hyperscale data centers will be a major driver of electricity demand for data centers moving forward.

As noted in Table 1, hyperscale data centers can require 1000+ MW of electricity. To efficiently scale and consider time to market, some organizations are constructing data center campuses with multiple data center buildings fabricated and installed sequentially. For example, Quantum Loophole has proposed a 2100-acre data center campus in Maryland at the site of a former manufacturing facility (Data Center Frontier, 2021). This campus is intended to house multiple data centers for various customers and is advertised as a "gigawatt-scale" data center city. The exact electrical load of the campus is not known, but it is reported that it will require a minimum of 500 MW of fossil backup power (Data Center Dynamics, 2023c).

[16] Typically, an availability zone is equivalent to a single data center.

The individual power density of server racks is also increasing. As noted in a Server Lift article (Server Lift, 2022):

> *More powerful hardware, including advanced server processors, graphic processing units (GPUs) and custom ASICs, use energy at a rate that far exceeds what the typical hardware data centers have used in the past. For example, a typical server processor in 2010-2015 used less than 100w of power, while processors today come in at nearly 500w. That's a stunning increase in less than a decade.*

This means that the power consumption of any data center may increase over time, and the primary power supply to the data center may need to be scaled as well.[17]

The electrical load of a data center changes over time. The changes fall into two categories. First, there are slow changes, such as those occurring seasonally (e.g., more power for cooling in summer) and daily (e.g., more processing power during business hours and increasing cooling demand as outside temperature increases). Those changes are on the order of 10–15% and are easier to compensate for with the power source. Second, there are nearly instantaneous workload changes over minutes and even milliseconds, which are mainly caused by power bursts from AI-driven GPUs. These can result in two to four times the normal power demand and can cause local voltage flicker, imbalance, and frequency issues. Those power bursts are new challenges and are mainly seen in data centers addressing AI workload (EPRI, 2024b).

Data centers use several techniques to manage these load changes, including server workload balancing, AI-powered load forecasting, geographical migration to other data centers, novel cooling strategies, resolution of load burst challenges at the chip level, and use of energy storage devices such as batteries, flywheels, and ultracapacitors, along with monitoring via data center infrastructure management tools (APC, 2011; Basmadjian, 2019; Dgtl Infra, 2024a). The difficulty of managing power fluctuations can be exacerbated when substantial amounts of renewable power are used (Data Center Dynamics, 2024b); therefore, high-quality, firm power from the grid can be advantageous. In addition, the impact on the power source (grid, behind-the-meter, or direct connection) increases with the size of the data center and associated energy demand.

To summarize:

- Data centers already consume a significant amount of electricity.
- New data center deployment and the corresponding need for electricity are expected to grow rapidly, with significant growth led by hyperscale data centers.
- Hyperscale data centers consume significant amounts of energy, and consumption at individual locations is likely to increase over time as rack power densities increase.

[17] Data center developers typically plan for load growth (APC, 2011) and include that in interconnection requests. But it's difficult to make predictions, especially about the future.

- Data center organizations are also looking to significantly increase their use of carbon-free energy to power existing and new facilities.
- Renewable energy is an option, but intermittency and land requirements limit its use, even when paired with storage, and often require complicated PPAs.
- The ability of utilities to meet the demands for new generation, particularly carbon-free generation and new transmission, on timelines requested by data centers is constrained.
- Backup generation is also a concern, as it is currently typically carbon emitting, and current technologies may not be allowable or workable for larger sites.

The above drivers are leading data center operators, particularly hyperscale operators, to consider the use of nuclear power, which can offer non-carbon emitting generation with the highest capacity factor of any generation type, supporting 24/7 operations.

As can be seen in Table 6, nuclear power plants are typically categorized into four sizes. Based on data center needs and demand, MRs , SMRs, and large reactors could be candidates for directly powering a data center. By deploying multiple units, simultaneously or over time, nuclear reactors can also, in theory, be scaled to meet a data center's needs, or even grow with the data center as its power needs increase.

Data center organizations can leverage nuclear power in several ways. These will be discussed in more detail below in Section 2, but they all present both opportunities and challenges. These include connecting to the grid (Section 2.3.1.1), power purchase agreements (Section 2.3.1.2), behind-the-meter connections (Section 2.3.1.3), and direct connection (Section 2.3.1.4).

1.3 Getting Started

This report builds on several other published EPRI reports. Readers should be familiar with these in order to attain more than a basic understanding. Readers will want to review the following EPRI reports:

- *Advanced Nuclear Technology: Site Selection and Evaluation Criteria for New Nuclear Energy Generation Facilities (Siting Guide)—2022 Revision* (EPRI 3002023910) (EPRI, 2022c): Provides fundamental and detailed information on the siting of a new nuclear power plant.
- *Advanced Nuclear Technology: Single Site Evaluation Guide: Preliminary Assessment of a Predefined Site for Deployment of a New Nuclear Energy Facility* (EPRI 3002030533) (EPRI, 2024d): Provides guidance for preliminary evaluation of a single site identified for potential nuclear plant deployment.
- *Advanced Nuclear Technology: Owner-Operator Reactor Technology Assessment Guide (Reactor Technology Assessment Guide)* (EPRI 3002025344) (EPRI, 2022a): 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; however, not having one or two designs identified will limit the evaluation without significant assumptions because some decisions are design dependent.

- *From Coal to Nuclear: A Practical Guide for Developing Nuclear Energy Facilities in Coal Plant Communities (Coal to Nuclear)* (EPRI 3002026517) (EPRI, 2023): Provides guidance on siting at a specific location and is specifically intended for use with an identified coal plant site. Those evaluating existing or retired coal sites for future nuclear deployment should use this report as key guidance.
- *New Build Nuclear Plant Development and Technical Assistance: Guide to EPRI Resources (NPTA)* (EPRI 3002025692) (EPRI, 2022b): Discusses the activities for a new build reactor project. This guide includes checklists for key information needed at each phase of the project and a bibliography of resources that EPRI has available. It is intended for those new to nuclear plant development (requires EPRI membership or purchase to access).

1.4 Energy Facilities, Plant, Sites, and Units

The terms *energy facilities, plant, sites,* and *units* are not well defined or universally used in the same way. In this report, unless otherwise specified, these terms typically refer to nuclear facilities and are typically intended to mean the following:

- **Energy facility**—An industrial complex that produces energy for any purpose (electricity, steam, or hydrogen).
- **Plant**—An industrial and organizational complex that houses an energy facility. Often used synonymously with energy facility, site, or unit.
- **Site**—The specific land area that hosts the plant or units.
- **Unit**—An individual complex that typically (but not always) contains one heat source and one generator.

1.5 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.

A detailed discussion of reactor type and size designations is beyond the scope of this report, but understanding these designations is important in the process that follows. Readers should see Section 1.4.1 of the EPRI *Siting Guide* (EPRI, 2022c) or Section 1.5.1 of the EPRI *Reactor Technology Assessment Guide* (EPRI, 2022a) for detailed discussion. Below is a summary.

Reactors are typically described by a subset of design attributes and features, which include:

- Coolant (water, gas, liquid metal, molten salt) (also see Table 3)
- Historical generation (I–IV)
- Mission (e.g., electricity, heat production)
- Thermal/electrical output (MWt/MWe) (also see Table 6)
- 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.

- **Historical generation:** The terms *generation (GEN) I, II, III, III+, and IV* primarily refer to the historical development period of a nuclear reactor design. Most reactors operating globally today are GEN II. All GEN III and III+ designs are water based, and many GEN III plants are currently operating globally, with more under construction or planned. GEN IV specifically refers to a set of ARs currently under development, being studied by the Generation IV International Forum, and expected to start operations in the 2030s (Woodhead Publishing, 2023). Light water SMRs offer attributes that bridge the GEN III/III+ and GEN IV classes.
- **Reactor size:**
  Note: See Table 6 for details on the relationship of size and thermal/electrical output.
  - **Large reactor (LR):** Most commercial nuclear plants operating today are GEN II, III, and III+ designs and would be considered LRs, typically about 600 MWe or larger.
  - **Medium reactor:** The term *medium reactor* is not often used but is incorporated in this report to span the size gap between SMRs and LRs, typically about 300 MWe to 600 MWe.
  - **Small reactor:** Small reactors are often referred to as SMRs, but SMR is an ambiguous term that can easily cause confusion if not specified in more detail. SMRs typically range from about 50 MWe to 300 MWe.
  - **Microreactor (MR):** Although there is no specific standard, this term typically refers to a very small reactor generating a relatively low amount of power, typically less than 50 MWe.
- **Technology generation:**
  - **Current generation:** The current generation of nuclear plant technology encompasses all types of commercial nuclear reactors currently operating globally (including developed LR designs not yet built and those under construction, but excluding light water SMRs).
  - **Advanced reactor:** Much like SMR or MR, the term AR can be ambiguous, and many organizations have developed their own definitions. This report defines an AR as any (fission) reactor concept or design beyond GEN III/III+ technologies, including non-light water designs, light water SMRs, and MRs.
- Reactor types and designations: Table 3 contains a summary of the various reactor types and their common abbreviations, which are often used in documentation and literature.

Table 3. 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[18]	Molten Salt (Liquid Fueled)	MSR
	Fluoride Salt (Solid Fuel)	FHR
Liquid Metal	Lead	LFR
	Sodium	SFR

Also, reports by the Nuclear Innovation Alliance (NIA) and the International Atomic Energy Agency (IAEA) offer good primers on the various types of ARs available (NIA, 2023; IAEA, 2020; IAEA, 2022).

1.6 Plant Parameter Envelope and Site Parameter Envelope

The terms *plant parameter envelope (PPE)* and *site parameter envelope (SPE)* are often used when siting a nuclear plant. While these terms sound similar, they are distinct in definition and purpose. These concepts can be useful when assessing siting, as well as technologies and designs. The purpose of a PPE is to allow for the identification of potential sites when a specific plant design or technology has not yet been selected, while the SPE is developed by the reactor designer for its specific design. The details of PPEs and SPEs are beyond the scope of this report, but readers should see Section 1.4.3 of the EPRI *Siting Guide* (EPRI, 2022c) or Section 1.5.3 of the EPRI *Reactor Technology Assessment Guide* (EPRI, 2022a) for an in-depth discussion. Understanding these concepts is important in the evaluation process.

[18] There are many different formulations of molten salts, and the choices depend on neutron energy design, whether the fuel is solid or liquid, 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).

1.7 Owners, Operators, Data Centers, and Organizations

Typically, the owner-operator of a nuclear plant is an electrical utility. However, if deploying a new nuclear plant to directly support a data center, the owner and operator could be any number of combinations. For example:

- The owner and the operator could be the data center organization. For several reasons discussed below, this is an unlikely option, but technically it is possible.
- The owner could be the data center organization and the plant operator a nuclear operating company. The operator is typically a utility with nuclear operating experience, but some AR developers are offering operating services as part of their overall deployment package.

The are many other combinations, and this matter can be complicated further during the siting process if the owner of the land is not a nuclear operating company, such as a utility. However, for simplicity, this report uses the term *owner-operator* to cover all options for the nuclear plant unless otherwise noted.

Like a nuclear power plant, a data center can have various combinations of owner and operator. For example:

- A large technology company could both own and operate its own data center.
- A company could lease space from another organization for a data center it then operates.
- A company could build an entire data center complex and then lease out space to several other organizations.
- The owner and operator of the data center could house and manage the data of another organization.

This report uses the term *data center* for the physical data center facility, whether one building or more, and the term *data center organization* for the company or companies with financial and decision-making control. Theoretically, the data center organization could also be an owner, or even an operator, of a nuclear plant, but this report uses the term *owner-operator* when referring to the nuclear plant.

1.8 End User Applicability

This report is intended to be applicable to any data center organization or nuclear plant owner-operator, regardless of locale, and to be as regulation neutral as possible. The topics identified in Section 2 are generally regulation agnostic and valid for almost any site or nuclear technology. Where reference to regulations is needed, U.S. regulations are used. Any noted 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 understand the topics and use the references and examples provided to help guide them under their own regulatory requirements.

2 DATA CENTERS AND NUCLEAR POWER

The following topics will be discussed in more detail below, but they all involve opportunities and challenges that must be addressed:

- **The benefits of nuclear**—Nuclear power can provide carbon-free, high-quality, reliable, and resilient generation, but it does present several challenges that must be understood before a commitment is made.
- **Defining the mission and business objectives**—The goals of the data center organization must be well understood, particularly the time frame for which power is needed. This also includes understanding its desired relationship with its power provider.
- **Choosing the best option**—Direct, behind-the-meter, and grid connection are all options for obtaining electricity generated by nuclear power, and each offers opportunities and challenges. Available options may be dictated by whether the data center or nuclear plant already exists or will be newly built and by the local regulatory environment.
- **Technology and design selection**—Current nuclear technology is still in flux. Large GW-sized plant designs (LRs) are currently available, but SMR and MR designs are under development. This leads to uncertainty regarding deployment schedule and cost.
- **Siting**—Nuclear plants have specific requirements for siting to ensure safety for the facility and the public. These requirements will have an impact on how and where a data center can interconnect with the plant.
- **Regulatory engagement**—Several regulatory challenges must be addressed. These can include nuclear regulatory issues, other energy-related issues (typically concerning grid reliability), financial issues, and air, water, and other environmental issues.
- **Cost and other economic evaluations**—The data center operator must address both the costs and the economic benefits of using nuclear power. The data center organization will need to evaluate the options per its mission and business objectives.
- **Public perception and acceptance**—While public acceptance of nuclear is currently increasing, a data center organization will need to understand how the local community feels about the potential deployment of a nuclear plant within it. Efforts to deploy a nuclear plant in a community that does not want it are unlikely to succeed.

2.1 Benefits of Nuclear for Powering Data Centers

The decision to use nuclear power for a data center cannot be made in a vacuum. It must be thoughtfully based on the data center organization's business objectives and consider all other potential energy options. For the purposes of this report, 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 power do not prevent its use. With that understanding, there are good reasons to include nuclear as a potential energy option. A nuclear plant can be:

- **Clean**—While country, state, and local regulations may value it differently, a nuclear plant 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% of the time (WNA, 2022a).
- **Dispatchable**—ARs will have the ability to operate flexibly, by ramping electricity generation up and down, on grids that include significant intermittent generation, such as solar and wind (EPRI, 2019). Nuclear plant designers can provide design-specific ramp rates.
- **Scalable**[19]—With the availability of MRs and SMRs, a range of deployment options are available, from less than 50 MWe up to more than 1000 MWe (U.S. DOE, 2024a; INL, 2024a). Also, MRs and SMRs are typically designed to allow for incremental growth over time (NuScale, 2024; Oklo, 2024), and technically, large light water reactors (LLWRs) can also be added over time, if desired and planned for (Wikipedia, 2024c; Wikipedia, 2024b; Wikipedia, 2024a).
- **Economical**—Although nuclear deployment can have a higher capital cost than other generation options, the long life and low fuel cost of nuclear plants can make them economically attractive over the long term (WNA, 2022b). Additionally, the inclusion of nuclear power as a firm power supply can offset the costs of building and operating the overcapacity that is required when using high levels of variable renewables.
- **A good neighbor**—The long life of a new nuclear plant is also an asset to the local community, providing much-needed economic stability with an impact on the tax base and ancillary service businesses (Good Energy Collective, 2021). Nuclear plants can also provide both direct and indirect jobs in numbers that can be attractive to the local community and typically exceed those provided by a data center alone (ScottMadden, 2021; U.S. DOE, 2022; Area Development, 2015).

Another potential benefit on the horizon is *steam adsorption cooling*. Nuclear power plants may be able to provide low-grade steam for data center cooling via steam adsorption chillers if located within a reasonable distance, about 20 miles (32 km), from the data center. This increases integration complexity but could reduce operating costs since the steam adsorption chillers are energized by the low-grade steam, as compared to vapor compression chillers,

[19] References to specific plants and companies are provided as examples only.

which are driven by energy-demanding motors. The details of steam adsorption chillers are beyond the scope of this report, but this cooling is mentioned as a potential benefit of nuclear integration with data centers. EPRI is currently researching this area and will provide updates in the future.

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 they must be understood and evaluated when making the business decision to deploy nuclear.

2.2 Defining the Mission and Business Objectives

The data center organization must consider its overall mission and business objectives. These include those of the whole organization (e.g., total deployments over time and ESG or CSR goals), including its long-term plans, as well as the details of any specific data center deployment (e.g., size and location). These objectives will be used to determine if nuclear is an option, technically and financially, and if so, how it might be incorporated.

With respect to siting a nuclear power plant, the EPRI *Siting Guide* (EPRI, 2022c) assumes that the future nuclear plant owner-operator has fully identified the mission and business objectives for nuclear deployment, but it does not specifically identify what those should encompass. This activity is one of the most crucial steps in the process and foundational to decision making, and a discussion on typical missions and business objectives for new nuclear projects can be found in Section 4.3 of the *EPRI Siting Guide*. In addition, Section 2.1.1 of the EPRI *Reactor Technology Assessment Guide* (EPRI, 2022a) identifies a minimum set of mission and business objective criteria that should be developed by the owner-operator when considering deployment of a new nuclear plant. They include items such as definition of / requirements for the nuclear power plant (e.g., electricity or heat), required output (i.e., MWe or MWt), reasons for choosing the target site, 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 complex decisions are made according to the owner-operator's goals.

Both the EPRI *Siting Guide* and the EPRI *Reactor Technology Assessment Guide* consider the concepts of *exclusionary* and *avoidance* factors regarding the criteria identified below in Sections 2.4.1 and 2.4.2. Section 2.1 of the EPRI *Reactor Technology Assessment Guide* provides good definitions of these terms and how they relate to mission and business objectives. These factors 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.

2.3 Choosing the Best Option

Once an organization has fully defined its mission and business objectives for the data center, the next step is to identify the best option or options for obtaining electricity. For any organization, this evaluation will include a review of all electricity generation options, including renewable, fossil, and other options, such as hydro. Depending on the size and mission of the data center, a mix of generation options may be appropriate.

The evaluation of options will tend to be a financial one, but non-financial aspects will also need to be addressed, such as the organization's goals for using non-carbon emitting generation, the options that may be available from a logistics perspective (e.g., the availability of natural gas or transmission and distribution lines), and goals for reliability and uptime. Most organizations will have processes and procedures for performing this analysis, and it is beyond the scope of this report. This report assumes that nuclear power is considered to be at least one viable option and concentrates on the evaluation of nuclear power.

Even when nuclear generation is identified as a primary option for a data center's energy portfolio, multiple options are available. Each presents its own opportunities and challenges, including some that may apply differently to existing or new data centers as well as existing or new nuclear plants. Several of these scenarios are discussed in the sections below, along with distinct options and considerations that must be addressed. The scenarios are non-exhaustive, and organizations may find that different possibilities are available. The goal is to provide the organization with a framework for its own evaluations.

Note: Section 2.4.4 discusses economic considerations that will impact nuclear evaluation.

2.3.1 Concepts

There are several concepts that apply to typical scenarios for making use of nuclear power: connecting to the grid, PPAs, behind-the-meter connections, direct connections, and construction of new nuclear plants. Each is discussed below.

2.3.1.1 Connecting to the Grid

The easiest way to take advantage of nuclear power is to simply connect to a grid that has a sizable portion of nuclear generation (see Figure 1).

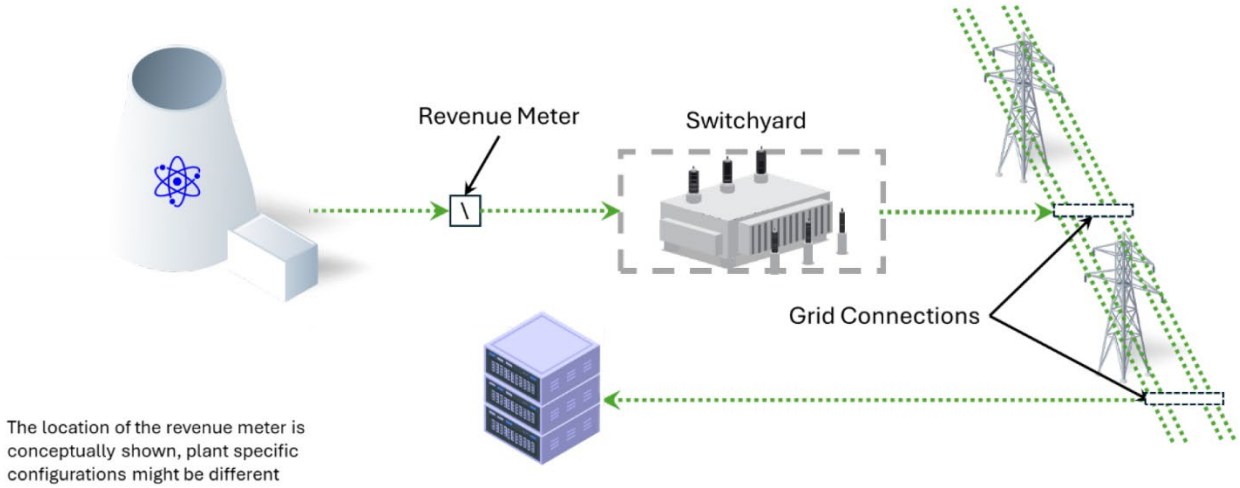


Figure 1. Example of a typical grid connection

Electrons do not care where they came from or where they go, so when a data center is connected to the grid, there is no guarantee that it will be getting energy from an individual power source.[20] However, in the context of the overall grid, a large amount of nuclear generation will still provide benefit. This is true even in the U.S., which is generally separated into three large interconnects. With subdivisions managed by regional transmission organizations (RTOs), independent system operators (ISOs) (U.S. FERC, 2024c), and individual utilities, one can identify regions with high proportions of nuclear generation.[21]

Connecting to the grid in proximity to high quantities of nuclear generation can provide several technical benefits:

- Nuclear plants typically provide a large amount of firm baseload power to the grid. This helps keep the grid stable and reliable, ensuring high-quality, frequency-controlled power, which is crucial for data centers (NREL, 2020a).
- In the U.S., the inertia provided by nuclear generation currently ranges from about 3% up to about 24%, depending on the amount of nuclear generation deployed in a particular balancing authority (U.S. DOE, 2023a).
- High nuclear plant capacity factors help ensure that power is continuously available (U.S. DOE, 2021).
- Nuclear plants typically have 18–24 months of fuel on site, helping to ensure power production in severe weather or when other logistical issues arise (NEI, 2024).

[20] No, electrons don't actually flow in AC circuits. To learn more, see the video The Big Misconception About Electricity for a simple answer and MIT's A Visual Tour of Classical Electromagnetism for a very detailed discussion.

[21] A review of EIA data (U.S. EIA, 2024b) shows that commercial nuclear plants are deployed in 28 U.S. states, but about 50% of all nuclear energy capacity comes from just seven states: Illinois, Pennsylvania, South Carolina, Alabama, North Carolina, Georgia, and Texas.

- Nuclear plants are non-carbon emitting (U.S. DOE, 2023b).

Making a standard grid connection is typically the easiest method for accessing the benefits of nuclear power, but unless a PPA (see Section 2.3.1.2 below) is used, the data center organization may not be able to take credit (e.g., contractual credit) for the non-carbon emitting generation. Connecting to the grid can also be complicated by the need for additional transmission and distribution infrastructure, and unless the local grid has enough power already, new generation may need to be added before the data center's connection. This can be time consuming and conflict with time-to-market strategic goals of the data center companies.

2.3.1.2 Power Purchase Agreements

Depending on the utility and local energy regulations, PPAs may be an option, allowing the data center to contractually purchase power from a utility's nuclear plants while physically connecting anywhere on the grid. As defined in *Energy Project Financing: Resources and Strategies for Success*, put simply, a PPA is a "long-term agreement to buy power from a company that produces electricity" (Thumann & Woodroof, 2021). PPAs can be physical or virtual. The specific details and differences are beyond the scope of this report, but it should be noted that currently, most PPAs are virtual and often include RECs[22] (RMI, 2019). The financial terms of PPAs may also allow for lower electricity costs for the buyer due to long-term commitments, but this could be offset by higher costs when buying from higher-cost generators for a specific purpose (e.g., when specifically buying from low- or zero-carbon emitting sources).

PPAs are typically associated with renewable power, but from a technical perspective, there is no reason they cannot be associated with nuclear energy. For an example, see *Nuclear Power Purchase Agreements Take Shape in the U.S.* (IIR, 2023). However, it should be noted that PPAs are typically regulated by energy commissions, for example, the Federal Energy Regulatory Commission (U.S. FERC) in the U.S. (U.S. FERC, 2024b). In the U.S., PPAs are also subject to state energy regulations, and thus their availability, policies, and financial conditions will vary, typically at the utility level. States with highly deregulated electricity markets will typically have more options. As of publication, 32 states (and Washington, D.C.) have some form of energy deregulation (Quick Electricty, 2024).

PPAs may also be used when making a behind-the-meter connection (see Section 2.3.1.3).

[22] See the definitions at the top of this report for descriptions of physical and virtual PPAs.

2.3.1.3 Behind-the-Meter Connections

A recent topic of importance is connection of end-user facilities, such as an industrial plant or a data center, to a nuclear plant behind the meter. *Behind-the-meter* generation refers to a variety of technologies that generate electricity at or near where it will be used.[23] The end-user facility is connected to the nuclear plant before the point where the plant is connected to the main grid and its output measured, or *metered*, as part of the overall electrical generation of the plant for use by the public on the grid (see Figure 2).

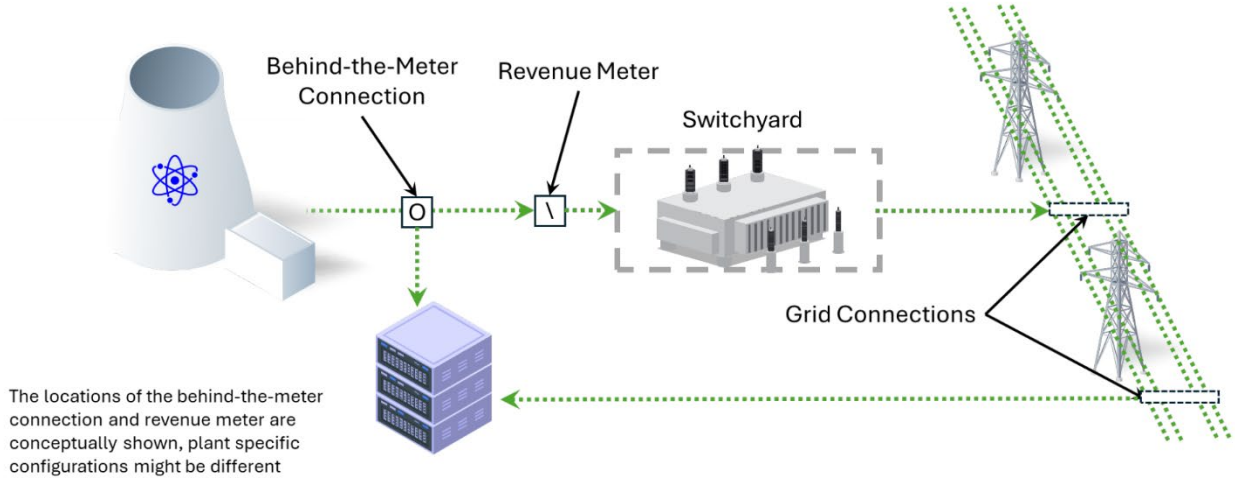


Figure 2. Example of a behind-the-meter connection

A behind-the-meter connection allows the plant to sell its electricity directly to the end user. This can potentially provide the buyer with a lower price for electricity if typical grid transmission and distribution cost can be avoided. More importantly, it can typically provide long-term price certainty for a certain type of generation (e.g., carbon free). This price certainty can be of value to both the buyer and the seller. Also, behind-the-meter connections can potentially speed interconnection, providing direct access to power without the delays associated with building high-voltage transmission lines over long distances. In the U.S., regulatory agencies are working through the cost allocation and other details associated with behind-the-meter connections (see **Note** below).

Typically, a behind-the-meter connection would power the data center and provide excess power to the grid when the data center does not need it. However, depending on the engagement structure, a behind-the-meter connection could also allow the generation plant to provide full power to the grid when needed, and then provide power to the data center when

[23] In most cases, one will find that simple definitions of behind-the-meter generation refer to co-located solar generation or battery storage. This is simply because these are very common today. However, any generation source and load center can be configured as a behind-the-meter connection. A technically detailed definition can be found in *PJM Manual 14G: Generation Interconnection Requests* (PJM, 2023).

the grid does not need all the plant's power, allowing the plant to potentially run at full power instead of ramping down. Such an arrangement could help maintain grid stability and possibly provide an avenue for the data center to receive low-cost power that might have gone unused.

Whether a generator and end user can participate in such an arrangement depends on the local electricity regulatory status. For example, in the U.S., states with regulated energy markets may not permit such arrangements, instead requiring all generated power to be bought and sold from the grid, while unregulated states may be more welcoming to the concept (KPMG, 2023).

Nuclear safety and electricity regulators, such as the U.S. Nuclear Regulatory Commission (NRC) and North American Electric Reliability Corporation (NERC), may also have an interest because behind-the-meter connections can have safety and reliability implications that must be addressed.[24]

A more detailed discussion on this topic is beyond the scope of this report, but there are a few things to keep in mind:

- Setting up a behind-the-meter connection requires additional planning and equipment. For nuclear, there are additional transients and safety aspects that must be addressed for both the nuclear plant and the end-user facility (e.g., switching transients, load rejection, additional electrical protections and isolations, stability impacts, harmonic impacts).
- Behind-the-meter connections usually need the end-user facility to be near the generation plant. Proximity is flexible, but to reduce new transmission costs, a distance up to about 5 miles (8 km) or less is practical. While the end-user facility can be located near a nuclear plant, there are considerations that must be evaluated and accounted for (see Section 2.4).
- With a behind-the-meter connection, a full loss of load from the data center (e.g., if the data center's main transformer goes offline) may not be buffered by the rest of the grid. If the loss is too great, it could result in a plant trip more easily than if the data center were connected to the grid. Nuclear plants are designed to manage losses of load and plant trips, but their designs typically specify the number of times such cycling events (or anticipated operational occurrences) are assumed to occur in the plant's lifetime.25 While plant trips are planned and designed for, they are undesired situations that can impose a safety risk to the plant and affect overall grid stability (IAEA, 2012).

[24] As examples, see Talen Energy's submittal to the NRC regarding potential environmental issues (Talen Energy, 2022) and an NREL report on behind-the-meter grid reliability issues (NREL, 2020b).

[25] As an example, Westinghouse training documentation (Westinghouse, 2020) notes that a loss of load greater than 50% will cause a plant trip. The EPRI Utility Requirements Document notes that advanced light water reactors and SMRs should be able to manage 100% load loss without a reactor trip (EPRI, 2014); however, the specific value for any nuclear plant will be design specific. On the other hand, a large behind-the-meter connection could potentially help prevent a plant trip due to loss of grid load, but again, this would be design specific and dependent on the overall load that is behind the meter (Lim & Park, 2020).

- A behind-the-meter connection is different from a direct connection, in which the electrical generation facility is only connected to the end-user facility, not to the grid. While direct connection is possible for some generation types, there are additional issues that must be addressed for nuclear generation (see Section 2.3.1.4).
- A behind-the-meter connection to an existing nuclear power plant could be the fastest time-to-market strategy for a data center owner-operator.

As with PPAs, the ability to take advantage of a behind-the-meter connection can be dependent on federal and state energy market regulations.

Note: As an example, readers should consider the recent development of a data center campus with a behind-the-meter connection to the Susquehanna nuclear plant, including regulatory issues raised (Data Center Dynamics, 2023d; PR Newswire, 2024; IEEE Spectrum, 2024; Utility Drive, 2024).

2.3.1.4 Direct Connections

In a direct connection scenario, a nuclear plant is directly connected to a data center. All power generated by the nuclear plant is provided to the data center (see Figure 3).

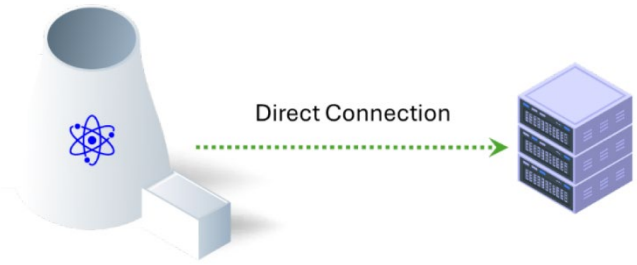


Figure 3. Example of a direct connection

Except for some specific niche situations, such as a data center deployed in a remote region connected to a specific type of nuclear plant with certain capabilities, direct connection is less likely than other options. In most cases, particularly for nuclear safety and reliability reasons, there will normally be some type of backup or contingency grid connection or multiple nuclear power plant units connected to power the data center with electrical cross ties. Some of the reasons for this are as follows:

- While some nuclear plant designs can operate without grid power during emergencies, most plants still prefer to have offsite power available when intentionally shutting down or during transient events. The loss of offsite power is a safety concern contributing to overall risk (U.S. NRC, 2024e). Although operating without offsite power can be demonstrated to be safe to the public, it can lead to plant damage. (For example, MSRs and SFRs require heating to keep their coolant liquified. If it is solidified, the plant could be irreparably damaged.) As noted in the EPRI Utility Requirements Document (URD) and EPRI Owner-Operator

Requirements Guide (ORG) (EPRI, 2014; EPRI, 2019), asset protection is a key policy expectation for new nuclear plants. Similarly, having nuclear plants rely on backup generators is typically undesirable for safety and operational reasons.

- The safety case for most nuclear plants involves addressing how the plant responds to load loss. If the data center is the sole load for the nuclear plant and it goes offline for reasons such as a main transformer failure, the plant must safely handle the situation. Typically, such load loss can trigger an automatic plant trip, a specific transient that the plant must demonstrate it can manage safely.
- While some nuclear plants may be able to start without a grid connection, a situation called a black start, this is typically undesirable for safety and reliability reasons.
- Nuclear plants typically run at fixed power levels, although some designs allow flexibility, and future SMRs and ARs are expected to allow for load following and flexible operation. With a direct connection, the nuclear plant's electrical output must follow the data center's demand. If a data center doesn't use all the generated power, the excess power must be redirected; if the data center needs more power than the plant can supply, additional power must be obtained. Also, flexible operations can reduce plant efficiency, increase component degradation by thermocycling, and lead to inefficient use of nuclear fuel. The nature and magnitude of these issues are design and technology dependent (see Section 2.4.1).
- A direct connection can create a single point vulnerability for the data center, especially if a single nuclear unit is the power source. If that unit shuts down intentionally, due to a transient or an emergency, the data center still requires power. Most nuclear plants need extended shutdowns of several days for refueling and maintenance. Although data centers usually have backup generators, they typically want to avoid running on backup power for extended periods as it increases their own operational risk. Also, depending on the technologies used, running emergency generators for non-emergencies could violate air permit requirements.[26]

For the reasons noted above, a simple direct connection to a single unit will not be an optimal choice for a data center. Instead, multiple nuclear power units or modules, or a grid connection for both the data center and the nuclear plant, would be desired or needed. The resulting situation would resemble a behind-the-meter connection. As a minimum, a microgrid capable of load balancing and backup generation could be needed.

[26] Nuclear plants use specialized backup generators for safety systems only, equivalent to a small percentage of their total power capacity. Conversely, data centers typically match backup generation to regular operations, which can cause significant emission differences, notably with diesel generators.

2.3.1.5 Constructing New Nuclear Plants

An option for a data center to take advantage of nuclear generation is to build a new nuclear plant. There are several ways that a new nuclear plant could provide power to the data center:

- The plant could simply be added to the local grid by a utility. This could include the purchase of power via PPAs by the data center.
- The plant could be added to the grid by a utility but be built in proximity to an existing or new data center for a behind-the-meter connection.
- The plant could be built in proximity to an existing or new data center for a direct connection.

Adding new nuclear power is the most complex option, requiring a detailed understanding of the financial implications as well as the technical aspects of building a new nuclear plant.

Note: The new nuclear power could be in the form of multiple nuclear plants (e.g., several SMRs or MRs). This scenario is discussed in several sections below, but for simplicity, most of this report will refer to adding a single nuclear plant, unless otherwise noted.

2.3.1.5.1 Utility Addition to the Grid

The most straightforward method for adding new nuclear would be for a utility to add new nuclear generation to its overall portfolio. The data center would then simply connect to the grid and take advantage of the benefits of nuclear generation, possibly using a PPA. The process for a utility to add new nuclear generation to its portfolio is well documented and typically governed by the local nuclear regulator, such as the NRC in the U.S. Readers should review the EPRI *Siting Guide* (EPRI, 2022c) and the EPRI *Reactor Technology Assessment Guide* (EPRI, 2022a) for more information on the general process requirements.

Though well defined, the process can be costly, and the time to license and construct, including any uncertainty, must be considered. If it is left to the utility to make the decisions and execute the process, the data center organization may need to wait a considerable time for completion. However, there are ways that the data center organization could positively impact the process. For example, it could:

- Work with the local utility to ensure that the data center organization's needs are considered in the utility's integrated resource plan (IRP) or similar long-term planning efforts. Data center deployment can be faster than completion of the IRP process, which can be quite methodical. Because the data centers need the power, there is a speed-to-market mismatch that data center organizations should proactively address. See Section 3.2.2 of EPRI's Single Site Evaluation Guide (EPRI, 2024d) for more information.

  Note: The EPRI white paper Powering Intelligence (EPRI, 2024c) points out that collaboration between data center organizations and utilities is an important strategy. Developing a deeper understanding of what both organizations need and making use of enabling technologies and policies opens opportunities to both increase grid reliability and reduce costs for data center operations.

- Perform up-front work to locate, procure, and potentially license a site for a new nuclear power plant. This is a significant endeavor and should only be considered in partnership with a utility. See EPRI's Single Site Evaluation Guide for more information on this topic.
- Engage with the utility on a PPA for future power purchases to help shore up the financial incentives for the utility (see Section 2.3.1.2 above).
- Become a fractional owner of the new nuclear plant, which could mean financially supporting its construction and operation or other arrangements between the parties. Several nuclear plants, particularly in the U.S., have multiple owners, with either one owner or a separate operating organization acting as the operator. For examples of such situations, see U.S. EIA's web page on nuclear reactor ownership (U.S. EIA, 2023). Potential data center organizations should understand that even fractional ownership of a nuclear power plant comes with responsibilities and liability risks. However, it could allow for a financial return on investment that would not be achieved simply by paying for electricity, and depending on the local financial regulatory status, it could allow for more favored electricity rates.

  Note: Data center organizations will want to carefully consider the roles they take in the ownership or operation of a nuclear facility. While it is possible to both own and operate the facility, there are technical, operational, financial, liability, and security issues that must be addressed. Also, some countries have laws regarding who may have ownership of a nuclear facility. For example, the U.S. NRC has rules for foreign ownership based on the Atomic Energy Act (U.S. NRC, 2023c). Before taking a substantial role as an owner or operator of a nuclear power plant, data center organizations need to be aware of the associated requirements and challenges, which are beyond the scope of this report. EPRI cannot provide specific guidance on how any organization should manage such a venture but recommends partnering with an existing owner-operator to ensure challenges are understood.

2.3.1.5.2 Utility Addition with a Behind-the-Meter Connection

This scenario is like the one above, but with the specific intent of locating the new nuclear plant in proximity to the data center to facilitate a behind-the-meter connection.

If the data center does not already exist, then the two facilities would typically be sited simultaneously during the same process, though not necessarily side by side (proximity is discussed above in Section 2.3.1.3). They could be sited almost anywhere, subject to the regulations and technical requirements for siting both. While targeting a specific location for both facilities is possible, following the procedures in the EPRI *Siting Guide* for selecting a region of interest and systematically reducing the options from candidate areas down to proposed and alternative sites, evaluating the nuclear site and the data center site simultaneously, would be the recommended practice.

If the data center already exists, then proximity becomes a limiting issue. A valid site for the nuclear plant must be found in reasonable proximity to the data center. While data center siting constraints (Data Center Frontier, 2020), such as climate, seismic risk, and transportation access, are like those of a nuclear plant (see the EPRI *Siting Guide*), they are not the same. For

example, data centers will want to carefully consider local network latency, which is usually not a concern to a nuclear plant. Therefore, a siting location valid for a data center may not be viable for a nuclear plant, and vice versa. If the data center location is known, using the process in the EPRI *Single Site Evaluation Guide* (EPRI, 2024d) would allow for a quick determination of whether a targeted location is likely viable for a new nuclear plant.

In both cases, the data center organization must work in concert with the utility to evaluate the siting options and understand how the project will be financed.

2.3.1.5.3 Direct Connection

As noted above in Section 2.3.1.4, a simple direct connection can be challenging in most cases. However, if the specific circumstances warrant such effort, the data center organization will need to work with some type of owner-operator to finance and construct the new nuclear facility. At this time, some AR developers are proposing such arrangements, and data centers may want to work with them directly. Also, some utilities that already own and operate nuclear plants may be willing to take on the role of operator if another organization takes financial ownership and responsibility for construction. As noted in Section 2.3.1.5.1, data center organizations should carefully consider their role in such scenarios.

A direct connection is unlikely to make sense for an existing data center because the power infrastructure is already in place. However, it could make sense for new data centers, particularly if located in more remote areas, when sufficient backup power and contingency plans, such as multiple nuclear reactor units, are established to guarantee safe and reliable operation.

2.3.2 For Existing Data Centers

Adding nuclear power to an existing data center comes with constraints. The generally available options, ordered by level of effort of the data center organization, are described below.

PPAs can be used to contractually procure more nuclear power and offset carbon emissions. This option is relatively easy and requires no new infrastructure. However, unless the PPA is used to obtain new carbon-free generation, it may do little to reduce system-wide carbon emissions. Also, this option does not provide any additional technical benefits from nuclear power beyond what is already on the grid. Furthermore, the availability and value of PPAs may be limited by federal or state energy market regulations.

Working with local utilities to add new nuclear power to the grid can provide many of the benefits of nuclear power to the data center (existing or new). The data center organization can promote a utility's addition of nuclear power though several means. At a minimum, it can work with the utility to help it understand the data center's needs as the utility works on its long-term generation portfolio planning (see Section 3.2.2 of the EPRI *Single Site Evaluation Guide* (EPRI, 2024d) for additional information on IRPs). Data center organizations could also use PPAs or direct investment as financial incentives to the utility.

As noted above, connecting an existing data center to a nuclear plant with a behind-the-meter connection requires the data center to be in proximity to the nuclear plant. If the data center is a reasonable distance from an existing nuclear plant, then running a transmission line from the nuclear plant may be possible. This will require procurement of land for the corridor; necessary permitting, including environmental evaluation; and construction. The nuclear plant will need to make technical modifications to its site and verify that it can safely provide the power, requiring some review with the nuclear regulator. The local grid operator will also want to understand how the loss of power to the grid (i.e., the power going to the data center instead of the grid) will affect grid stability and reliability, and how the sale of that generation would impact resource adequacy for other customers. The data center itself will also require some level of infrastructure modification to support the new incoming transmission lines.

Building a new nuclear plant with the intention of connecting to the data center behind the meter will require finding an appropriate site in proximity to the data center. If the data center organization owns substantial nearby property appropriately sized for a nuclear plant, then this could be an option. Otherwise, another nearby site must be identified. The EPRI *Single Site Evaluation Guide* (EPRI, 2024d) can be used to perform a preliminary evaluation on an identified site to see if it can potentially support hosting a new nuclear plant. If it can, then a full evaluation of the site will need to be performed in accordance with local regulations and as defined in the EPRI *Siting Guide* (EPRI, 2022c).

Previously industrialized sites can be good options for consideration for new nuclear plant sites. See the EPRI *Coal to Nuclear Guide* (EPRI, 2023), Section 3.1 of the EPRI *Single Site Evaluation Guide* (EPRI, 2024d), and Section 4 of the EPRI *Siting Guide* (EPRI, 2022c) for more information on this topic.

As noted above, deploying a new nuclear plant as a direct connection does not make much sense for an already existing data center since there are many challenges with not having a tie to the grid, and a grid connection already exists.

2.3.3 For New Data Centers

When evaluating options for new data centers, many of the concepts noted in Section 2.3.2 will apply. However, there are differences in some cases.

One option is to locate the new data center in an area with a high concentration of nuclear power already deployed on the grid and connecting to a utility. This provides many of the functional benefits of nuclear power to the data center. If the utility and its corresponding nuclear plants are in a state or region where the use of PPAs is an option, then these can be used to offset carbon emissions and potentially provide favorable pricing.

The most significant opportunity for new data centers and nuclear power is siting them in proximity to each other for either a behind-the-meter or a direct connection. The simplest and fastest time-to-market option could be to identify suitable land in proximity to an existing nuclear power plant that could support a behind-the-meter connection from both regulatory and power perspectives.

If both a new data center and a new nuclear plant are needed, the primary challenge is finding a location that can support both facilities from technical and regulatory perspectives. From a technical perspective, both data centers and nuclear plants require locations that are seismically appropriate, where cooling water is available, and where environmental and community impacts can be limited. Both facilities will need to meet safety and environmental regulations and be able to obtain the necessary permits for items such as water withdrawal and discharge and environmental emissions. In general, it would be expected that any location that can support a nuclear plant will likely meet or exceed the requirements of a data center. However, data centers may have their own needs, such as proximity to fiberoptic lines and telecommunications interconnects, that are not specifically applicable to nuclear facilities.

While targeting a specific location for both facilities is possible, the recommended practice would be to follow the procedures in the EPRI *Siting Guide* for selecting a region of interest and systematically reducing the options from candidate areas down to proposed and alternative sites, evaluating the nuclear and data center sites simultaneously. Previously industrialized sites can not only be considered for new nuclear, but also be good candidates for data centers. For example, Quantum Loophole has chosen such a site for its data center campus in Maryland (Data Center Frontier, 2021).

2.4 Developing New Nuclear for Powering Data Centers

Note: The following sections assume that the data center organization is considering active involvement in the selection and siting of a specific nuclear technology and design for powering a data center. If undertaken by a utility for the inclusion of nuclear in its generation portfolio, the utility would assume this responsibility. Data center organizations may still want to review these sections to gain a better understanding of the process and requirements.

Once both a specific site and a nuclear plant design have been identified, the process for new nuclear development and deployment is well established, typically following national regulatory requirements and recognized project management principles. However, for those early in the process of considering development of a new nuclear power plant, the EPRI *Single Site Evaluation Guide* (EPRI, 2024d) provides a process for performing such an evaluation, as depicted in Figure 4.

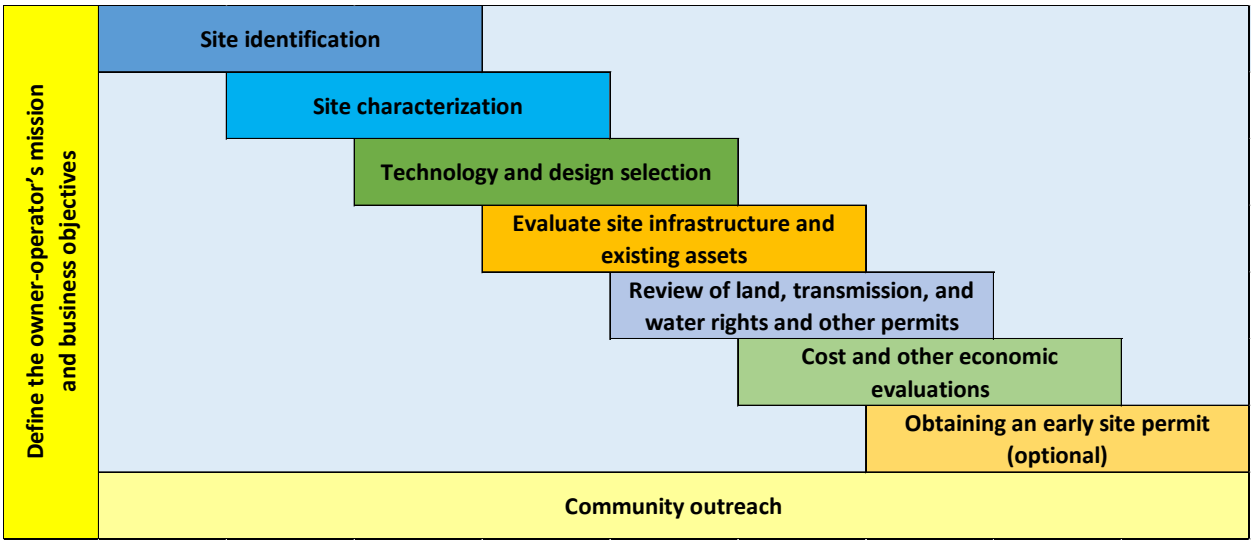


Figure 4. Early process steps for deploying nuclear on a targeted site

The overall process is not discussed in detail here, and readers should refer to the EPRI *Single Site Evaluation Guide* for more details. However, the following sections do touch on many of the most important points. They are intended to give data center organizations the information needed to familiarize themselves with the process and perform early assessments of viable solutions that will meet their business goals.

2.4.1 Technology and Design Selection

EPRI recommends that nuclear technology and design selection be done as an iterative process with siting (see Section 2.4.2). This is because the 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 into the topic, readers are reminded of two important definitions in the EPRI *Reactor Technology Assessment Guide* (EPRI, 2022a):

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

Today, nearly all operating nuclear plants are water-based technologies, with the majority being PWRs or BWRs. These plants are about 1 GW in size and are often referred to as LLWRs. Currently a couple of more recent LLWR designs, often referred to as advanced light water reactors, are available. These have the potential to be deployed in the near term, but they require larger land areas, larger amounts of cooling water, longer deployment times due to the size of the construction, and overall higher overnight project costs.

There are many innovative technologies in development from several plant designers (OEMs). These include novel light water designs as well as other technologies, such as gas-cooled or molten salt reactors. These ARs are typically defined by a combination of their fuel form and primary coolant, and each has unique traits that should be considered (see Section 1.5). Key features of these designs include:

- A smaller MWe output (e.g., MRs, SMRs)
- The ability to deploy multiple units (in a staggered approach to match demand with data center construction in parallel, if desired) to target a specific final energy output
- Potentially higher temperatures, which result in increased efficiency and enable other product options, such as process heat applications for non-electric missions (e.g., industrial applications)
- Increased flexibility options
- Smaller land requirements
- Lower cooling water requirements, including the potential for air cooling
- A nuclear safety profile that could allow deployment closer to populations and reduced emergency planning zone (EPZ) sizes

EPRI's *Reactor Technology Assessment Guide* (EPRI, 2022a) can be used to help an owner-operator select a technology and design that fits its mission and business objectives and the constraints of the site. The guide includes 31 specific criteria to be analyzed to first identify potential technologies and finally settle on one or two specific designs to pursue. When performing a preliminary evaluation of a single site, a limited set of 12 criteria can be evaluated quickly for an understanding of viable options. See Section 2.3.2 and Table 4 of the EPRI *Single Site Evaluation Guide* (EPRI, 2024d) for guidance on this evaluation, including details on the reduced set of criteria, which includes the following items:

- Plant energy output
- Fuel selection
- Used fuel storage and disposal
- Site evaluation
- Design completion
- Reactor systems
- Reactor non-safety auxiliary systems
- Engineered safety systems
- Fueling, refueling, and fuel handling systems
- Other systems or critical path components
- Regulatory and licensing
- Supply chain maturity, remaining effort, capability, and capacity

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, 2020b; U.S. NRC, 2023e), but there are several other ARs in various stages of preapplication or licensing review (U.S. NRC, 2022b). As examples in the U.S., as of publication of this report, Kairos Power has received a construction permit (CP) for a 35 MWt non-power test reactor (U.S. NRC, 2023d) and is in the process of applying for a CP for a 20 MWe test reactor (U.S. NRC, 2024c); TerraPower is in the process of applying for a CP for a 500 MWe plant (U.S. NRC, 2024h); Natura Resources and Abilene Christian University have received a CP for a non-power research reactor (U.S. NRC, 2024a); and nine other companies are working with the NRC on preapplication activities (U.S. NRC, 2023f).

As other examples, the Canadian Nuclear Safety Commission (CNSC) has reviewed or is in the process of reviewing 14 designs under its vendor design review program, which provides early, non-licensing feedback to OEMs (CNSC, 2024b), and OPG has submitted an application for its license to construct the GEH BWRX-300 at Darlington (CNSC, 2024a). Also, the U.K.'s Office of Nuclear Regulation (ONR) is currently assessing three AR designs under its Generic Design Assessment Program (U.K. ONR, 2024). Owner-operators considering ARs will need to perform due diligence to ensure they understand the capabilities and viability of these options and, most importantly, the time frame for their deployment.

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 are still in their infancy, partnering with an OEM will help move forward the site-specific engineering details that are necessary. It may be beneficial to identify more than one design and OEM because the current state of the art and state of the market are in flux, and having options can be valuable.

While the reduced set of EPRI *Reactor Technology Assessment Guide* criteria can be used to develop a quick sense of technologies and designs that could 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 *Reactor Technology Assessment Guide* will result in a well-vetted primary design and a couple of optional designs. Once one or more candidate designs have been identified, the needed land size (see Table 6 below) and other criteria related to siting can be better identified.

Although all criteria in the EPRI *Reactor Technology Assessment Guide* will need to be evaluated, 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, time frames, 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 to meet the goals of the mission and business objectives. The fourth bullet is not 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 can be justified, 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 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.

When selecting a technology and design for a data center, some key issues that must be addressed are:

- Data center load and growth over time
- Technology needed to support goals
- Land Size needed to support reactor siting
- Cooling water availability
- Nuclear safety and security

While some of these concepts also apply to siting, they are discussed here because they are often constrained by the chosen reactor technology or design. As mentioned, however, technology and design selection typically must be an iterative process with site selection.

2.4.1.1 Data Center Load and Growth over Time

One of the most important determinations is the electrical load needed by the data center, including its future load growth. This evaluation should be part of defining the mission and business objectives as it is a key factor in determining what technology and design options are available.

A major concern is ensuring that any nuclear plant will provide the power needed for the data center. If everything were perfect, it would provide the exact amount of power needed, no more and no less. Costs would not be sunk into capital expenses for capacity that will not be used, and the maximum value of the nuclear plant versus obtaining power from other sources would be received. However, this perfect situation is not likely.

Nuclear power plants are designed and licensed to specific power ratings. While some plants can operate flexibly, they cannot exceed their design ratings, and operating below full capacity typically increases fuel and operations and management (O&M) expenses. This means that either some outside power will typically be needed during normal operations, or unused power will need to be provided to the grid (or some other load).

Note: Some organizations are considering the concept of energy parks, where one or more nuclear power plants may provide power to a data center, the grid, and other energy loads, such as for hydrogen generation, potentially for use as backup generation, all balanced based on the overall energy needs combined (Data Center Dynamics, 2024a; World Nuclear News, 2023). This is a complex scenario that can impact technology and design selection as well as siting.[27]

With the advent of SMRs and ARs with smaller capacities, it may be possible to build several smaller units and use them collectively to power a data center. Even in this case, however, it may be difficult to exactly meet the load requirements of the data center. Table 4 below shows some options for hypothetical data center and reactor combinations.

Table 4. Data center load and multiple reactor units

Data Center Load (MWe)	Reactor Power (MWe)	Number of Units	Result
150	250	1	100 MWe need to go to the grid or another load.
	150	1	Under normal operations, demand and generation match; otherwise, adjustments are necessary.
	100	1	50 MWe are needed from the grid or another source, or the data center needs to be run below capacity.
	50	3	Under normal operations, demand and generation match; otherwise, adjustments are necessary.

Another challenge can be data center load growth over time. As noted in Section 1.2, rack power density is progressively increasing. This means that even without adding facilities, the load of any data center can increase over time (Server Technology, 2016). Data center campuses can also grow with the addition of more data centers.

Assuming a grid connection, this growth could be powered by additional grid supply. It may also be possible to add new SMR units over time. The latter option must be accounted for early in the process. For example, the land needed for future expansion must be identified, cooling water must be available, and the site must be licensed and permitted for these additional units (also see Section 2.4.2.6.3).

Finally, when multiple units are located at the same site, there are other considerations that must be addressed (see Sections 2.4.1.4 and 2.4.1.5).

[27] Data centers typically need about 20–30 MWe of construction power while the site is in development. A data center will use about 5 MWe for many years while a campus is under construction and periodically spike to about 25 MWe during commissioning of new sections. This will require some power source during original construction, and load balancing once the nuclear plant is built, as the campus continues to grow.

2.4.1.2 Technology Needed to Support Goals

When evaluating nuclear technologies and designs for future deployment, data center organizations must ensure the technologies meet their mission and business objectives. A key point here is that data centers typically only need electricity, not industrial heat, as an energy source. This means that high-temperature reactors are typically not specifically required, and lower-temperature water-based reactors could suffice.

This does not mean that high-temperature reactors cannot be used or make sense, but the technology and design evaluation should ensure the investment is not made in reactor capabilities that are not needed. This is primarily a cost evaluation that includes not only capital costs, but O&M costs as well. Deployment schedule needs will also play a role as high-temperature reactors are currently in the initial stages of development and licensing.

2.4.1.3 Land Size Needed to Support Reactor Siting

The land needed to support the desired technology must align with the land intended for siting. This alignment includes both the total area of land available and geometry. While there can be some flexibility in laying out a nuclear plant site, the OEM's design footprint is typically part of the licensed design. Just because the required area is available does not mean that the reactor will fit within the available footprint. Because reactor designs come in various sizes and geometries, they must be matched with the available land. If multiple reactors are intended, then all of them must be accounted for, especially if the intent is to build more units over time.

See Sections 2.4.1.5 and 2.4.2.2 below for additional information.

2.4.1.4 Cooling Water Availability

Unless some form of dry cooling is used, nuclear plants require significant amounts of cooling water. Ensuring the appropriate amount of water is available is a key step in evaluating a potential nuclear site (see Section 2.4.2). This can be complicated by the fact that data centers, if not using dry cooling, also use significant amounts of cooling water.

If the two are in proximity or otherwise intended to use the same water source, water availability for both must be confirmed. This confirmation includes ensuring not only that the amount of water is physically available, at all times of the year, over the life of the facilities, but also that it can be practically obtained via appropriate water withdrawal and discharge rights, including ensuring appropriate source water temperatures can be maintained for environmental purposes.

For these reasons, the cooling water requirements of distinct designs must be well understood. See Sections 2.5 and 3.2.2 of the EPRI *Single Site Evaluation Guide* (EPRI, 2024d) for more information.

2.4.1.5 Nuclear Safety and Security

2.4.1.5.1 Exclusion Area Boundary, Low Population Zone, and Population

Important considerations in selecting a nuclear design include the sizes of the nuclear plant's exclusion area boundary (EAB) and low population zone (LPZ), and the local area's population.

In the U.S., these principles are governed by 10 CFR 100.21, Non-Seismic Siting Criteria (U.S. NRC, 2013); 10 CFR 100.11, Determination of Exclusion Area, Low Population Zone, and Population Center Distance (U.S. NRC, 2017); and Regulatory Guide (RG) 4.7, General Site Suitability Criteria for Nuclear Power Stations (U.S. NRC, 2024g). These topics are discussed in detail in the EPRI *Siting Guide* (EPRI, 2022c).

As noted in 10 CFR 100.21, locating nuclear reactors in areas of lower population is preferred:

> *Reactor sites should be located away from very densely populated centers. Areas of low population density are, generally, preferred. However, in determining the acceptability of a particular site located away from a very densely populated center but not in an area of low density, consideration will be given to safety, environmental, economic, or other factors, which may result in the site being found acceptable.*

Per 10 CFR 100.11, the exclusion area (EA) is defined as an area around the plant of such size that people just outside the perimeter would not receive excessive radiation exposure during a postulated accident. The size of an EA is determined by the nuclear plant's design, including the total amount of fuel in the reactor, and it is required that the nuclear plant have control of all activities and people within the EAB. While it is technically possible for some or all of the data center property to exist within the EAB, this would mean that data center operations would be subject to some level of operational control by the nuclear plant. Therefore, it is recommended that the nuclear site be situated far enough away that the data center is not within the EAB.

The NRC defines the LPZ, like the EA, as an area outside which no person will receive an excessive dose from a radioactive cloud during a postulated accident. The LPZ is dependent on atmospheric dispersion and population characteristics, as well as plant design. The details of determining the size of the LPZ are beyond the scope of this report. It should be noted that in the most recent 2024 update to RG 4.7, the NRC has offered alternative calculations that could reduce the size of the LPZ. However, these calculations are very dependent on plant design and thus should be considered as part of the overall technology and design selection.

With respect to population, and as noted in RG 4.7:

> *Preferably, a reactor should be located so that, at the time of initial site approval and for about 5 years thereafter, the population density, including weighted transient population, averaged over any radial distance out to 20 miles (cumulative population at a distance divided by the area at that distance), is at most 500 persons per square mile. A reactor should not be located at a site where the population density is well in excess of this value.*

As with the LPZ, the NRC has recently included in RG 4.7 alternative guidance that can be used to potentially allow siting in more densely populated areas, but again, this is dependent on plant design. When performing initial evaluations, the EPRI *Siting Guide* recommends using a figure of 300 people per square mile (116 people per square km) to account for future growth.

Also, RG 4.7 notes that a nuclear reactor should generally be sited such that its distance to the boundary of the nearest densely populated center containing more than about 25,000 residents is at least one and one-third times its distance to the outer boundary of the LPZ. In the recent RG 4.7 update, the NRC has included alternative calculations that can provide for siting in a more densely populated area, but this is dependent on the plant design. For an early evaluation, the EPRI *Siting Guide* recommends using the distances listed in Table 5 below.

Table 5. Nuclear plant distances from population centers for early evaluation

Population Center Size	Minimum Distance from Nuclear Plant[28]
25,000	4 mi (6.4 km)
100,000	10 mi (16.1 km)
500,000	20 mi (32.2 km)
1,000,000	30 mi (48.3 km)

In 10 CFR 100, the NRC also notes that multiple reactors on a site could impact the EAB, LPZ, and population calculations. If it cannot be demonstrated that the individual reactors are fully independent in the case of an accident (i.e., an accident in one cannot initiate an accident in another, and there is not some other potential for a common cause failure), then these evaluations need to be based on all reactors together. This could be a concern, for example, when multiple SMRs are used to power a data center. Again, this is a function of the overall nuclear plant design and must be analyzed as part of the licensing process.

Population considerations are pertinent when considering a behind-the-meter or direct connection to the nuclear plant. The need to locate the nuclear plant in a lower-population area may be inconsistent with a need to locate the data center in a more developed area, with access to fiberoptic lines, telecommunications equipment, and end users.

Because many of these considerations are design specific, working with an OEM and AE on these evaluations is recommended.

[28] If the alternative RG 4.7 calculations are used, it may be possible to demonstrate that a reactor can be placed within a population center of 25,000 people or less.

2.4.1.5.2 Emergency Planning Zones

Nuclear plants must establish two EPZs, the *plume exposure pathway* EPZ and the *ingestion pathway* EPZ (U.S. NRC, 2020a). Within these areas, the plant must have protective action plans in place to limit radiation exposure to the public, including plans for sheltering, evacuation, and the use of potassium iodide pills as appropriate. Most important to a data center is the plume exposure pathway EPZ (typically referred to as just the EPZ).

For LLWRs, the NRC notes that the EPZ is generally an area with a radius of about 10 miles (16 km) from the nuclear plant. For gas-cooled reactors or those with power levels less than 250 MW thermal, the EPZ may be determined on a case-by-case basis (U.S. NRC, 2023a). Recently, the NRC has issued new guidance for SMR and AR designs (U.S. NRC, 2023g) that can allow a smaller EPZ, perhaps with a radius of around two miles (3.2 km) or as low as within the nuclear plant's site boundary, depending on the design (U.S. NRC, 2022c; U.S. NRC, 2019b).

Locating a data center within a nuclear plant's EPZ is not particularly a problem, but managing an EPZ can impose O&M costs on the nuclear plant and could slightly impact the operations of the data center. If the opportunity arises for a smaller EPZ, it is recommended that locating the data center outside the EPZ be considered.

As with the EAB, LPZ, and population evaluations, the size of the EPZ could be affected if multiple reactors are located on the same site.

2.4.1.5.3 Nearby Hazardous Land Use

When siting a nuclear plant, an evaluation must be done on *nearby hazardous land use*, which means that hazards within a certain distance of the nuclear plant must be evaluated to ensure they cannot impact the safety of the plant. As noted in the EPRI *Single Site Evaluation Guide* (EPRI, 2024d), the typical goal is to avoid locating the plant within 10 miles (16 km) of major airports and military installations and to identify hazardous facilities within 5 miles (8 km). Examples of hazardous facilities include industrial facilities, railroads, and gas pipelines. These distances are general considerations and can be changed if the nuclear plant can demonstrate these facilities will not impact the plant, particularly during some type of accident at one of the subject facilities, which will be dependent on the design of both the facility and the nuclear plant.

One might think a data center would not be a concern because it is mostly electronic equipment that would pose little hazard. However, concern could be raised by the backup generators, particularly fuel reserves, gas lines, or hydrogen fuel cells. Additionally, if a nearby data center's diesel generators were to operate for an extended period, their emissions might be a concern for nuclear plant control room habitability. This potential can be dependent on local atmospheric dispersion, which must be evaluated (U.S. NRC, 2021e). A large fire in the data center could pose similar problems.

2.4.1.5.4 Security

While data centers typically have extensive security protocols, these are generally centered around protecting the information to ensure its integrity (i.e., that it is not lost and that authorized users can access it when needed) and prevent it from being inadvertently exfiltrated (stolen or seen by those not authorized). Data centers in the U.S. and globally must adhere to certain laws, regulations, and standards, but many of those, particularly the standards, are voluntary. For examples, see *Data Center Regulations for the US* (Site24x7, 2024a) and *Data Center Security and Privacy Guidelines 101: Europe* (Site24x7, 2024b). Data center security will include both physical and cyber security protections.

Nuclear plant security is typically governed by the national regulator. In the U.S., the NRC has this responsibility (U.S. NRC, 2021c). Nuclear security is fundamentally meant to ensure that nuclear material is not stolen or diverted from civilian facilities for possible use for nefarious purposes and does not pose an unreasonable risk owing to radiological sabotage, and that the plant cannot be damaged in some way that could pose a hazard to the population or environment. Nuclear security includes physical protection, radioactive material control and accounting, and cyber security. Some of the physical security is specifically based on the design of the plant and should be evaluated during design selection, while other portions are managed through access control and staff background checks.

As with data centers, cyber security is a major concern for nuclear plants, and it is heavily overseen by regulators. In the U.S., nuclear plant cyber security is governed by 10 CFR 73.54, Protection of Digital Computer and Communication Systems and Networks (U.S. NRC, 2015), with guidance available in NRC RG 5.71, Cybersecurity Programs for Nuclear Power Reactors (U.S. NRC, 2023b), and NEI 08-09, Cyber Security Plan for Nuclear Power Reactors (NEI, 2010; NEI, 2018). Additionally, FERC has determined that NERC's Critical Infrastructure Protection Reliability Standards (NERC, 2024), including cyber security requirements, are applicable to certain portions of a nuclear plant. Implementation of the standards is overseen through a memorandum of agreement between the U.S. NRC and FERC (U.S. NRC/FERC, 2015). EPRI provides additional guidance for nuclear plant cyber security in *Cyber Security Technical Assessment Methodology: Risk Informed Exploit Sequence Identification and Mitigation* (EPRI, 2018).

When siting a new nuclear plant near a data center, it is highly recommended that security areas and physical buffer zones be accounted for, such that data center operations are not intermingled with nuclear plant security concerns and regulations. This is true for cyber security as well as physical security.

2.4.2 Siting

The deployment of nuclear is more tightly coupled to the physical site characteristics and technology selection than that of other generation 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, so an iterative process is often

required to identify the best site that supports a design that meets business objectives. If a desired site location is targeted, the site must be well characterized to identify available technologies that will be a good fit. This process will still involve some iteration because site characterization is normally completed in multiple stages, with the evolving information and data enlightening and evolving the technology and design selection process.

The EPRI *Siting Guide* (EPRI, 2022c) provides a regulation-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 a site to support a potential nuclear plant and the potential technologies and designs that could be deployed.

2.4.2.1 Site Identification

The EPRI *Siting Guide* (EPRI, 2022c) identifies a process for site identification and selection, including the identification of a primary site and alternative sites, which is a U.S. NRC requirement for obtaining a CP (U.S. NRC, 2016), early site permit (ESP) (U.S. NRC, 2007b), or combined license (COL) (U.S. NRC, 2007a). The identification of alternative sites may or may not be required by regulators in other locales but is nonetheless 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 identified in the NRC review guidance for consideration of alternative sites, including Section 9.3 of NUREG-1555 (U.S. NRC, 2007c; U.S. NRC, 1999) and Section 9.3 of RG 4.2 (U.S. NRC, 2018; U.S. NRC, 2022a). 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, RG 4.2, and COL/ESP-ISG-027 (U.S. NRC, 2014b) all provide guidance for selection of the ROI in various circumstances.

Development of the ROI is of key importance for deploying a nuclear plant at a specific location, such as in proximity to a data center. For regulated electrical utilities, the ROI is typically defined by the utility's service territory or the combined service territory of participants in a jointly owned project. Owner-operators developing a merchant plant or having other business objectives for the project must define their ROI based on those business objectives. For example, if the objective is to supply power to a data center, the ROI would allow for examination of sites near the boundaries of the desired data center's location. In accordance with COL/ESP-ISG-027, such a project 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.

Formal identification of alternative sites is one of the last steps in the full siting process and 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 of two early issues:

- The development of mission and business objectives and the ROI that meets those objectives is a needed early step in the process.
- While a specific 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 evaluating nuclear as a potential option at a targeted site need *not* look at alternative sites beyond the development of their mission and business objectives and ROI. However, moving beyond an initial review will require more in-depth analysis, and licensing, at least in the U.S., will require identification of alternative sites.

More details on single site analysis can be found in Section 2.2 of the EPRI *Single Site Evaluation Guide* (EPRI, 2024d) and the *EPRI Siting Guide*.

2.4.2.2 Land Area

A factor that must be addressed first is the site's available land area. The EPRI *Siting Guide* (EPRI, 2022c) identifies general land area requirements in Section 1.4.2. Table 6 below is excerpted from the EPRI *Siting Guide* for reference.

Table 6. Typical plant land area vs. size[29]

Size	Operating (MWt)	Output (MWe)	Typical Land Area Needed (acres [hectares])		
			Plant Footprint	Overall Site	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)

[29] Table 1-1 in the EPRI *Siting Guide* includes several footnotes that should be reviewed. In summary, consultation with an OEM and AE is recommended to obtain accurate values for the plant footprint, overall site, and additional construction area needed. Also, with SMRs, multiple units could be built on a single site, likely requiring more land, but not necessarily proportionally more.

The amount of land that is available for new development is a key factor in identifying potential technologies and designs and ensuring that a facility that meets the mission and business objectives can be deployed on the site. If the land cannot support a reactor (or multiple reactors) meeting the mission and business objectives, then either it cannot be used, or the mission and business objectives will need to be changed. Readers should review the EPRI *Siting Guide* for additional information regarding land area.

The size of a targeted site can vary significantly based on the overall residential, commercial, and industrial development density of the area, the amount of space owned by the owner-operator, and other factors. Some potential sites may already be industrialized but large enough that a portion may be cleaved off, allowing nuclear development to start while the facility continues to operate (e.g., if the new nuclear plant is intended to support a data center) or prior to decommissioning of the main facility and remediation of the land. In these cases, care should be taken to ensure that operation of the existing facility will not interfere with construction, and vice versa. Other industrialized sites may be perfectly sized but need prior decommissioning and remediation to allow space for any new development (see Section 3.1 of the EPRI *Single Site Evaluation Guide* (EPRI, 2024d) and Section 4 of the EPRI *Siting Guide* for more information on this subject).

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 an early evaluation for an already identified site can be found in Section 2.3.1 of the EPRI *Single Site Evaluation Guide*.

Table 6 above 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 adjacent to the actual plant site if there is an adequate transportation corridor that can support the 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* (EPRI, 2022c) 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.

2.4.2.3 Initial Site Characterization

The EPRI *Siting Guide* (EPRI, 2022c) provides 42 technical criteria needed to characterize a site for licensing. However, a limited set of 18 criteria (including land area) can be evaluated to identify the potential for a targeted site to support a nuclear plant, as noted briefly below and identified in detail in Table 3 of the EPRI *Single Site Evaluation Guide* (EPRI, 2024d):

- Land area
- Geology/seismology
- Cooling water supply

- Flooding
- Nearby hazardous land use
- Population
- Atmospheric dispersion
- Groundwater radionuclide pathway
- Disruption of important species/habitats—aquatic
- Disruption of important species/habitats—terrestrial
- Disruption of wetlands
- Land use
- Pumping distance
- Optional: railroad access, highway access, transmission, topography, and land rights

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. Evaluation of these limited criteria should be sufficient to provide early identification of a targeted site to determine if nuclear is a viable option. Readers should review the EPRI *Siting Guide* for more detail on these criteria and how to evaluate them.

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 or, unless the optional items are assessed, the cost to add transportation infrastructure, perform any topography grading, or install any needed transportation or transmission access. A more comprehensive evaluation will need to include these items.

Readers should refer to Section 2.3.1.3, Initial Site Characterization, of the EPRI *Single Site Evaluation Guide* for more detail on this subject.

2.4.2.4 Final Site Characterization

The abbreviated review of site characteristics discussed above can be a great tool for quickly evaluating the viability of a targeted site for nuclear deployment, but eventually the site will need to be fully characterized as defined in the EPRI *Siting Guide* (EPRI, 2022c) and local regulations. While this can technically wait until a design is fully identified and specific plans for deployment are made, waiting can significantly impact deployment schedules. Performing a more comprehensive analysis early and providing that information to potential developers can help identify development partners early. It is common, and in fact preferred, for site characterization and technology and design selection to use an iterative approach.

The targeted site could be greenfield land or could have been industrialized in some manner. Any site characterization data for previous industrialization may have value, but the data used for licensing a nuclear plant must meet nuclear quality requirements. These concepts are discussed briefly in Section 3.1 of the EPRI *Single Site Evaluation Guide* (EPRI, 2024d), and Sections 4.1 and 4.2 of the EPRI *Siting Guide* contain detailed information on how to qualify a site's level of industrialization and potential state of characterization. This information is important because how characterization data is collected and managed early can affect the project downstream.

Readers should also review Section 3.2 of the EPRI *Reactor Technology Assessment Guide* (EPRI, 2022a) for additional discussion on site selection and characterization.

2.4.2.5 Quicker Evaluation for Potential of Nuclear Deployment

Some organizations are looking for a more rapid assessment of the viability of a specific site to support a nuclear plant. The criteria identified in Section 2.4.2.3, which are already limited, were chosen to best reflect a reasonable due diligence process that balances a solid review against reasonable effort for a preliminary evaluation.

However, the review can be performed based on significantly fewer criteria, as discussed in Section 2.3.1.5 of the EPRI *Single Site Evaluation Guide* (EPRI, 2024d). These criteria are:

- **Geology/seismology**—A site that cannot meet the plant's seismic requirements for peak ground acceleration for a safe shutdown earthquake should be excluded.
- **Cooling water supply and pumping distance**—The unavailability of cooling water, typically within less than 5 miles (8 km), is considered exclusionary unless dry cooling is a clearly viable alternative.
- **Nearby hazardous land use**—It is recommended that areas subject to nearby hazardous land use criteria be excluded.
- **Population**—The exclusion of sites with more than about 300 people per square mile is recommended at this early stage.
- **Land use**—While land use issues can sometimes be mitigated, at this early evaluation stage excluding areas with impacts is recommended.
- **Land size**—If the site cannot meet at least the minimum land area requirements noted in Table 6, it should be excluded.

Performing this shorter and narrower evaluation can provide a quick assessment of the ability of any target site to support a nuclear plant. Care should be taken because this review will be extremely limited and can provide suboptimal results.

2.4.2.6 Other Siting Considerations

Potential owner-operators should also review the following sections of the EPRI *Single Site Evaluation Guide* (EPRI, 2024d) for additional considerations on siting:

- Section 2.4—Evaluate Site Infrastructure and Existing Assets
- Section 2.5—Obtaining Land, Transmission, Water Rights and Other Permits
- Section 2.7—Obtaining an Early Site Permit
- Section 2.9—Documenting the Review
- Section 3.1—Previously Industrialized Sites
- Section 3.3—Permits

While these topics are specific to certain situations, they may provide valuable guidance on the overall process of siting a new nuclear plant.

A few additional siting considerations could also be pertinent when deploying a nuclear plant near a data center, as discussed below.

2.4.2.6.1 Noise

Noise levels must be evaluated for both construction and operations. For example, when developing an environmental report (ER) for a nuclear plant in the U.S., NRC regulations require that noise levels be addressed for potential impact on workers, the public, and wildlife (U.S. NRC, 2018; U.S. NRC, 2022a; U.S. NRC, 1999; U.S. NRC, 2007c). In the U.S., allowable noise levels are typically set by state or local regulations and may vary between day and night.

Noise is not usually a significant issue for nuclear plants. Construction noise is well understood and temporary and can be reduced at night if needed. During operations, nuclear plants are typically quiet (for industrial facilities), with the largest component noise coming from cooling towers, which typically operate at about 60 dBA. Typically, levels below 55–65 dba near residences (U.S. NRC, 1999; U.S. NRC, 2007c) are considered a small impact for siting.

While noise levels inside an operating data center can reach 90 dBA or more (C&C Tecnology Group, 2024), the noise levels outside will typically be less. However, noise can still approach levels between 55 and 85 dBA. As with nuclear plants, noise is primarily driven by the cooling system. While noise levels are not additive, there is some reinforcement (e.g., adding two 60 dBA sources will increase the overall sound level to about 63 dBA (PressBooks, 2024)), and this increase could cross over governing regulations.

While noise issues are not limited to data centers, there has recently been much community concern about noise from these centers, and data center organizations should proactively design the data centers to minimize noise and work with the community to ensure acceptance (Data Center Knowledge, 2023a; Data Center Knowledge, 2022; Data Center Acceleration, 2023).

2.4.2.6.2 Visual Impacts

The visual impact of a nuclear facility from a land use perspective is an important consideration. For example, when developing an ER for a nuclear plant in the U.S., NRC regulations require that land use be addressed for potential visual impact to the public, particularly when considering visual resources, such as federal, state, local, or tribal parks and natural resources (U.S. NRC, 2018; U.S. NRC, 2022a; U.S. NRC, 1999; U.S. NRC, 2007c). Simply put, those viewing precious natural resources typically don't want to see a large industrial site in the background, ruining the natural view.

Nuclear plants will often be sited behind hills and tree lines to limit such impact, and this can drive plant design as well. For example, mechanical cooling towers may be needed instead of natural draft towers because, while mechanical cooling towers are typically less efficient, they are much shorter and can be hidden from view. See the North Anna Unit 3 COL (Dominion Energy, 2016) for an image showing such a case.

The important point to consider regarding visuals is that data centers are becoming taller and more sprawling (Data Center Dynamics, 2019; Dgtl Infra, 2023). If a data center is constructed in proximity to a new nuclear plant, the visual impacts of both may become pertinent in siting.

2.4.2.6.3 Phased Construction

It is common to build data centers using a phased deployment approach, building the infrastructure (i.e., buildings and other equipment) out over time. This gives the data center facility the flexibility to expand as demand increases and funding becomes available (Dgtl Infra, 2023). One potential promise of SMRs is that they can be built out over time for the very same reasons.

While it is possible to build the data center and the nuclear plant near each other, even over time, it is important to assess, manage, and limit the logistical and financial impacts of construction on both facilities, and potentially the public.

Any known intention to build out the infrastructure of either facility over time will need to be addressed up front. The evaluation needs to identify future land for development, including areas such as construction laydown areas and traffic access. From the nuclear plant's perspective, any nearby construction could be considered a hazardous land use and would need to be evaluated (see Section 2.4.1.5.3). If these issues are not addressed up front, then they will need to be evaluated later before activities begin, which could impact schedule and cost.

2.4.3 Regulatory Engagement

2.4.3.1 Nuclear

The development of a new nuclear facility will require significant interaction with the nuclear regulator. The EPRI *NPTA* report (EPRI, 2022b) discusses nuclear regulator engagement, but there are 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. It is important to understand the regulator's process and schedule up front so that the schedule can be accommodated along with the owner-operator's need date for the facility to be online and generating power.
- The intent to develop a nuclear plant on a specifically identified site can introduce novel issues for the regulator. Early interactions with the regulator can be helpful, even if informal. It is important to identify the regulator's concerns as early as possible.
- Globally, the regulatory environment is much less mature for ARs than for LLWRs. This can impart risk to schedule and cost. If possible, there should be three-way engagement between the owner-operator, potential OEMs, and the regulator, due to the relationships among design, siting, and licensing.

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, 2007a)

Each of these processes comes with its own set of opportunities and challenges. In addition, the U.S. NRC is working on a new 10 CFR Part 53 (U.S. NRC, 2021b) process specifically intended for ARs. As noted in Power (Power, 2024):

> *Part 53, as prescribed by NEIMA [Nuclear Energy Innovation and Modernization Act], is meant to offer a "voluntary" alternative to advanced nuclear applicants under a framework that would be technology-inclusive (applicable to all reactor technologies); risk-informed (using information from risk assessments to focus safety analyses on important issues); and performance-based (to ensure plants are regulated based on how they perform and not just how they are designed).*

However, 10 CFR Part 53 is still a work in progress, with a final rule expected by the end of 2025, and will not be discussed further here.

In general, the 10 CFR 50 process includes separate development of a 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 AR developers, such as Kairos and Terra Power (see Section 2.4.1). The 10 CFR 52 process includes only a single COL but is based on either an essentially complete OEM design that has obtained a design

certification (DC) or a partial design that has received a standard plant approval. As an example, a NuScale design has recently received a DC (U.S. NRC, 2023e) and thus is a suitable candidate for the 10 CFR 52 process.

Section 2.7 of the EPRI *Single Site Evaluation Guide* (EPRI, 2024d) notes that an organization considering nuclear should consider the development of an ESP (U.S. NRC, 2007b). The ESP is technically part of the 10 CFR 52 regulations, but it can support both a 10 CFR 50 CP and a 10 CFR 52 COL. Nuclear site development cannot begin without an ESP, COL, or limited work authorization, which can be issued to ESP, COL, or CP applicants (U.S. NRC, 2019a). The effort to develop and obtain an ESP can be considerable. Working with the regulator in advance of, and during, the process is crucial to minimize costs and schedule.

The main 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. It 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.

2.4.3.2 Utility Commission Engagement

In the U.S., it will be necessary to engage with the 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 U.K. (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.

If the prospective new nuclear plant owner-operator is a utility, it would already have a relationship with one or more state PUCs and understand the basic rules, requirements, and regulations for generating electricity and putting it on the grid.

As with the nuclear regulator, there is a need to begin engagement with the PUC early in the process when considering the development of new nuclear. In regulated states, the owner-operator will need to specifically work with the local PUC to understand how the costs of new plant development will be covered. Issues that need to be addressed include the following:

- Can, or should, any decommissioning costs be covered 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 PUC will also want to understand the need for power as identified by the owner-operator, the timing for power generation, and the need for new or upgraded transmission lines.

The PUC will also need to issue a certificate of public convenience and necessity (CPCN). Eleven U.S. states, as of September 2023 (NCSL, 2023),[30] have moratoriums against new nuclear development, and some of these moratoriums are based on laws that prevent the issuance of a CPCN. Often the 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 need to engage not only with their PUCs, but also with their state legislatures before embarking on a new nuclear development program.

Assuming the owner-operator is a utility, a key need in engaging with most PUCs (and other regulators) will be its IRP. As of 2021, 35 U.S. states require the development of an IRP (PNNL, 2021). IRPs are typically updated every two to five years and have planning horizons of 10 to 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.

For a utility considering development of new nuclear, the IRP would need to identify the time frames for retiring generation and options for new generation. The owner-operator would need to identify in its plan how new nuclear development fits and makes sense. Different utility commissions will have different requirements for their jurisdictions, but typically the utility will need to demonstrate a positive value for the new nuclear plant in its 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.

If a non-utility adds a new power plant to the grid, perhaps for a behind-the-meter connection (see Section 2.3.1.3) for a data center, then additional power provided to the grid and any needed power from the grid will still require interaction with the local utility and the PUC.

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, in recent history, nuclear development costs have well exceeded original estimates in some cases (Eash-Gates, et al., 2020). Additionally, many AR designs are still in a state of development such that confidence in their costs to deploy and operate is low (ETI, 2020). The owner-operator will want to ensure that due diligence is done with potential OEMs to get the best estimate for costs. Refer to the EPRI *Reactor Technology Assessment Guide* (EPRI, 2022a) for more information on evaluating OEM designs and costs.

[30] As of December 2023, Illinois has passed legislation reversing its moratorium starting in 2026 (AP, 2023). Also, as of 2022, Connecticut's moratorium no longer applies to the existing nuclear plant.

Utilities in U.S. states and other locales that do not generate formal IRPs will typically need to provide similar information to their regulators. If nothing else, they will need to do so internally for their own, or their investors', needs.

2.4.3.3 Environmental Protection

In the U.S., the U.S. Environmental Protection Agency (U.S. 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 originate with those governments, while others may be delegated to them by the EPA. Similar examples outside the U.S. are the U.K.'s Environment Agency (Environment Agency, 2023) and 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 of the EPRI *Coal to Nuclear* report (EPRI, 2023).

Of key importance for developing new nuclear is the relationship and engagement with environmental protection regulators during the licensing process. The engagement process will be different in each locale, but in the U.S., it is effectuated through the ER developed 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 required to comply with the National Environmental Policy Act (NEPA) (U.S. EPA, 2024), which requires federal agencies to assess the environmental effects of their proposed actions prior to making decisions.[31] 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 supplementary NEPA procedures. These procedures vary across agencies because they are tailored for the specific mission and activities of each. 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 include any other federal agency with special expertise with respect to any environmental issue. For example, the NRC has a memorandum of

[31] The U.S. administration has recently updated NEPA regulations, with a final rule issued in May 2024 (U.S. CEQ, 2024). These changes are intended to streamline and accelerate environmental reviews, promote early public engagement, and ensure long-term climate trends and environmental justice are addressed. Implementing agencies, such as the NRC, will need to modify their internal policies and procedures to address these changes. One such possible outcome is the issuance of an EA in lieu of an EIS, which was completed for the Kairos Hermes 2 test reactor (U.S. NRC, 2024b; U.S. NRC, 2024d).

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 United States" (U.S. EPA, 2023).

To support the NRC in development of the EIS, 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, 2007c; U.S. NRC, 1999)
- RG 4.2, Revision 3, 2018, Preparation of Environmental Reports for Nuclear Power Stations (U.S. NRC, 2018)
- RG 4.7, Revision 4, 2014, General Site Suitability Criteria for Nuclear Power Stations (U.S. NRC, 2024g)
- COL/ESP-ISG-026, Interim Staff Guidance on Environmental Issues Associated with New Reactors (U.S. NRC, 2014a)
- COL/ESP-ISG-027, Specific Environmental Guidance for Light Water Small Modular Reactor Reviews, Interim Staff Guidance (U.S. NRC, 2014b)
- Also see NUREG-2249, Proposed Rule: Advanced Nuclear Reactor Generic Environmental Impact Statement (U.S. NRC, 2021d) and draft RG DG-4032 (RG 4.2 Rev 4) Preparation of Environmental Reports for Nuclear Power Stations (U.S. NRC, 2022a).

As noted in Section 2.4.2.1, this guidance requires the development and evaluation of alternatives, including alternative generation options and alternative sites.

Note: The above statement is critical for organizations looking to deploy a nuclear plant on a specific site in support of another operation, such as a data center. The owner-operator will need to demonstrate why building a nuclear plant for that application, at that location, is environmentally superior to other generation options, such as solar or gas, as well as the option to not build at all and simply connect the data center to an existing grid (U.S. NRC, 2014a; U.S. NRC, 2024g). Compared to solar or wind, the actual nuclear power plant footprint and associated land disturbance is significantly smaller for similar generation capacity.

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

2.4.4 Cost and Other Economic Evaluations

As part of the decision-making process, the owner-operator should perform a cost analysis. This includes an evaluation of costs for internal development and project management; support for an OEM or suppliers through development and licensing (if applicable); site characterization and licensing; construction and operating licensing; engineering, procurement, and construction; O&M; fuel; and decommissioning. As noted in the EPRI Reactor 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 require more effort in a Techno-Economic Assessment (TEA) approach versus just a cost estimating exercise.*

There are several TEA methods available, but all address key concepts: understanding and evaluating economic status, understanding maturity and remaining effort, and understanding uncertainty and risk. See Section 3.5 of the EPRI *Reactor Technology Assessment Guide* (EPRI, 2022a) for more information.

Any organization will need to ensure that it evaluates all costs associated with the project. These include costs for any decommissioning and remediation of the site prior to nuclear construction, if applicable. It is beyond the scope of this report to describe all the scenarios for new development costs and financing, but it is important to address all costs that will affect the organization. In an early evaluation, it will not be possible to accurately assess the actual costs; rather, wide-ranging estimates will need to suffice. However, it is possible, with enough due diligence, to assemble a good list (i.e., work breakdown structure) of the cost account items. Effort should be made to understand the range (+/-) of those estimates. See *A Generalized Nuclear Code of Account for Cost Estimation Standardization* (EPRI 3002028937) (EPRI, 2024a) and *Meta-Analysis of Advanced Nuclear Reactor Cost Estimations* (INL, 2024b) for additional information.

Note: Economic evaluations typically include a comparison of cost against revenue. It is beyond the scope of this report to discuss potential revenue from a new nuclear plant; any utility would understand how this would be calculated for its situation (e.g., regulated or not), and the evaluation may differ when providing power to another self-owned facility, such as a data center. 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.

2.4.5 Public Perception and Acceptance

The development of a nuclear plant can significantly affect the local community, with its citizens having varied opinions on the subject. For example, some may view nuclear power favorably, others may have safety concerns, and a few may have mixed opinions, viewing the clean energy as a positive, but waste as a negative.

Therefore, it is important that the owner-operator work in concert with the local community, without assuming the degree to which that community embraces nuclear. The experience of the community with the data center organization or other industrial organizations and whether or not they were considered good neighbors can impact public acceptance. Further, while the local community may specifically embrace a new nuclear plant, surrounding communities, including nearby Indigenous communities, may have different opinions.

Appendix J of the EPRI *Siting Guide* (EPRI, 2022c) 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 and other disadvantaged communities (Good Energy Collective, 2021; U.S. Administration, 2023; U.S. DOE, 2024b). Owner-operators should understand the options, including those available from local business councils and economic development agencies, and use them as applicable or guide the stakeholder communities to them for their own use.

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 supportive community is a great asset in deploying new nuclear. 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. 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. Beyond potential tax revenue, a key benefit most communities expect is an increase in jobs. However, simply stating statistics, like the number of new jobs, may or may not address the benefits the community is seeking.

A report by Idaho National Lab (INL), done in collaboration with Argonne National Lab and Oak Ridge National Lab for the Department of Energy (U.S. DOE, 2022), takes an in-depth look at potential community benefits of building a nuclear plant in an existing coal community. It 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

While the INL report specifically covers repowering coal plants with nuclear, it demonstrates that all three types of jobs would be expected to increase for the cases studied, and this would be typical for any community where a new nuclear plant is deployed. See Section 3.7 of the EPRI *Coal to Nuclear* report (EPRI, 2023), which contains additional information on the local workforce that, while specifically targeted at repowering coal plants with nuclear, may provide value to the reader.

While data centers can bring significant positive benefits to a community via an increase in tax base and infrastructure development, they typically do not create a substantial number of jobs for the local community's residents. They typically only employ 20 to 50 people, and many of the jobs require very specific skills that may not be available in the community without training (TechRepublic, 2016; Area Development, 2015). However, building a data center in tandem with a nuclear plant in a community can significantly increase the available jobs, and doing so at a retired coal facility can provide opportunities for local workers who already have many of the needed qualifications.

However, even a demonstrated increase in jobs may not be sufficient to earn a community's trust, and the owner-operator must ensure it has a full understanding of the community's goals and concerns. This requires the appropriate level of communication and engagement.

Readers should review Section 2.8, Community Outreach, and Section 3.4, Community Engagement, of the EPRI *Single Site Evaluation Guide* (EPRI, 2024d) for more information on the subject, particularly the care an organization should take to understand the community, its goals, and the impact a new nuclear plant will have.

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

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