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Navigating Integration:

Key Challenges for Data Centers, Nuclear Stakeholders, And Utility Operators

Center for Securing Digital Energy Technology

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EXECUTIVE SUMMARY

The rapid expansion of data centers, driven by the exponential growth in data-processing and storage needs, presents significant challenges and opportunities for various stakeholders, including data center developers, nuclear energy providers, and utility companies. Data centers are projected to consume 6.7–12% of United States (U.S.) electricity by 2028,[a] driven by artificial intelligence (AI) and cloud-computing demands. Nuclear energy offers reliability and dispatchable baseload power, but data centers need power now while nuclear still needs time to address siting, fast power ramping, and regulatory hurdles. Utilities must keep pace with the unprecedented acceleration of large load interconnection requests and urgently adapt to high-density loads while maintaining grid stability, reliability, and accelerating interconnection timelines. This report dives into these challenges and proposes key collaboration strategies to streamline data center integration that aligns with recent federal initiatives like America's AI Action Plan and related executive orders[b] that emphasize the importance of data center growth, nuclear energy expansion, and maintaining a competitive edge in the global AI race.

Key Takeaways for Individual Stakeholders

- **Data Centers** need rapid deployment, high uptime, and reliable high-quality power, but face grid congestion, a complex regulatory landscape, and power-infrastructure delays. Data centers need robust and flexible power-procurement strategies, often involving multiple power sources, backup generators, and uninterruptible power supplies (UPSs) to ensure uninterrupted operation.
- **Nuclear Power** is emerging as a compelling option to provide consistent, high-capacity electricity for data centers. Nuclear plants offer firm power but face challenges, including modernizing and expanding nuclear capacity, ensuring safety and regulatory compliance, integrating with other solutions to address dynamic power needs of data centers, and addressing public perceptions.
- **Utilities** are responsible for maintaining grid stability and reliability while accommodating the rapid deployment of data centers. They are challenged by fast-changing demand profiles, the lack of validated data center load models for planning and operations, and the risk of large load loss to the grid.

Cross-Sector Challenges and Opportunities

Based on the individual challenges for these key stakeholders, the report identifies key cross-sector challenges and opportunities to collaboratively support rapid deployment of large loads that, in turn, support objectives to increase grid capacity and provide supporting infrastructure to ensure the U.S. remains competitive in AI innovation. These challenges and opportunities are summarized in Table ES-1.

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[a] Arman Shehabi et al. "2024 United States Data Center Energy Usage Report," Lawrence Berkeley National Laboratory, Berkeley, CA LBNL-2001637. Dec. 2024. DOI: 10.71468/P1WC7Q.

[b] The White House. 2025. "America's Action Plan." https://www.whitehouse.gov/wp-content/uploads/2025/07/Americas-AI-Action-Plan.pdf.

Table ES-1. Shared challenges and collaborative opportunities of nuclear integration with data centers.

Category	Shared Challenges	Collaborative Opportunities
Infrastructure & Siting	Land use and zoning for data centers and nuclear Queues for transmission and generation, along with long lead times for associated infrastructure	Co-siting of nuclear energy and data centers offers several efficiencies On-site power for data centers can enhance resilience for critical loads and provide grid services Joint siting of nuclear power and data centers alleviates pressure on strained power systems. Nuclear plants and data centers can work together to reduce water consumption
Grid Integration & Load Management	Load variability from data centers Long interconnection queues Nuclear power's limited fast-ramping capability	Hybrid power-purchase agreements and load-following models Data centers as flexible grid assets Joint planning for infrastructure alignment
Cultural & Operational Differences	Misaligned planning horizons and risk tolerance Differing regulatory and decision-making styles	Joint planning forums and liaison roles Flexible contracting and shared risk frameworks Cross-sector training and communication
Land Use & Public Perception	Nuclear challenges with public perception and safety concerns Data center noise, land use, and low job creation	Unified community engagement Buffer zones for data centers and nuclear campuses Economic development and job creation Transparency and engagement
Regulatory & Policy Alignment	Fragmented oversight across sectors Long licensing timelines for nuclear Cybersecurity and data protection	Fast-track permitting and regulatory sandboxes Market participation for co-sited assets Joint workforce development initiatives Shared governance structures

Category	Shared Challenges	Collaborative Opportunities
Funding, Investment, and Market Participation	High capital costs and investor caution Justification of expenditures to ratepayers	New market participation strategies for modern assets Tech sector investment in nuclear Innovative financing and tax incentives
Stakeholder Coordination	Siloed approaches to joint challenges Lack of government direction	Engagement with policymakers and regulators Local community outreach Engineering and consulting firms as integrators Regional energy hubs and advisory councils

Calls to Action

This report recommends proactive collaboration, policy innovation, and shared infrastructure planning to ensure the U.S. remains a global leader in AI, energy resilience, and economic competitiveness. Additional research is needed to investigate hypotheses from this report that warrant further investigation.

Nuclear-data center collocation requires collaborative planning and communication, but has the potential to simplify permitting, enhance safety, and reduce costs, thus accelerating projects.

Collocating nuclear and data center facilities can leverage the steady high power of nuclear generation to serve base loads of data centers. Faster interconnection timelines and reduced costs may be achieved through careful coordination with utilities and treatment of the facilities as a joint portfolio. Exactly where the cost savings are, how safety is impacted, and how permitting and licensing can be accelerated are still open questions. Providing concrete estimates of cost and time savings can identify the most beneficial integration strategies for these facilities. Differences in development timelines, regulatory oversight, and operational cultures can create friction unless addressed through joint planning frameworks and shared risk assessments. When executed effectively, collocation can accelerate project timelines by aligning infrastructure investments and streamlining permitting.

Policy and regulatory alignment are needed to address cultural and operational differences and changes will be driven by public-private partnership.

The current regulatory environment often reinforces siloed decision-making across sectors. Data center developers, utilities, and nuclear operators operate under different mandates, risk tolerances, and planning horizons. Bridging these divides requires policy reforms that incentivize integrated planning and clarify roles in large load interconnection processes. Public-private partnerships will be essential to drive these changes, enabling stakeholders to co-develop regulatory pathways, pilot new coordination models, and align incentives for shared infrastructure development. While data center, nuclear, and utility stakeholders have individual and joint challenges, a fourth intermediary stakeholder could accelerate nuclear data center deployment. This intermediary could be a company or a consortium of the other stakeholders. Knowledge sharing and collaboration among stakeholders through this intermediary could efficiently address common challenges confronted by each organization and bridge the gap with expertise spanning across technology areas. Department of Energy (DOE) laboratories can support collaboration by bringing stakeholders together and helping establish consortia. Surveying stakeholders to identify how an intermediary could facilitate stakeholder collaboration and remove barriers to deploying nuclear data centers would help to define the role of partnerships and the opportunities for policy alignment.

Data Centers Can Become Grid-Stabilizing Assets Through Operational Integration and Policy Innovation

As data centers grow in scale and sophistication, they have the potential to evolve from passive energy consumers into active grid participants. When collocated with nuclear generation or equipped with advanced energy-management systems, data centers can provide valuable grid services such as frequency regulation, voltage support, and demand flexibility. However, realizing this potential requires new operational models that treat data centers as dispatchable or semi-dispatchable loads, capable of modulating demand in response to grid conditions. Collaboration among stakeholders could also help to reduce risk for all parties. For example, risk-sharing strategies like ordering multiple nuclear power plants among multiple data centers could limit the risk exposure for each collaborator. Success in this area also demands policy innovation, such as updated interconnection standards, compensation mechanisms for grid services, and regulatory recognition of hybrid nuclear-load configurations. By enabling data centers to operate as grid-stabilizing assets, stakeholders can unlock new pathways for reliability, resilience, and dispatchability.

Technological innovations and advancements are needed to gain efficiencies in integrated-energy-system deployment.

Data centers can impose challenges on grid operations, but collaboration among stakeholders can ensure equipment longevity, resource adequacy, and grid stability. Pairing nuclear power with energy storage and other resources in an integrated energy system can help mitigate load volatility concerns and provide backup power to the data center. Existing planning tools and modeling frameworks are not well suited to capture the dynamic, high-density load profiles of modern data centers or the operational characteristics of advanced nuclear technologies. Innovations in grid modeling, load forecasting, and integrated resource planning are needed to support more accurate and actionable decision-making. This includes the development of secure data-sharing protocols, modular planning tools, and simulation platforms that can evaluate the co-optimization of generation, transmission, and load. These advancements will be critical to reducing uncertainty, improving grid reliability, and enabling more strategic infrastructure investments.

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FIGURES

TABLES

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ACRONYMS

AI	Artificial intelligence
CFR	Code of Federal Regulations
CLM	Composite load model
CPU	Central processing units
DOE	U.S. Department of Energy
EPRI	Electric Power Research Institute
ERCOT	Electric Reliability Council of Texas
FERC	Federal Energy Regulatory Commission
GPU	Graphics processing units
IEEE	Institute of Electrical and Electronics Engineer
INL	Idaho National Laboratory
IRP	Integrated resource plans
MW	Megawatt
NERC	North American Electric Reliability Corporation
NRC	Nuclear Regulatory Commission
PPA	Power purchase agreement
PSLF	Positive Sequence Load Flow
PSSE	Power System Simulation for Engineering
PUC	Public utility commissions
PUE	Power-utilization effectiveness
SMR	Small modular reactors
UPS	Uninterruptible power supply
U.S.	United States
WECC	Western Electricity Coordinating Council

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Navigating Integration: Key Challenges for Data Centers, Nuclear Stakeholders, and Utility Operators

1. INTRODUCTION

The demand for reliable and scalable power solutions has become a critical concern for numerous industries. Among these, data centers stand out as major consumers of electricity, given their role as the backbone of the modern digital economy. The rapid expansion of data centers, driven by the exponential growth in data processing and storage needs, presents significant challenges and opportunities for various stakeholders, including data center developers, nuclear energy providers, and utility companies. This report highlights these challenges and proposes solutions that align with recent federal initiatives emphasizing the importance of data center growth, nuclear energy expansion, and maintaining a competitive edge in the global artificial intelligence (AI) race.

The integration of data centers with utility and nuclear energy infrastructure presents a complex landscape of challenges. These include mismatches in development timelines, regulatory fragmentation, and divergent risk tolerances across sectors. Data centers often operate on aggressive buildout schedules driven by AI and cloud demand while utilities and nuclear developers face longer permitting and construction cycles. Additionally, grid interconnection queues, cybersecurity concerns, and evolving federal and state policies introduce further uncertainty. These challenges are compounded by the need to balance reliability, resilience, affordability, and economic competitiveness in an environment of accelerating load growth.

Recent federal directives have underscored the critical role of data centers in national security and economic prosperity, prioritizing the rapid and efficient buildout of AI-centered data centers. Addressing the challenges outlined in this report will directly support these objectives by ensuring that data centers can be developed swiftly and reliably. Additionally, federal initiatives on nuclear energy growth set forth a bold vision to modernize nuclear energy regulation, streamline reactor testing, and significantly increase nuclear capacity by 2050. By overcoming the hurdles faced by nuclear stakeholders in powering data centers, collective action from nuclear, data center, and utility stakeholders can contribute to the realization of these ambitious goals. This alignment not only supports the expansion of reliable energy sources but also enhances the resilience and efficiency of data center operations. Last, strategic plans to maintain U.S. technological dominance, like America's AI Action Plan,[1] emphasize the importance of AI infrastructure. These plans include specific actions to expedite the development of data centers and integrate advanced energy solutions. By addressing the challenges identified in this report, we can ensure that the U.S. remains at the forefront of AI innovation, leveraging cutting-edge technologies to bolster national security and economic competitiveness.

The primary objective of this report is to identify and analyze the challenges associated with facilitating large load growth from the perspectives of nuclear operators, data center managers, and utility stakeholders, highlighting how each of these roles interacts and how collaboration among stakeholders can enable rapid large load growth and secure the reliable integration of nuclear energy to help power this change. Each stakeholder group brings distinct technical and organizational characteristics to the table. Data centers prioritize speed, scalability, and digital infrastructure resilience, often leveraging modular designs and distributed energy resources. Utilities, by contrast, are tasked with maintaining grid stability and regulatory compliance while managing long-term capital investments. Nuclear generators contribute high-capacity, firm baseload power, but face unique licensing, safety, and public perception hurdles. Understanding these differences is essential to identifying where alignment is possible—and where targeted coordination mechanisms are needed to bridge gaps in planning, investment, and operational integration. By presenting an overview of the roles, perspectives, and insights of each stakeholder group, this report aims to foster a deeper understanding of the critical issues at play and further seeks to highlight potential opportunities for collaboration and offer strategic recommendations to overcome common obstacles.

To meet national objectives for AI leadership and grid modernization, stakeholders must move beyond siloed approaches. This report calls for the establishment of cross-sector integration frameworks that enable shared planning, joint risk assessments, and streamlined regulatory pathways. By fostering early engagement between data center developers, utilities, and nuclear stakeholders, the U.S. can accelerate the deployment of secure digital infrastructure. The time to act is now, before fragmented decision-making locks in inefficiencies that could undermine both energy and technology goals.

1.1. Stakeholder Analysis

Stakeholder analysis forms a crucial component of this report. By examining the key players involved—data center owners, nuclear energy providers, and utility operators—we delineate their respective roles and perspectives, encapsulating the diverse inputs and feedback received from industry experts. This analysis serves as a foundation for the subsequent sections, which delve into the specific challenges faced by each group, as well as the cross-stakeholder issues that necessitate a collaborative approach. A summary of stakeholder roles and responsibilities is presented in Table 1.

Table 1. Stakeholder roles and responsibilities.

Stakeholder	Roles	Responsibility	When They Are Involved	Needs to Work with
Data center owner	Capital provider, long-term operator	Define performance requirements, secure financing, ensure uptime and return on investment	Early (site selection, power procurement) through operations	Campus Developer, Utility, Grid Operator, Nuclear Owner/General Operator
Data Center Campus Developer	Project manager, infrastructure integrator	Oversee site development, permitting, interconnection, and construction	Early to mid-stage (site planning to commissioning)	Data Center Owner, Utility, Grid Planner, Local Authorities
Nuclear Owner/General Operator	Power generator, reliability provider	Provide firm, dispatchable power; manage licensing and safety compliance	Mid-stage (power procurement) through long-term operations	Utility, Grid Operator, Data Center Owner, Regulators
Grid Operator	Real-time system balancer, reliability coordinator	Maintain grid stability, manage interconnection and dispatch	Mid to late stage (interconnection, operations)	Utility, Nuclear Owner/General Operator, Data Center Developer, Grid Planner

Stakeholder	Roles	Responsibility	When They Are Involved	Needs to Work with
Grid Planner	Long-term capacity and transmission planner	Forecast load growth, plan infrastructure upgrades, assess system impacts	Early to mid-stage (planning and feasibility)	Utility, Grid Operator, Data Center Developer, Regulators
Utility Regulator	Policy enforcer, rate and reliability overseer	Approve infrastructure investments, set tariffs, ensure compliance with public interest	Throughout (policy setting, rate cases, project approvals)	Utility, Grid Planner, Nuclear Owner/General Operator, Data Center Owner

The successful facilitation of large load growth requires robust collaboration among these key players, as visualized in Figure 1. Data centers, with their escalating energy needs, see opportunities through partnership with nuclear stakeholders to provide safe, reliable, and abundant energy. Nuclear providers often rely on utility interconnections and robust demand for their power output. Meanwhile, utility operators must ensure the seamless integration of new loads and generators into the grid, maintaining stability and reliability and meeting regulatory standards. The interdependencies between these groups underscore the importance of strategic partnerships and coordinated efforts to address the multifaceted challenges that will arise.

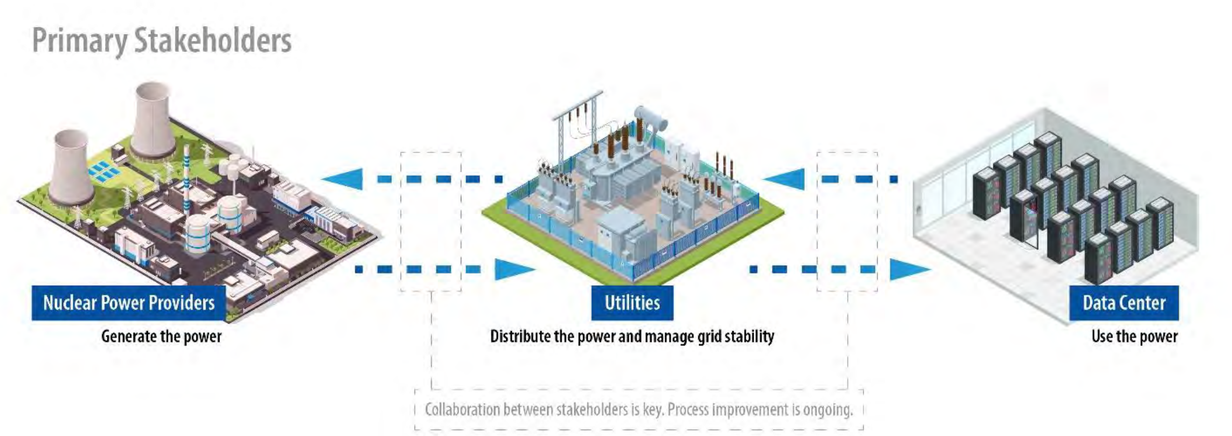

Figure 1. Nuclear power providers, utilities, and data centers must work together to achieve grid stability and meet data centers' energy needs.

Through exploration of the challenges faced by each of these stakeholders, the interdependencies between them, and the opportunities for cross-sector collaboration, we will identify key hypotheses that need further investigation through research and industry evaluation.

1.1.1. Data Center Campus Developers

Developers of data center campuses play a central role in the evolving digital infrastructure ecosystem, managing facilities that are critical for data processing, storage, and AI development. Reliable and scalable power supply has emerged as the most-significant constraint identified by data center developers in enabling timely and scalable data center deployment. Designing data centers requires addressing issues related to power, such as the need for uninterrupted power, backup power in case of grid unavailability, power quality, and cooling requirements, while minimizing costs spent on energy, to include selling energy or power services back to the grid. Owners must also navigate regulatory landscapes and ensure that their facilities can adapt to evolving technological advancements.

1.1.2. Nuclear Energy Providers

Nuclear energy providers are expected to play a crucial role in supplying firm power to data centers. Their main challenge is to modernize and expand nuclear capacity, along with other connected resources, to meet the high uptime requirements and ramp rates of data centers while ensuring safety and regulatory compliance. Data centers demand uptimes from 99.671–99.995%, depending on their classification,[2,3] which nuclear plants, with their high capacity factors and low forced outage rates, are well-suited to provide. However, the rapid changes in data center power demand pose a challenge because nuclear plants are not traditionally designed to adjust their output quickly. System integration strategies, such as energy storage or alternative energy sources, are essential to balance generation and load dynamically, while allowing nuclear to serve baseload. Additionally, siting nuclear plants for onsite generation can reduce transmission costs, but is limited by stringent siting requirements. Safety and security concerns, including physical- and cybersecurity, must be addressed, especially when directly coupling data centers with nuclear plants. Additional considerations for integrating nuclear power into the grid to support data centers involves overcoming public perception, streamlining reactor testing, and developing advanced-reactor technologies. Small modular reactors (SMRs), as seen in Figure 2, are a promising solution, offering a scalable and flexible approach to nuclear power generation, but no SMR technologies are ready to commercially deploy immediately while data centers are being built now. Gigawatt-scale reactors are more mature and can be deployed more readily. Providers must also collaborate with data center developers to align energy supply with demand, ensuring that the power generated is efficiently utilized.

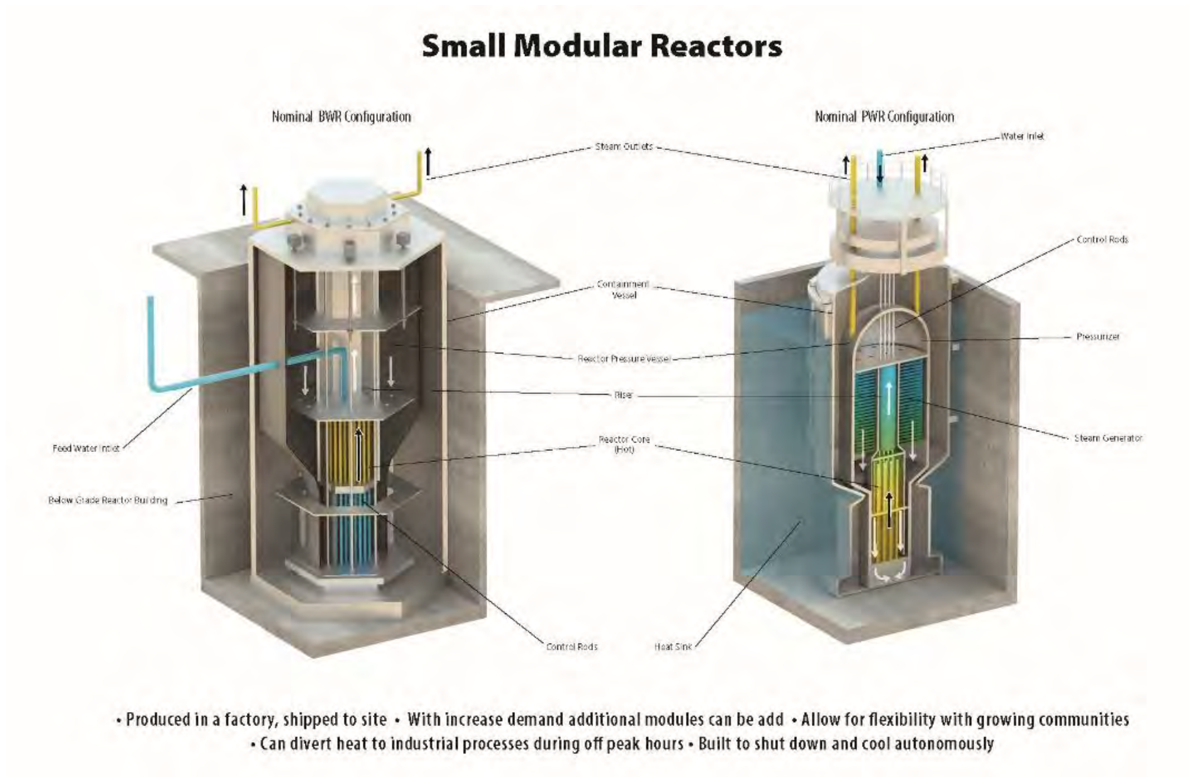

Figure 2. Small modular reactors have potential to help meet firm energy demand from data centers.

1.1.3. Utility Companies

Utility companies and grid operators are responsible for both the long-term planning and real-time operation of the power grid to accommodate the growing and dynamic load from data centers. From a planning perspective, the rapid deployment timelines of data centers often outpace traditional infrastructure development cycles, creating challenges in forecasting, permitting, and capital investment. Grid planners must anticipate large, concentrated loads with limited visibility into data center buildout schedules or load profiles, complicating transmission planning, interconnection studies, and resource adequacy assessments. The lack of standardized modeling practices and limited data sharing from data center developers further hinders integrated system planning, especially when coordinating with nuclear energy providers, whose generation profiles differ significantly from the fast-ramping needs of AI-driven workloads.

Once operational, data centers' unpredictable and variable load characteristics can strain grid stability, with rapid demand fluctuations and voltage sensitivity posing risks. Risk of large load loss and the sensitivity of data center equipment to voltage disturbances further exacerbate these challenges. Additionally, non-computational loads, such as cooling motors, can adversely affect power quality. To meet data center customer needs, the delivery of high-quality power remains a top priority, with power electronics and sensitive computational loads vulnerable to damage or tripping if "dirty" power is delivered. Addressing these challenges necessitates coordinated efforts to enhance grid resilience, implement technologies to support power quality, and ensure reliable power supply while managing the increased load from data centers. Additionally, utilities must coordinate with both data center developers and nuclear energy providers to ensure a seamless and efficient energy supply chain.

1.2. Building Bridges Across Energy and Technology

While technical innovation and policy enablers are essential to advancing integrated energy solutions, they alone are not sufficient. A critical, and often underestimated, barrier to progress lies in the cultural and operational divides between utilities, nuclear integrators, and data center developers. Each sector brings deeply ingrained norms, planning horizons, and risk tolerances that shape how they approach infrastructure development and collaboration. Utilities operate within a regulated environment that emphasizes days-ahead to years-ahead planning, public accountability, and a cautious approach to innovation. Nuclear developers face strict regulatory oversight, with safety and stability as their paramount concerns, leading to highly structured and conservative decision-making processes that consider multi-year development plans. Data center developers, by contrast, thrive in fast-paced, competitive markets where agility, rapid deployment, and innovation cycles measured in months are essential to maintaining a technological edge.

These differences can create friction even when technical alignment is possible. Misaligned timelines, divergent regulatory expectations, and incompatible decision-making styles can stall otherwise promising projects. Without a shared framework for communication and collaboration, even the most well-designed technical or policy solutions may falter. As this report explores in Section 5.1, bridging these cultural gaps is not a peripheral concern – it is a foundational requirement for success. Recognizing and addressing these differences early in the planning process can unlock more effective partnerships and accelerate the deployment of resilient, future-ready infrastructure.

2. KEY CHALLENGES FOR DATA CENTER CAMPUS DEVELOPERS

Data centers are the fastest growing sector of U.S. power consumers, with their share of total U.S. power demand expected to rise from the current 4% to between 11 and 12% by 2030, as seen in Figure 3.[4] This massive shift in the way power is consumed forces major changes to the power industry on a scale that has not been seen in decades. Much of the power system is aging rapidly and unable to support this sudden rise in demand.

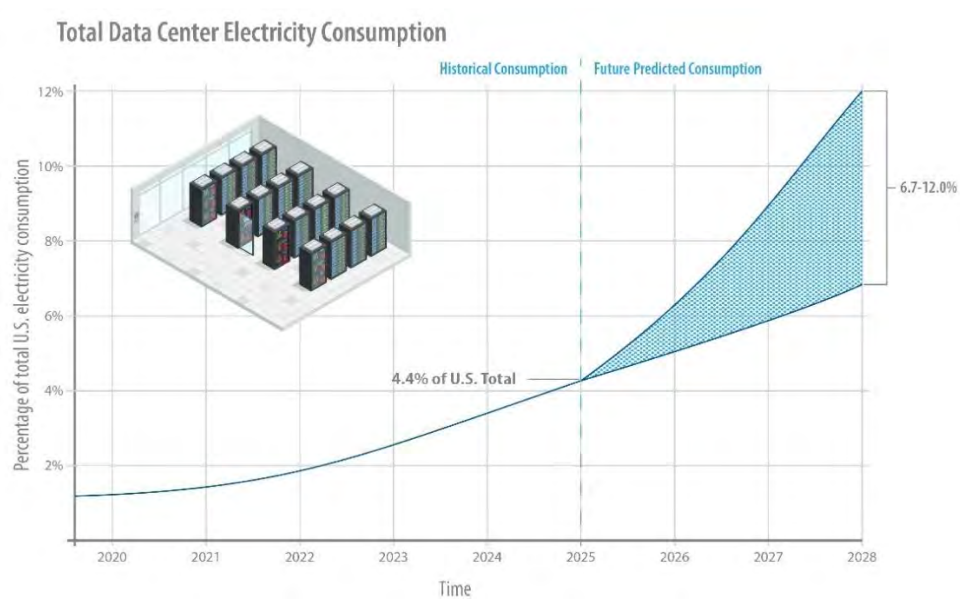

Figure 3. Data center electricity consumption is estimated to rise significantly over the next 5 years.

Generation and transmission systems were designed based on load forecasts that underestimated today's data center growth, and this is causing challenges for traditional large load customers, including data centers, particularly as the nation seeks to expand domestic manufacturing capabilities.[5,6] While data centers may share some concerns with conventional large loads, their unique characteristics present novel challenges for the power industry. These similarities and differences are visualized in Figure 4.

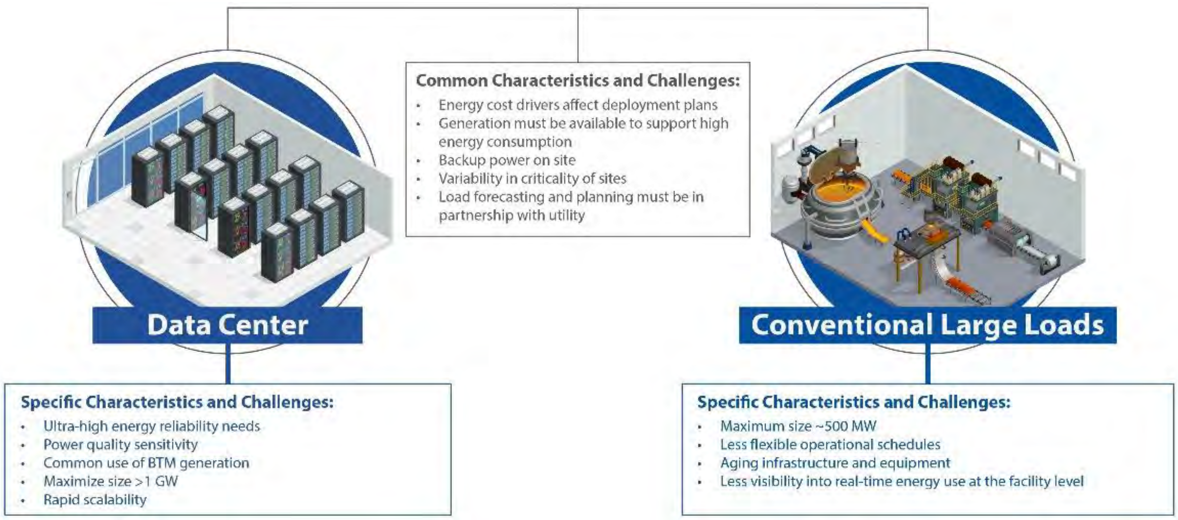

Figure 4. Data centers and conventional large loads share several characteristics and challenges, but also have their own unique factors.

2.1. Power Demand

One of the primary challenges for data centers is their high power demand, characterized by both a large demand for individual data centers and a rapid increase in the number of data centers overall.[7] Data centers require a substantial amount of electricity to operate their servers and cooling systems. Given forecasted data center growth, the existing power infrastructure will be strained to meet these load-growth expectations. Securing reliable supplies of energy is critical because any interruption can result in costly downtime and potential data loss.[8] This need for reliability is more stringent compared to conventional large industrial loads, which often have a comparatively higher tolerance for power interruptions. This echoes a broader tolerance for lower quality power of industrial loads compared to data centers, which require very smooth and predictable voltage waveforms to operate.

The cooling requirements for data centers are extensive, consuming significant power to manage the heat generated by information-technology equipment. As a result, the total power demand of a datacenter is not a linear relationship with its computational capability. The most commonly used metric of datacenter energy efficiency is power-utilization effectiveness (PUE), which is the ratio of total facility energy used versus the amount used for compute. Modern datacenters have a typical PUE of ~1.5, indicating that as much as a third of their energy consumption goes to cooling.[9,10] Both computation- and cooling-power consumption contribute to more unpredictable load patterns of data centers.[11] As shown in Figure 5, UPSs are used to ensure continuous delivery of high-quality power to the data centers, supporting transitions between the grid and backup power sources or short interruptions. Overall, while both data centers and conventional industrial loads share the need for reliable and sufficient power supplies, the unique operational characteristics and rapid expansion of data centers introduce distinct challenges that require near- and long-term solutions to deploy more power infrastructure and strengthen grid resilience.

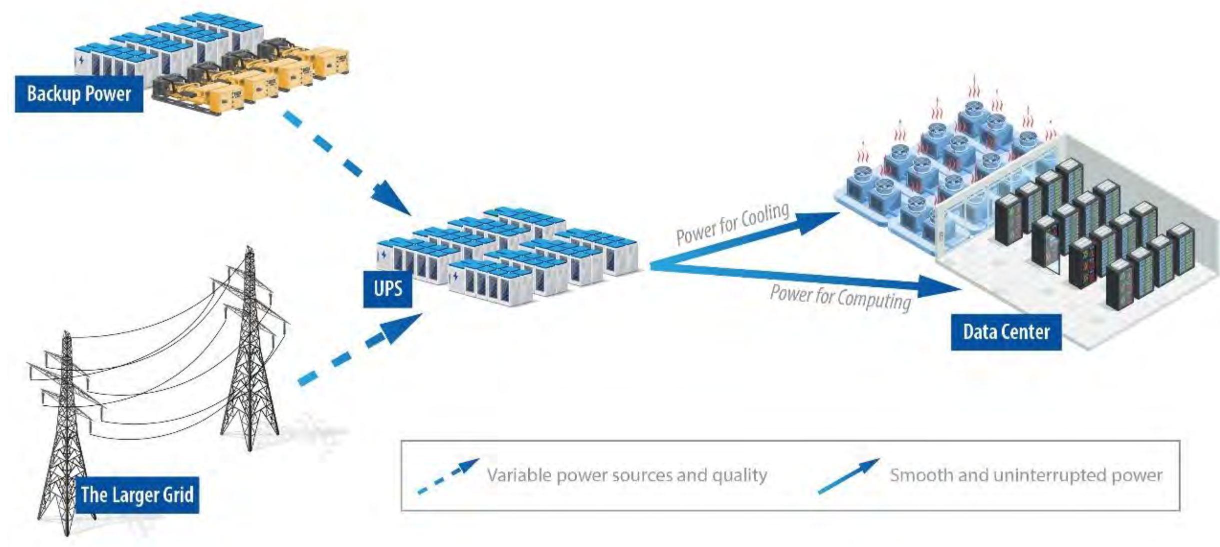

Figure 5. Primary data center power consumption supports cooling and computing processes.

2.2. Supply Reliability

Data centers are highly sensitive to power disruptions, making supply reliability a foundational requirement for their design and operation. Even brief outages can lead to significant data loss, service interruptions, and financial penalties, particularly for facilities supporting real-time applications such as AI inference, cloud computing, and financial transactions. The stringent uptime requirements necessitate not only robust grid connections but also redundant power systems, including uninterruptible power supplies (UPSs), diesel or gas backup generators, and increasingly, battery energy-storage systems.[7] UPSs are also commonly used in power-conditioning applications for data centers.

The challenge of ensuring reliable power is compounded by the scale and speed of data center growth. As facilities expand to multi-hundred-megawatt campuses, their power demand can rival that of small cities, placing stress on local grid infrastructure. This makes coordination with utilities and grid operators essential, particularly in regions where transmission capacity or generation reserves are constrained. Moreover, the increasing use of AI workloads introduces highly variable and dense power profiles, requiring more-sophisticated power-quality management and thermal-control strategies to maintain operational stability.

To address these challenges, data center developers are exploring partnerships with nuclear and other onsite generation providers, as well as advanced grid services that can offer firm capacity and fast response. However, these solutions must be integrated into a broader reliability strategy that includes regulatory compliance, cybersecurity protections, and long-term energy procurement planning. As the digital economy becomes more-deeply embedded in national infrastructure, ensuring the reliability of power supply to data centers is not just a technical necessity—it is a strategic imperative.

2.3. Onsite Generation and Market Participation

There are also significant issues for data center owners related to interconnection. The variability of data center loads, driven by fluctuating data-processing and storage demands, creates a challenging environment for maintaining grid stability and efficiency.[7] This variability is usually absorbed by the larger grid today, but as data center deployments scale, the variability and uncertainty will create larger challenges. Dedicated onsite energy-storage and/or power-generation capabilities may become necessary to manage sudden spikes or drops in power consumption. Onsite energy-storage solutions, such as battery systems, provide a buffer that can smooth load fluctuations and ensure continuous operation during externally initiated grid disturbances.[12] Similarly, onsite power generation through backup diesel generators or solar generation, offers additional reliability and can reduce dependency on the grid. Large-scale storage and generation is required to provide the capacity of backup power required for data centers, as seen in Figure 6.

Figure 6. Onsite generation and storage is needed at a large-scale to provide the scale of backup power required for data centers.

Onsite energy assets present datacenters with both a challenge and an opportunity: participation in energy markets. Although data centers have not traditionally participated as producers in bulk-energy markets or reserve markets, there are several reasons for data center owners to consider doing so. By taking part in ancillary-service markets, data centers can monetize their excess capacity and flexibility, providing services like frequency regulation or reserve energy through demand response. This can generate additional revenue streams and help offset some of the operational costs associated with maintaining high reliability and managing variable loads. Engaging in these markets requires sophisticated energy-management systems that can dynamically adjust power usage without compromising operational integrity. Additionally, some markets may mandate that large loads be capable of providing grid service to allow them to interconnect at all, particularly if their operation begins to threaten overall grid stability.

2.4. Interconnection and Siting Challenges

Data center developers encounter multifaceted challenges when it comes to interconnection and siting, particularly in securing agreements for the necessary power supply. As data demand grows exponentially, ensuring a reliable power supply to support this infrastructure becomes increasingly difficult. Regulatory frameworks and utility capacity often lag behind market demand, leading to scenarios where the power grid cannot sustain new or expanding data centers. Lack of generation and transmission capacity—along with the expensive and time-consuming processes to grow these capacities—are key contributors to the delays. Sources such as the U.S. Energy Information Administration highlight that regional transmission organizations and independent system operators sometimes struggle with maintaining resource adequacy, especially during peak demand periods or in regions with rapid data center expansion.[13]

Another significant challenge is the lengthy connection queues data center projects often face. The process, from application to having an operational connection, can span several years, exacerbated by bureaucratic hurdles and the technical complexity of integrating new loads into existing grids. The North American Electric Reliability Corporation (NERC) reports that large load interconnection queues across North America are growing, with delays stemming from rigorous environmental assessments, stakeholder negotiations, and the sheer volume of requests.[14] These protracted timelines can delay the construction and commissioning of data centers, impacting not only the service providers but also end users reliant on their services. Data center owners will often submit interconnection requests for multiple different locations simultaneously and only begin construction once one is approved. This adds congestion to the system, further increasing delays as well as causing overspeculation in resource planning.[15]

2.5. Infrastructure Scaling and Resilience

Infrastructure scalability is a growing concern for data centers, particularly in how their rapid expansion affects grid congestion and reliability. As data centers scale to meet growing demand, they place increasing pressure on local power grids, which can lead to congestion and reduced reliability for the local system.[16] From the perspective of a data center owner, this grid congestion can inhibit deployment by making it more difficult to secure necessary power capacity and interconnection agreements.[17] Utilities may be hesitant or unable to provide the required infrastructure upgrades quickly, leading to delays or increased costs for data center projects.

The conflict between the high- and variable-power demands of data centers and the stability requirements of the power grid can lead to operational and regulatory friction. Data centers, with their need for continuous and reliable power, can exacerbate grid stability issues, especially in regions where the existing infrastructure is already stretched thin.[18] This tension can lead to strained relationships with utilities, regulatory hurdles, and potential operational risks for data centers. The need to collaborate with utilities to ensure that grid enhancements keep pace with data center growth is paramount, yet can be a complex and time-consuming process.

For data center owners, addressing these challenges involves strategic planning and investment in scalable and resilient infrastructure. This may include developing partnerships with utilities to coordinate infrastructure upgrades, investing in advanced grid technologies, and exploring innovative solutions such as microgrids or localized energy generation. Balancing the need for rapid deployment with the imperative to maintain grid reliability is a delicate act, and failure to do so can threaten both the viability of new data center projects and the stability of the broader power system.[19]

2.6. Regulatory and Standards Compliance

Another major challenge is navigating the diverse and often fragmented regulatory landscape that governs power procurement, interconnection, and grid reliability[20] Data centers must comply with various federal, state, and local regulations that dictate how they can connect to and interact with the power grid. This includes adhering to standards for power quality, reliability, and safety, which can vary significantly across different jurisdictions. The lack of uniform regulations and standards can create uncertainty and additional hurdles for data center developers, complicating efforts to ensure consistent and reliable power supply.

The rapid growth of data centers has outpaced the development of regulations and standards tailored to their unique needs and operational characteristics. This regulatory gap can lead to challenges in integrating data centers smoothly into the existing power grid. For example, without data on the expected variable power demands of data centers, utilities and grid operators may struggle to accommodate new data center deployments without compromising grid stability.[21] A few jurisdictions have already begun to recognize this issue and taken steps to address it.[22] This lack of suitable regulations or data exchanges can result in delays, increased costs, and potential conflicts between data center developers and regulatory authorities.

3. KEY CHALLENGES FOR NUCLEAR STAKEHOLDERS

As data centers continue to grow in both scale and importance, ensuring a stable, resilient, and high-uptime power supply has become a central challenge for data center operators and utilities alike. Nuclear power is emerging as a compelling option to provide this power due to its ability to deliver consistent, high-capacity electricity. This section explores the technical, operational, and regulatory considerations involved in integrating nuclear power—both existing and advanced designs—with large-scale data centers. It examines how nuclear generation can meet the stringent uptime and reliability requirements of modern data centers while also addressing the challenges posed by rapid load fluctuations, siting constraints, and evolving regulatory frameworks.

3.1. Matching Nuclear Power Generation with Data Center Load Profiles

The uptime requirements and potential power ramp rates pose a challenge for power providers. Uptime requirements for data centers can range between 99.671% for Tier I facilities and 99.995% for Tier IV data centers.[23] Reliable power is a key component to meeting these uptime requirements. Nuclear power plants are best suited to provide this consistent power, with existing individual plants averaging a 92% capacity factor and a 2.5% equivalent forced-outage factor.[24] Employing multiple nuclear power plants to service a data center enables the operator to coordinate scheduled generator maintenance efficiently. This arrangement also provides redundancy, ensuring continuous operation even in the event of unplanned outages. The optimal size and number of these nuclear power plants depend on the, uptime requirements, and nuclear-power cost parameters of the data center.[25] Redundancy and generation-capacity requirements also depend on how the generators are electrically connected to the data center, with potential configurations ranging from providing power exclusively through grid transmission infrastructure to fully islanded power delivery.

Beyond electrical coupling, nuclear power plants could thermally couple with data centers to help meet their cooling needs through technologies like steam-absorption chillers. This type of coupling could reduce the energy used for cooling the data center but would require siting the nuclear power plant in proximity to the data center and would increase integration complexity.[26]

The power demand of a data center can change quickly with computational load and heating requirements. Several instances of data center electricity demand dropping over 100 megawatt (MW) in a short time have been recorded in recent years,[27,28] but existing nuclear power plants are often limited to ramping their power output by 5% of rated output per minute, making it difficult to accommodate these large ramp events. Another example of rapid load swings is shown in Figure 7. Rather than trying to match these rapid ramps in demand, excess power produced by the nuclear reactor during low-demand periods could be stored or used for another purpose, such as onsite production of synthetic fuels to power backup generators. These configurations, known as integrated energy systems, can further enhance the reliability and responsiveness of the overall system.[29,30]

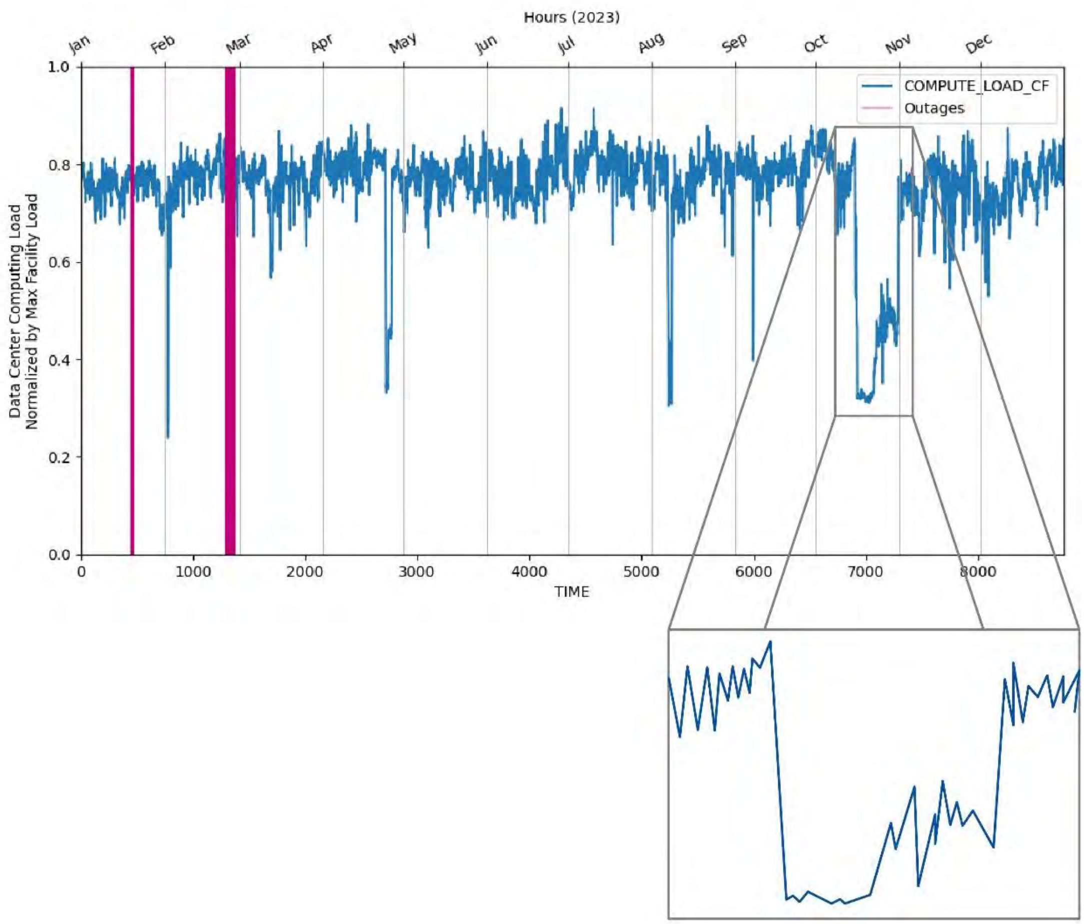

Figure 7. 2023 hourly power profile for a high-performance computing data center at Idaho National Laboratory.

3.2. Siting for Onsite Generation

Onsite power generation with nuclear power plants can reduce transmission and interconnection costs and enable direct connection between the data center and the power plant.[31] However, stringent siting requirements for nuclear plants can limit the number of potential sites, as described in the Nuclear Regulatory Commission (NRC) regulations in 10 Code of Federal Regulations (CFR) Part 100, and combined land and water requirements for data centers with onsite nuclear generation facilities can further restrict site selection.[32] These siting requirements must be balanced with network carrier availability for the data center.[33]

3.3. Safety and Security Concerns

Nuclear power plants have significant physical- and cybersecurity requirements. Risk assessment strategies for nuclear plants are mature, but including additional integrated facilities in that risk analysis is a developing field.[34] Directly coupling a data center and nuclear power plant can expose a larger attack surface for both facilities relative to when they do not interact directly.[35] Physical- and cybersecurity risks are not unique to nuclear plants, and the data pathways between different organizations should be carefully evaluated and enforce controls to minimize risk.

3.4. Regulatory and Licensing Hurdles

Siting, construction, and operations of nuclear plants are governed by the NRC. This permitting and licensing process can take several years, adding to the overall time before new generators are able to provide power. However, these regulatory processes only affect the construction of new nuclear power plants. Existing plants have already obtained the necessary licenses to be built and begin operating. As long as the operations of these existing nuclear power plants continue to follow NRC regulations, no additional NRC regulatory requirements must be met during normal plant operations.

For existing nuclear power plants, the regulations around grid interconnection may be the more conspicuous hurdle. Grid interconnection agreements are regulated by the Federal Energy Regulatory Commission (FERC) and completed with each regional transmission organization.[36] This process can take 18–30 months for large generators.[37] Some potential integration configurations for onsite generation with nuclear power would not require a grid connection, either as behind-the-meter generation or operating fully off-grid. However, this type of power provider agreement is currently the subject of deliberation among regulators, power providers, power customers, and utilities.[38] This is particularly pertinent for data centers considering onsite generation because it involves mostly direct-integration configurations, which have drawn scrutiny.

3.5. Public Perception and Community Engagement

Public sentiment towards nuclear energy in the U.S. is a complex issue, influenced by current and historical world events, cost, environmental concerns, and safety. Trends among U.S. social media users reveal a predominantly positive or neutral perception of nuclear energy, with overall online discussion of the topic growing over time, and discussion of reliability, efficiency, and safety supporting these positive views.[39] However, concerns around spent nuclear fuel, historical nuclear disasters, the association of nuclear energy with nuclear weapons, water usage, and cost and schedule overruns for recently constructed nuclear power plants prominently contribute to anti-nuclear sentiment in public discourse. Recent activity within the federal government has worked to promote nuclear power as a means towards energy security and accelerate the regulatory approval and deployment of advanced nuclear technologies.[40,41]

4. KEY CHALLENGES FOR UTILITY OPERATORS

Addressing grid-operator challenges is critical, not only to maintain a stable and resilient grid for all stakeholders, but also to enable the U.S. to maintain a competitive advantage in the AI race. This section gives an overview of data center deployment challenges based on industry reports at various platforms, including NERC, the Institute of Electrical and Electronics Engineers (IEEE), National Academies of Sciences, Engineering, and Medicine, Electric Reliability Council of Texas (ERCOT), and Western Electricity Coordinating Council (WECC). These challenges span both the deployment phase—site selection, construction, and interconnection—and the operational phase: maintaining continuous power supply, managing load growth, and ensuring cybersecurity.

4.1. Challenges in Grid Deployment

4.1.1. Interconnection Timeline

Deploying a data center requires considerations that are different relative to an industrial load.[42] While a large industrial load may accept interconnection lead times of more than 3 years, data centers, driven by the competitive nature of the tech industry and the AI revolution, necessitate rapid deployment within months rather than years.[42,43,44,45,] Data center developers, however, desire deployment within 6 months to a year.[43,45] Given the drive for fast deployment, some data center developers have been known to initiate large load interconnection requests in multiple locations, waiting to see which will be approved most quickly. This creates extra burden on utilities, which may put significant effort into a study only to see the request rescinded. To combat this challenge, some jurisdictions now require higher fees to initiate interconnection studies and apply penalties when an application is withdrawn.

While facing increased time pressures, grid operators must still perform due diligence through impact studies and other reviews that are part of the interconnection process to ensure the reliability of the system for all stakeholders. Consideration, not just of a single large load request, but of multiple in batches, enables some efficiencies while also considering the joint effects of multiple large loads in a local area. Grid operators must adapt their processes to accommodate these shorter timelines, which may involve streamlining interconnection procedures, enhancing coordination between stakeholders, and leveraging advanced planning tools to predict and manage the impact of new data center loads on the grid.

4.1.2. Infrastructure Costs

A clear protocol for determining financial responsibility for electrical upgrades when a data center load is connected has yet to be established.[42,45] Establishing financial risk-sharing mechanisms—in case of data–center-project cancellations or lower-than-expected power demand—is essential before any load is connected. High costs associated with upgrading grid infrastructure to support data centers can be a significant barrier. These costs include not only the physical upgrades to transmission and distribution systems or new generating facilities, but also the integration of advanced power-management technologies and energy-storage solutions. Developing a transparent and equitable cost-sharing framework is crucial to ensure that the financial burden is appropriately distributed among data center developers, utility companies, and other stakeholders, and not transferred on to other commercial, industrial, or residential customers.[45]

4.1.3. Modeling and Planning

Data center planning is one of highly regulated and time-consuming processes for any utility that slows the deployment of data centers. Permitting takes anywhere from 3 to 13 years to complete.[43,45] Data center developers, however, desire deployment within 6 months to a year. Beyond bureaucratic timelines and complex processes, there are challenges associated with interconnection studies related to model availability. Only user-made models exist because there is a lack of commercially made composite load models (CLM) in standard power system analysis tools, like Power System Simulation for Engineering (PSSE) and Positive Sequence Load Flow (PSLF). The lack of validated models complicates interconnection studies and further delays permitting. Currently, existing user-defined models lack accuracy on data center loads, and this leads to inaccurate assessment of voltage swell or sag conditions, time delay, and frequency sensitivity in the load disconnect and reconnect logic of PSSE's CMLD.[46] PSLF CMLD also lacks accuracy, and mismatching has been detected in the dynamic response.[44] More-accurate models will allow grid planning and mitigation of issues to be understood and addressed prior to becoming a surprise for grid operators or leading to hesitation and delays in the interconnection process.

In addition to the modeling challenges, the process itself is often slowed by fragmented data exchanges and coordination processes. Utilities must coordinate with multiple regulatory bodies, local jurisdictions, and interconnection stakeholders, each with their own documentation requirements and review cycles. This creates a patchwork of approvals that can stall progress at multiple points. The lack of standardized data-sharing protocols between utilities and data center developers complicates the early exchange of load profiles, operational expectations, and infrastructure constraints. These gaps make it difficult to initiate accurate modeling early in the process, which in turn delays the identification of grid impacts and mitigation strategies. Without streamlined permitting workflows and interoperable modeling tools, utilities are left navigating a slow, reactive process that is misaligned with the rapid deployment timelines expected by data center developers.

4.1.4. Load Growth Forecasting

While electricity demand has been stagnant over the past decade, it is anticipated to increase significantly in the upcoming decade. Data centers are projected to account for 6–12% of the grid's overall demand.[44] This surge in demand necessitates accurate forecasting, which informs risk or uncertainty quantification to ensure affordable grid reliability and stability. These forecasts are also used for resource adequacy plans, which must be updated and approved regularly. Grid operators must enhance their load-growth forecasting models to account for the rapid growth of data centers and other emerging technologies. Utilities are also tasked with ensuring reliability for the growing grid while minimizing costs for all ratepayers. By improving load forecasting accuracy, grid operators can better anticipate future demand and implement necessary infrastructure upgrades in a timely and cost-effective manner.

4.2. Challenges in Grid Operation

Data centers can have widely varying load characteristics, several of which differ from historical industrial large loads, which typically had a high degree of predictability. Energy-demand profiles from data centers change rapidly as different computing modes are executed. The demand change results in highly unpredictable and variable ramp rates in load. The nature of these loads impacts the bulk-power system in ways that create challenges for grid operations that could lead to equipment damage, low power quality, and loss of nonconsequential loads. Combined with the size and prevalence of data centers, these challenges must be addressed in the near term to enable continued growth.

4.2.1. Rapid Variations in Demand

Once a data center is commissioned, its interactions with the grid present further challenges. Data centers can rapidly increase and decrease their demand on the grid due to fluctuating computing jobs, and a growing number of large loads can change their power consumption rapidly enough to exhaust available regulation service.[43] The difference between fluctuations in AI computational workloads vs. non-AI computational workloads is shown in Figure 8. EdgeTunePower reported instances of steep ramps in power consumption for a megawatt-scale data center, with one instance showing a 24 MW ramp up in under 0.3 seconds.[43] These rapid fluctuations require the grid to respond almost instantaneously to prevent imbalances that could lead to frequency deviations and equipment stress. The grid's resources must be flexible enough to ramp up or down quickly to match these load changes, which can be particularly challenging for traditional power plants that are not designed for such rapid adjustments. Additionally, the unpredictability of these load variations complicates load forecasting and planning, making it difficult for grid operators to anticipate and prepare for peak demand periods. This can lead to inefficiencies and increased operational costs as the grid must maintain a higher level of operating reserve capacity to handle unexpected surges in demand. Overall, the rapid and unpredictable nature of data center loads poses operational challenges that require advanced grid-management strategies and better studies of the aggregate load from many unpredictable computations being run and technologies to ensure reliable and efficient power delivery.

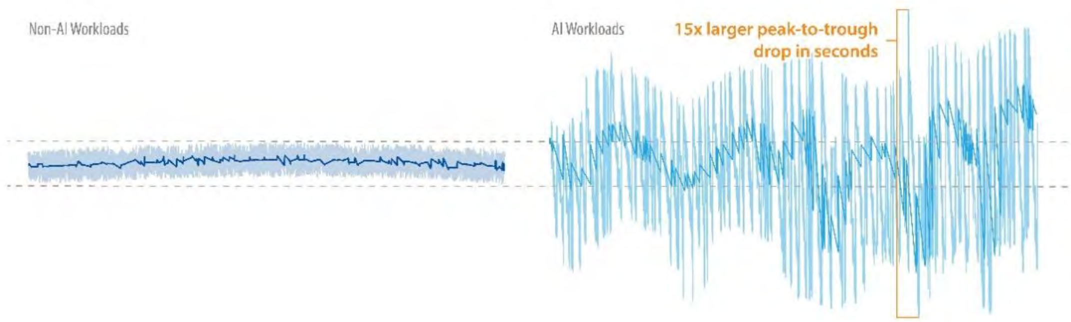

Figure 8. AI workloads can vary at a much large scale than even non-AI computation loads.[47]

4.2.2. Voltage Excursions and the Risk of Load Loss

The sensitivity of data centers to voltage disturbances exacerbates the issue of rapidly changing demand. As the grid responds to changing load, attempting to keep supply evenly matched with demand at all times, there may be slight variations in voltage. Even minor voltage sags can cause equipment to trip offline to protect itself from damage, setting up a significant amount of load to suddenly drop off the grid, a concept highlighted in Figure 9. This can lead to a cascade which increases the magnitude of the problem for the grid. Voltage ride-through in data center design has been identified as a high-priority issue that requires resolution.[48,49]

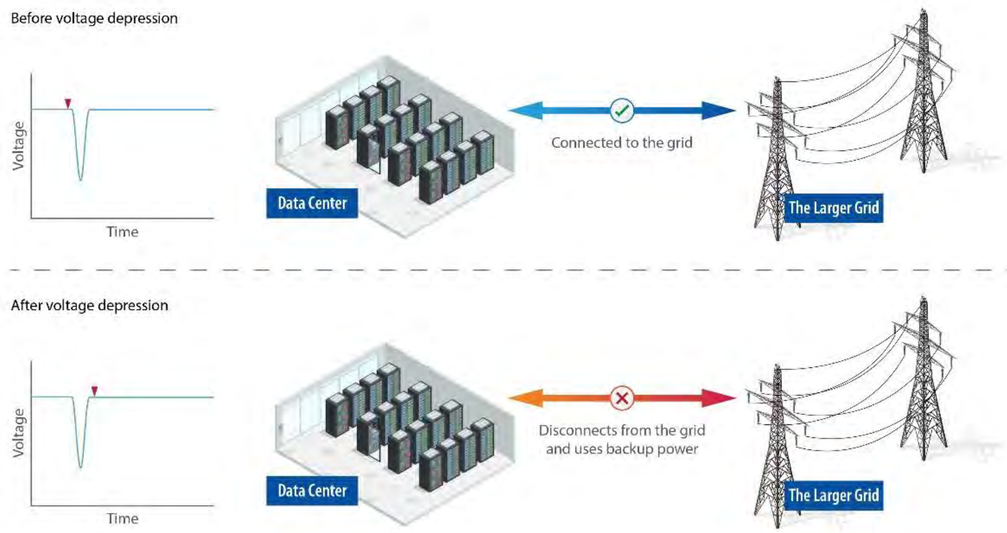

Figure 9. After a voltage deviation, data centers have been known to disconnect from the grid, leading to sudden load loss from the perspective of the grid operator.

As the proportion of voltage-sensitive loads increases and system strength decreases, the severity of cascading voltage disturbances also increases. A review of ERCOT filings revealed more than 30 near-miss incidents[c] since 2020 triggered by large loads disconnecting.[42] One of these incidents included a loss of nearly 400 crypto miners, data centers, and oil and gas facilities, disconnected without warning, forcing 112 MW of generation to shut down.[49] These quick actions were taken as emergency procedures to prevent reliability problems for the utility. During these voltage disturbance events, when these loads disconnect from the grid, the facilities are not losing power, but rather switching over to their onsite backup power sources. There is a lack of incentive for data centers to remain connected to the grid during small fluctuations, which is why voltage ride-through requirements have been proposed as regulations or incentives.

The challenge of maintaining real-time load and generation matching can create other cascading effects. Underfrequency load shedding is a critical measure designed to maintain the balance between generation and load when an imbalance causes the grid frequency to drop rapidly. These programs establish thresholds below which frequency must not fall; if it does, some load will be automatically shed to prevent further frequency decline.[50] The underfrequency event may then cause other loads to drop, leading to larger-scale outages. Additionally, noncomputational loads at data centers can adversely affect power quality. Cooling motors, for instance, can stall, leading to a depressed voltage that is slow to recover after a fault, a phenomenon known as fault-induced delayed voltage recovery.[50] Overall, maintaining voltage stability is critical to protect data center loads and their sensitive power electronics. From the grid operator's perspective, maintaining steady voltage helps ensure that data centers stay connected to the grid, rather than switching to backup power during a perceived disturbance, a practice which contributes to even larger frequency deviations and negatively impacts reliability.

[c] A near-miss incident is one which had potential to cause a power outage, equipment damage, or other negative consequences but did not result in actual harm.

4.2.3. Load Cycling and Oscillations Risks

Another major consideration for data center operation is the risk of oscillations associated with data centers. This challenge is further exacerbated by the increased use of graphics processing units (GPUs) for AI relative to non-AI data centers that rely more on central processing units (CPUs). GPUs are designed to handle parallel-processing tasks, which often result in rapid and substantial fluctuations in power demand. CPUs have more-predictable and steady power consumption. For AI workloads, GPUs process tasks in batches, leading to sudden surges in demand that can stimulate existing modes in the grid or synchronous machinery drivetrains. This can result in permanent equipment damage; in one case, the demand from a data center surged 24 MW in 290 milliseconds.[43] These power surges can permanently damage synchronous machinery because these machines require a relatively stable grid with which to synchronize.

5. CROSS-STAKEHOLDER OPPORTUNITIES

Imagine a quiet nuclear power station on the edge of town, producing steady electricity day and night. Now picture a large data center next door, filled with servers humming away to power Internet services. At first glance, they might seem like an odd pair: one generates energy, and the other consumes it. Yet, pairing them could address significant challenges and create new opportunities. By leveraging nuclear energy's reliable power for data centers, stakeholders aim to drive the digital world forward. This vision requires collaboration across various industries and addressing concerns from infrastructure and water use to regulations and public perception.

As the global dependence on digital services and energy demand accelerates, the convergence of data centers, nuclear power, and the electric grid presents a pivotal opportunity and a complex challenge. These sectors, once largely siloed, are now increasingly interdependent, driven by the need for uninterrupted energy access, strong grid resilience, and scalable digital infrastructure. However, aligning their distinct regulatory frameworks, operational cultures, and technological systems requires deliberate coordination and innovation. This section explores the key challenges that can hinder collaboration, as well as the transformative opportunities that arise when these critical infrastructures work in concert to build a secure energy future. See Table 2, which summarizes the key challenges across all stakeholders.

Table 2. Summary of challenges across key stakeholders.

Category	Challenge	Data Center Impact	Power Impact	Nuclear impact
Siting and Infrastructure Constraints	On-site generation siting	Demand profiles require both high capacity and fast ramping, which are difficult to co-locate	Grid-scale generation often mismatched with site-specific ramping needs	High capacity, but lack of fast ramping capability to match AI load variability
	Infrastructure Scaling	Rapid campus expansion outpaces local infrastructure upgrades	Strains on substation capacity, transmission, and distribution systems	Nuclear plants are large and centralized, requiring long lead times and robust transmission infrastructure
Grid Integration and Load Management	Power Demand	High and growing demand, often in the hundreds of MW per campus	Requires new resource adequacy and transmission planning	Nuclear can meet baseload demand but may not align with peaky or variable loads
	Supply Reliability and Resilience	Short term variations impact equipment	Data center load can destabilize local grid if not managed	Nuclear provides stable baseload but lacks flexibility for short-term fluctuations
	Forecasting	Difficult to predict AI-driven load growth	Inaccurate forecasts hinder grid planning and investment	Nuclear planning depends on long-term, stable demand forecasts

Category	Challenge	Data Center Impact	Power Impact	Nuclear impact
	Modeling and Planning	Hesitant to share detailed models, which may reveal intellectual property	Need to model data centers and nuclear to plan	Requires integrated modeling to assess nuclear's role in meeting data center demand
Land Use and Public Perception	Public Perception and Community Engagement	Local community pushback on large-scale data center developments	Public resistance to new transmission lines or substations	Local opposition to nuclear siting due to safety and environmental concerns
Regulations, Policy, and Workforce Development	Interconnections	Long queues delay project timelines	Long queues for generation and load interconnections; lack of standardized models slows studies	Nuclear interconnection studies are complex and often deprioritized due to long timelines
	Safety and Security	Must comply with cybersecurity and physical security standards	Grid security concerns increase with large, concentrated loads	Nuclear facilities face strict NRC safety and security requirements
	Licensing	Must comply with federal, state, and local regulations for grid connection	Lack of clear regulatory pathways for large load interconnections	NRC licensing is lengthy and complex, delaying deployment
Funding, Investment, and Market Participation	Emerging Market Participation	Limited access to capacity markets or ancillary services	Grid services markets not designed for large flexible loads	Nuclear often excluded from fast-response markets despite reliability value
	Infrastructure Costs	High upfront costs for power infrastructure and redundancy	Utilities face cost recovery challenges for upgrades serving single customers	Nuclear projects require large capital investments and long return-on-investment timelines

The first challenge we present in this section, cultural and operational differences, is one that does not appear in the table above. Lying squarely at the intersection of relationships and expectations between these stakeholders, this challenge is one that must be considered in the context of all the other technical and policy discussions. By establishing clear expectations and open lines of communication, these stakeholders can achieve mutual success in growing grid capacity and operating a stable, reliable, and resilient grid at affordable costs.

5.1. Cultural and Operational Differences

One of the most persistent barriers to effective cross-sector collaboration among utilities, nuclear operators, and data center developers lies in their fundamentally different organizational cultures and operational priorities. Utilities and nuclear operators are traditionally risk averse and are focused on long-term planning. Utility operations are governed by strict regulatory oversight, public accountability, and a mandate to ensure safety, reliability, and affordability. While cautious, utilities have always been pushed to innovate, especially in areas of grid modernization. Nuclear facilities operate under an even more-highly regulated and safety-critical environment. As a result, decision making processes tend to be deliberate, conservative, and highly structured, often requiring years of planning and regulatory approval. In contrast, the tech sector, including data center development, tends to prioritize speed, innovation, and scalability. These companies operate in fast-moving markets where competitive advantage is often defined by how quickly infrastructure can be deployed and scaled. Agile development cycles, rapid iteration, and a tolerance for calculated risk are hallmarks of this approach. This cultural emphasis on "move fast and optimize later" can clash with the more cautious, methodical pace of utilities and nuclear operators.

These cultural differences are compounded by misaligned incentives and planning horizons. Utilities may require 3–5 years to plan and build new substations or transmission lines, while nuclear developers may operate on even longer timelines, with licensing, safety, and capital planning extending over decades. On the other hand, data center developers may seek to bring new facilities online in 12–24 months, driven by customer demand, cloud service expansion, or AI-workload growth. This disconnect can lead to friction in joint projects. For example, a utility may be hesitant to commit to major transmission upgrades without long-term certainty while a data center developer may be unwilling to wait for multiyear permitting and construction timelines. Similarly, nuclear operators may be cautious about integrating with highly variable loads that could affect plant stability or licensing conditions.

These differences also manifest in language, priorities, and expectations. Utilities and nuclear operators often speak in terms of regulatory compliance, grid reliability, and system planning while tech companies focus on uptime, latency, and cost per megawatt. Without a shared framework for communication, misunderstandings can arise, slowing down collaboration or leading to mismatched expectations (Table 3).

Table 3. Comparison of cultural attitudes among the principal stakeholders of a nuclear-integrated data center.

Category	Utilities	Nuclear Operators	Data center developers
Primary Focus	Reliability, affordability, regulatory compliance	Safety, stability, regulatory adherence	Speed, scalability, innovation
Planning Horizon	10–20 years (integrated resource plans [IRPs], grid modernization)	20–60 years (plant lifespan, licensing cycles)	1–3 years (deployment cycles, market demand)
Risk Tolerance	Moderate – cautious but adapting to innovation	Low: highly risk-averse due to safety and regulatory stakes	High: embraces calculated risk for competitive advantage

Category	Utilities	Nuclear Operators	Data center developers
Regulatory Environment	State and federal oversight (public utility commissions (PUCs), FERC, NERC)	Strict federal oversight (NRC, Department of Energy [DOE])	Minimal direct regulation; driven by market and uptime service-level agreements
Decision-Making Style	Consensus-driven, public accountability	Hierarchical, compliance-driven	Agile, data-driven, fast-paced
Operational Flexibility	Moderate: evolving with distributed energy resources and grid tech	Low: optimized for baseload, limited ramping	High: adaptable to workload and energy needs
Communication Style	Technical, policy-oriented	Formal, compliance-focused	Business-driven, outcome-focused

5.1.1. Opportunity: Building Operational Harmony

Despite the cultural and operational differences that often separate utilities, nuclear operators, and data center developers, there are meaningful opportunities to foster collaboration and alignment. These opportunities lie not only in shared infrastructure and technology, but also in the way these sectors communicate, plan, and manage risk together.

One of the most effective ways to bridge these divides is through the creation of joint planning forums. These forums can serve as structured spaces where stakeholders from each sector come together to align on timelines, share constraints, and identify mutually beneficial solutions early in the development process. By establishing a shared understanding of each sector's priorities and limitations, these forums can help prevent misalignment before it becomes a barrier to progress.

Another potential approach is the development of translational roles or liaison positions. These individuals who understand the operational language and priorities of both the energy and tech sectors would be embedded in organizations as liaisons and representatives for other sectors. For example, an energy strategist within a data center company can help interpret utility-planning processes while an innovation lead within a utility or nuclear operator can advocate for more-agile, tech-informed approaches. These roles can accelerate decision-making and reduce friction by acting as cultural bridges.

Flexible contracting models also offer a path forward. Traditional power purchase agreements (PPAs) may not always accommodate the fast-paced deployment needs of data centers or the long-term planning cycles of utilities and nuclear operators. By designing contracts that allow for phased commitments, load-following capabilities, or hybrid supply models, stakeholders can better align their operational realities while still meeting business and regulatory requirements.

In addition, developing shared-risk frameworks can help stakeholders find common ground. Rather than viewing risk through a single-sector lens, such as safety for nuclear, reliability for utilities, or uptime for data centers, cross-sector teams can co-develop models that account for all dimensions of risk. This can lead to more balanced decision making and a clearer understanding of where tradeoffs are acceptable.

Finally, cross-sector training and knowledge exchange can play a critical role in building long-term collaboration. Workshops, site visits, and joint training programs can help demystify each sector's operations and foster empathy among teams. Over time, this shared experience can lead to a more-cohesive working culture, where differences are not just acknowledged but leveraged as strengths.

Together, these strategies offer a roadmap for transforming cultural friction into collaborative momentum, enabling utilities, nuclear operators, and data center developers to work more effectively toward shared infrastructure goals.

5.2. Siting and Infrastructure Constraints

Siting and infrastructure considerations are at the forefront of challenges for data centers, utilities, and nuclear generators in the context of building out large loads, but each sector has unique challenges to address. Data centers require large strategically located parcels with access to robust power, water, and fiber-optic networks, often in industrial zones. Landowners must navigate local land-use and zoning regulations, secure necessary permits, and engage with communities to mitigate concerns over energy use, noise, and environmental impact. Nuclear generators must consider the stringent siting requirements outlined by NRC in 10 CFR 100. Additionally nuclear facilities have significant physical and cybersecurity requirements. Utilities, facing rising loads and lengthening queues for generation and transmission, attempt to balance fair distribution for the costs of upgrades with a goal to keep energy prices low for all consumers. Not only does it take from months to years to approve generation and transmission projects, which come with siting, permitting, and land-use challenges of their own, but the cost and availability of materials to complete these projects also poses a barrier to timely commissioning of new infrastructure to support both large loads and new nuclear generators.

5.2.1. Opportunity: Reduce Infrastructure Requirements Through Co-Siting Development Models

Co-siting of data centers with nuclear power requires careful planning to address infrastructure compatibility, but it can help address several of the individual challenges faced by key stakeholders. This setup offers a direct connection to a constant power source, ensuring 24/7 electricity for data centers. By placing a data center on the same site or near the plant, power can be delivered directly, cutting down on power losses, improving efficiency, and reducing use of transmission capacity. For example, in Pennsylvania, Talen Energy built a large data center campus with a direct link to the Susquehanna Steam Electric Station's nuclear plant, avoiding the need for long-distance transmission.[51] However, FERC has repeatedly denied expansion of this interconnection service agreement to allow more capacity to flow between the nuclear plant and the data center, highlighting that regulatory hurdles to direct coupling is still an impactful barrier.[52] This arrangement can benefit all parties: data centers receive reliable, cost-effective power, nuclear plants secure a steady revenue stream, and utilities experience reduced strain on transmission systems and generation queues to move power from a source to a large load.

In addition, joint-sited or islandable data center with nuclear microgrids can enhance resilience by maintaining operations during periods of grid unavailability. These microgrids can operate independently, providing a secure and stable power supply, separate from the main grid, for critical infrastructure. Utilities may also find value in partnering on microgrid development, which can enhance resilience for critical loads while providing such grid services as frequency regulation or black-start capabilities. This decentralization of digital and energy systems also strengthens national security by reducing vulnerability to large-scale disruptions.

Beyond operational benefits, joint siting of nuclear power and data centers can also lead to avoided costs. From the utility perspective, joint siting can help alleviate pressure on already strained transmission and distribution systems. By reducing the need to move large volumes of power over long distances, utilities can avoid or defer costly infrastructure upgrades and reduce congestion in interconnection queues. This is particularly valuable as utilities face increasing demand from electrification, distributed energy resources, and large-scale digital infrastructure. Additionally, joint siting can support grid reliability by localizing supply and demand, which simplifies load balancing and reduces vulnerability to regional disruptions.

However, joint siting also requires careful planning to address infrastructure compatibility. Nuclear facilities are high-security sites with strict safety protocols. Building a nearby data center requires that it not interfere with plant safety. Centers also require robust fiber-optic links, which can be challenging for remote power plants in certain locations. In the Susquehanna case, developers built new fiber routes to ensure fast Internet connectivity.[51]

5.2.2. Opportunity: Shared Resources, Collaborative Efficiencies

Nuclear plants and data centers both require significant cooling, often by water. Nuclear reactors use water to dissipate heat, typically drawing from local water sources. Data centers, packed with heat-generating servers, also need cooling, frequently employing air conditioning or evaporative systems that consume large amounts of water. Siting a data center near a nuclear plant could amplify water usage, raising concerns about local resources and environmental impact. For instance, a data center outside Phoenix used 56 million gallons of water annually, equivalent to hundreds of households.[53] Combining this with a nuclear plant's needs could strain local water supplies.

The good news is that stakeholders are aware of these concerns and are exploring solutions together. Data center developers are improving cooling technology to use less water. Modern facilities use air cooling, liquid refrigerants, or even "zero-water" cooling systems to minimize their costs and impact.[54] Companies like Microsoft and Google have pledged to become "water positive," meaning they will put more water back into stressed water systems than their data centers consume.[53] Advanced nuclear plant operators can mitigate water impacts too, with many plants using recycled wastewater instead of fresh river water or passive water cooling systems to enhance safety.[55] Joint nuclear-data-center projects can employ reclaimed water or advanced cooling to reduce freshwater usage. For example, in dry Pheonix, data centers could be built proximate to the Palo Verde Nuclear Generating Station which has infrastructure already in place to use the metropolitan area's wastewater. Policies are also moving in this direction, requiring data centers in places like Santa Clara, California, to use responsible power sources and avoid water-intensive methods.[53] A nuclear-powered data center could meet these requirements, ensuring it protects water resources for the area's constituents. Ultimately, successful joint-siting models depend on early and sustained collaboration among utilities, nuclear operators, and data center developers. With coordinated planning, these partnerships can unlock system-wide benefits, accelerating infrastructure deployment, improving reliability, and optimizing capital investment across the energy and digital sectors.

5.3. Grid Integration and Load Management

Another challenge is the rapid and dynamic growth in power demand from data centers, which necessitates robust and flexible power-procurement strategies. Data centers require substantial electricity to operate both servers and cooling systems. Any interruption can result in costly downtime and potential data loss. Load variability increasingly necessitates dedicated onsite energy storage or dispatchable-power generation capabilities to manage sudden spikes or drops in consumption. Nuclear power, which traditionally serves baseload, may struggle to handle the variability in load without grid support or other onsite resources, like storage.

Several perspectives exist across stakeholders as to the best way to manage these challenges. Some have suggested that data centers should be operated entirely off-grid, providing their own power in a microgrid configuration that does not rely on the grid for generation or transmission infrastructure, is not subject to regional grid instability or transient events, and does not burden the grid with their large, fluctuating loads. Off-grid advocates also point to the time delays in large load interconnection requests and propose that allowing data centers to serve their own loads could bring them on line faster by avoiding those queues altogether. Others have suggested that due to their size, data centers must be grid-tied, suggesting that reliance solely on a local microgrid is a risk for high-uptime requirements. Grid-integration proponents argue that grid connectivity provides essential redundancy, access to varied energy sources, and the ability to participate in energy markets. For utilities, grid-tied data centers can also serve as flexible loads that support grid balancing, if properly managed.

5.3.1. Opportunity: Partnering for Resilience: Joint Approaches to Power Flow Management

Several opportunities exist for utility, nuclear, and data center stakeholders to work together to facilitate fast and reliable data center deployment. Utilities and nuclear operators can develop dynamic PPAs that allow for load-following or hybrid supply models. These agreements could include provisions for ramping support, storage integration, or time-of-use pricing to incentivize load shaping. Joint planning between utilities and data center developers can ensure that grid infrastructure upgrades, generation capacity, and interconnection timelines are aligned with projected demand growth. This reduces the risk of stranded assets or delayed deployments. Data centers can be equipped to provide such ancillary services as frequency regulation, voltage support, or spinning reserves. With the right controls and incentives, they can act as virtual power plants, helping stabilize the grid while optimizing their own energy use.

5.4. Land Use and Public Perception

Whenever nuclear power is involved in a project, public perception becomes a key factor. Nuclear plants have long had to earn the trust of their local communities, addressing fears about safety, radiation, waste management, or potential accidents. Even in communities that host existing nuclear plants, proposals for expansion or co-development can reignite concerns, particularly if residents feel excluded from the planning process or uncertain about the long-term implications. Introducing a data center to the mix adds a new layer of complexity. From one perspective, a data center is a far-less controversial neighbor than a reactor; it involves no hazardous materials, nor does it carry the same social connotations. However, data centers do bring their own set of local concerns: they take up land, they can be noisy—with industrial-scale cooling systems, backup generators, and heating, ventilation, and air-conditioning equipment—and they can affect local water supplies.[56] Moreover, while they are large capital investments, they do not create many permanent jobs once built, due to low permanent-staffing needs relative to other industries. Even supporting-utility projects, like adding more generation or building new transmission lines, can face publish pushback related to land use, noise concerns, and more. In some cases, public resistance to transmission development has delayed or derailed otherwise viable energy projects.

5.4.1. Opportunity: Earning Trust Through Collaborative Projects

To address these challenges, early and transparent community engagement is essential. Cross-sector collaboration between utilities, nuclear operators, and data center developers can help build a unified narrative around a project's benefits: grid reliability, energy resilience, and long-term economic development. By coordinating messaging and outreach, stakeholders can avoid mixed signals and demonstrate a shared commitment to community well-being.

Pairing data centers with nuclear plants can help address perception issues. Nuclear sites typically have large buffer zones, allowing data centers to be built away from residential areas, reducing noise and visual impact. For example, the data center campus next to the Susquehanna plant spans 1,200 acres, minimizing disruption to neighbors and reducing the need for new power lines or substations.[51] Local leaders see economic benefits: jobs during the construction phase, potential business attraction, and local investments in infrastructure. Additionally, data centers can justify keeping nuclear plants open, saving jobs and tax revenue. In Pennsylvania, a partnership with Microsoft aims to restart the dormant Three Mile Island reactor to supply power for data centers, potentially bringing hundreds of jobs and boosting the local economy.[57]

Transparency and engagement are crucial. Nuclear operators and data center companies must communicate their plans clearly to the public, addressing safety, health impacts, and local benefits. The technology sector can help sway public opinion positively through community outreach and economic commitments. When residents see a data center using nuclear power, it can reframe nuclear power as a robust, safe, and affordable solution. This narrative is increasingly recognized by policymakers and industry leaders, who aim to deliver low-cost and reliable electricity, thereby garnering community support.

5.5. Navigating Regulations, Policy, and Workforce Alignment

Each sector operates under a different regulatory framework—i.e., FERC/NERC for the grid, NRC for nuclear, and often local/state regulations for data centers. The lack of unified policy can slow down joint projects or infrastructure integration.

Combining nuclear power plants and data centers involves regulatory hurdles. Nuclear power is highly regulated, and private direct-supply agreements need to align with energy policy. Even advanced nuclear technologies like SMRs, which promise faster deployment and smaller space requirements, are still subject to rigorous oversight. For instance, direct "behind-the-meter" deals, like the $650 million agreement between Talen Energy and Amazon Web Services, raise concerns about fairness and grid maintenance costs.[58] Regulators worry that if a data center bypasses the customary grid fees, it might increase electricity costs for others and increase the risk that generation will be insufficient to meet demand. Collaborative frameworks allow innovative partnerships while ensuring fair grid funding.[59]

Permitting and licensing are significant hurdles. Building a data center usually takes 1–2 years, but constructing a new nuclear reactor extends the timeline dramatically. Advanced reactors like SMRs promise quicker builds, but still require rigorous safety reviews, pushing widespread deployment to the 2030s.[58] Tech companies need power immediately, leading to creative interim solutions. For instance, Oklo aims to supply nuclear power to data centers with its Aurora reactors, but partnered with RPower to provide natural-gas generators as a stopgap.[60] This phased approach meets immediate power needs and introduces nuclear units later. Regulators must be flexible, and government efforts are underway to fast-track energy projects for data centers, highlighting their importance for national competitiveness and security.

Moreover, cybersecurity is a shared concern for both nuclear plants and data centers. Both represent critical infrastructure and potential targets for cyberattacks. Collaboration necessitates rigorous security protocols to safeguard systems. Nuclear operators employ strict digital-security measures, ensuring reactors are impervious to hacking attempts. Data centers, likewise, protect customer data and service continuity. Coordination on network separation and threat intelligence is vital. Regulators like the NRC integrate cybersecurity-risk considerations into reactor designs, ensuring safety. This partnership enhances resilience, enabling data centers to operate autonomously during emergencies like power outages. Nuclear plants' consistent operation and scheduled refueling contribute to high power reliability, promising robust support for industries relying on uninterrupted service.

5.5.1. Opportunities: Clearing the Red Tape

Despite these challenges, several promising avenues are open for collaborative solutions that can align regulatory, policy, and workforce strategies across sectors. First, regulatory innovation and policy alignment can help streamline project development. Federal and state agencies can create fast-track permitting pathways for critical infrastructure projects that combine reliable energy and digital capacity. Regulatory sandboxes or pilot programs could allow utilities and nuclear developers to test new business models, such as hybrid ownership structures or flexible interconnection agreements, without triggering full regulatory review.

Second, market participation frameworks can be expanded to include joint-sited nuclear and data center facilities. Allowing onsite generation or storage to participate in wholesale energy, capacity, or ancillary-services markets would create new revenue streams and improve project economics. Utilities can play a key role here by facilitating market access and integrating these resources into grid operations.

Third, joint workforce-development initiatives can help build a talent pipeline that spans all three sectors. Universities, national labs, and industry consortia can develop interdisciplinary programs that blend nuclear engineering, power systems, and digital infrastructure. Cross-sector apprenticeships and fellowships can expose workers to the operational realities of each industry, fostering a more-adaptable and collaborative workforce.

Finally, shared-governance structures, such as regional energy hubs, public-private task forces, or cross-sector advisory councils can provide a platform for ongoing coordination. These bodies can align project timelines, clarify regulatory responsibilities, and ensure that cybersecurity, workforce, and equity considerations are addressed holistically.

5.6. Funding, Investment, and Market-Participation Strategies

Funding and financing are key challenges for all stakeholders. Nuclear projects require substantial upfront investment and lengthy approval processes, making investors cautious. Data centers, though expensive, generally offer quicker returns, creating a mismatch. Nuclear projects face high regulatory oversight and capital costs, deterring traditional investors. Utilities often must justify capital expenditures through regulatory processes and must balance the needs of all ratepayers. While utilities may be interested in supporting nuclear-powered data centers, especially if they help anchor new generation or transmission investments, they must also ensure that such projects align with IRPs and do not unfairly shift costs onto other customers. Additionally, utilities must consider how these projects participate in wholesale energy markets, capacity markets, and ancillary services, especially if onsite generation or storage is involved.

5.6.1. Opportunity: Joint Investments for Shared Success

Despite these challenges, there are increasing examples of cross-sector investment models that align the interests of utilities, nuclear developers, and data center owners. Tech giants like Microsoft, Google, and Amazon invest directly in nuclear projects to meet their goals, providing patient capital for long-term energy needs. Microsoft's investment in TerraPower's Natrium reactor in Wyoming exemplifies corporate involvement accelerating nuclear innovation.[61] Utilities can also benefit from these arrangements by acting as market facilitators and infrastructure partners. For example, if a co-sited nuclear/data center facility includes energy storage or flexible load capabilities, it could participate in energy, capacity, and ancillary-service markets, providing new revenue streams for both the utility and the nuclear operator.

To unlock these opportunities, innovative financing mechanisms are essential. Public-private partnerships can help de-risk nuclear investments by combining government loan guarantees (such as those offered by the U.S. DOE) with private capital. Bonds tied to performance and impact metrics are drawing interest from investors focused on long-term societal outcomes, channeling capital into projects that enhance operational resilience and resource efficiency. Policy mechanisms, such as tax incentives for advanced energy technologies, can improve the financial outlook for nuclear-powered data center initiatives. Strong collaboration among public institutions, financial entities, technology firms, and nuclear operators is essential. Leveraging cross-sector partnerships, corporate-responsibility frameworks, and innovative financing instruments can help realize the full potential of nuclear-powered infrastructure; supporting dependable, forward-looking growth.

Realizing the full potential of nuclear-powered data centers will depend on strong collaboration among public institutions, utilities, financial entities, technology firms, and nuclear developers. By leveraging complementary strengths—patient capital from tech, infrastructure expertise from utilities, and innovation from nuclear startups—these partnerships can deliver dependable, forward-looking energy solutions that serve both digital and societal needs.

5.7. Benefits for All Stakeholders

Despite the many challenges faced by individual stakeholders and multistakeholder coordination teams, leveraging nuclear energy as part of the solution to address large-scale data center growth is incredibly promising. Collaborative approaches, highlighted in Figure 10, across these stakeholders bring unique opportunities to each participant.

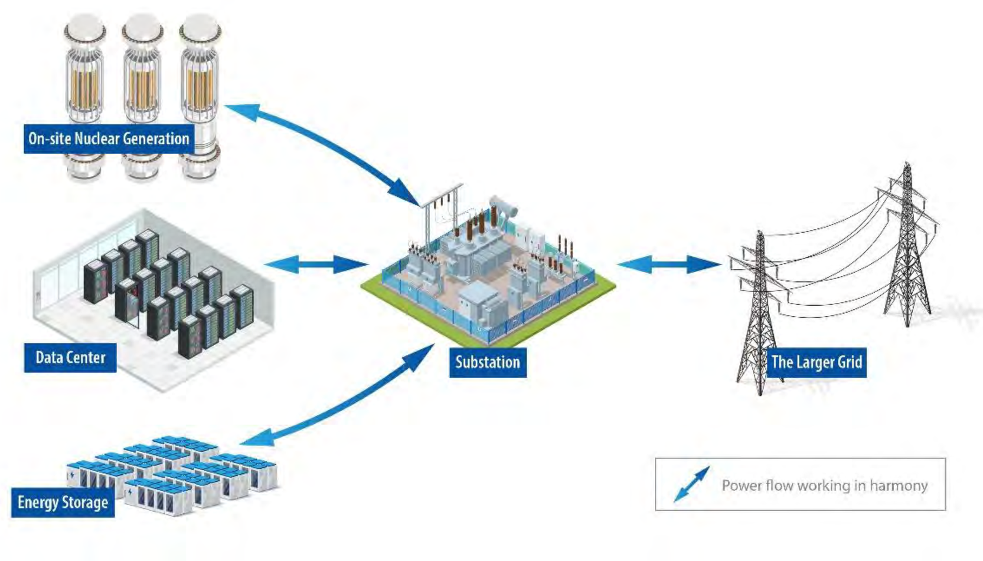

Figure 10. All stakeholders working together creates several opportunities and benefits for all.

Nuclear-Plant Operators: Operators of nuclear plants find that partnering with data centers brings new economic viability. Deals like Microsoft's 20-year purchase from Three Mile Island, Unit 1, and Talen Energy's plans for data center sites at their power stations highlight this strategy. Selling directly to data centers can be lucrative, thanks to the price that some data centers are willing to pay and around-the-clock power demand that aligns with the continuous energy supply of nuclear plants.[62] Integration is most effective when coordinated with utilities, regulators, and developers for shared infrastructure investment and alignment with broader grid-policy frameworks.

Data Center Companies: Data center developers gain a reliable power source via nuclear energy, and many are interested in this solution as part of their overall portfolios to meet power needs. The urgency to build new data centers leads to an all-solutions approach, and major players like Amazon, Google, and Microsoft are integrating nuclear power to ensure continuous operation. For instance, Amazon Web Services' $650 million investment in Pennsylvania transforms a nuclear site into a data center hub, reflecting confidence in nuclear energy's ability to meet their needs.[63]

Electric Utilities and Grid Operators: Utilities and grid operators play central roles in enabling large load growth, and their coordination with both data centers and generation providers is critical. Collocating data centers with power plants reduces strain on transmission lines and may improve grid stability with careful coordination of onsite generation assets (e.g., using battery storage to absorb fluctuations). A nearby data center, drawing power directly from a plant, frees up grid capacity for other customers and local generation integration. Utility companies with nuclear fleets are excited about deals with tech firms because they secure long-term revenue. Grid operators benefit from predictable, well-integrated loads that can provide ancillary services or demand flexibility. To support this, utilities must work closely with nuclear and data center developers to align infrastructure upgrades, streamline interconnection processes, and ensure that grid reliability is maintained as new loads come online.

Policymakers and Regulators: Government bodies see strategic opportunities in combining nuclear energy with digital infrastructure and grid modernization. This addresses energy innovation and digital economy growth, simultaneously. While nuclear energy is a strategic asset, policies must also accommodate hybrid-energy models and emerging technologies. Public-private partnerships can help pilot new regulatory approaches, accelerate infrastructure deployment, and ensure that reliability, security, and equity goals are met. Supportive measures like federal loan guarantees and funding for advanced reactors showcase American technology at its best. Policymakers aim to meet reliability targets and create high-quality jobs, but regulations need updates to accommodate these models. PUCs and national security officials are involved to ensure reliable power for data centers. Regulators focus on maintaining safety and fairness while enabling innovation, enforcing safety standards, and ensuring local ratepayers are not disadvantaged.

Local Communities: Communities can greatly benefit from hosting these ventures. A nuclear plant provides jobs, local contracts, and tax revenues that support public services. Adding a data center amplifies these benefits with well-paid tech jobs and infrastructure investments, such as improved fiber-optic networks and electrical systems. During construction, local labor and contractors are employed, and the presence of a data center can spur further investments. Tech and energy companies often support local education, offering science, technology, engineering, and mathematics initiatives; internships; and training courses that prepare students for jobs in these fields. This dual-industry presence can foster pride and identity in communities, showcasing them as integral to the future of power and technology. Economic development can thrive if challenges like water use, safety, and community involvement are addressed. Successful examples include Ohio and Pennsylvania, where nuclear plants supply electricity to Bitcoin mining centers, turning struggling power stations into high-tech hubs. These ventures diversify local economies and keep young talent from leaving.

This report largely focuses on the key challenges for stakeholders who are front and center of the grand challenge to enable large-scale data center growth. In our exploration of utility, nuclear, and data center challenges and cross-sector coordination, we note the critical role played by policy makers and regulators along with local communities. However, we acknowledge here that there are gaps among these stakeholders. To whom does a data center reach out if they want to explore nuclear power projects, but do not have a single point of contact to drive the project? How would small and rural utilities develop the requirements and structures to support large–load-interconnection requests at a scale they have never seen before? Public-private partnerships can help address some of these challenges, but there are hidden stakeholders worth highlighting. These are companies that glue stakeholders together: traditional engineering support or engineering-procurement construction firms or burgeoning custom consulting firms capitalizing on this need. These companies will be crucial to the success of data centers' receiving the energy they need, whether through bringing their own power, collocating with existing power plants, or working with local utilities to meet their power requirements.

The union of nuclear power and large-scale data centers represents a blend of reliable energy with the demands of the digital age. This synergy requires navigating technical, legal, and community challenges, but the benefits are clear. Open collaboration can turn this vision into reality, ensuring data centers are powered safely, affordably, and reliably. This partnership promises an energy-secure future, combining digital and energy advancements for the 21st century.

6. CONCLUSION AND NEXT STEPS

Rapid growth in the data center industry provides an opportunity to explore the ways nuclear power can support technological innovation. The need for abundant and reliable energy has never been higher.

We have explored the unique considerations of data center growth from three owner-operator perspectives: data center developers, nuclear generators, and utilities. Key concerns are referenced in Table 4. While the opportunities and obstacles are specific to each of these perspectives, ample opportunity exists for collaboration, growth, and synergistic development.

Key concerns from the **data center** campus developers' perspective include power and supply reliability, interconnection challenges and market participation, infrastructure and grid resilience, and regulatory and standards compliance. As data centers pursue reliable sources of quality power, many innovative options are available for operational regimes that benefit the data center as well as connected grids.

Key concerns from the **nuclear generation** owners and developers include direct integration with data centers as high uptime, yet potentially volatile loads, siting for adjacent campuses, increased requirements to assure safety and security, public perception and community engagement, and regulatory and licensing hurdles. While direct coupling with data centers provides a nominal baseline load well suited to nuclear generation, it also represents new interfaces that require consideration for safety and regulation. However, pairing nuclear energy with data centers could serve as a novel outreach strategy, potentially strengthening its image among the public and other stakeholders.

Key concerns from the **utility** perspective include deployment and interconnection timelines, infrastructure costs and cost allocations, load forecasting and resource planning, energy dispatch and operational challenges, and power quality and oscillations stemming from the unique power-demand profiles of data centers that challenge power system stability.

Table 4. Summary of key stakeholder concerns.

Key Stakeholder Concerns		
Data Centers	Nuclear Power	Electric Utilities
Power, Supply Reliability	Direct Integration	Deployment Timeline
Interconnection Requirements	Volatile Loads	Interconnection Timeline
Market Participation	Adjacent Campus Siting	Infrastructure Costs, Allocation
Infrastructure, Grid Resilience	Safety and Security	Resource Planning
Regulations and Standards	Licensing	System Stability/Inertia
		Voltage Stability

Spanning the perspectives of data centers, nuclear generation, and utilities, key concerns include joint siting and infrastructure compatibility, shared local resource impacts, public perception, land use, regulatory complexity, cybersecurity and operational resilience, and financing and investment alignment. Any of these challenges in isolation may be insurmountable from any of the stakeholders' perspectives. However, new opportunities for addressing these challenges arise as stakeholders pool their collective strengths.

Strategic opportunities to address the key concerns we have identified will require a balance of systematic solutions and nuanced treatment. We propose four hypotheses for developing these solutions.

1. **Nuclear-data center collocation requires collaborative planning and communication, but has potential to simplify permitting, enhance safety, and reduce costs, thus accelerating projects.**

   Collocating nuclear and data center facilities can leverage the steady high power of nuclear generation to serve base loads of data centers. Faster interconnection timelines and reduced costs may be achieved through careful coordination with utilities and treatment of the facilities as a joint portfolio. Exactly where the cost savings are, how safety is impacted, and how permitting and licensing can be accelerated are still open questions. Providing concrete estimates of cost and time savings can identify the most beneficial integration strategies for these facilities. Differences in development timelines, regulatory oversight, and operational cultures can create friction unless addressed through joint planning frameworks and shared risk assessments. When executed effectively, collocation can accelerate project timelines by aligning infrastructure investments and streamlining permitting.

2. **Policy and regulatory alignment are needed to address cultural and operational differences, and changes will be driven by public-private partnership.**

   The current regulatory environment often reinforces siloed decision-making across sectors. Data center developers, utilities, and nuclear operators operate under different mandates, risk tolerances, and planning horizons. Bridging these divides requires policy reforms that incentivize integrated planning and clarify roles in large–load-interconnection processes. Public-private partnerships will be essential to drive these changes, enabling stakeholders to co-develop regulatory pathways, pilot new coordination models, and align incentives for shared infrastructure development. While data center, nuclear, and utility stakeholders have individual and joint challenges, a fourth intermediary stakeholder could accelerate nuclear/data center deployment. This intermediary could be a company or a consortium of the other stakeholders. Knowledge sharing and collaboration among stakeholders through this intermediary could efficiently address common challenges confronted by each organization and bridge the gap with expertise spanning across technology areas. DOE laboratories can support collaboration by bringing stakeholders together and helping establish consortia. Surveying stakeholders to identify how an intermediary could facilitate stakeholder collaboration and remove barriers to deploying nuclear data centers would help to define the role of partnerships and the opportunities for policy alignment.

3. **Data centers can become grid-stabilizing assets through operational integration and policy innovation.**

   As data centers grow in scale and sophistication, they have the potential to evolve from passive energy consumers into active grid participants. When collocated with nuclear generation or equipped with advanced energy-management systems, data centers can provide valuable grid services, such as frequency regulation, voltage support, and demand flexibility. However, realizing this potential requires new operational models that treat data centers as dispatchable or semi-dispatchable loads, capable of modulating demand in response to grid conditions. Collaboration among stakeholders could also help to reduce risk for all parties. For example, risk-sharing strategies like ordering multiple nuclear power plants shared among several data centers could limit the risk exposure for each collaborator. Success in this area also demands policy innovation, such as updated interconnection standards, compensation mechanisms for grid services, and regulatory recognition of hybrid nuclear-load configurations. By enabling data centers to operate as grid-stabilizing assets, stakeholders can unlock new pathways for reliability, resilience, and dispatchability.

4. **Technological innovations and advancements are needed to gain efficiencies in integrated energy system deployment.**

   Data centers can impose challenges on grid operations, but collaboration among stakeholders can ensure equipment longevity, resource adequacy, and grid stability. Pairing nuclear power with energy storage and other resources in an integrated energy system can help mitigate load-volatility concerns and provide backup power to the data center. Existing planning tools and modeling frameworks are not well suited to capture the dynamic, high-density load profiles of modern data centers or the operational characteristics of advanced nuclear technologies. Innovations in grid modeling, load forecasting, and IRP are needed to support more accurate and actionable decision-making. This includes the development of secure data-sharing protocols, modular planning tools, and simulation platforms that can evaluate the co-optimization of generation, transmission, and load. These advances will be critical to reduce uncertainty, improve grid reliability, and enable more strategic infrastructure investments.

All perspectives considered here stand at the precipice of rapid technological advancement. During these periods of accelerated evolution, growth for one is growth for all as lessons learned across each industry drive more efficient and reliable solutions. Without requiring specific projects to divulge business-sensitive outcomes, shared knowledge is a powerful mechanism to avoid the risk of energy and technological poverty and secure an abundant future. Research, development, and deployment of AI technology are critical to the development of security, economic competitiveness, and value leadership. Energy abundance is among the primary resources for this effort, possibly even the most critical resource. Energy scarcity presents a risk to future well-being that cannot be ignored. To achieve energy abundance, all generation technologies must be considered for the strengths they can provide to a robust and reliable energy grid. Among these technologies, nuclear energy generation provides a wealth of excellent properties to enable data center deployment, including unmatched reliability and uptime, predictable baseload generation, highly efficient land use, scalability and siting flexibility, and stable long-term costs. While deploying nuclear generation to support data center growth introduces challenges for owners and operators of data centers, nuclear generation, and utilities, the benefits to all three industries far outweigh the challenges posed, especially when interested parties work together to find solutions to common obstacles.

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