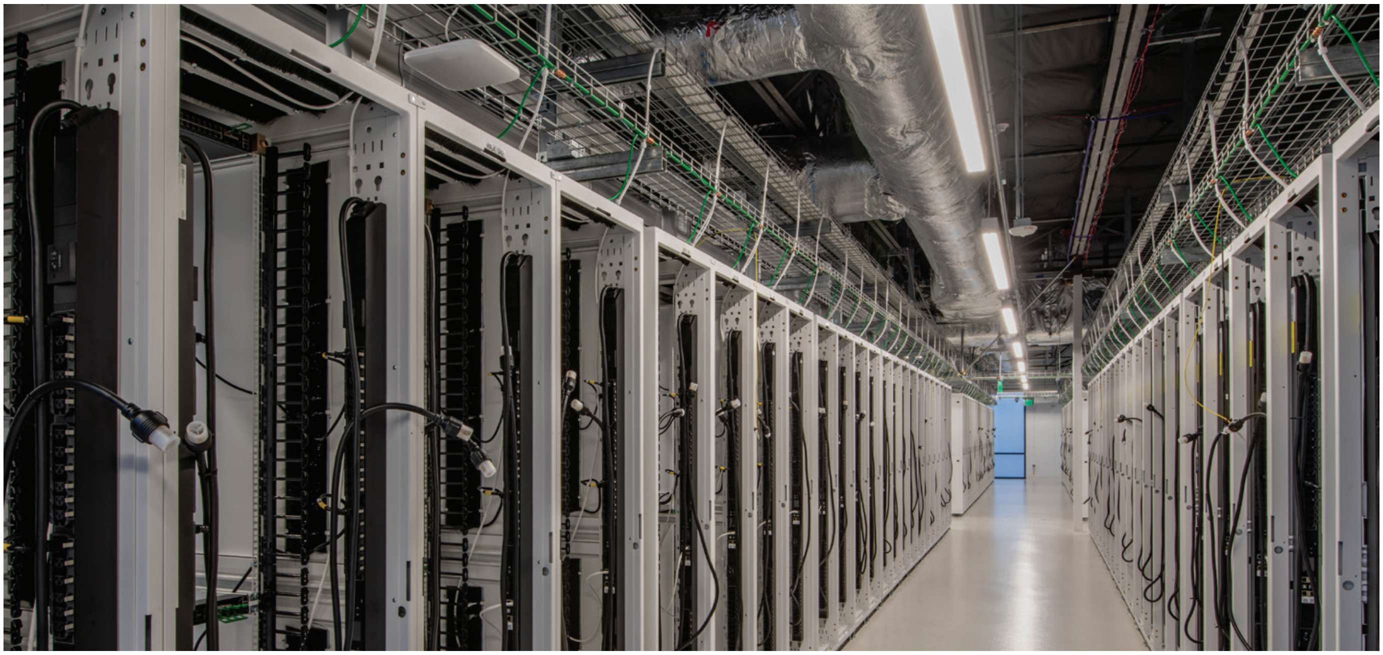
ESIG
Large Loads
Task Force

ESIG
ENERGY SYSTEMS
INTEGRATION GROUP

Resource Adequacy with Large Loads

Planning for Flexibility to Accelerate Integration

EXECUTIVE SUMMARY



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Electricity demand in the United States is growing at a pace not seen in decades, driven primarily by a new large loads such as data centers, industrial electrification, hydrogen production, and electric vehicle fleets. These loads are unprecedented in size, with some hyperscale data center loads approaching or surpassing 1 GW at a single point of interconnection, and they are emerging during a time of tightening supply conditions caused by fossil plant retirements and supply chain bottlenecks for new generation.

> **By treating large loads' flexibility as a planned capacity resource considered up front in planning, utilities and regional grid operators can transform a potential source of resource adequacy risk into a system asset.**

This convergence of surging demand and constrained supply puts significant pressure on the resource adequacy of the bulk power system. Traditional planning frameworks, designed for incremental load growth and predictable resource mixes, are being tested by customers that can drive multi-gigawatt shifts in demand on short timelines. The risks are clear: if load growth outpaces the addition of new resources, system reliability could be eroded; conversely, delaying interconnections to preserve reliability threatens the economic viability of new developments and the nation's competitiveness in critical industries like artificial intelligence (AI) and advanced manufacturing.

See the full report—
Resource Adequacy with Large Loads: Planning for Flexibility to Accelerate Integration


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To manage these risks, the industry can move beyond short-lead-time measures developed outside of long-term planning—such as curtailment programs—and assess large load impacts up front in the electricity system planning process. This includes evaluating the latent flexibility potential of large data center loads, which can be operated through several pathways such as intelligent workload management, thermal control strategies, and on-site generation. Utilities, grid operators, and large loads—including hyperscale data center developers—from across the United States and globally have already called on the industry to align on a flexibility framework as a key tool for accelerating time to power.*

By treating this flexibility as a planned capacity resource considered up front, utilities and regional grid operators can transform a potential source of resource adequacy risk into a system asset. Integrating large load flexibility into modeling for long-term resource adequacy allows planners to flatten the peaks that drive capacity requirements, reducing the need for new firm generation, while increasing the utilization of existing capacity and thereby increasing system efficiency and reducing electricity system costs.

Managing Resource Adequacy Risks in a Tight Supply Environment

Unlike the incremental, population- and economy-driven load growth of the past, today's large load development is characterized by discrete, binary events: a single data center or industrial facility can add hundreds of megawatts of demand in a stepwise shift. Forecasting these loads is exceptionally difficult, as data center developers often pursue multiple sites simultaneously to maximize interconnection success, clogging interconnection queues with many requests that may never materialize.

Furthermore, the operating characteristics of these loads are diverse and rapidly evolving. The hour-to-hour operations of large loads are unique, even within a single class of large loads. For example, a data center's impact on the grid varies significantly depending on whether it is used for AI training, inference, or cloud storage—distinctions that are often invisible to the host utility or other grid operator. Without granular data on these end uses, planners may be challenged to model the potential coincidence of these loads with electricity system peaks or assess the ability of these loads to provide demand flexibility.

The forecasting uncertainties are compounded by supply-side resources that are increasingly capacity-constrained. New large loads are seeking to interconnect just as aging fossil generation is retiring and the deployment of new resources faces headwinds. Supply chain bottlenecks for critical equipment, such as gas turbines and transformers, along with lengthy generator interconnection queues, have limited the ability to add firm capacity in the near term.

This imbalance creates a growing tension between the utility's "obligation to serve" and the physical imperative

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* https://dcflex.epri.com/flex-mosaic

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to maintain system reliability. Navigating this environment requires finding solutions to integrate these loads without compromising resource adequacy.

Current Approaches to Mitigating Near-Term Resource Adequacy Risks

Faced with the magnitude of new large loads and the urgency of near-term interconnection requests, utilities and regional grid operators are deploying a range of short-term measures to preserve reliability. Broadly, these approaches fall into three categories: interconnection moratoriums, load-curtailment programs, and "bring your own new generation" (BYONG) arrangements.

Interconnection Moratoriums

In regions where system conditions have become too constrained to reliably interconnect new load, some utilities have issued interconnection moratoriums on new data centers. These pauses allow utility planning departments time to study the reliability impact of pending service requests and identify necessary mitigations. While effective at preserving near-term reliability, moratoriums are blunt instruments that can undermine broader economic development goals.

Load-Curtailment Programs

Curtailment-based reliability programs allow new large loads to connect under the condition that their net output may be reduced during system emergencies or periods of high risk to preserve resource adequacy. Some curtailment-based reliability programs, such as SPP's Conditional High-Impact Large Load Service (CHILLS), allow large loads to interconnect on an accelerated timeline in exchange for being subject to curtailment during system emergencies. Others, such as those required by Texas Senate Bill 6, do not provide accelerated interconnection and instead impose mandatory requirements for large loads. These programs ensure that new large loads do not degrade reliability for existing customers and place operational risk onto these new loads. That potentially makes these programs less attractive than firm service pathways or those that provide large loads with greater agency in how and when they provide flexibility services.

Bring-Your-Own-New-Generation Arrangements

Another approach involves BYONG arrangements, such as under SPP's High-Impact Large Load Generation Agreement (HILLGA), or PJM's January 2026 Critical Issue Fast Path Proposal, which allow large loads to offset their grid impact through self-supplied capacity. By committing to rely on on-site or contracted generation resources, large load customers can bypass certain capacity constraints and interconnect more quickly.

Limitations of Interim Measures

While these mechanisms provide valuable tools for managing near-term risks, integrating them into long-term planning processes and frameworks is necessary to support the most cost-effective outcomes for long-term resource adequacy. Without integration, these tools can lead to suboptimal outcomes: piecemeal procurement of on-site resources may not align with broader electricity system needs, and curtailment risk can undermine the business case for large load development. Furthermore, without careful design, these programs can distort investment signals, potentially reducing the incentives for new firm capacity to enter the market. Moving from these short-lead-time solutions to a robust, long-term resource adequacy strategy requires integrating large load flexibility up front into system planning.

A Framework for Implementation: The Six-Step Process

This report outlines a standardized six-step process to effectively integrate large load flexibility into long-term electricity system planning—specifically, for resource

FIGURE ES-1

Six-Step Process to Plan for Large Load Flexibility Up Front in the Capacity Planning Process

Step 1	Step 2	Step 3	Step 4	Step 5	Step 6
Characterize loads with greater fidelity	Improve large load forecasts	Quantify capacity requirements of large loads without flexibility	Quantify capacity contributions of large load flexibility	Calculate the avoided infrastructure investments resulting from large load flexibility	Develop regulatory mechanisms that account for the value of large load flexibility

Source: Energy Systems Integration Group.

capacity (Figure ES-1). The framework leverages established planning tools, including capacity expansion and probabilistic resource adequacy models, to systematically evaluate how load flexibility affects resource adequacy and investment needs. By isolating the incremental impact of flexibility, the framework offers a transparent, data-driven foundation for decision-making.

Step 1: Characterize Loads with Greater Fidelity

Planners need to move beyond generic load representations by segmenting large loads based on key operational features such as size, ramp rates, and flexibility potential. In addition, distinguishing between end uses, such as AI training versus inference or hydrogen production, enables planning models to capture critical differences between loads such as weather dependence and coincidence with system peaks.

Step 2: Improve Large Load Forecasts

Planners can develop “large-load layers” that separate these loads from other loads and employ scenario-based forecasting approaches to address uncertainty. Planners can also ground large load forecasts using evidence beyond interconnection requests and include high- and low-growth “bookend” scenarios to capture the full range of potential load-growth realization outcomes.

Step 3: Quantify Capacity Requirements of Large Loads Without Flexibility

This step establishes a baseline by calculating the total amount of accredited capacity required to meet the resource adequacy criterion if new large loads were to come online as fully firm, inflexible demand. This “no-flexibility” scenario can be compared against scenarios that consider large load flexibility (Step 5) to compute its incremental value. The no-flexibility scenario can also be compared against a “business as usual” scenario that assumes no new large loads come online, allowing planners to attribute specific capacity requirements and costs directly to inflexible new large loads.

Step 4: Quantify Capacity Contributions of Large Load Flexibility

Using probabilistic methods like effective load-carrying capability (ELCC), planners can accredit large load flexibility as a capacity resource, allowing it to be treated comparably to generation resources in capacity expansion modeling. This accreditation quantifies the firm capacity value of flexibility and can reflect how that value may vary based on parameters such as response duration, frequency of calls for flexibility, and load availability. Alternatively, the capacity contributions of large loads can be represented through a reduction in the planning reserve margin (PRM) requirement, whereby only the firm (non-flexible) portion of large load demand counts toward the PRM requirement. This approach does not require capacity accreditation of flexible large loads and instead socializes their flexibility benefits across all customers.

Step 5: Calculate the Avoided Infrastructure Investments Resulting from Large Load Flexibility

By incorporating the accredited flexibility (or reduced PRM) into capacity expansion models, planners can determine the type and amount of supply- and demand-

TABLE ES-1

Summary of Recommendations

Stakeholder	#	Recommendation
Resource adequacy modelers	A1	Incorporate multiple load-growth scenarios
	A2	Ensure close coordination with demand forecasters
	A3	Evaluate the incremental impact of large load flexibility
Resource planners at vertically integrated utilities	B1	Plan and procure large load flexibility up front
	B2	Model multiple planning scenarios to isolate the capacity requirements attributable to large loads
	B3	Incorporate flexible-load accreditation (e.g., ELCC) in integrated resource plans
	B4	Solicit flexibility in negotiated tariffs and exchange faster interconnection for flexibility
Independent system operators' and regional transmission organizations' market operators and planners	C1	Clarify the treatment of on-site generation and “bring your own new generation” (BYONG) options in capacity markets
	C2	Develop clear accreditation rules and participation pathways for large load flexibility in capacity markets
	C3	Incorporate flexibility options into interconnection and capacity market processes
	C4	Design non-voluntary load curtailment programs carefully to avoid distorting capacity investment signals
Data centers and other large loads	D1	Plan for flexibility early in the large load design and development process
	D2	Ensure grid operator visibility through robust control architecture and telemetry configurations
	D3	In bilateral contracts with utilities, provide firm flexibility commitments with clear limits
	D4	Consider utility contracts that monetize avoided capacity and support faster interconnection
	D5	Work with utilities and regional grid operators to provide representative, detailed operational data to support effective resource adequacy modeling
State utility regulators	E1	Isolate the costs of capacity attributed to new large loads to ensure that cost allocation and retail rate structures are fair to all utility customers
	E2	Use results from integrated resource planning modeling that assess incremental large load impacts—with and without flexibility—to inform cost allocation and tariff design
	E3	Assess whether traditional/existing demand response programs provide appropriate incentives for desired flexibility responses
	E4	Set goal posts around the types of flexibility that are needed rather than prescribe specific flexibility technologies
	E5	Incorporate flexibility incentives and/or requirements in large load tariffs and rate designs
	E6	Leverage utility resource adequacy analysis to set a cap on the amount of large load flexibility needed

side resources that can be avoided or deferred. This step yields quantifiable metrics on system cost savings, providing an economic foundation on which to design flexibility incentives.

Step 6: Develop Regulatory Mechanisms That Account for the Value of Large Load Flexibility

Finally, the quantitative insights from the previous steps are translated into regulatory mechanisms. Avoided costs and deferred investments can inform the design of large load tariffs, interconnection agreements, and market rules that fairly allocate costs and reward demand flexibility, aligning the economic interests of large customers with system adequacy goals.

Methods and Data Needs for Effective Modeling

Accurately representing large loads within resource adequacy and capacity expansion models depends on integrating detailed, segment-specific data into planning workflows. Critical to this effort are 8,760-hour chronological load profiles that capture the coincidence of large load demand with system peaks. Where relevant, it is important that these profiles reflect weather dependence, particularly for cooling-intensive loads like data centers. Large load forecasts can also specify zonal locations to evaluate local resource capacity and transmission constraints, as well as ramp rates to capture how quickly demand will scale after the large load is energized.

In addition, planners need detailed specifications on on-site generation and storage assets, including generator size and run-hour limitations, to assess their potential reliability contributions. Given the high uncertainty around large load development, modelers can employ “bookend” scenarios that span both high and low load-growth outcomes and assign probabilities of realization to individual large load projects to better capture uncertainty.

Effectively accrediting large load flexibility as a capacity resource—for example, to support the six-step framework described in this report—requires additional data. Planning models can vary parameters such as the size of the flexibility response (MW), frequency of deployment, and duration of each flexibility event to test different combinations and assess how they affect demand flexibility accreditation. Models can account for event-specific limits, such as maximum depth of flexibility response, as well as horizon-wide constraints like annual energy budgets or total call limits. And to ensure operational realism, models ideally would incorporate response performance rates, representing the probability that flexibility will materialize when called, and account for weather-driven variations in flexibility availability.

Recommendations

Operationalizing the six-step framework requires coordinated action across the industry. Table ES-1 (p. 5) summarizes targeted recommendations for stakeholders to support proactive, flexibility-driven large load planning.

To ensure a reliable and affordable grid in the face of unprecedented load growth, the electric power industry can develop demand flexibility solutions that are harmonized with long-term planning and market design processes. Incorporating large load flexibility up front in the resource adequacy assessment process is one such solution essential for ensuring the timely interconnection of large loads while managing costs and system-wide reliability impacts. By quantifying the flexibility capabilities of large loads and potential capacity savings through the proposed six-step framework, planners can support win-win solutions for key stakeholders.

Resource Adequacy with Large Loads: Planning for Flexibility to Accelerate Integration, by the Energy Systems Integration Group's Large Loads Task Force, is available at https://www.esig.energy/reports-briefs/large-loads-resource-adequacy.

To learn more about ESIG's work on large loads, please see https://www.esig.energy/working-groups/large-loads/ or send an email to info@esig.energy.

The Energy Systems Integration Group is a nonprofit organization that marshals the expertise of the electricity industry's technical community to support grid transformation and energy systems integration and operation. https://www.esig.energy.