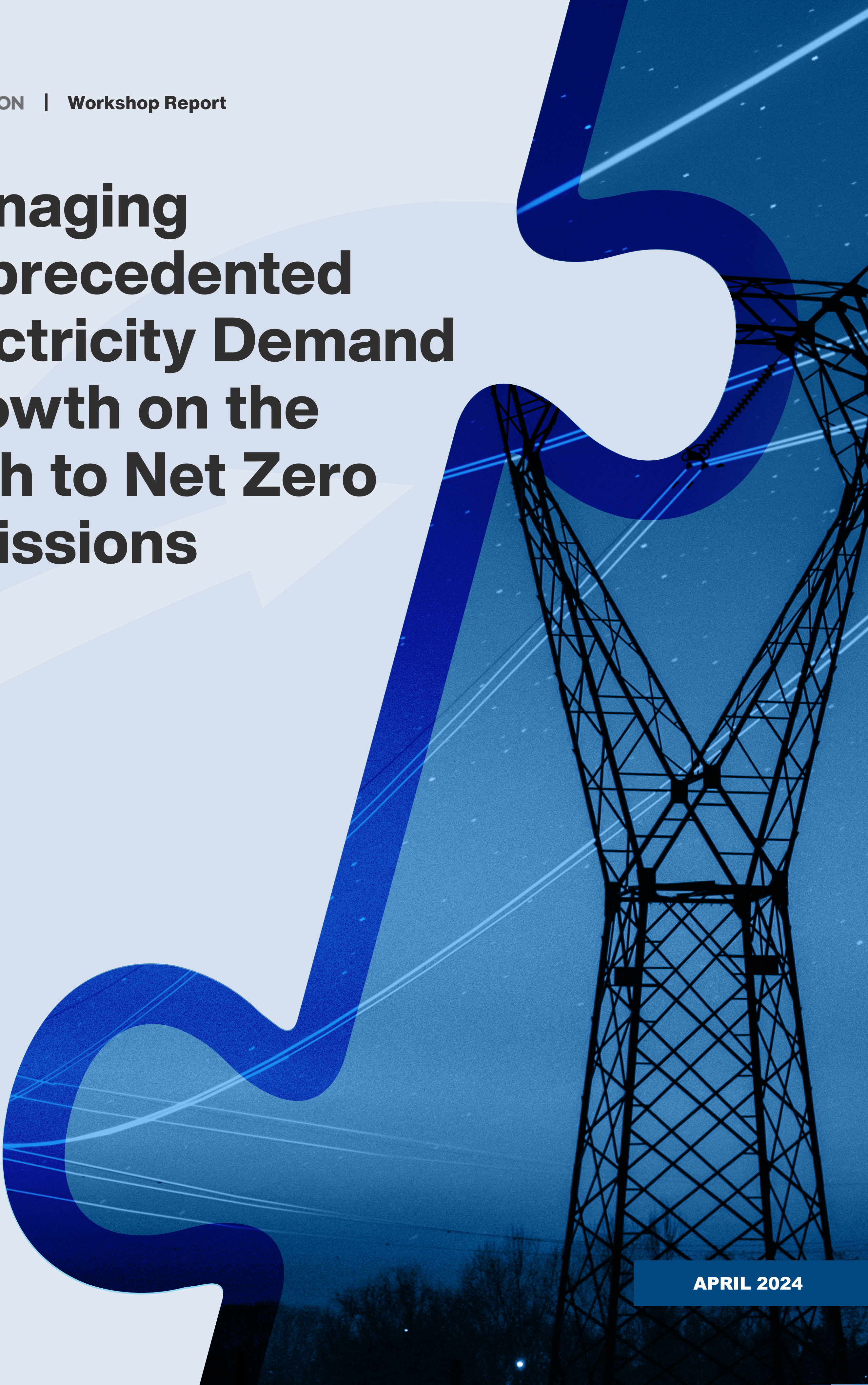
EFI FOUNDATION | Workshop Report

Managing Unprecedented Electricity Demand Growth on the Path to Net Zero Emissions



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The EFI Foundation advances technically grounded solutions to climate change through evidence-based analysis, thought leadership, and coalition-building. Under the leadership of Ernest J. Moniz, the 13th U.S. Secretary of Energy, the EFI Foundation conducts rigorous research to accelerate the transition to a low-carbon economy through innovation in technology, policy, and business models. EFI Foundation maintains editorial independence from its public and private sponsors.

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Summary

As the United States works to address the climate crisis, the urgent push for decarbonization stands in stark contrast to the immediate challenges of managing near-term electricity load growth. Recent incentives to re-shore clean energy supply chains in legislation like the Inflation Reduction Act (IRA), the Infrastructure Investment and Jobs Act (IIJA) and the CHIPS and Science Act have prompted some of these new load demands, many of which will require firm power 24/7. Data center proliferation is also a major driver of near-term load growth, and the rapid expansion of AI is exacerbating their load requirements. In the mid- to long-term, increased electrification of end uses, such as vehicles, heat pumps and some industrial processes, compound the issue. To capitalize on these economic development opportunities, states and regions are seeking creative solutions to deal with load growth such as building out grid infrastructure and investing in projects that accelerate clean energy innovations.

The load growth dilemma is intensifying the strain on existing infrastructure, and addressing it requires inventive solutions and strategic foresight. Many utilities have dramatically increased their projected electricity load growth and have proposed meeting this in the near term by increasing their use of existing and/or new thermal plants. The tension between economic development and the associated increased electricity load and declared utility decarbonization targets in the 2030-time frame has stimulated important discussions.

On Feb. 12, 2024, the EFI Foundation hosted a group of nearly 30 senior-level experts from utilities, system operators, industry, and nongovernmental organizations, as well as former policymakers and regulators, consumers, and equipment (e.g., turbine) manufacturers to discuss the implications of recent public announcements of unprecedented load growth across many regions of the country.[1,2,3]

Several challenges were identified at the workshop that will need to be addressed in an era of dramatic acceleration in load growth. They are as follows.

1. **1.** Load growth is not uniform across the country and regionality impacts the tools available to address it. Regional differences in resource availability, including the appropriate geology for carbon storage and access to water resources, as well as the availability of generation resources like wind and solar means that strategies for addressing load growth must be tailored to regional resources, infrastructure needs, and limitations, particularly in the near term.
2. Load growth is likely to further accelerate. Data centers dominate the headlines today, but new manufacturing combined with electrification of transportation, space heating, and industry will place even greater strain on the grid in the coming decades.
3. Ensuring reliability and resiliency is paramount. While grid-enhancing technologies and storage solutions may lessen near-term load growth challenges, new gas-fired generation capacity will come online to provide firm power. As a result, power sector emissions may rise in the short term, while

generation and transmission with longer lead times will address emissions in the longer term.

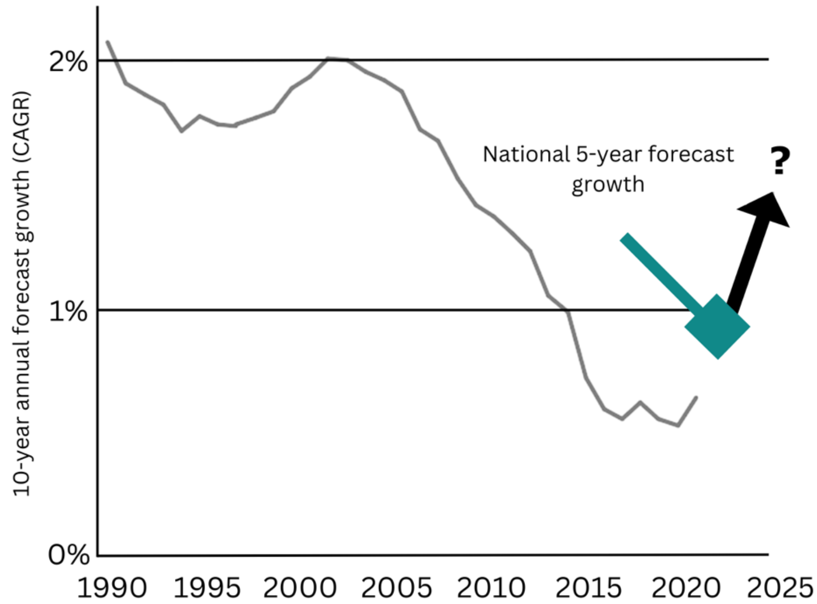
4. Policies need to be harmonized. New proposals seek to limit power sector emissions in the wake of recent policies promoting electrification. These proposals may constrain the sector's ability to meet increasing load demands. If the U.S. continues to encourage electrification, complementary policies will be needed to expedite grid modernization.
5. Very large, unexpected loads like gigawatt-sized data center campuses could require utilities to rethink their five-year plans. Longer term, grid managers may also need to create the frameworks and the associated regulatory structures to enable more proactive infrastructure buildout.
6. Though the threat of litigation has long been considered a serious impediment to building out new infrastructure, it has increased in prevalence and now seems to pervade the entire political spectrum.

Introduction

The economywide transition to net zero emissions will rely heavily on successfully decarbonizing the power sector. For years, relatively flat power demand provided grid operators a clear and certain view of the scale of clean energy resources needed to reach zero carbon emissions. Now, driven in part by massive incentives in domestic manufacturing; trends in electrification of transportation, buildings, and industry; clean energy targets across the economy; and new investments in data centers and artificial intelligence, the pace of electricity load growth could nearly double or even triple over the next five years (Figure 1).[4,a] These load growth trends have potentially paradigm-shifting implications for the power sector, affecting system-wide reliability in the near-term and changing the course of deep decarbonization in the mid-term.

[a] Electricity load is the amount of power required to meet the demands of all customers on the grid. For example, a new data center may require 750 megawatts (MW) of power capacity. Once it is connected to the grid, the data center adds 750 MW of load. Grid managers are now facing the challenge of serving an unexpected growth in new load.

Figure 1. North American Electric Reliability Corporation's 10-year load growth forecast trend



For the last decade, grid planners have forecast only 0.5% annual electricity load growth, as reported by the North American Electric Reliability Corporation. However, in 2023, that forecast changed to 0.9%, as indicated by the blue box in the graph. Regional utility profile filings have revealed that electricity load will likely increase even more than that. Adapted from: North American Electric Reliability Corporation, Long-Term Reliability Assessment, December 2022, p. 20, Supplemental Table F, https://www.nerc.com/pa/RAPA/ra/Reliability%20Assessments%20DL/NERC_LTRA_2022.pdf.

Held under Chatham House Rule[b], the private EFI Foundation Load Growth Workshop was designed to elicit stakeholder discussion of both the opportunities and challenges of these recent trends, addressing the following questions:

- What is contributing to the potentially paradigm-shifting changes in near- and midterm load growth forecasts?
- What are the immediate needs for meeting electricity demand in the next one to five years, and how can stakeholders stay on track to decarbonize the sector by midcentury?
- How can longer-term planning and coordination efficiently enable the transition to a reliable, carbon-free electricity grid by midcentury?

The workshop discussion made clear that stakeholders are grappling with a new reality. Previously unforeseen load growth presents challenges with respect to continuing coal plant retirements, integrating renewables, and maintaining reliability. However, on the path to long-term climate goals, utilities, system operators, and policymakers also have

[b]Unattributed quotes throughout the report originate from the workshop discussion.

an opportunity to proactively collaborate and plan for a future that supports technologies that are clean, reliable, and affordable.

Four major themes emerged during the conversation:

1. **Recent projections are likely underestimating actual load growth.** Participants agreed that the projection that the pace of electricity load growth will double in five years is likely an underestimate as more utilities update their load growth forecasts.[5] This reinforces the idea that the era of flat demand is truly over for the near- and mid-term.
2. **Region-specific approaches are necessary for managing near-term load growth.** Regions across the U.S. are experiencing different paces of load growth and have varying options for its management. It is clear that reliable and affordable electricity cannot be compromised as cities, states, and regions work to meet climate goals. However, few existing technologies can provide cleaner, reliable, and affordable electricity. To meet near-term demand, natural gas generation with lower carbon intensity is an option consistent with various federal policies including the Inflation Reduction Act's (IRA) methane emissions fee. Grid-enhancing technologies, demand-side management, transmission and distribution system investments, and energy storage can also help. In parallel, continued investment in research, development, and demonstration projects is crucial to commercializing and deploying advanced clean energy technologies like CCS, clean hydrogen, small modular reactors, and long-duration energy storage.
3. **Stakeholder alignment is critical to meet the dual challenges of load growth: manage reliability and plan for deep decarbonization.** While the issue of certainty was discussed along many dimensions, what is clear is that the key stakeholders that collectively manage significant new loads must be aligned for the necessary investments in generation, transmission and distribution, and other resources that help manage the system. For example, how can policymakers and regulators unlock large amounts of private capital for projects? New large loads need to be developed in close coordination with grid planners and operators.
4. **Stakeholders are seeking flexibility to manage load growth uncertainty.** Investors, grid managers, and end users are all seeking certainty: Will new demand materialize to justify investments in generation and transmission infrastructure, and will it do so on the anticipated timeline? If electricity prices rise (which some stakeholders expect), will that reduce future load growth in turn? Increased transparency and collaboration can reduce uncertainty. Durable policies are also critical for investors to feel confident deploying large amounts of capital to projects.

Given the cross-cutting nature of many of the topics, some themes recur throughout this workshop report as they did in the conversation. Such cross-cutting themes demonstrate that these issues—along with many others—must be considered holistically by decision-makers.

1 Recent projections are likely underestimating actual load growth.

"[F]ive years ago, we had relatively flat growth in the industrial sector. … Certainly, data centers were growing, but not quite the pace that they are suddenly now, so I think this is just a challenge to change to a new era."

"10 years ago, everybody thought a 25 [megawatt, MW] load was big. These [loads today] are huge—725 MW."[c]

Until recently, demand in the electricity sector was relatively stable. In recent years, however, investment in large sources of new load—manufacturing facilities and data centers—has reached $630 billion.[6] This rapid growth is driven, in part, by recent legislation: the Infrastructure Investment and Jobs Act (IIJA), the Inflation Reduction Act (IRA), and the CHIPS and Science Act (Figure 2).[7] While recent projections from utilities, RTOs, analysts, and others are being revised upwards to account for these investments, workshop participants agreed that the projections are lagging economic development indicators.

Affordable and reliable electricity is non-negotiable on the road to net zero. One participant summed up comments from the group in saying, "Our first and foremost responsibility is reliability—to keep the lights on." As electricity demand grows from rapid electrification, manufacturing, and proliferating data centers that require more energy, electricity generation and transmission capacity must be adequate to meet demand. That capacity must also be able to integrate clean energy sources, or decarbonization goals in this sector will be undermined.

[c] As mentioned, quotes from workshop participants are unattributed as the workshop was held under Chatham House Rule.

Figure 2. Regional growth drivers

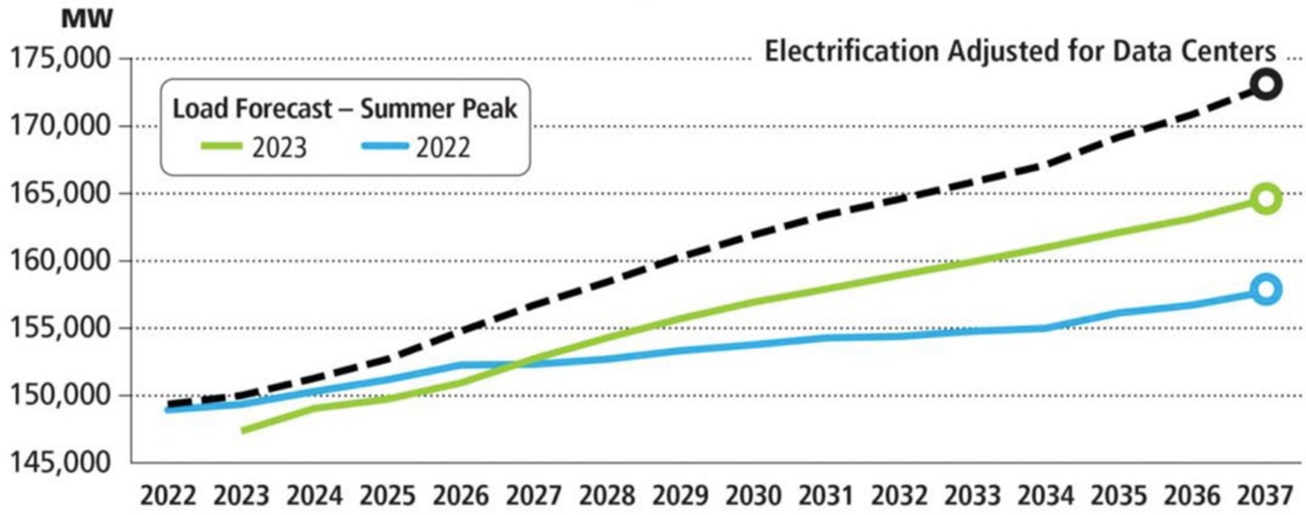
	Data centers	Industrial facilities	Hydrogen plants	Electrification
ERCOT	●	●		
PJM	●			
Duke Energy	●	●		
Georgia Power	●	●		
NYISO	●	●	●	●
Arizona Public Service	●	●		
CAISO				●
Portland General Electric	●	●		

In recent years, grid planners' load forecasts pointed to economic growth, population growth, temperature patterns, and electrification as driving electricity demand. However, in seven of the eight load forecasts above, data centers (including for cryptocurrency and artificial intelligence) and industrial facilities (mainly battery and automotive, but also hydrogen plants) are the key drivers of this sudden surge in load growth expectations. Adapted from: John D. Wilson and Zach Zimmerman, Grid Strategies: The Era of Flat Power Demand is Over, December 2023, https://gridstrategiesllc.com/wp-content/uploads/2023/12/National-Load-Growth-Report-2023.pdf.

At present, data centers account for 2.5% of U.S. electricity consumption but are expected to reach 7.5% to 10% of the nation's electricity demand by 2030.[8] At the same time, demand for cloud computing services is surging, and the COVID-19 pandemic has accelerated the shift toward centralized data storage.[9]

Together, these estimates suggest a potential undercount of three to five gigawatts (GW) in national forecasts through 2028, although participants emphasized that projection is likely still too low.[6] Concerns about undercounting are warranted: a single data center coming on line in the Southeast in 2027, for example, will require 950 MW of capacity.[10] The developers expect it to take two to four years to reach full capacity and anticipate demand will peak somewhere between 70% and 90% of capacity, which enables a reserve margin to account for weather variation and unexpected demand.[10] As data centers of this magnitude proliferate, advanced, proactive planning by system operators and utilities to meet the increased demand is critical. Figure 3 provides an overview of the projected load growth from a regional transmission organization (RTO), PJM Interconnection, that exemplifies the change in projections in as little as one year.[11]

Figure 3. PJM's projected load growth



PJM's load forecast has been reviewed twice in recent years to account for future expected load growth, including from data centers. In the latest projection, for instance, the 2028 forecast increased from 152.7 GW to 155.7 GW in the past year, a 2% increase. PJM is a regional transmission organization (RTO) that has about 50 participating electric distribution utilities operating in 13 states from New Jersey to Illinois and the District of Columbia. Source: PJM, Energy Transition in PJM: Resource Retirements, Replacements, and Risks, February 2023, https://www.pjm.com/-/media/library/reports-notices/special-reports/2023/energy-transition-in-pjm-resource-retirements-replacements-and-risks.ashx.

In the short term, increasing electricity demand is driven by new large loads, including data centers and manufacturing facilities. In the long term, electrification and electric vehicles are expected to contribute larger shares of the overall load demand.

"It's not only adding generation for load growth; it's adding generation to get out of that coal."

Amid this growth in demand, utility companies are continuing their decade-long efforts to reduce the use of coal, which further increases the need for new electricity generation. Participants emphasized a need for "new, firm, reliable power on a short timeline to serve new large loads." However, one individual noted the "need to find a way of doing that that doesn't make us go backward on our climate commitments."

Meeting unexpected near-term load growth may necessitate expediting the construction of rapidly deployable plants like natural gas combustion turbines or the increased use of existing thermal power plants (e.g., extending the operational life of coal-fired plants or maximizing the usage of natural gas plants). These measures present potential conflicts to pursuing decarbonization goals while adhering to environmental regulations and meeting electricity demand.

2 Region-specific approaches are necessary for managing near-term load growth.

"At the end of the day, we're utility customers and our operations are dependent on the grids where we are located. … I can't be in [one state] and switch to someone else's grid to get electricity."

"I'd love to have a large clean energy resource that I could bring on line by 2030. It doesn't exist right now."

The levels of load growth that were discussed will depend on building new generation in many regions of the country. Workshop participants pointed to the importance of considering regional differences in electricity demand, resource availability, and policy landscapes. Regionality was, in fact, the most discussed topic of the workshop as it is inextricably linked with every other issue in the load growth conundrum.[d]

Load growth, in particular, has remained relatively consistent in some parts of the country while changing quickly in others. To the extent that neighboring regions have excess generation, enhancing interregional transmission can play a role in addressing this challenge. For example, much of the nation's anticipated industrial load growth is occurring in three regions: the Southwest, particularly Arizona and Nevada; the Midwest, concentrated in Michigan and Indiana; and the Southeast in Georgia and the Carolinas. One participant said that Arizona alone is expecting at least 40% load growth over the next five years.[e,1,12]

Among the technologies for addressing load growth today, it is particularly difficult to find ones that are readily available, reliable, and clean, with large capacity. Participants observed that natural gas partially fills such a gap because of its reliability and affordability but does not provide the emissions reduction benefits of emerging clean energy technologies.[f] Natural gas usage has markedly increased as coal usage has decreased (Figure 4), in part because it has become cost-competitive due to policy and technological advancements.[13] Addressing upstream and point-source methane emissions will help decrease the greenhouse gas emissions from natural gas and increase its acceptability.

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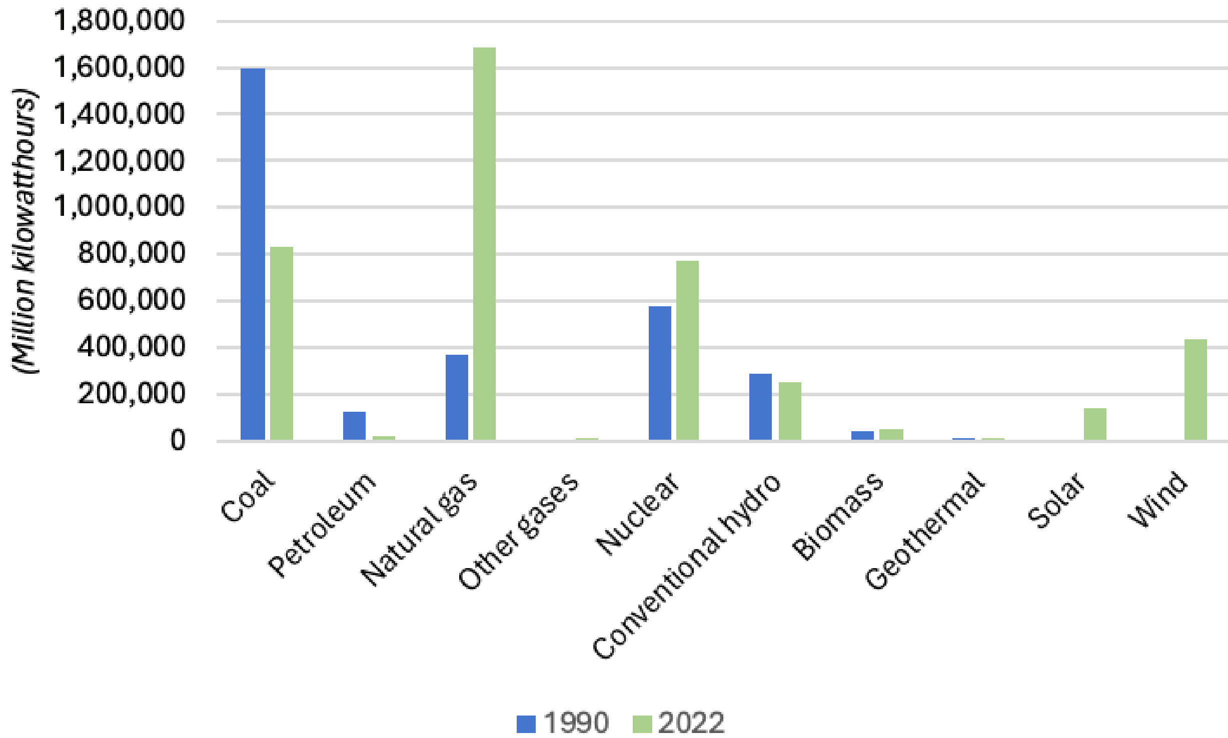
[d] In our thematic coding of the workshop themes, regionality was the most frequent code, including the words "region," "regionality," and the names of individual regions such as "MISO" (Midcontinent Independent System Operator) and "the Southwest."

[e] Though data centers account for the largest share of expected load growth overall, that growth is more evenly dispersed around the country. Data center growth is highest in the PJM region, which covers much of the mid-Atlantic, including Virginia, where data centers and cloud markets are expected to concentrate. PJM recently updated its load forecast and tripled its estimated growth expectations over the next decade from the previous year (see endnotes 4 and 29) to accommodate the expected increase in data centers, particularly those that support generative AI, which is especially energy-intensive. Increased electrification of transportation and industry was another reason for the PJM update.

[f] Natural gas was the fifth most frequent topic of discussion, with 42 mentions, accounting for 11% of all coded segments.

Figure 4. U.S. annual electricity generation by source



Comparing trends from 1990-2022, 78.4% of U.S. power generation in 2022 was from natural gas and zero-carbon sources, a substantial increase over the last three decades. Zero-carbon sources accounted for 39.6% of U.S. power generation in 2022. "Other gases" refers to blast furnace gas and other manufactured and waste gases derived from fossil fuels. Through 2010, this includes propane gas. "Biomass" includes wood and wood-derived fuels, along with municipal solid waste from biogenic sources, landfill gas, sludge waste, agricultural byproducts, and other biomass. Through 2000, this includes non-renewable waste, as well. "Solar" includes generation from solar thermal and photovoltaic energy at utility-scale facilities. It does not include small-scale photovoltaic generation. Data from: U.S. Energy Information Administration (EIA), Monthly Energy Review, Table A2: Approximate Heat Content of Petroleum Production, Imports, and Exports, January 2024, https://www.eia.gov/totalenergy/data/monthly/pdf/sec12_3.pdf.

Many utility representatives expressed concerns that recent policy proposals may constrain their ability to meet increasing load demands. For instance, EPA's proposed greenhouse gas rules could decrease utilities' flexibility in technology selection; and many utilities indicated they would need to limit their natural gas plants' capacity factors to meet the requirements.[14] The challenge will be how to design policies and regulations that drive toward a cleaner grid while still ensuring affordability, reliability, and resilience even as electricity load growth far exceeds recent expectations.

Although the average capacity factor of natural gas combined-cycle power plants in the United States is 64%,[15] materially increasing this number to meet additional load is not seen as feasible for some utilities: "Just not enough," one participant said, "it's not efficient for the plants to run much higher than they're already running."

In addition to running current plants at higher capacities where possible, utilities confirmed they were planning to bring more natural gas on line to meet the growing load and that additional natural gas capacity will be hydrogen- and carbon-capture-and-storage-ready, with a tendency to favor carbon sequestration over hydrogen. As one participant noted, “We’re not committing to one or the other by any specific point in time, but if we had to bet on one, we’re betting on carbon [sequestration] in the time frame we’re looking at.”

When participants considered additional strategies for managing load growth, the themes that emerged ranged from regulatory and infrastructure challenges to opportunities for technological innovation to unlock new options. Technologies with longer deployment lead times that were discussed included carbon capture and storage (CCS), small modular reactors (SMR) and advanced nuclear reactors, nuclear fusion, hydrogen, and long-duration energy storage.

Regulatory

Federal and sub-national policymaking impacts utilities’ ability to meet load growth demands, sometimes in unanticipated ways. Each region is also subject to its own regulatory structures that complicate utilities’ ability to meet load growth with clean electricity. For example, New York state’s ozone peaker rule requires 1,500 MW of combustion turbines, or peakers, to shut down by 2025.[16] However, because of predicted summer shortfalls, one participant noted that 600 MW of peaker capacity is being retained for “a period of two years, possibly extended up to four years.”

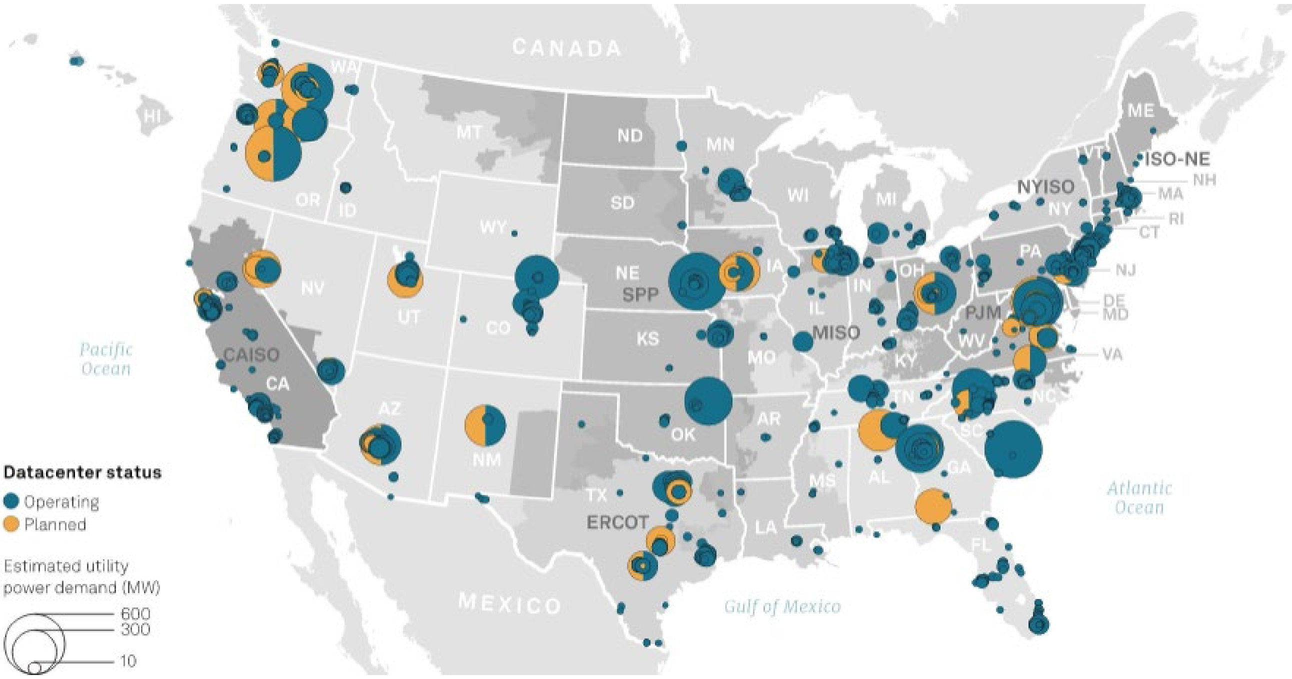
Infrastructure

Increased transmission capacity will be an important complement to building new generation and deploying other strategies for modernizing the grid (e.g., grid-enhancing technologies, innovative market designs). Where and how new infrastructure is built remains an open question (Figure 5).[17]

At present, some stakeholders believe the United States lacks sufficient large, interregional transmission lines to move electricity from regions with excess generation to those with the fastest load growth – to the extent that excess generation exists as coal retirements continue. Furthermore, local and regional transmission investments are needed to continue integrating renewable energy as well as new sources of electricity demand. Not only is it expensive to add new transmission lines, it also is slow. “When you start to think about even bringing transmission lines across areas, places that shouldn’t be—you would think—all that controversial just take a tremendous amount of time,” one participant said.

Furthermore, “inadequate transmission capacity/linkages across the country” prevents utilities from maximizing output from existing generation. Some solutions to address this in the short run are to make use of grid-enhancing technologies like dynamic line ratings and advanced power controls, both of which are expected to be included in an upcoming rule from the Federal Energy Regulatory Commission (FERC) regarding transmission.[18] Some participants agreed that focusing on transmission is a way to help support near-term load growth while addressing generation that is currently curtailed.

Figure 5. Estimated data center growth by grid region



This figure illustrates the estimated growth in data center capacity across various regions, highlighting the need for corresponding infrastructure development to meet growing load demand. Source: S&P Global, POWER OF AI: Wild predictions of power demand from AI put industry on edge, October 2023, https://www.spglobal.com/commodityinsights/en/market-insights/latest-news/electric-power/101623-power-of-ai-wild-predictions-of-power-demand-from-ai-put-industry-on-edge.

Pipelines, underground storage (e.g., salt domes), and other infrastructure requirements also limit the technologies available for electricity production in each region. Some parts of the Southeast have ample access to CO_2 storage, but not in the Southwest or other parts of the Southeast like the Carolinas, where "there's no pipelines, no places to store it" near the load.[22]

Participants observed that the threat of litigation is a serious impediment to building out new infrastructure and that "it really seems to be moving across the entire political spectrum," impacting states like Ohio and Illinois, which have not been resistant to such industrial activity in the past. Given "all the opportunities for lawsuits to really slow that down," the workshop emphasized the need for efficient and effective permitting regimes and stakeholder engagement that enables rather than frustrates infrastructure development.

CCS

Workshop participants touched on the status of CCS in the power sector and what is needed to move the technology forward. They expect that some natural gas power plants could be retrofitted to incorporate CCS, while new natural gas units already are considering CCS (and/or hydrogen) in the initial planning stage. Participants also reinforced the importance of the infrastructure theme above, noting that the development of supporting infrastructure (e.g., CO_2 pipelines and storage sites) will be central to enabling CCS deployment. Additionally, policies to accelerate supporting infrastructure buildout and foster community acceptance were cited as essential for CCS development.

Nuclear (SMRs, advanced reactors, and fusion)

Nuclear power is seen as a promising option for addressing load growth because of its high capacity factor, zero emissions generation, and potential to contribute to a balanced energy mix.[19] SMR deployment, however, is still a few years away. “Nobody wants to go first. How do you de-risk and enable SMRs?” asked one participant.

Certainty of fuel supply will play a role in reducing risks. According to another participant, “We need a lot of policy changes and a lot of streamlining to get SMRs on quicker and faster; our resource plan is showing the quickest is 2035.”

Collaboration among the U.S. Department of Energy, SMR developers, utilities, and regulators was mentioned as a pathway to reduce risks and streamline SMR uptake. The EFI Foundation’s concept for a “cost stabilization facility” was discussed as a potential solution to manage risk between the government and private sector that could help move initial projects forward.[20] Specifically, a consortium of buyers would all commit to buying the same design – enabling a nuclear manufacturer to build an “order book” – and then public-private cost sharing could commence if project costs exceeded the negotiated threshold.

Nuclear fusion is making remarkable progress, with over $6B of private funding invested in an array of different fusion technologies.[21] If demonstrated in a commercial pilot project, fusion would present a major long term opportunity for carbon-free firm power that can be sited with great flexibility.

Hydrogen

Clean hydrogen could play a role in addressing load growth, particularly in hydrogen-capable natural gas combustion turbines that can ultimately operate with pure hydrogen. The major question that was posed, though, was whether those turbines would ever actually use a meaningful amount of hydrogen. Building electrolyzers on-site for green hydrogen production was discussed as a strategy to minimize hydrogen transportation costs. Some regions of the country are seen as more suitable for hydrogen storage because of existing geological formations (e.g., salt caverns, aquifers, and depleted hydrocarbon reservoirs).[22]

Long-duration storage

In a power system with a large penetration of solar and wind, energy storage helps to manage load growth effectively, ensure reliability, and meet peak demand, especially during winter mornings.[23] Participants highlighted that, ideally, energy storage would need to evolve to long-duration, on the order of two days, rather than the current capacity of about four hours. While energy storage today is dominated by pumped hydropower and lithium-ion batteries, new energy storage solutions like thermal storage and iron-air batteries potentially offer cost-competitive multiday storage.[24,25]

3 Stakeholder alignment is critical to meet the dual challenges of load growth: manage reliability and plan for deep decarbonization.

Stakeholder collaboration was highlighted as crucial for the successful transition to a sustainable energy future. The workshop underscored the importance of involving a broad spectrum of stakeholders, including utilities, governments, communities, and businesses in the planning and implementation of strategies related to load growth. This can be helpful to reduce uncertainty and to identify innovative solutions to challenges. Further, to coordinate effectively, stakeholders must understand one another's decision-making processes and incentives along with the downstream effects of major decisions.

Supply-side and demand-side coordination is critical. Very large, unexpected loads like GW-sized data center campuses require utilities to rethink their five-year plans. When grid operators (RTOs and utilities) were asked if they felt "confident that you're seeing those requests for service as quickly as you need to," the response in the room was a resounding "No, not at all." This can be a particular challenge for RTOs/ISOs, which do not have as much direct engagement with new sources of demand, and the time scale of imagining new capabilities may be mismatched to the capability of providing the infrastructure. Without close coordination, grid operators lack the certainty to do the proactive planning necessary to address increasing load requests.

Data centers and utilities, in particular, have a dynamic relationship because they are each other's customers in the electricity and data markets. As one participant noted, "When you are beholden to the grid you are on, you work with utilities as best you can to try to influence their decisions. … I can't go to a utility and say I need like nine SMRs."

Such "influence" translates into looking for innovative ways to partner with utilities to bring more clean electricity generation to the grid and support policy efforts that will enable the energy transition. For instance, utilities can use AI and drones to inspect transmission lines; data centers can use AI to assist in permitting applications to accelerate the process by minimizing back-and-forth; and project developers and utilities can partner on on-site selection for large loads.[26,27] Large load customers, transmission operators, system operators, and planners can also collaborate on long-term load forecasts beyond five years.

Large customers, like data centers and manufacturing plants, are increasingly pressuring utilities to match clean energy supply with load at an hourly level. Simultaneously, utilities are adapting to a new paradigm in which both supply and demand are more flexible. Utilities can develop creative ways to help customers keep their climate commitments such as "creative rate designs" to shift flexible loads (e.g., electric vehicle charging and data center computing) to off-peak periods: "Planning for peaks is going to be really critical, as well as finding those opportunities for demand response and flexibility." In turn, customers can help utilities minimize reliability challenges by making available backup generators and energy storage currently used for redundancy.

4 Stakeholders are seeking flexibility to manage load growth uncertainty.

Workshop participants from a variety of perspectives—end users, utilities, RTOs, and former regulators—all noted the importance of increasing certainty (or decreasing uncertainty) for decision making, albeit from different, sometimes competing perspectives. As one participant observed, "They're looking for certainty of the load to show up, and I'm looking for certainty that generation is there." Another commented, "It's very difficult to get the regulator to say 'Yes, I want you to go ahead and build that 500-KV backbone across your entire state' without already knowing where the load is coming from."

Customers want guarantees that their electricity will be provided from a clean, affordable, and reliable resource; utilities want to know they will "get cost recovery, whether it's through the regulatory commission or through the wholesale market structure"; and regulators want more assurances about how much load will materialize in order to assess whether infrastructure is needed.

To address uncertainty, participants also highlighted the need for flexibility, particularly for regulatory approaches, market and technological innovation, demand-side management, and policy development. As one example, a participant highlighted that in joint comments with other independent system operators (ISOs) on the U.S. Environmental Protection Agency's (EPA) proposed greenhouse gas rule for power plants, ISOs (and RTOs) advocated for a "safety valve" to address reliability if needed. There was also a call for flexibility in policymaking to avoid premature retirement of existing resources before replacements are ready, ensuring system reliability.

The discussion strongly suggested the need for systems that can adapt to varying levels of demand. It also pointed to responsive demand as an increasingly important tool for balancing the grid. Some new loads may offer flexibility (e.g., cryptocurrency mining, electric vehicle charging) with appropriate incentives and pricing structures, while others may be less flexible. This differentiation underscores the importance of incorporating the right incentives along with flexibility in planning and operational strategies to accommodate varying types of loads and their impacts on peak demand and system reliability. Increasing transparency and collaboration between stakeholders through proactive engagement and information sharing can help unlock demand flexibility and other solutions.

Participants described four contexts in which certainty is particularly important:

Grid management

The conversation highlighted the need for regulatory bodies to provide certainty, or at least predictability, for grid management and planning. Interconnection queues, for instance, have long been blamed for transmission backups. However, one participant cited an informal poll of ISOs and RTOs nationwide that showed "close to 300,000 MW of projects that signed interconnection agreements," suggesting "it is more about a construction backlog than an interconnection queue backlog."[g,28,29,30,31,32,33,34] As a comparison, a 2023 analysis from S&P Global reports a smaller figure: 178,000 MW.[35] It is difficult to determine how much of the interconnection queue is speculative until queue reforms are complete, but regardless of the exact magnitude, such figures point to a major shift in hurdles to deploying clean energy.

The lack of capacity may also cause grid managers to rethink plans for decommissioning existing assets or shifting to cleaner forms of electricity generation. For example, one participant mentioned a Panasonic factory being built in Kansas that will require 200 MW to 250 MW of power to operate.[36] "That company is going to come on line and coal-fired power plants [will] not be retired to serve [the load] to build new electric vehicle batteries. And it just becomes this need for new firm, reliable power on a short timeline to serve new large loads." As timelines for interconnecting new generation lengthen, it is likely that we will continue to see baseload thermal resources remain on line to meet short-term needs for new load.

Transmission planning

Decisions about where to site new transmission lines depend in part on projections of where new electricity generation and load will occur. Planners must balance the risk of overbuilding in areas where load and/or generation do not materialize with the risk of expensive incremental upgrades if the system does have sufficient capacity to serve new load and/or generation.

Further, planners must secure consensus for new transmission capacity among myriad regional stakeholders, and they must reach consensus not only on where new transmission lines are needed, but also on who will pay for them. Increasing transparency and collaboration—and thus reducing uncertainty—in transmission planning can enable a more proactive approach to connect expected generation and load over the next 20-plus years in the most efficient way possible at both the local and regional levels.[37]

Supply chains

Robust and resilient supply chains are critical to enabling utilities to "systematically prioritize and systematize their interconnection," as one participant noted. Recent supply chain constraints on transformers, aluminum, and copper have led to higher costs and delays, often measured in years.[38]

Complicating the issue further, while securing domestic supplies can help alleviate some supply chain constraints, it also introduces additional load on the grid as new domestic production facilities come online. Utilities and end users are often "competing for very similar components," resulting in an increased risk of project delays.

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[g] Data based on an informal poll conducted among ISOs and RTOs that publicly display such information on their websites. For instance, the following is potential new generation projected to meet commercial operation in 2025 for specific regions: ERCOT estimates 78,277 MW; PJM estimates 81,852 MW; SPP estimates 22,651 MW; ISO-NE estimates 9,887 MW; NYISO estimates 4,840 MW; CAISO estimates 2,293 MW; and MISO estimates 51,858 MW for summer peak demand and 51,997 for winter peak demand.

Investment

High costs, interconnection challenges, and the risk of litigation add significant uncertainty to investment decisions. For example, one participant noted that they may have "tens of millions of dollars at risk" because they're "looking for 100,000 feet of copper or aluminum."

Further, new generators seeking to connect to the grid are often required to pay for significant transmission upgrades to do so.[39] As a result, otherwise economical projects become too expensive and are canceled.[40] Large sources of new load, like data centers, are increasingly facing multiyear delays in gaining electricity access due to transmission constraints. Across project types, the ever-increasing risk of litigation creates uncertainty about whether a project will ever go on line, threatening investors' ability to recoup their capital, let alone earn a competitive return.[41]

Clear, transparent, and accurate market signals are necessary to stimulate the investment and technological advancement needed to meet load additions. As load increases and coal-fired generation retires, several participants said they expect prices to start rising. Whether or not those price increases cause a boomerang effect in shifting load back down remains to be seen.

Conclusion and next steps

"I think there's an opportunity to take some lessons learned in the next few years that we can then carry forward to the next 25 years."

The EFI Foundation Load Growth Workshop conversation highlighted the multifaceted nature of the energy transition, emphasizing the need for coordinated and creative approaches to decarbonization and electrification. The rapid shift in load growth projections will require greater flexibility and agility by grid managers to meet demand, especially in the near term. We are already seeing extension of existing fossil generation assets, otherwise planned for closure, online for longer periods of time as well as rapid deployment of new single-cycle natural gas power plants to augment currently planned increased deployment of renewable generation projects. Such a strategy, however, will result in higher than projected emissions in the near term, which will need to be reconciled with longer-term goals, shared by both grid managers and customers, to transition to clean electricity generation.

The workshop highlighted the need for decision-makers to prioritize investments in infrastructure, leverage technological innovations, advocate for supportive policies, engage with a wide range of stakeholders, and develop strategies that are responsive to regional dynamics. By embracing these recommendations, the energy sector can navigate the challenges of the transition and move closer to achieving a sustainable, resilient, and equitable energy future for all.

In addition to the primary themes emerging from the workshop, several other issues arose that warrant further research and discussion.

1. Innovative business models, policies, and regulations will be needed to accelerate the deployment of clean energy resources onto the grid. In the near-term, regulatory models could provide greater financial certainty for proactive investments in clean generation and associated infrastructure, whether through rate basing or assurances that resources will be deployed. Longer-term, grid managers could explore adjustments to traditional cost-of-service regulatory models to ones that reward outcomes like reliability, affordability, and decarbonization.
2. Policymakers and regulators could consider creative measures to deploy readily available technologies that maximize the effectiveness of the grid. Workshop participants highlighted the need for grid-enhancing technologies to upgrade transmission infrastructure, but changes to incentives may be necessary to drive adoption. For example, near-term investments in dynamic line ratings and virtual power plants can provide a complement to longer-lead infrastructure investments in new generation and transmission.
3. RTOs/ISOs and state regulators may need to establish new safe harbor protections to facilitate needed investments in new generation, life extension of existing assets, and customer-led behind-the-meter solutions. With electricity growth increasing rapidly, there is space for creative problem-solving, including additional exploration of alternative pathways to improve and optimize load capacity, such as energy conservation and supporting edge-of-grid technologies and localized (behind-the-meter) generation and storage.[42]
4. Hyper-scale data centers present fundamentally different challenges relative to traditional sources of large load, both because of the speed with which they're coming online and the sheer capacity required. Further, centers could potentially also offer significant load flexibility.[43] As such, utilities, regulators, and data center customers will benefit from exploring new and creative tariff structures.
5. Participants also emphasized that their primary responsibilities include ensuring reliability and affordability of electricity supply. This commitment is especially vital in underserved communities.[44] Underserved communities often incur greater electricity costs; increasing loads threaten to exacerbate that tendency.[45] As one participant observed, "I think that's just an interesting dynamic that individual regions are bearing costs that are associated with national prerogatives." More strategies need to be developed to meet increasing demand with cleaner electricity sources while also prioritizing equitable access to reliable and affordable electricity for all.
6. Though many large customers (end users) are committed to decarbonizing, several of them recognize space for "carbon-managed" electricity sources, not just "carbon-free." For example, natural gas with CCS is considered carbon-managed but not carbon-free, which investors indicated would not count toward their decarbonization goals. As one participant said, "You can't lump in gas with capture with solar… You just can't get away with it in the investor community." What is unclear at present is how the investor community will incorporate carbon-managed electricity, carbon-free electricity, and carbon offsets in their climate

calculus for achieving their environmental, social and governance (ESG) goals. Further exploration is needed to develop agreed-upon, transparent methodologies for calculating emissions to ensure steps forward in the energy transition align with the diverse goals and expectations of stakeholders.

7. Addressing the water-energy nexus presents a significant challenge for stakeholders, as major electricity consumers like data centers have substantial water needs. Water could become a limiting factor for clean hydrogen production, data center expansion, and hydropower generation. As climate change alters precipitation patterns, exacerbates droughts, and influences water availability, the issue of water use has become a central concern in the deployment of certain clean energy technologies. Stakeholders may want to develop strategies tailored to regional conditions, taking into account future climate scenarios, local water resources, and energy requirements to ensure both resilience and sustainability in the era of climate change.

8. Innovative zero GHG emission technologies, including enhanced geothermal, fusion, SMRs, and long-duration storage, are unlikely to be on a deployment timescale that can meet near-term load growth needs. Accelerated innovation efforts, including new risk-sharing mechanisms to enable increased investments, could help shorten deployment timelines. Load growth can spur innovation into technology areas that are not currently available for meeting near-term load, especially with zero-carbon firm power.

Access to adequate data and information is crucial and permeates all the areas listed above, allowing stakeholders to formulate effective strategies and allocate resources efficiently to manage load growth and enhance grid reliability. Examples of data that could be collected and made available are real-time data on consumer electricity usage; EV charging demand, locations, and times, along with EV battery storage capacities and usage patterns; cross-sector (industrial, commercial, residential, transportation) electricity usage data that comprehensively allow energy management strategies; efficiency improvements; and holistic approaches to reducing carbon footprints. Comprehensive data collection and sharing also enhance certainty by enabling investors and technology solution providers to make well-informed decisions and accurately assess risks.

Moving forward, stakeholders will face the delicate challenge of keeping the lights on day in and day out while simultaneously navigating profound shifts in the demands placed on the grid. As a result, long-term planning will only increase in value.

Planning, regulatory, and financing processes must evolve to enable proactive investments for the future while providing flexibility to accommodate near-term fluctuations. Planning will be an effective tool, however, only if it is based on realistic projections of future grid needs and represents a consensus view regarding what investments are needed and who will pay for them.

To that end, a growing chorus of perspectives (e.g., host communities, data center operators) must engage in planning efforts—and be equipped to engage effectively—to build the consensus necessary to meet the goals of reliable, resilient, affordable, and clean power today and in the decades to come.

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