From Rivals in Gridlock
to Champions of a Stronger, Smarter Grid

Chase Weir & Mariko Geronimo Aydin | The Earthshot Foundation

ABOUT

This is a synthesis paper. It condenses what more than 200 practitioners surfaced across a year of GridIron dialogue into the findings that follow—faithful to what the room said. It is not a position paper. It does not advocate for specific policy mechanisms or technologies. Earthshot is non-partisan by design; our motive is intelligent system design and trust in our nation's energy and resource policies, not the advance of any one of them. The tru•grid named in these pages is a working idea—an invitation to define a truer, better grid from where each reader stands—not a settled term.

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The success of the GridIron hinges on our wonderful partnerships and collaborations with industry leaders, with a special thanks to OurEnergyPolicy for bringing together a balanced, bipartisan group of discussants and the rest of the GridIron planning team who made the dialogues possible. Our sincere thanks go to the many thoughtful, experienced, collaborative contributors to the dialogues. Special thanks also go to our partners, event hosts and moderators, primary discussants and technical guides, and all those who provided feedback in the white paper development process.

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Founded in 2008, the Earthshot Foundation brings together leading minds in meaningful dialogue to promote intelligent design, future-proofed systems, and trust in our energy and resource policies. Earthshot's contributors are Terranauts: practitioners who turn their ambitions to Earth—its people, its natural capital, and the systems we build to sustain both.

earthshot.foundation | trugrid.org | GRIDIRON FINALE

PREFACE

This paper is the synthesis product of the 2025 GridIron Dialogues—eight cross-sector working sessions, four virtual and four in-person, including a final synthesis convening in April 2026, conducted under Chatham House Rule, followed by a series of "for attribution" one-on-one reflections, that drew more than 200 discussants over the course of a year. The unedited record runs to roughly 32 hours of dialogue and approximately 740,000 words. To put that volume in scale: it is almost twice the number of entries in Merriam-Webster's Unabridged Third New International Dictionary, comparable to Tolstoy's War and Peace, or to nine standard trade books. By another translation, it is approximately the size of a single context window of a frontier language model in 2026—about one million tokens, the largest "single thought" a contemporary AI system can hold at once. Read straight through, the raw transcript would take a careful reader more than 50 hours. The paper in your hand reads in just over 30 minutes. The thousands of hours between those two numbers—convening, listening, reviewing, editing, analyzing, synthesizing—turned a year of dialogue into something accessible without losing fidelity to what was said. What the reader holds distills to roughly 9,000 words. The compression ratio is roughly 82 to 1.

Those ratios are not the most important numbers on this page. The more important number is the one we cannot count: the years of accumulated practitioner judgment that produced what was said in those rooms. The GridIron's source material is not data. It is reasoning—and, specifically, it is reasoning together, under disciplined conditions, by the moderators, hosts, staff, and discussants whose professional lives are spent inside the systems they are reasoning about inside the dialogue. Long before the phrase had a different meaning, this was the original large language model: human minds in dialogue with one another, refining understanding through the friction of honest disagreement and the protection of attribution-free conversation. We make no apology for the analog form of the model. We champion it among the foundation's core motives. For questions of this complexity, we are convinced it remains the most reliable and accountable one we have—more trustworthy, and more generative.

This is the conviction underneath the Terranaut Dialogues. Frontier language models can read a corpus of this size in seconds. They cannot convene the room. They cannot earn the trust that lets a regulator, a hyperscaler, a transmission planner, and local publicly-owned utilities speak frankly with one another within the same hour. The dialogue that follows from that trust is the foundation of this paper. The half-hour the reader will spend here is the return on their time, and on yours.

A few orientation notes for the reader. This is a synthesis paper, not a position paper. It names the structural conditions the dialogues surfaced, and the framings practitioners used; it does not advocate for specific policy mechanisms or technologies. The work is non-partisan by design—the grid is not a Republican or Democratic system, and the questions that animate this paper admit of many ideological framings while resting on shared technical and economic reality. The phrase tru•grid is used as a working idea, not a defined term: it points toward a grid that is truer, better, smarter, more resilient. Each contributor brings a different definition. The Finale on June 8, 2026, is where those definitions are debated, and where the next cycle of work begins.

This paper is a snapshot of a living dialogue. It is also a small piece of evidence that public discourse, properly held, still produces understanding that no other method can produce. We invite the reader to test it, argue with it, extend it, and bring their disagreement to the next conversation. We asked at the outset: **what is energy for?** The closing question—and the one this paper rests on—is **what is dialogue for?** It is also, we suspect, what the future will need more of, not less.

Chase Weir and Mariko Geronimo Aydin
Earthshot Foundation, June 2026

1. THE GRID IN AN EMERGING ELECTRICITY AGE

Our electricity grid's ongoing functionality and accessibility is a powerful driver of our economic and innovative strength. It is a matter of national security. It is a key determinant in the health and prosperity of people and their communities.

Decades of underinvestment in grid capacity, rising dependence on foreign energy and equipment supply chains, delays in deploying sustainable domestic resources, and growing disconnects in matching grid service with community- and customer-level needs have constrained affordable electricity. This can only weaken economic productivity, public health, and national security.

Today's constraints on electricity service act as systemic brakes and friction—an *illiquidity*—on the multipliers of economic prosperity. They must be resolved. The usefulness of our legacy grid goes only so far as it can meet our demands upon it. Our ability to embrace industry disruptors as the biggest innovation opportunity in decades will determine the might of tomorrow's energy systems.

> *"The companies that secure kWh liquidity will have competitive advantage. Those that don't will face zero-sum choices."*

Going from zero-sum to nonzero is a crucial shift. Deep innovation sets us on the nonzero path. It releases us from the win-lose scenarios of zero-sum and its adverse dynamics we see throughout the electricity industry. Nonzero holds the potential for electricity abundance: more available, more reliable, delivered faster, at lower cost, unlocking economic productivity nationwide.

> *"When energy is plentiful, reliable, and affordable, everyone from customers to communities to utilities can win."*

We define electricity abundance as a positive and collaborative objective, grounded in the economics of supply-driven growth, and in what it means to be *of service* to electricity customers. Electricity abundance holds the promise of not just technology innovation, but innovation in how we work together, how we make the best use of our built and natural capital, and how we expand that capital to benefit all stakeholders.

Industry leaders across the GridIron converged on a single observation: the old playbook no longer works. It creates constraints where we need freedom to grow and innovate. It picks winners and losers in a system where everyone could lose from a divided approach. And it fails to acknowledge how unreliable, inflexible, unaffordable grid service affects real people.

> *"Reliability is decreasing, costs are increasing, residential customer satisfaction is declining. That was almost verbatim Australia 15 or 20 years ago. Australia in a lot of ways is something of a postcard from the future."*

The transition the United States is entering is not without precedent. Practitioners in other large grids have lived versions of it. Participants from Australia, in particular, described a system that fifteen to twenty years ago faced the same headlines now appearing in the U.S. press: reliability declining, costs rising, customer satisfaction falling. Today, Australia operates a grid with world-leading distributed solar penetration, regions that periodically run on near-fully distributed generation in midday hours, and a coal fleet on track to retire entirely by the early 2030s. The lesson is that the transition is not easy and the underlying system architecture must be redesigned, not patched. The patches stop working, eventually.

Each of our 200+ contributors were invited to define a truer, better, grid—to define it teleologically: its purpose, intended outcome, and designed outcome. We call it a **tru•grid**. What follows is not a prescription. It represents a cross-section of industry practitioners working together to define that truer grid and what it demands in smarter design, faster service, genuine affordability, and the liquidity to power what comes next. We can't wait to see our nation's bright energy future unfold.

> *"We treat energy as a market optimization or regulatory optimization challenge, but energy is already historically cheap, by any reasonable measure of percentage of GDP. The question we forget to ask is what energy is for."*

Underneath every dialogue, the same question kept surfacing in different forms. Practitioners frame their work as an optimization problem—the right rate design, the right interconnection process, the right capacity market—but every optimization presupposes an answer to a deeper question that gets less airtime than it deserves: what is energy for? Energy is for economic productivity, the foundational kind that makes people able to do more. Energy is for new business creation, lowering the cost of standing up a company or a product. Energy is for the discoveries that turn the volume of human knowledge into compounding value. The grid is the instrument that delivers energy to those purposes. A grid worth having is one designed with an honest answer to what it is for.

2. THE GRIDIRON DIALOGUES

The GridIron Dialogues brought together more than 200 industry leaders, across nearly as many institutions, spanning 9 events and all elements of grid planning, investment, and operations.

Dialogue participants' focus: **the grid**—the single largest machine ever built, and the infrastructure upon which every sector of our economy depends.

We build from Earthshot's 2024 Minologues on sustainable mining as the source of critical minerals needed to power our future. The GridIron then informs forthcoming Natural Capital Dialogues on how our built and natural infrastructure can either collide or coexist.

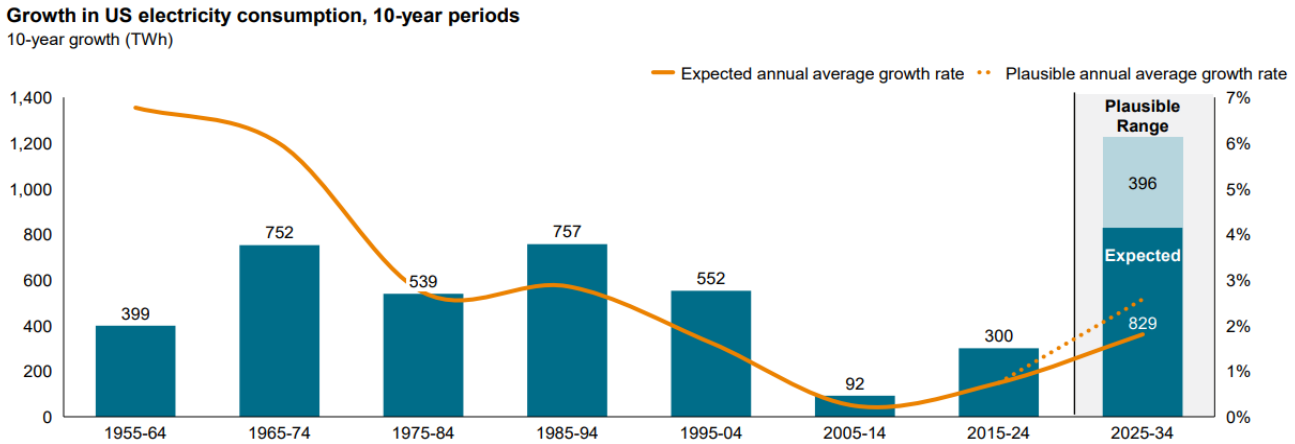
A sharp upswing in realized and projected U.S. electricity demand, after decades of near-flat growth, sets an unavoidable backdrop and a sobering preview of the consequences of the industry's reliance on the old playbook to shape the future grid. It also points to opportunities.

2025 GridIron Dialogues in Nine Parts

1. Enter the GridIron (May 2025)
   A whole-of-grid view of cross-cutting risks
2. Fuel Supply (Jun 2025)
   Secure and scale an evolving fuel mix
3. To Utilities (Jul 2025)
   Lower customer costs through innovation
4. To Customers (Sep 2025)
   Transform the system from brittle to flexible
5. Load Management (Oct 2025)
   Join with customers for a better grid
6. Stored Potential: Energy Storage (Dec 2025)
   Deeper exploration of grid flexibility
7. Stored Potential: AI Loads (Feb 2026)
   Understanding new demand at scale
8. Synthesis Session (Apr 2026)
   Insights from moderators, key discussants
9. Finale (Jun 2026)
   Assembly of Terranauts and call to action

ACP's U.S. National Power Demand Study Results

U.S. electricity demand is projected to grow at ~2.6–4x historical pace, driven by data centers, electrification, and manufacturing reshoring



Source: (ACP 2025). The study was conducted by S&P Global Commodity Insights and commissioned by The American Clean Power Association (ACP), with the support of its partners: the American Petroleum Institute, Alliance to Save Energy, Clean Energy Buyers Association, Nuclear Energy Institute, the U.S. Chamber of Commerce, and the National Electrical Manufacturers Association.

A synthesis session in April 2026 brought a cross-section of GridIron contributors back together to test the emerging findings. Participants ranked the key takeaways from each dialogue track by importance: Critical, To Be Determined, or Not Critical. Where this paper claims convergence, the synthesis session results substantiate it. Where it identifies open questions, the same results show where the room is still working things out. Selected poll findings are cited inline below.

The GridIron surfaced more agreement than disagreement. Practitioners converged on shared objectives, named the same roadblocks, identified the information gaps that no single discipline could close, and together produced a composite view of the whole grid and the potential it holds.

What the dialogues produced is more than diagnosis. It is a working roadmap—a set of findings, levers, and design principles that together describe a path to electricity abundance. This white paper presents that roadmap as the Electricity Abundance Playbook.

3. THE ELECTRICITY ABUNDANCE PLAYBOOK

1 Speed to Service

Connecting new customers and new loads when they need service and where they are. Across the dialogues, participants identified the timing gap—separating when a customer needs power and *when* the grid can deliver it—as one of the most consequential failures in current industry practice. Data centers are built in months; interconnection takes years. This mismatch is not just an inconvenience; it is a structural deficiency that pushes customers toward alternatives.

2 Quality of Service

Electricity service and resources that every customer can count on, on a normal day and in an emergency, with the attributes and functionality they want. Quality degrades through time on aging infrastructure, under changing weather stressors, and as grid functionality departs from modern use cases. A system designed for yesterday's conditions does not reliably serve today's customers.

3 Affordability of Service

Costs that don't break wallets or businesses, borne from real efficiency and innovation gains in the industry. Affordability compounds or collapses through time: investments that deliver value over decades differ fundamentally from those that defer cost to the next rate case. A consistent finding across the GridIron: the industry's cost trajectory is unsustainable without a change in how we invest.

4 Security of Service

Electricity service supported by long-term, whole-economy, supply chain, technology, and infrastructure investment strategies consistent with the essential nationwide public good that it is. Strong domestic energy security is built and sustained through an expansive view of the grid's system dynamics with the other systems it depends on. The cumulation of these strategies over years and decades can either mitigate major economy-wide risks or leave us exposed.

Achieving these four objectives urgently requires us to:

Better understand the customer experience.

Clarity on customers and their diverse service issues brings clarity to effective solutions, shapes common goals, builds trust in utility service.

Increase productivity of existing infrastructure.

Get the most out of investments we've already made—from latent capacity in a historically peak-focused industry, and from supply and demand flexibility at a scale never seen before.

Incorporate, scale up distributed solutions.

From disruptor to opportunity: scale up community-driven local and onsite solutions that expand the definition of the grid and build trust in a coordinated, customer-oriented, grid investment strategy.

Clear the path for new large-scale infrastructure.

With a stronger supply chain, effective decision-making, and deeper industry collaboration.

Targeting the Abundance Loop

A consistent finding across the twelve months of GridIron working sessions: the grid's future depends on which feedback loop takes hold.

When grid service improves, through faster connections, fewer outages, and more manageable costs, customers expand their use. They electrify buildings and transportation. They invest in onsite solutions that complement, rather than replace, the grid. Trust grows. More demand means more revenue to invest and innovate. The industry can manage or even reduce the cost of service. This virtuous cycle compounds through time: national grid wealth growing with each turn.

When grid service deteriorates, the opposite dynamic accelerates. Customers contract demand. Economic loss follows. Trust erodes. Customers substitute away and self-produce. Less grid demand means less capital to invest. A contracting industry squeezes remaining customers harder. The cycle feeds on itself.

This is not a theoretical construct. Participants across every dialogue described versions of both loops playing out in their markets, with their customers, in real time. The direction is not yet determined. This is why the playbook matters: *the actions the industry takes now will tip the balance*.

KEY FINDINGS

The industry is at a tipping point between two self-reinforcing dynamics. The path toward electricity abundance requires coordinated action across all parts of the grid—not isolated investments that solve one problem while worsening another.

4. DISRUPTORS ON THE FIELD

… or opportunities for innovation?

The grid is a system of systems. The industry manages its complexity through natural functional silos: systems providing fuel to generators, a bulk grid that delivers power to local utilities, a distribution grid that brings power to customers, and customers who manage their own facilities and energy decisions. We operate, plan, build, and think within these functional areas. But a set of industry disruptors now traverse those boundaries and present business and operating risks to veteran industry players:

- **Changing weather and new extremes**, including storms, heat waves, wildfires
- **Distributed energy resources** from customer self-supply, behind-the-meter solutions, microgrids
- **New electricity supply technologies**, like renewable energy, energy storage

GRIDIRON PARTICIPANT

"The real work is identifying where coordination is breaking down—and designing it more intentionally."

These disruptors are cross-cutting by nature. They do not respect the functional silos we have built. A consistent theme across the GridIron: until the industry recognizes these as system-wide forces—and understands how decisions in one silo affect outcomes in another—we will continue to apply siloed solutions to interconnected problems.

In the GridIron we split the grid's production line into recognizable points of delivery and stock: fuel supply, delivery to utilities, delivery to customers, and customer energy management. Within each traditionally siloed area—a player's view—we expanded the dialogue to consider broader grid objectives, challenges, and potential solutions toward a whole-grid strategy.

The Player's View:

5. FUEL SUPPLY

Fuel mix and generation challenges:

- Bulk electricity supply is not keeping up with demand growth.
- Weather stressors on fuel supply are complex, changing, and proving difficult to prepare for.
- Operational near-misses are raising significant reliability concerns.
- Regulatory uncertainty is high, scattering industry focus.

Avoiding the zero-sum trap

An industry obsessed with the "petrostate versus electrostate" investment clash (Walter et al. 2025) is distracted from what really matters to a functioning grid: serving customers.

The battle scatters focus and amplifies regulatory uncertainty, which amplifies costs and stalls deployments. Each side's growth depends on the undoing of the other—a win/lose dynamic sharpened by decades of flat demand projections and rivalry over who gets to serve. Today's whole-grid reality reveals why it is ultimately self-defeating: customers have more choice than ever, and new demands for traditional grid service are not guaranteed if customers find the grid too costly and unreliable. For both views of the grid's future, the result is the same: lose/lose.

A diversified portfolio, not a binary choice

The zero-sum trap also presents what some practitioners in the GridIron describe as false choice. The grid has always relied on a diverse portfolio and will likely continue to do so. Wind and solar generation are growing visibly at a national scale, partly replacing a two-decade decline in coal- and oil-fired generation (EIA 2026). At the same time, the U.S. is the world's largest producer of oil and gas (IEA 2025). Both solar and natural gas-fired generation are expanding beyond the bulk grid and into the distributed grid. Nuclear and hydroelectric generation—consistently supplying 20% and 6% of national demand for decades—are key assets in the mix (EIA 2026). These are investments we've collectively already made. They are ready, available, and part of the team. Of the synthesis session takeaways from the fuel supply and delivery to utilities tracks, "we should optimize for a diversified portfolio, not a binary choice" was ranked Critical by every participant who answered—the most unanimous finding the dialogues produced. By contrast, the framing of fuel supply as a zero-sum trap was the lowest-ranked takeaway, with most participants placing it in the "To Be Determined" or "Not Critical" categories. The room is unified in rejecting either-or framings of the fuel mix.

First, mobilize what we have

Participants highlighted a set of potentially cost-effective resources at our fingertips: building efficiency measures to offset demand, nuclear license extensions and uprates, hydroelectric license renewals. Do retirements planned a decade ago still make sense today? For new resources approved and procured, can we clear unnecessary development and interconnection hurdles?

Weather risks threaten the grid's functionality across every fuel type and region (Robb 2021;

NERC 2025a; NERC 2025b; NERC 2025c). Changing weather patterns and extremes are a practitioner's reality, not a political abstraction (NOAA NCEI 2025). In the GridIron, the fossil industry's deep expertise in analyzing and managing weather risk was acknowledged—and participants were clear that knowledge-sharing on this topic needs to be de-politicized and urgently put to use for enhancing grid performance. Coordination of natural gas supply across grid and direct use during winter is a well-documented challenge (NERC 2025a; NPCC 2025). As the fuel mix evolves, so does its exposure to weather. These are cross-cutting realities the whole grid must manage.

GRIDIRON PARTICIPANT

"We have shifted from stored fuels to just-in-time fuels—and introduced a new layer of fragility."

Then, chart a decisive path forward

The Earthshot Foundation mission is to sustain human and natural capital. The Foundation welcomes all views of what that means. Regardless of who "wins" in the petrostate-electrostate arena, one thing is clear: policymakers urgently need to clear supply chain, interconnection, and permitting hurdles. Deployment delays translate into cost escalation. Uncertainties translate into investment risks passed onto ratepayers. A nationwide, long-term plan should integrate the diversity of fuel availabilities and preferences across the country into a comprehensive plan, secure domestic supply chains, support national workforce development, and continue to invest in industry-leading research and development.

But fuel supply alone won't solve the grid's problems

KEY FINDING

If bulk grid reliability is a five-alarm fire, then distributed grid reliability is akin to a statewide emergency. Most actual reliability failures occur on the distributed grid.

The industry maintains bulk grid reliability at or near the 1-day-in-10-years standard that translates to expected outages of less than 1 minute per year per customer (Lumen, forthcoming; Pfeifenberger et al. 2013). But in 2024, customers experienced 680 minutes of service interruptions on average (EIA 2025b). That average hides a wide distribution: customers in Puerto Rico (4,400 minutes), South Carolina (4,100 minutes), Maine (1,750 minutes), North Carolina, and Florida (1,500 minutes) are among the hardest-hit (EIA 2025b). At the circuit level, customers in any state can experience annual outages lasting weeks or months.

Customers face costs of the whole grid, not just fuel supply and generation. Utility spending on distribution and transmission wires is increasing, most notably in distribution capital expenditures (EIA 2024; Wiser et al. 2025). Isolated within the larger grid context, the right fuel supply strategy is solving the wrong equations.

Relief for fuel supply players—and for the customers they serve—lies in other parts of the grid. The challenge is whether those other parts can deliver. This brings us further into the transmission system, where the pain point is not reliability but cost.

The Player's View:

6. DELIVERY TO UTILITIES

Transmission, bulk grid, and wholesale market challenges:

- Transmission planning, permitting, and cost allocation bottlenecks remain.
- Bulk grid interconnection queues are increasingly backlogged.
- New large loads are proving difficult to integrate.
- Behind-the-meter dynamics strain the efficiency of bulk grid operations and markets.

The uncomfortable truth: the bulk grid's pain point is cost, not reliability

Most GridIron participants agree that *the industry is very good at maintaining bulk grid reliability*—even under the barrage of today's disruptors. That's not to say action isn't needed. The industry has many layers of oversight, planning, market, and operational mechanisms to identify and mitigate risks. Alarms raised by system operators must be taken seriously and acted upon. But these alarms are evidence of the *industry's ability to mobilize a strong solution set to maintaining bulk grid reliability*—these are balancing mechanisms—not evidence of whole-grid de-stabilization.

The cost dilemma is different. Because the reliability problem is most tangible on the distributed grid, transmission investments can only promise more cost without meaningfully changing the experience of grid service to everyday people. *Customers connected to an unreliable distribution circuit will still experience unreliable service regardless of transmission investment*. This means a siloed approach to bulk grid investment can only put us at odds with customers, creating an undesirable dynamic (loop). But there is a better way forward.

Harvest latent capacity first

Our grid is sized to meet peak use. New, flexible, demand and supply resources change that paradigm, revealing latent capacity on what we already have. Operating solutions such as transmission topology control, dynamic line ratings, and grid-enhancing technologies yield benefits by better utilizing existing infrastructure (Tsuchida 2025). Innovative expansions like reconductoring (Business Wire 2025) and repurposing retired generator sites can help relieve cost pressure. Every kilowatt-hour of latent capacity mobilized is electricity abundance delivered without a single new permit. Put another way, the price of an electron is a division problem: what it costs to maintain the grid, divided by how many useful things move across it. Better utilization is the fastest path to lower rates—and to the kilowatt-hours we need for AI, manufacturing, and the broader economy.

The synthesis session ranked "opportunities to harvest latent capacity are significant" among the most Critical takeaways from the upstream dialogues, second only to the diversified portfolio finding. The room is asking the industry to start with what already exists.

> *"In most places, the price of an electron is what does it cost to have a grid, and how many things can you sell over it. It's a division problem."*

Weather: the cross-cutting threat

As established in the fuel supply dialogue, weather is the cross-cutting threat. For the bulk grid specifically, three rolling blackouts in recent U.S. history—extreme heat in California (2020), Winter Storm Uri in Texas (2021), Winter Storm Elliott in the Carolinas (2022)—were all weather-driven, occurring when customers were most vulnerable (CAISO et al. 2021; Donald 2021; Behr 2023). Heat reduces transmission wire performance. Wildfire and smoke risks to, and from, transmission lines are complex and impactful.

Deployment bottlenecks persist

GRIDIRON PARTICIPANT

"Time to interconnect has become the binding constraint across the system."

For decades, a mix of technical, market, and policy barriers have created a logjam in building what we've already agreed upon. In transmission development, time is money and second-best solutions are more costly. Interconnection queues for new capacity now approach three times America's total installed, operating capacity. Capital sits idle. FERC Order 1920 is one of the more recent key advancements (FERC 2024). Interconnection queues need further reform (Rand et al. 2025; Gorman et al. 2024). Interstate alliances set examples for effective collaborations (ACEG 2024; NSCIT 2025). But the pace seems too slow. We've drawn up the play—the problem is now getting it out of the huddle.

GRIDIRON PARTICIPANT

"We are solving problems after demand shows up, not before."

In the absence of practicable whole-grid strategies, the industry innovates toward a more compartmentalized future. States manage interregional transmission risk with in-state resource strategies. Customers invest in onsite solutions to secure their own access to essential services.

KEY FINDING

The rise of energy storage is the transmission-across-time substitute for transmission-across-space. The rise of behind-the-meter solutions is the substitute when grid service is inaccessible or too costly. These are innovative balancing mechanisms—but they are also industry disruptors. The grid must earn its customers, or it will lose them to alternatives.

Large loads herald the Age of Electricity

At the end of 2025, data centers consumed about 50 GW of electricity (NLR 2026). Another 36 GW were under construction, with 200 GW planned (NLR 2026). Thirty-six GW exceeds the consumption of most individual U.S. states (EIA 2025b). Two hundred GW planned equates to a quarter of the peak demand of the entire lower 48 (EIA 2025a). Hyperscalers have declared us in the Age of Electricity.

Demand *will* equal supply. If demand is not met, it is either lost, moved, substituted with another fuel, or substituted away from the grid entirely. Faced with project-threatening delays, data center developers turn to onsite, behind-the-meter solutions. In mid-2025 xAI received a permit to power a supercomputer facility with onsite simple-cycle natural gas turbines (Kolodny 2025; Thomas 2026). By early 2026, about 30% of planned datacenter demand was expected to come from behind-the-meter resources (Thomas 2026).

But the GridIron offers hope: generally, *hyperscalers prefer to be grid-connected*—even those who already turned to behind-the-meter solutions. The question is not whether they will connect, but how. Participants highlighted cost allocation, thoughtful market integration, and social license as critical considerations.

Social buy-in from risk containerization

> *"Shareholders win regardless. But in the case that it's not the right stuff, ratepayers definitely lose, because we're on the hook for paying those grid costs when they show up in our power prices."*

One of the dialogues' most pointed questions asks, who carries the risk of getting this build-out wrong? Across markets, utilities are filing rate cases of unprecedented size, to serve loads that did not exist five years ago. Capital is being deployed under the same cost-of-service framework that socialized utility investment to ratepayers for the better part of a century. That framework was designed for a slow-growing public good. It was not designed for a counterparty with a decade-long contract, defined private upside, and the option to walk away.

The asymmetry the dialogues exposed is structural. Utility shareholders earn a regulated return whether the build proves prudent or not. Hyperscaler shareholders capture the upside if the load materializes. Residential and small-business customers, who did not request the build and have no path to capture its upside, are positioned to absorb the cost if the bet is wrong.

Practitioners across the room converged on a structural answer: isolate the cost of serving large new loads from the cost of serving everyone else. The vehicle is the sleeved bilateral large-load contract—whether structured as a large-load tariff, a direct bilateral, or an energy service agreement. Florida Power & Light's large-load tariff is the live model: the data center customer pays the full incremental cost of its connection, including capacity, smoothing, and the network upgrades it triggers. MISO market participants are converging on similar structures. Other utilities are watching.

One participant in the dialogues called this "putting risk in the right boxes." Each risk container does specific work. It assigns the cost of new capacity to the customer requesting it. It articulates how the broader risk of being wrong is shared with the data center and the utility. It preserves the speed-to-service that hyperscalers need without inviting them to walk off-grid. The container is not without trade-offs, especially if taken too far: if sleeved bilaterals proliferate without an anchoring market, important industry advancements in interconnections and markets are unwound. The dialogues surfaced this concern openly and did not resolve it. What they did establish is the principle: in a system where the upside is privately captured, the downside should not be publicly socialized.

And, as we reshape the grid in the Age of Electricity, one question from a GridIron participant cut through the complexity: *what if we defined the grid's purpose as quality of life?*

That question leads us to the distribution system—where cost and reliability collide in grid service to customers, and where the game is won or lost at the line of service.

The Player's View:

7. DELIVERY TO CUSTOMERS

Distribution, utility service, and retail market challenges:

- Distribution system access, planning, and investment is deadlocked in a stagnated expansion model.
- Inability to integrate distributed energy resources disengages customers from the grid.
- Investments fixated on capacity expansion, not solutions, worsen cost and reliability outcomes.

Social buy-in comes from shaping a future grid worth investing in

Smaller customers connect to the (mostly) radial distribution system. This part of the grid is under the most pressure to evolve but also the least equipped to do so. It is deadlocked in status quo investment plans that cannot address today's problems, leading toward untenable costs and declining service quality. Serving today's variety of customer loads requires a collective deeper understanding of the customer perspective and a re-prioritization of industry efforts. Only then can we halt the erosion and begin to rebuild trust.

The industry is not well oriented to the customer's experience

Year-over-year trends are clear: grid reliability is decreasing, costs are increasing, and residential customer satisfaction is declining (EIA 2025b; JD Power 2024; JD Power 2025). A large majority of grid reliability failures are on the distribution grid (EIA 2025b)—a problem bulk grid solutions cannot solve. Utility distribution reliability investments traditionally prioritize potential load growth circuits over reliability for existing customers.

> KEY FINDING
>
> Unlike the bulk transmission system, the industry has no reliability standard for delivery of electricity to customers. Households are paying more for increasingly unreliable electricity, with no industry mechanism for pinpointing and correcting the problem. This is not an oversight—it is a gap in system design that the dialogues identified as among the most urgent to address.

In the GridIron we found that community-led players, like smaller publicly-owned utilities, offer guidance in how to invest in a grid that serves customer needs. Rigorous customer surveys yield deep insights to customer experiences, preferences, and preferred solutions (EWEB 2024; SECC 2025). Whether larger utilities can achieve the same connection depends on the industry's willingness to reorient.

Weather at the distribution level

The weather risks established in our fuel supply and transmission dialogues are most acutely felt at the distribution level. Hurricanes, winter storms, heat waves, wildfires, smoke, and floods drive the most impactful failures to customers (Lumen 2023). Changing patterns and aging infrastructure compound the problem (Climate Central 2024; Westfallen and Kiboma 2025). Utility investments misaligned to the locational nature of these risks are missed opportunities to deliver real improvements.

Community-driven grid planning

Community-driven solutions are critical to prioritizing investment dollars that solve the local problem. But the broader industry is not structured to identify, facilitate, or integrate them. Disconnects in federal, state, and local priorities result in disjointed investment plans. Lack of access to the utility-guarded distribution grid to integrate distributed energy resources is becoming deeply problematic (Kristov 2023).

Significant barriers persist throughout the industry (Baldwin et al. 2025; Lumen 2024). Although beneficial utility/community partnerships are demonstrated (Carter 2020; Ava Community Energy 2025), large-scale community engagement remains an ongoing challenge. Planning cycles and deployments are too slow and non-transparent to make the logistical connection with community solutions.

From financial threat to future-proof utility lifeline

Traditional distribution reliability planning focuses on maintaining average system-level reliability and expanding for peak load growth. It is not suited to address disparities in circuit-level reliability, nor to manage the interaction of more extreme weather on aging infrastructure. This means ramping up status quo investments incurs costs without directly addressing customers' immediate problems. Customers—*who can*—are driven to explore alternatives. The GridIron reveals opportunities to innovate and interrupt this undesirable dynamic.

> *Out of the 3,000 utilities we have, over 800 are distribution co-ops, and they serve 92% of persistent poverty counties. They are also among the most agile players.*

The nation's three thousand distribution utilities fall into three major company types: investor-owned, municipal, and cooperative (co-op) (Westfallen and Kiboma 2025). Co-ops serve roughly ninety-two percent of the nation's persistent poverty counties (NRECA 2025), and they are exposed to the same types of increasing cost pressures as their utility peers (Wiser et al. 2025). Yet co-ops have proven among the most agile players in the dialogues—negotiating large-load arrangements that protect existing members, deploying distributed resources where the economics warrant, and innovating on rate design without the same regulatory overhead. The co-op model is a reminder that the structural diversity of the U.S. grid is, itself, a resource.

Today's distributed grid solutions have the potential to combine better utilization of existing resources with innovative technologies that provide quick, customized solutions. If utilities seize this opportunity they can propel, rather than hinder, a sustainable utility business model. If they do not, customers will continue to find their own answers—and the grid will be less *true* for it.

Finally, we look to the endline for whom the grid exists: the customer.

The Player's View:

8. CUSTOMER ENERGY MANAGEMENT

Facilities, campuses, energy wallets, electricity loads, and customer-driven investments and behaviors:

- Utilities cannot provide the speed to service and tailored solutions customers need.
- Customers are making energy decisions the industry does not understand and cannot predict.
- Behind-the-meter resources remain structurally disconnected from the grid they could strengthen.

Customers need stronger, smarter, more flexible service

Three upstream dialogues make several things clear. Reliability of electricity service is a top priority and varies considerably across customers and locations. Customers are shopping around. Weather is a major cross-cutting risk driving both grid failures and customer decision-making.

Electricity is not a homogeneous product anymore. Some customers seek clean energy. Some seek locally-sourced energy. Some need to interconnect quickly. Service smart enough to keep up with technology, weather, and customer preferences—and to serve reliably through it all—is more important than ever. If customers don't believe their utilities and regulators can provide this product in abundance, they now have the tools to flex their energy independence.

Understanding customers: the key to moving forward

Behind the customer meter, the complexity of energy decisions is growing beyond the industry's understanding. Compared to 10 years ago, demand dynamics have become much more difficult for planners and operators to predict. A recent national survey shows 34% of household energy decision-makers are "informed and engaged;" another 28% are "curious and capable" (SECC 2025). These are not passive ratepayers. Customers are no longer spectators. They're on the field.

We *can* understand the customer perspective with today's technology. Advances in computing enable granular locational analysis. Grid topology and outage data can be comprehensively analyzed (Do et al. 2023; Brelsford et al. 2024). Survey tools are widely available. But understanding customers means seeing them as more than ratepayers.

From ratepayers to customers

For more than 25 years, considering costs and benefits to the "ratepayer" has been deeply engrained in the regulatory framework (CEC and CPUC 2001). The ratepayer construct asks us to think about customers in terms of large blocks, on average. By design, it excludes societal impacts beyond the utility transaction and ignores the customer's other energy burdens and fuel choices.

That construct served the industry well for decades, but it is no longer sufficient. We don't have ratepayers anymore. We have a diversity of dynamic, engaged customers, living with complex and energy-hungry technologies. A truer picture of the grid starts with a truer picture of whom it serves.

From behind-the-meter to part of the grid

Customers are privately investing in the grid. They are making electrification decisions, buying generators, installing rooftop solar, investing in storage, scaling up data centers. They are now part of the grid. Bulk grid-harmonized deployment of distributed energy resources continues to face significant barriers (Baldwin et al. 2025; Lumen 2024), but the primary use case of onsite resources—serving their immediate customer—will proceed regardless. Part of understanding customers is understanding their tolerances and preferences to trade wholesale market revenues for outage protection. Demand reduction produces the same grid effect as generation, yet it does not appear on any balance sheet. Recognizing this equivalence—and rewarding it—is among the clearest near-term opportunities the dialogues identified.

> GRIDIRON PARTICIPANT
> "Energy is increasingly about when it is used—not just how much is consumed."

From top-down to bottom-up

The bulk grid brings great economies of scale, but it is not designed to provide tailored, local service. The distributed grid cannot realize those economies, but with the guidance of customers and their communities, it can offer targeted solutions. A whole-of-grid strategy integrates and optimizes both.

Restoring trust

One word resounded loudly every time it was uttered in the dialogues: **trust**. Trust in the grid and trust in utility service is crucial to a grid-abundant future.

Trust, like reliability, can be measured. Data tell a coherent story: residential electricity customer satisfaction has declined every year since 2020, while monthly bills have set successive records (JD Power 2020–24; JD Power 2025b). What improves customer satisfaction? Lower bills, more reliable service, proactive utility communications, access to service-related information, utility support of local development (JD Power 2020–24; JD Power 2025b). On the commercial side, in 2025, **a quarter of business customers reported financial losses from a power outage in 2025** (JD Power 2025a). The industry is not failing in any one place; it is failing in sum total, over time.

What earns trust? Across the dialogues, participants returned to the same answers: consistency of service over time. Transparency in investment decisions. True responsiveness to what customers need, not what the industry finds convenient. And results—not promises, but measurable improvements in reliability, cost, and speed.

A grid that earns trust is a grid that tells the truth about its performance, invests where the need is greatest, and serves every customer as if they matter. That grid would be, in the truest sense, a better grid. It would be the grid worth building.

9. A WHOLE-GRID STRATEGY

From Gridlock to Unlocking Grid Value

Cross-cutting challenges, opportunities, and the path toward a truer grid

> GRIDIRON PARTICIPANT
> "The opportunity is not just to build more—but to use what we have more intelligently."

Through the GridIron Dialogues, a composite picture of the grid has emerged—one that no single dialogue could have drawn alone.

Changing weather and new extremes, distributed energy resources, and new electricity supply technologies are not temporary disruptions. They are permanent features of the system, fundamentally changing the dynamics of grid service. Compute hyperscaler loads have exposed the industry's unpreparedness for rapid demand growth—and, in doing so, have exposed a broader set of the industry's most pressing challenges that cut across every stage of electricity production.

GridIron participants identified four desired industry improvements that lead toward electricity abundance from better grid design, faster deployment, and real cost discipline:

- Speed to service
- Quality of service
- Affordability of service
- Security of service

The industry's greatest dilemma today is that *achieving meaningful improvement in all four at once is impossible within a traditional siloed industry approach*. However, we CAN meet these objectives with a whole-grid approach and industry action guided by four imperatives:

- Better understand the customer experience
- Increase productivity of existing infrastructure
- Incorporate and scale up distributed energy resources
- Clear the path for new large-scale infrastructure

What the dialogues exposed, more than anything else, is a structural asymmetry. The bulk grid is held to a reliability standard the industry takes seriously and meets. The customer's actual experience of electricity service is held to no standard at all. Data make the asymmetry visible.

Annual Outage Durations for Representative States, 2024

The bulk grid is held to a reliability standard. Customer-level service is not.

Customer or system	Outage duration (per customer per year)	Standard / status
Bulk grid (transmission system)	Less than a few minutes	1-day-in-10-year standard
U.S. state customer average	680 minutes (about 11 hours)	No standard for delivery to customers
Best-performing states (Massachusetts, Nevada, Arizona, Delaware)	~1 minute, and less than 1 interruption per customer per year	No federal standard—outcome of state/local conditions and grid management
Maine	1,750 minutes (~29 hours)	Vulnerable to storms; tree canopy distribution exposure
North Carolina & Florida	1,500 minutes (~25 hours)	Hurricane-vulnerable states; no recovery-time standard
South Carolina	4,100 minutes (~69 hours)	
Puerto Rico	4,400 minutes (~74 hours)	*No hurricanes in 2024*; persistent grid fragility; no standard applies

Sources: (Lumen, forthcoming; Pfeifenberger et al. 2013, 3; EIA 2025b; NOAA NHC/CPHC 2026).

Outage durations shown in the figure are not weather anomalies that will revert. They are what reliability looks like in a system designed for an earlier set of conditions, under an institutional framework that has never measured what customers actually receive. A truer grid begins by measuring the right thing.

KEY FINDING

The grid is not only domestic infrastructure. It is increasingly the substrate of national competitiveness. While the United States debates permitting reform, other nations are building. The kWh itself is becoming a unit of economic sovereignty—and the grid is the instrument that delivers it. A whole-grid strategy is, in this sense, also a national strategy.

How far we go toward electricity abundance depends on the industry's ability to reimagine the purpose of the grid. Not as a regulated delivery system for electrons, but as the infrastructure of quality of life—a system that earns trust by telling the truth about its performance, invests where need is greatest, integrates the resources customers are already deploying, and proves that coordinated action across silos produces better outcomes than any silo can achieve alone.

That is what a truer grid looks like. That is the tru•grid this dialogue is building toward.

> *"We have the technology. The capital. The resources. And the demand. The GridIron cultivates the institutional intention to design these systems the way they deserve to be designed."*

This paper is a snapshot. The GridIron Finale, June 8 in Washington, is where these definitions are debated, where the next cycle of Terranaut work begins, and where the conversation continues.

KEY FINDING

GridIron participants have shared their definition of a tru•grid: *a grid worth having*. The feature-length film will be released later this year. If you would like to participate, please contact: ina@earthshot.foundation

REFERENCES

ACEG (Americans for a Clean Energy Grid). 2024. State Policies to Advance Transmission Modernization and Expansion. September 2024. https://cleanenergygrid.org/wp-content/uploads/2024/09/ACEG_State-Policies-to-Advance-Transmission.pdf.

ACP (American Clean Power). 2025. U.S. National Power Demand Study. March 2025. https://cleanpower.org/resources/us-national-power-demand-study/.

Ava Community Energy. 2025. Resilient Facilities. https://avaenergy.org/community/municipal-programs/resilient-facilities/.

Baldwin, Diane, Jessica Kerby, Devyn Powell, Robert Margolis, Jarett Zuboy, Shahnawaz Siddiqui, Karyn Boenker, Eran Schweitzer, and Thomas McDermott. 2025. Distributed energy resource interconnection roadmap. U.S. Department of Energy. January 16, 2025. https://www.energy.gov/sites/default/files/2025-01/i2X%20DER%20Interconnection%20Roadmap.pdf.

Behr, Peter. 2023. "Bomb cyclone sparks fierce debate over grid readiness." E&ENews. January 3, 2023. https://www.eenews.net/articles/bomb-cyclone-sparks-fierce-debate-over-grid-readiness/.

Brelsford, Christa, Sarah Tennille, Aaron Myers, Supriya Chinthavali, Varisara Tansakul, Matthew Denman, Mark Coletti, Joshua Grant, Sangkeun Lee, Karl Allen, Evelyn Johnson, Jonathan Huihui, Alec Hamaker, Scott Newby, Kyle Medlen, Dakotah Maguire, Chelsey Dunivan Stahl, Jessica Moehl, Daniel Redmon, Jibonananda Sanyal, and Budhendra Bhaduri. 2024. "A dataset of recorded electricity outages by United States county 2014–2022." Scientific Data. (2024) 11:271. https://doi.org/10.1038/s41597-024-03095-5.

Business Wire. 2025. Google and CTC Global announce initiative to expand American electric grid and transmission capacity, U.S. supply chain with advanced conductors. https://www.businesswire.com/news/home/20250617507388/en/Google-and-CTC-Global-Announce-Initiative-to-Expand-American-Electric-Grid-and-Transmission-Capacity-U.S.-Supply-Chain-with-Advanced-Conductors.

CAISO (California Independent System Operator), CPUC (California Public Utilities Commission), and CEC (California Energy Commission). 2021. Final root cause analysis mid-August 2020 extreme heat wave. January 13, 2021. http://www.caiso.com/Documents/Final-Root-Cause-Analysis-Mid-August-2020-Extreme-Heat-Wave.pdf.

Carter, David. 2020. Redwood Coast Airport Renewable Energy Microgrid: Multi-customer, front-of-the-meter, critical facility microgrid. https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/energy-division/documents/resiliency-and-microgrids/resiliency-and-microgrids-events-and-materials/redwood-coast-airport-renewable-energy-microgrid.pdf.

CEC (California Energy Commission), and CPUC (California Public Utilities Commission). 2001."California Standard Practice Manual: Economic Analysis of Demand-Side Programs and Projects." October 2001. https://www.cpuc.ca.gov/-/media/cpuc-website/files/uploadedfiles/cpuc_public_website/content/utilities_and_industries/energy_-_electricity_and_natural_gas/cpuc-standard-practice-manual.pdf.

Climate Central. 2024. "Weather-related Power Outages Rising." Climate Matters. April 24, 2024. https://www.climatecentral.org/climate-matters/weather-related-power-outages-rising.

Do, Vivian, Heather McBrien, Nina M. Flores, Alexander J. Northrop, Jeffrey Schlegelmilch, Mathew V. Kiang, and Joan A. Casey. 2023. "Spatiotemporal distribution of power outages with climate events and social vulnerability in the USA." Nature Communications. (2023) 14:2470. https://doi.org/10.1038/s41467-023-38084-6.

Donald, Jess. 2021. "Winter Storm Uri 2021: The Economic Impact of the Storm." FiscalNotes. October 2021. https://comptroller.texas.gov/economy/fiscal-

EIA (U.S. Energy Information Administration). 2024. "Grid infrastructure investments drive increase in utility spending over last two decades." In-Brief Analysis. November 18, 2024. https://www.eia.gov/todayinenergy/detail.php?id=63724.

———. 2025a. "U.S. electricity peak demand set new records twice in July." In-Brief Analysis. August 5, 2025. https://www.eia.gov/todayinenergy/detail.php?id=65864#:~:text=Data%20source:%20U.S.%20Energy%20Information,Texas%20and%20in%20Northern%20Virginia.

———. 2025b. Annual Electric Power Industry Report: Form EIA-861. 2024 final data. October 7, 2025. https://www.eia.gov/electricity/data/eia861/. Notes: State peaks roughly estimated based on a 55% load factor. Data for years prior to 2024 are included as of the date of this reference.

———. 2026. Electricity Data Browser. Accessed February 2026.

EWEB (Eugene Water & Electric Board). 2024. What Our Customers Think: 2024 Survey Results. November 2024. https://www.eweb.org/customersurvey.

FERC (Federal Energy Regulatory Commission). 2024. Fact sheet: building for the future through electric regional transmission planning and cost allocation. https://www.ferc.gov/news-events/news/fact-sheet-building-future-through-electric-regional-transmission-planning-and.

Gorman, Will, Joseph Rand, Julia Matevosyan, and Fredrich Kahrl. 2024. Transmission Interconnection Roadmap: Transforming Bulk Transmission Interconnection by 2035. Prepared for the U.S. Department of Energy. April 2024. https://www.energy.gov/sites/default/files/2024-04/i2X%20Transmission%20Interconnection%20Roadmap.pdf.

IEA (International Energy Agency). 2025. World Energy Investment 2025. June 5, 2025. https://www.iea.org/reports/world-energy-investment-2025. See Regional Deep Dive: United States (page 184).

JD Power. 2020. "Press Release: Electric Utilities' Good Deeds—and Communication about Them—Pay Off During Pandemic, JD Power Finds." JD Power 2020 Electric Utility Residential Customer Satisfaction Study. December 16, 2020. https://www.jdpower.com/business/press-releases/2020-electric-utility-residential-customer-satisfaction-study.

———. 2021. "Electric Utility Providers Can Increase Satisfaction by Supporting Local Economic Development Efforts, JD Power Finds." JD Power 2021 Electric Utility Residential Customer Satisfaction Study. December 15, 2021. https://www.jdpower.com/business/press-releases/2021-electric-utility-residential-customer-satisfaction-study.

———. 2022. "Customer Satisfaction with Electric Utilities Declines Due to Increased Monthly Bills, JD Power Finds." JD Power 2022 Electric Utility Residential Customer Satisfaction Study. December 14, 2022. https://www.jdpower.com/business/press-releases/2022-electric-utility-residential-customer-satisfaction-study.

———. 2023. "Higher Monthly Bills Contribute to Decline in Customer Satisfaction with Electric Utilities, JD Power Finds." JD Power 2023 Electric Utility Residential Customer Satisfaction Study. December 13, 2023. https://www.jdpower.com/business/press-releases/2023-electric-utility-residential-customer-satisfaction-study.

———. 2024. "Press Release: Monthly Residential Electric Utility Bills at Highest Level Ever, JD Power Finds." JD Power 2024 U.S. Electric Utility Residential Customer Satisfaction Study. December 18, 2024. https://www.jdpower.com/business/press-releases/2024-us-electric-utility-residential-customer-satisfaction-study.

———. 2025a. “Press Release: Rising Costs and Widespread Power Outages Strain Business Customer Satisfaction with Electric Utilities, JD Power Finds.” JD Power 2025 U.S. Electric Utility Business Customer Satisfaction Study. November 12, 2025. https://www.jdpower.com/business/press-releases/2025-electric-utility-business-customer-satisfaction-study.

———. 2025b. “Press Release: Residential Electric Utility Satisfaction Ranks Lowest Among JD Power Residential Utility Studies.” JD Power 2025 U.S. Electric Utility Residential Customer Satisfaction Study. December 17, 2025. https://www.jdpower.com/business/press-releases/2024-us-electric-utility-residential-customer-satisfaction-study.

Kolodny, Lora. 2025. “AI Effect Musk’s xAI scores permit for gas-burning turbines to power Grok supercomputer in Memphis.” AI Effect. July 3, 2025. https://www.cnbc.com/2025/07/03/musks-xai-gets-permit-for-turbines-to-power-supercomputer-in-memphis.html.

Kristov, Lorenzo. 2023. “Chapter 10 - A new value proposition for electric distribution networks.” Editor(s): Fereidoon Sioshansi. The Future of Decentralized Electricity Distribution Networks. Elsevier, 2023, Pages 219-236. ISBN 9780443155918. https://doi.org/10.1016/B978-0-443-15591-8.00005-X.

Lumen (Lumen Energy Strategy, LLC). 2023. “Climate Resilience in Integrated Resource Planning.” CPUC Rulemaking 19-09-009. March 21, 2023. https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/infrastructure/resiliency-and-microgrids/resiliency-and-microgrids-events-and-materials.

———. 2024. Scaling up and crossing bounds. Prepared for the California Public Utilities Commission. http://cpuc.ca.gov/-/media/cpuc-website/divisions/energy-division/documents/energy-storage/2024-05-01_lumen_scaling-up-and-crossing-bounds-reportfinal.pdf.

———. Forthcoming. WARP to Resilience: Demonstration of Achievable, Quantified Resilience Improvements through Weather-Adapted Resource Planning. Prepared for the California Energy Commission. Note: estimate of expected customer impact of 1-in-10 LOLE is based on the 2020 rolling blackouts in California.

NERC (North American Electric Reliability Corporation). 2025a. 2025 Summer Reliability Assessment. May 2025. https://www.nerc.com/globalassets/programs/rapa/ra/nerc_sra_2025.pdf.

———. 2025b. 2025 State of Reliability: Assessment Overview of 2024 Bulk Power System Performance. June 2025. https://www.nerc.com/pa/RAPA/PA/Performance%20Analysis%20DL/NERC_SOR_2025_Overview.pdf.

———. 2025c. 2025–2026 Winter Reliability Assessment. November 2025. https://www.nerc.com/globalassets/our-work/assessments/nerc_wra_2025.pdf.

NLR (National Laboratory of the Rockies). 2026. Accelerating Speed to Power: Data Viewer. Planned, operating, and in construction capacity as of December 15, 2025. Accessed February 2026. https://maps.nrel.gov/speed-to-power/data-viewer.

NOAA NCEI (National Oceanic and Atmospheric Administration National Centers for Environmental Information). 2025. U.S. Billion-Dollar Weather and Climate Disasters (2025). https://www.ncei.noaa.gov/access/billions/.

NOAA NHC/CPHC (National Oceanic and Atmospheric Administration National Hurricane Center and Central Pacific Hurricane Center). 2026. 2024 Atlantic Hurricane Season. Last updated: February 17, 2026. https://www.nhc.noaa.gov/data/tcr/index.php?season=2024&basin=atl.

NPCC (Northeast Power Coordinating Council. 2025. Northeast Gas/Electric System Study. January 21, 2025. https://www.npcc.org/news/npcc-northeast-gas-electric-system-study.

NRECA (National Rural Electric Cooperative Association). 2025. Electric Co-op Facts and Figures. Published June 25, 2025. https://www.electric.coop/electric-cooperative-fact-sheet.

NSCIT (Northeast States Collaborative on Interregional Transmission). 2025. Strategic action plan. https://www.mass.gov/news/massachusetts-and-northeast-partners-issue-strategic-action-plan-to-explore-cost-saving-transmission.

Pfeifenberger, Johannes P., Kathleen Spees, Kevin Carden, and Nick Wintermantel. 2013. Resource Adequacy Requirements: Reliability and Economic Implications. Prepared for the Federal Energy Regulatory Commission. September 2013. https://www.ferc.gov/sites/default/files/2020-05/02-07-14-consultant-report.pdf#:~:text=The%201%2Din%2D10%20Resource%20Adequacy%20Standard%20Alternatively%2C%20one,the%20magnitude%20or%20number%20of%20such%20outages.

Rand, Joseph, Nick Manderlink, Steven Zhang, Chris Talley, Will Gorman, Ryan H Wiser, Joachim Seel, Julie Mulvaney Kemp, Seongeun Jeong, Fredrich Kahrl. 2025. Queued Up: 2025 Edition, Characteristics of Power Plants Seeking Transmission Interconnection as of the End of 2024. December 2025. https://emp.lbl.gov/publications/queued-2025-edition-characteristics.

Robb, James B. 2021. Reliability, Resiliency, and Affordability of Electric Service in the United States Amid the Changing Energy Mix and Extreme Weather Events. Testimony on behalf of the North American Electric Reliability Corporation. https://www.energy.senate.gov/services/files/EB1D7E02-BC93-4DFF-A6A9-002341DA34CF.

SECC (Smart Energy Consumer Collaborative). 2025. Press release: Research Release: "Consumer Pulse and Market Segmentation – Wave 9." August 25, 2025. https://smartenergycc.org/research-release-consumer-pulse-wave-9/.

Thomas, Michael. 2026. Bypassing the Grid: How Data Centers Are Building Their Own Power Plants. Executive Summary accessed February 2026. https://cleanview.co/content/power-strategies-report.

Tsuchida, T. Bruce, Linquan Bai, S. Ziyi Tang. 2025. Incorporating GETs and HPCs into Transmission Planning under FERC Order 1920. Prepared for the American Council on Renewable Energy. April, 2025. https://acore.org/resources/incorporating-gets-and-hpcs-into-transmission-planning-under-ferc-order-1920/.

Walter, Daan, Sam Butler-Sloss, Kingsmill Bond. 2025. The Electrotech Revolution: The shape of things to come. Ember. September 2025. https://ember-energy.org/app/uploads/2025/09/Slidedeck-The-Electrotech-Revolution-PDF.pdf.

Westfallen, Vincent, and Lawryn Kiboma. 2025. "Utility and Grid Operator Resources for Future Power Systems Webinar Series." NREL Webinar Series. National Renewable Energy Laboratory (n.k.a. National Laboratory of the Rockies). July 24, 2025. https://docs.nrel.gov/docs/fy25osti/93573.pdf.

Wiser, Ryan, Galen Barbose, Peter Cappers, Jeffrey Deason, Sydney Forrester, Will Gorman, Eric O'Shaughnessy, Ryan Hledik, Long Lam, and Audrey Yan. 2025. "Factors Influencing Recent Trends in Retail Electricity Prices in the United States: What do we know? Where are the gaps?" Lawrence Berkeley National Laboratory and The Brattle Group. Presentation PDF. October 2025. https://emp.lbl.gov/publications/factors-influencing-recent-trends.

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