Large Loads Task Force at Energy Systems Integration Group

ESIG
ENERGY SYSTEMS INTEGRATION GROUP

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International Workshop on Managing Global Energy Demand of AI Data Centres, Imperial College London

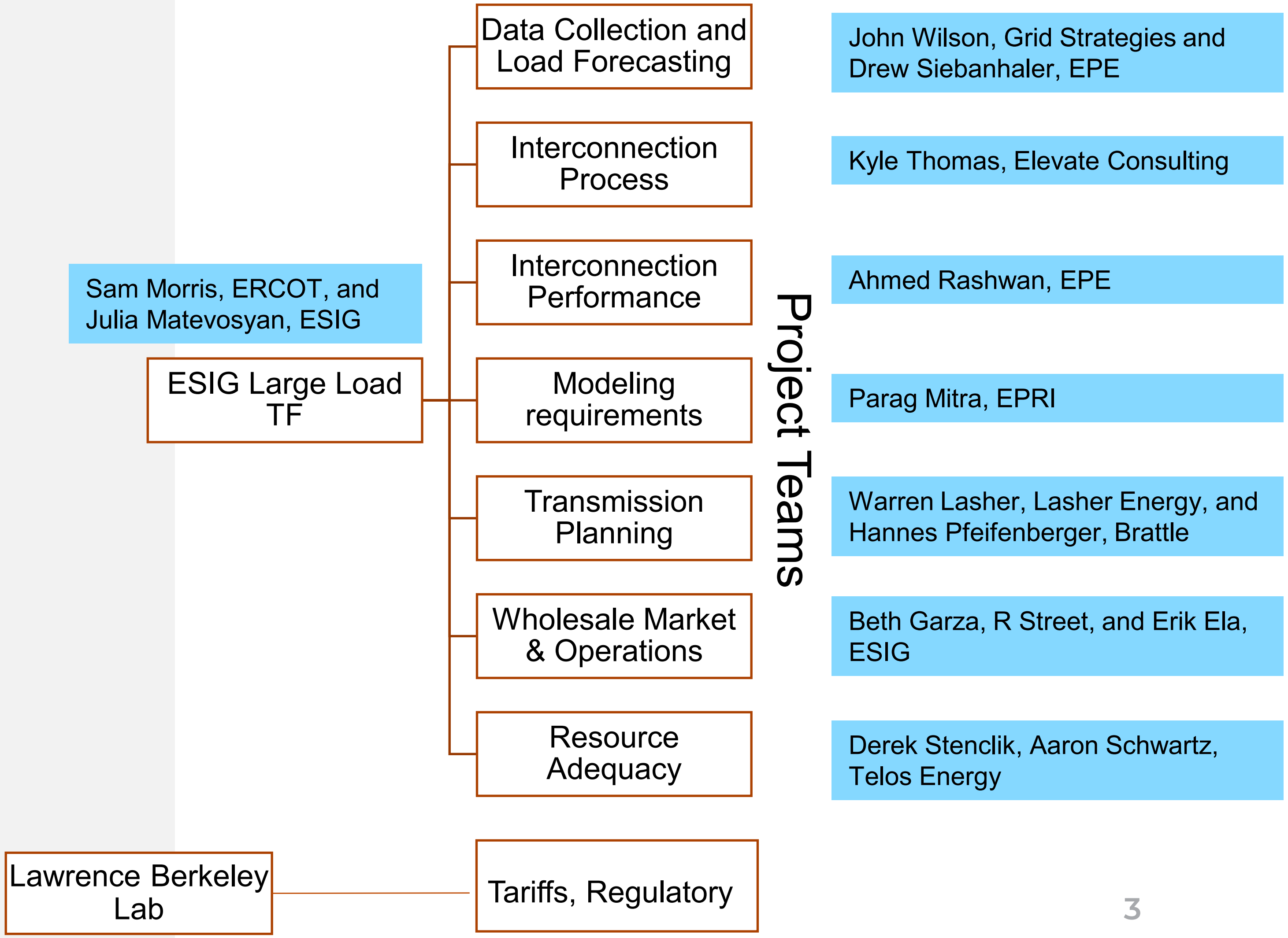
Energy Systems Integration Group (ESIG)

- ESIG is a member-driven organization that addresses technical challenges for transforming energy systems. We do this through collaboration, education and knowledge sharing.
- ~300 members worldwide broadly focused on decarbonization and integration of energy systems
- Workshops, webinars, reports available freely on our website (https://www.esig.energy/) and on YouTube (@EnergySystemsIntegrationGroup). Join our mailing list!
- We create task forces to address topics such as weather datasets or resilience during extreme events or resource adequacy and these task forces do analysis, run simulations, synthesize best practices, etc.

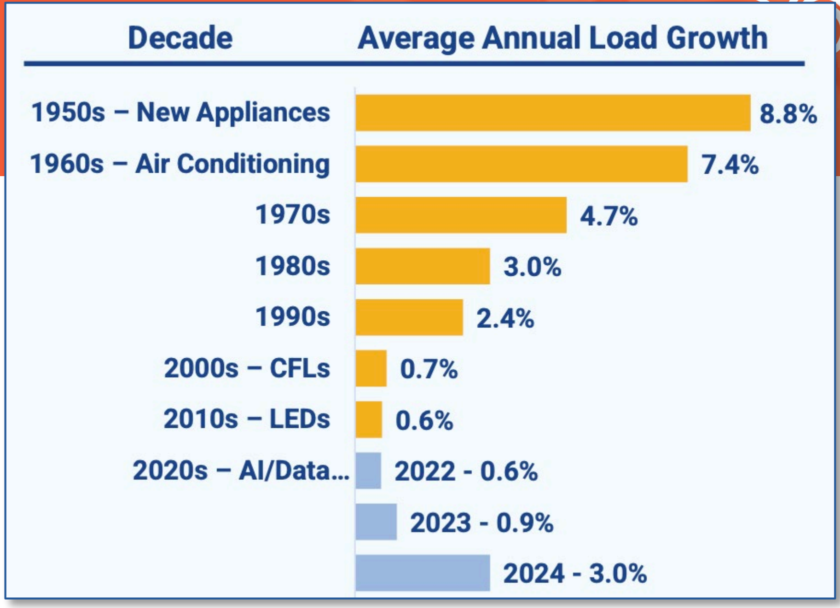
ESIG's Large Load Task Force

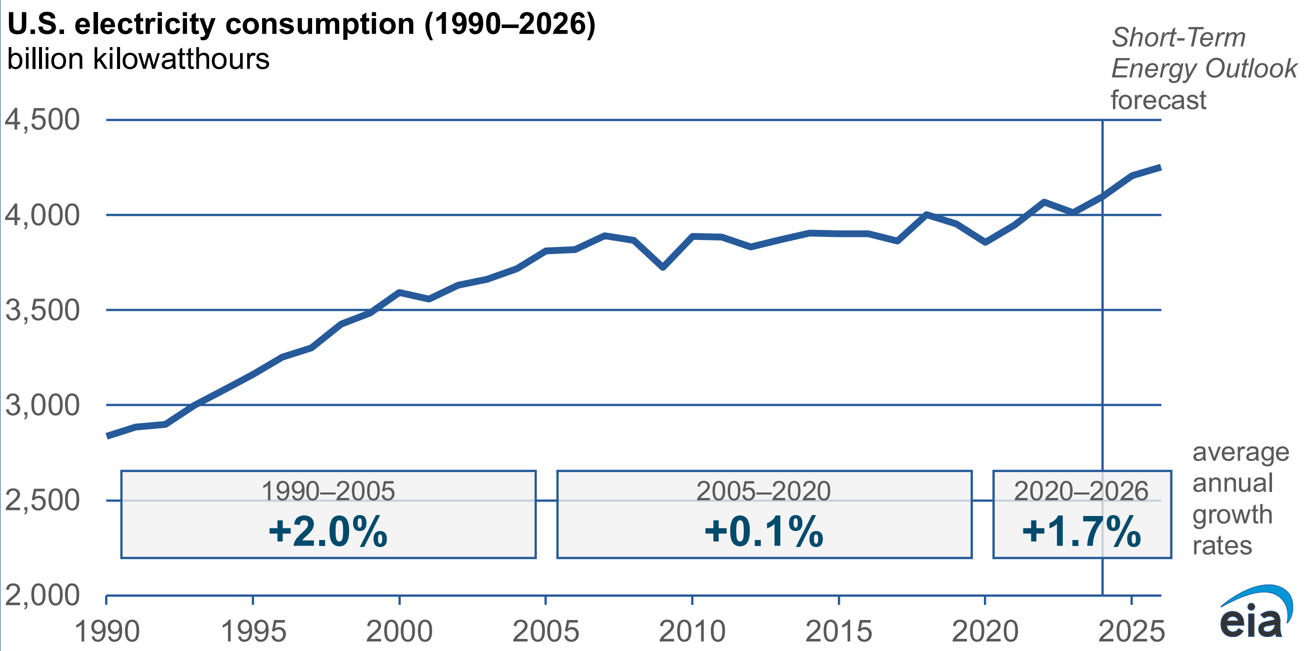
- The goal is to bring together members across the energy industry to
  - Share perspectives
  - Summarize the existing state-of-the-art
  - Identify existing or future gaps
  - Identify practical solutions

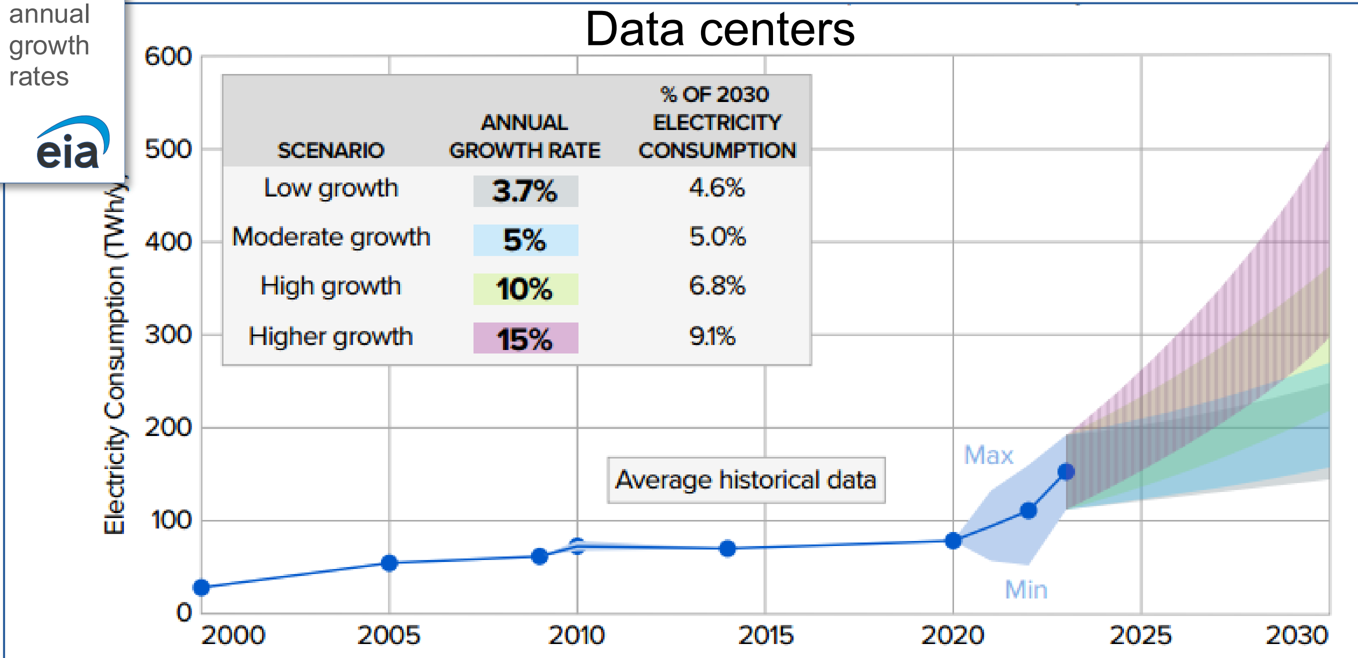
Acknowledgement: The U.S. Department of Energy Office of Energy Efficiency and Renewable Energy and Meta are supporting this effort as are ESIG members.



Load is increasing after many years of flat growth







Source: EPRI, Powering Data Centers 2024; https://www.eia.gov/todayinenergy/detail.php?id=65264; Grid Strategies, National Load Growth Report, 2024

Definition of Large Loads (LL)

- At present, no industry consensus on the definition of a Large Load (LL)
- North American Reliability Corporation's (NERC's) Large Load Task Force (LLTF), conducted a survey on size thresholds for "Large Load" for the purposes of development and enforcement of future NERC reliability standards.
  - Most of the 384 respondents suggested > 50 MW, and the single size most commonly suggested was 75 MW.
  - However, NERC LLTF could not reach consensus on a threshold and settled on a high-level definition:

    Commercial or industrial facilities (or aggregations) that can pose BPS reliability risks due to their size, operational behavior, or control systems, e.g., data centers, crypto mining, hydrogen electrolyzers, industrial manufacturing.
- A similar definition is adopted for a new CIGRE Role and Requirements for Large, Inverter Based Loads TF:
  - *Large demand facilities that are interfaced with power electronics and have the capacity, on an individual or aggregated basis, to have material impact on the host grid.*
- The definition adopted by ESIG LLTF:
  - ***A large load is a load that the connecting utility/ISO/RTO identifies as having a material impact on its system either due to its individual size and/or characteristics or on aggregate basis.***

What is Different About Modern Large Loads?

- **Scale** – Individual facilities (e.g., hyperscale data centers, hydrogen plants) now reach 100s of MW to GW scale, far beyond past industrial loads.
- **Interconnection** – Connect at transmission level (instead of distribution) due to size/reliability needs
- **Clustering** – Concentrated in grid-constrained regions (e.g., Northern Virginia, Texas industrial corridors) creating local demand spikes.
- **Power electronics** – Converter-dominated interfaces bring new challenges: power quality, protection, and sensitivity to disturbances.
- **Fault behavior** – Many switch-over to backup during routine faults, risking cascading grid impacts from simultaneous large load losses.
- **Dynamic profiles** – AI clusters, electrolyzers, EV charging, and heat pumps cause rapid swings and new peak risks.
- **Opaque to operators** – Private developers often limit data sharing, complicating forecasting and operational planning.
- **Growth vs. infrastructure** – Loads materialize in 2–3 years; new grid build-out takes 7–10 years, causing backlog and bottlenecks.

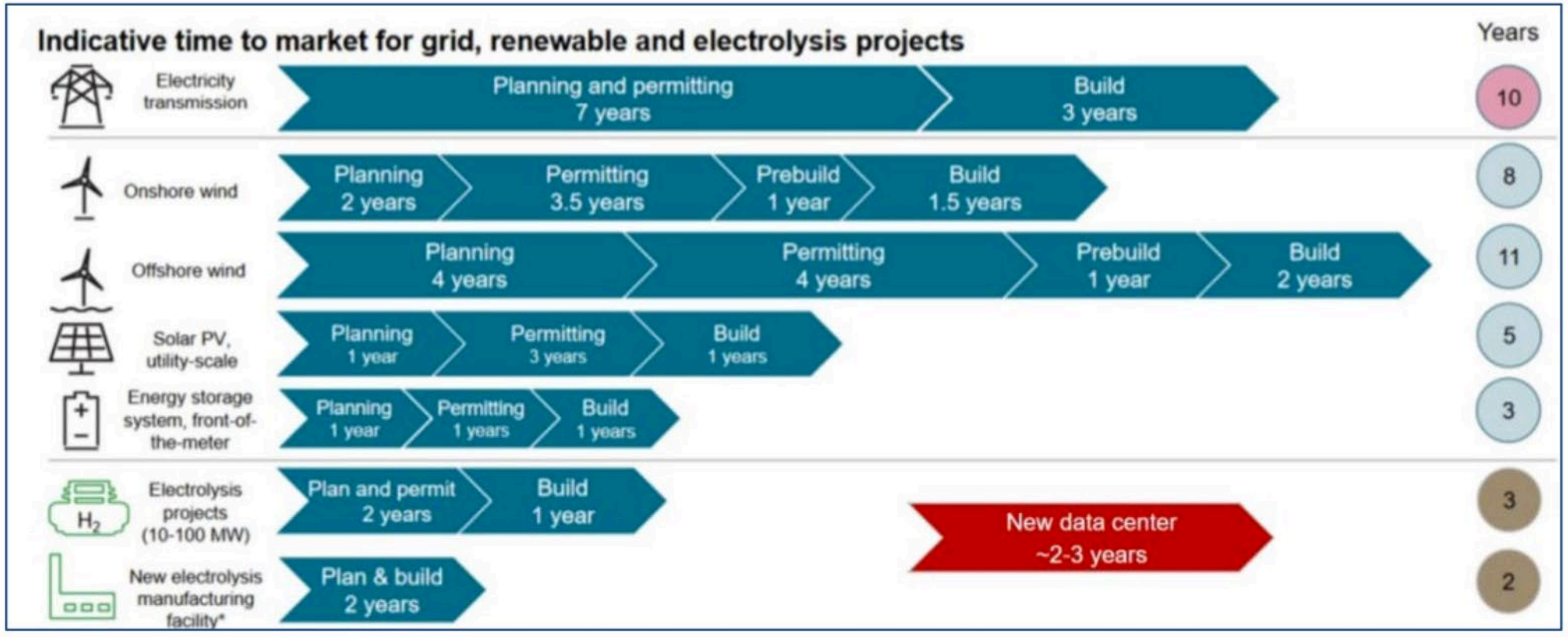
System Level Implications

- **Planning:** Load growth far outpaces connection request processing ability, transmission & generation buildout; forecasts highly uncertain.
- **Operations:** Short-term forecast errors drive inefficient unit commitment & higher reserve needs.
- **Reliability:** Risks to stability, load-shedding, and restoration from large, concentrated loads.
- **Power Quality:** Harmonics, flicker, and reactive swings from converter-based systems.
- **Observability:** Need for PMUs/DFRs as loads now require high-speed monitoring.
- **Markets:** Drive congestion, price impacts, and incentive shifts.
- **Transmission:** Load siting often mismatched with available transmission capacity.

ESIG LLTF is analyzing proposing solutions and best practices for these issues

Planning: Generation and Transmisison

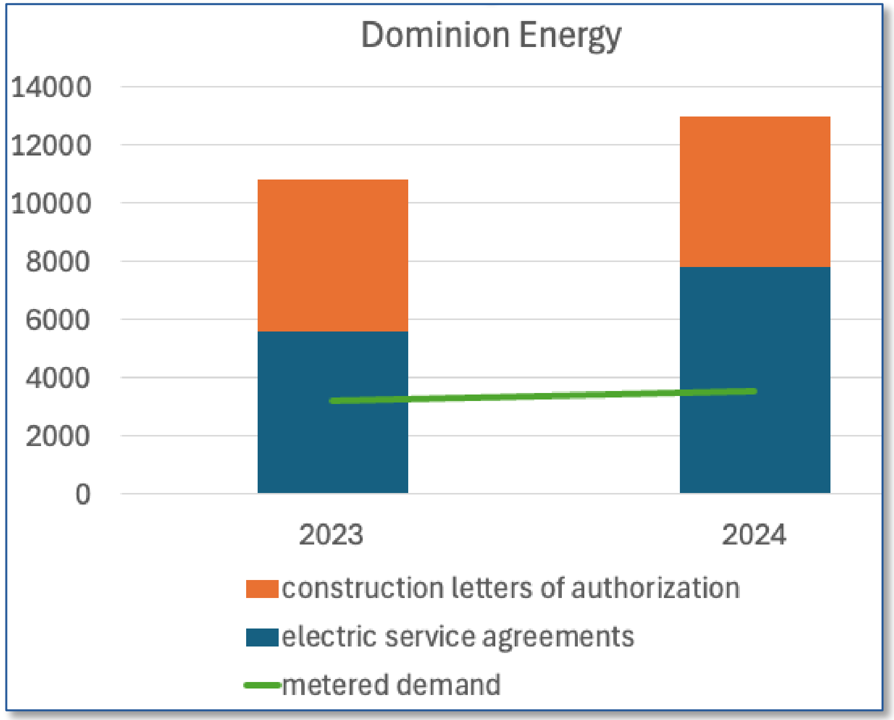
- Today, large loads want to interconnect faster and they are unprecedentedly large
- Significant, fast load growth puts pressure on generation capacity prices.
- Generation may take longer to build and the generation interconnection queues are slow and backlogged.
- Transmission requires even more time to build.



Source: S&P Global Commodity Insights

Planning

- How do we deal with generation or transmission that is built for loads that never show up? Those costs may be borne by ratepayers.
- How do we deal with generation and transmission that is built for nameplate capacity when loads may use less energy than their request.

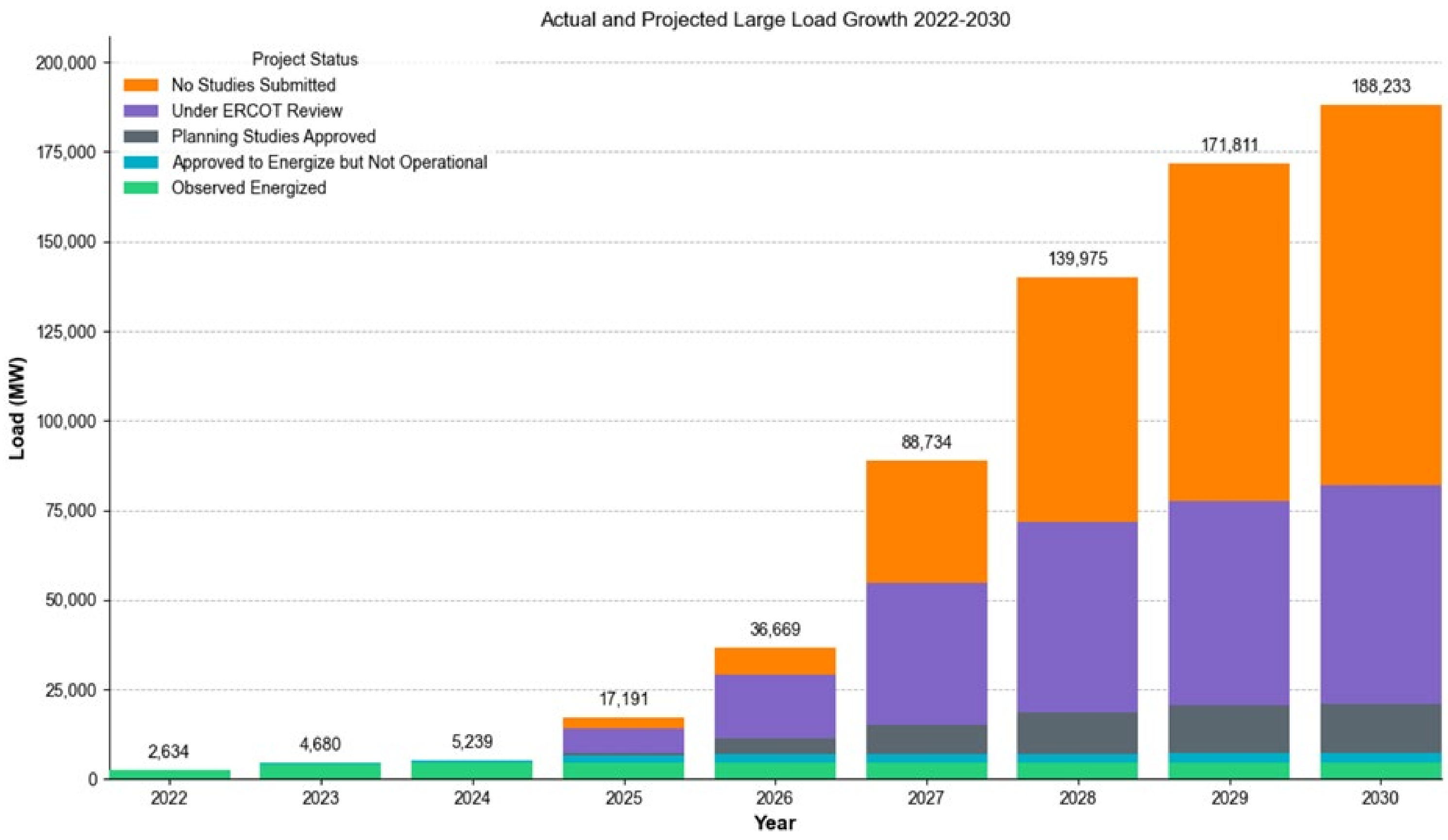


Source: NERC LLTF 4/10/25; Data from S. Blackwell, Dominion, EPRI load forecasting meeting, 2/20/25

Planning: Load forecasting issues

- Many utilities/ISOs have low bars to entry.
  - Load developers file requests in multiple regions for 1 project, to see which is cheapest or fastest. Utilities/ISOs are swamped with requests.
- Increasing levels of commitment with each step in the process can help:
  - Study fees, material collateral, site control
- Certify whether the request is duplicative of others at the same company.
- Take or pay contracts
- Bring your own generation

ERCOT Large Load Interconnection Queue (end of July 2025)



Source: [ERCOT Monthly Operational Overview](), July 2025

Flexibility as an enabler for large loads

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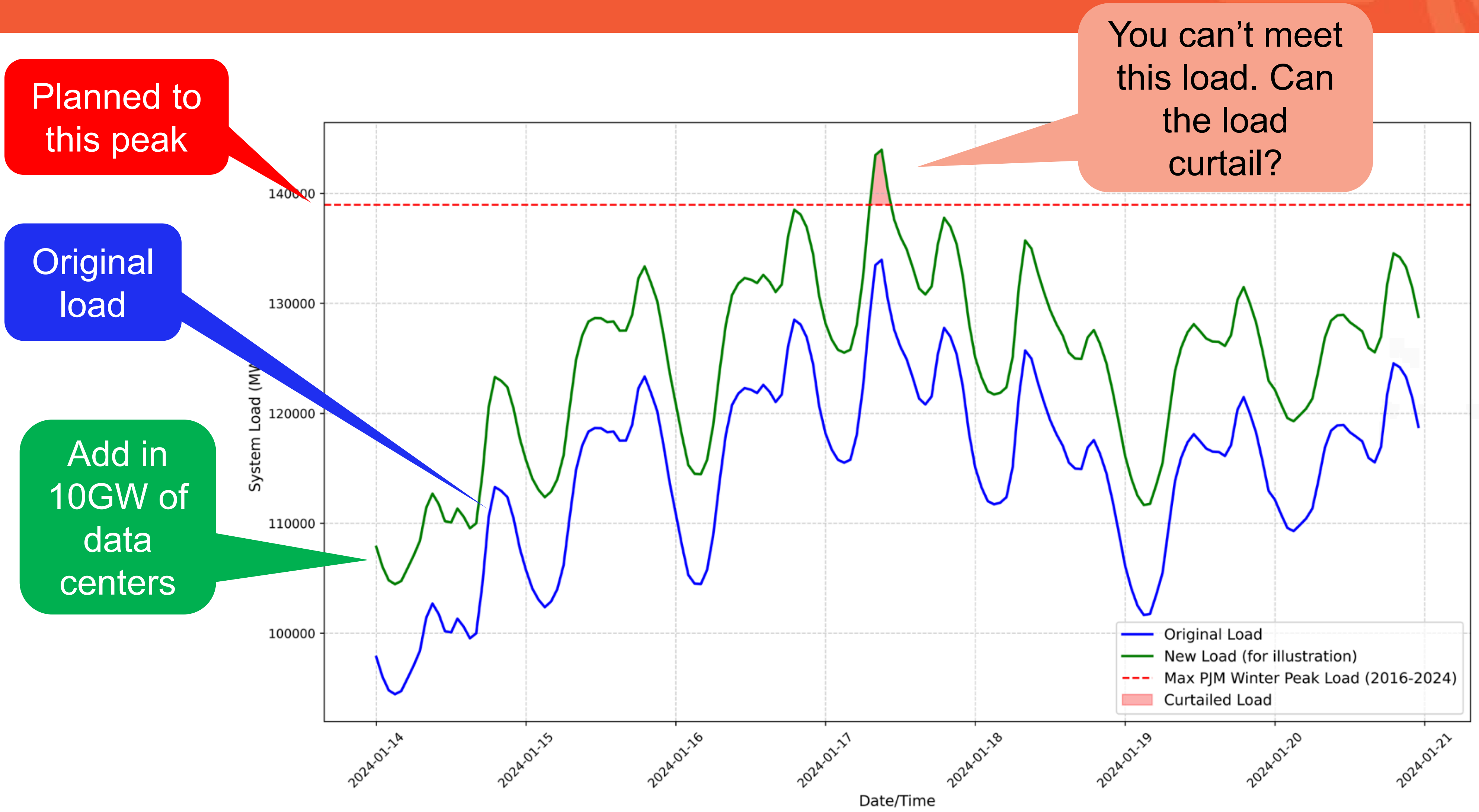
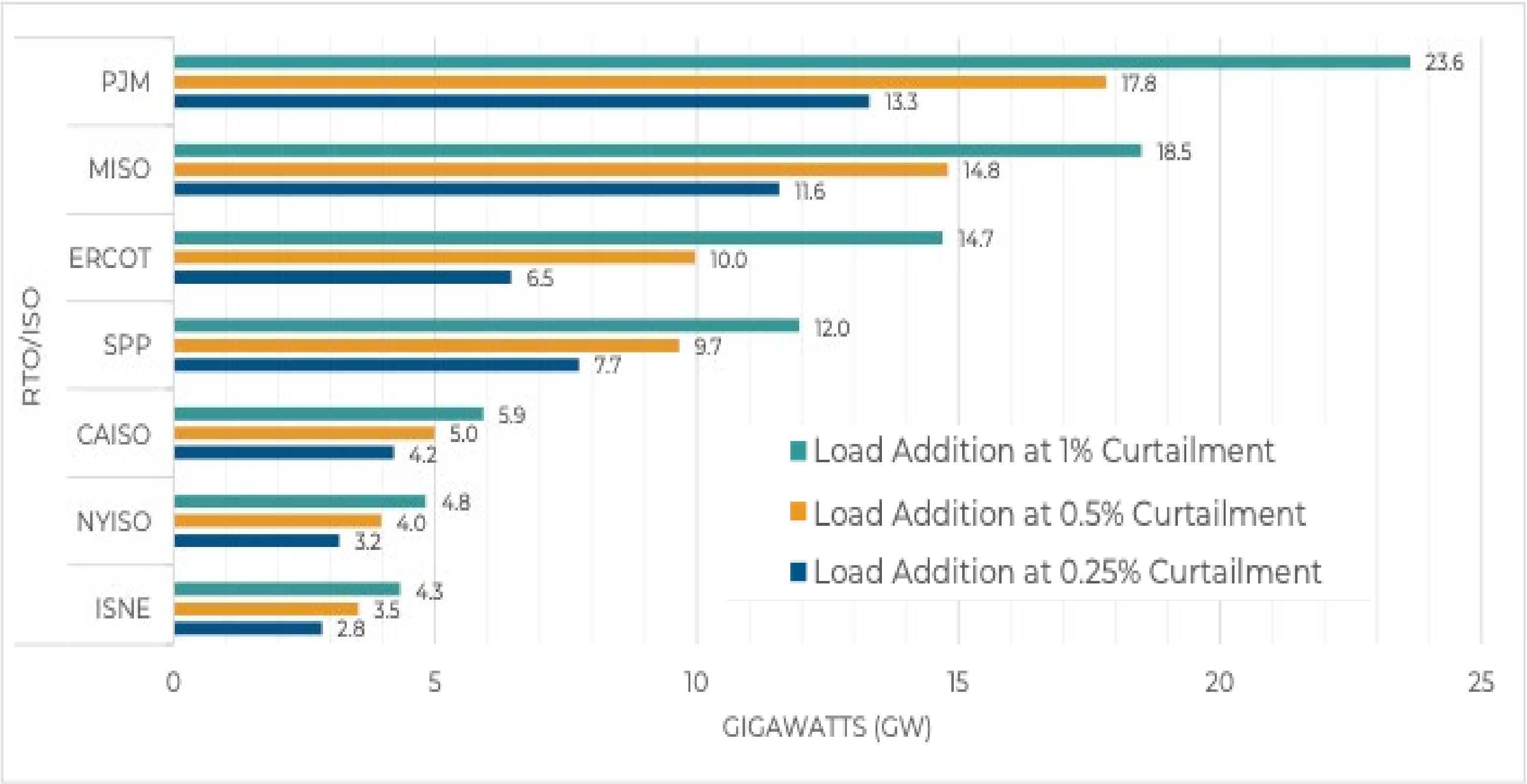


Source: T. Norris et al, Duke University, Rethinking Load Growth, 2025

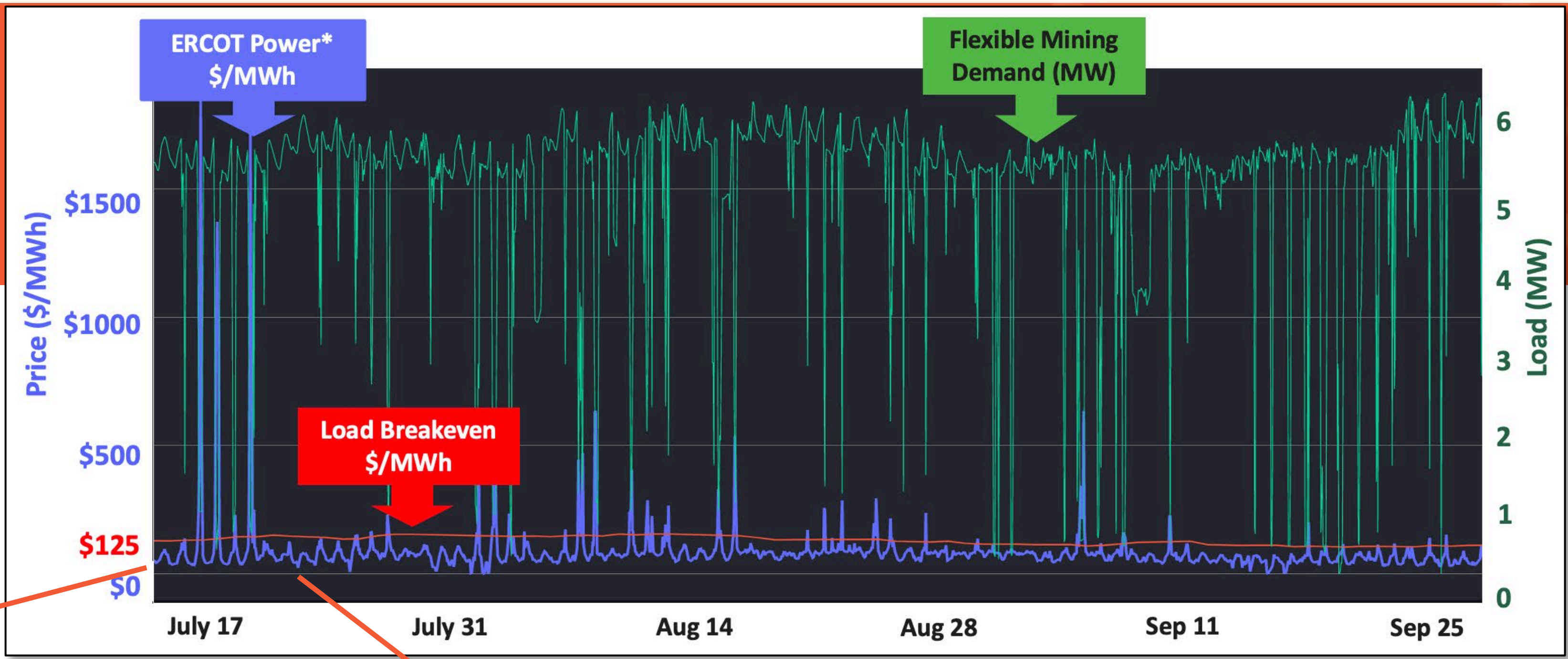
Flexibility enables faster load interconnection

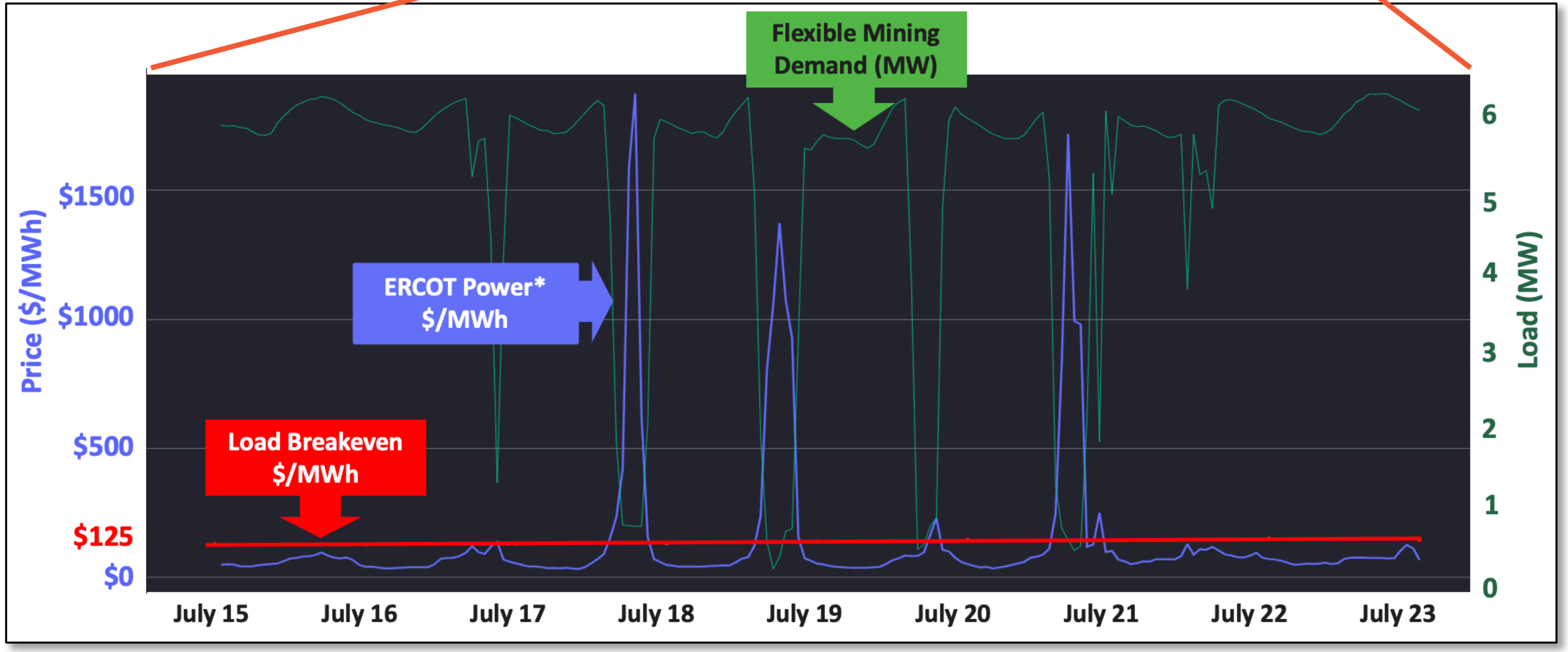
Duke University study finds 76 -126 GW of new load could be integrated if those loads were able to curtail for 0.25 – 1% of their maximum uptime.



T. Norris et al, Duke University, [Rethinking Load Growth](), 2025

Some loads are naturally flexible





ERCOT's Controllable Load Resources are treated equivalent to generators

Shaun Connell, Lancium, 2023

Onsite generation/storage

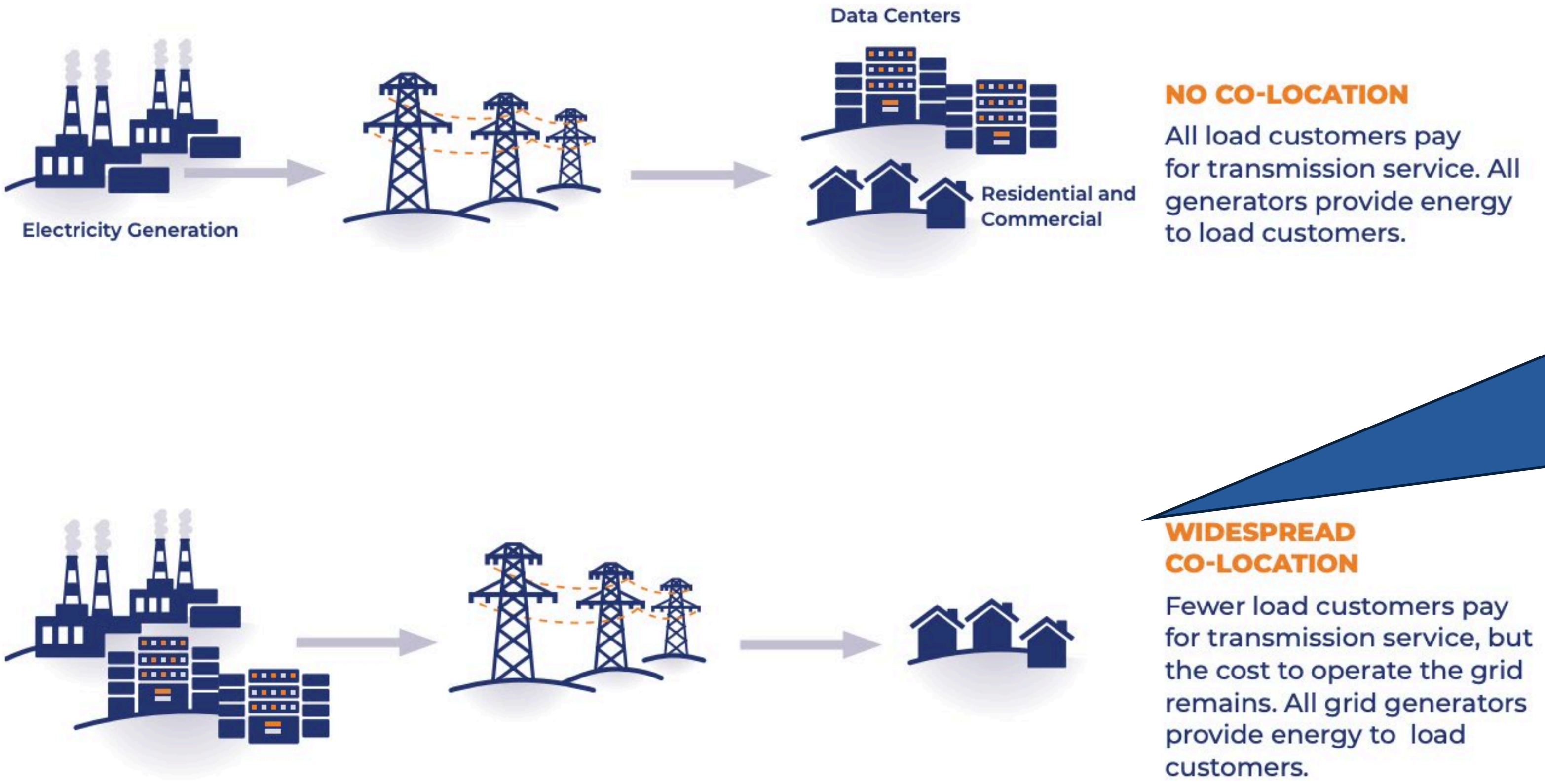
- Black Hills Energy and Microsoft designed Large Power Contract Service Tariff that allows utility to tap into Microsoft's backup generation during high demand periods.
- Defers need to build new power plant
- Utility purchases power, including renewables, in the market to serve the data center
- Microsoft gets lower cost market energy and ratepayers do not need to cover cost of a new power plant
- Note that flexible generation to be designed from the start. Gas turbines, batteries, reciprocating engines can likely do this. Diesels may not be able to.

In the future, data centers will be grid assets. They all have storage and backup generation. We just need to incentivize this.

https://datacenters.blackhillsenergy.com/resources/energy-solutions-data-centers; Sean Jones, Tesla, NERC LLTF 4/10/25

Market issues:
Co-location of load and generation

These generators effectively "retire" which can drive capacity prices for ratepayers higher

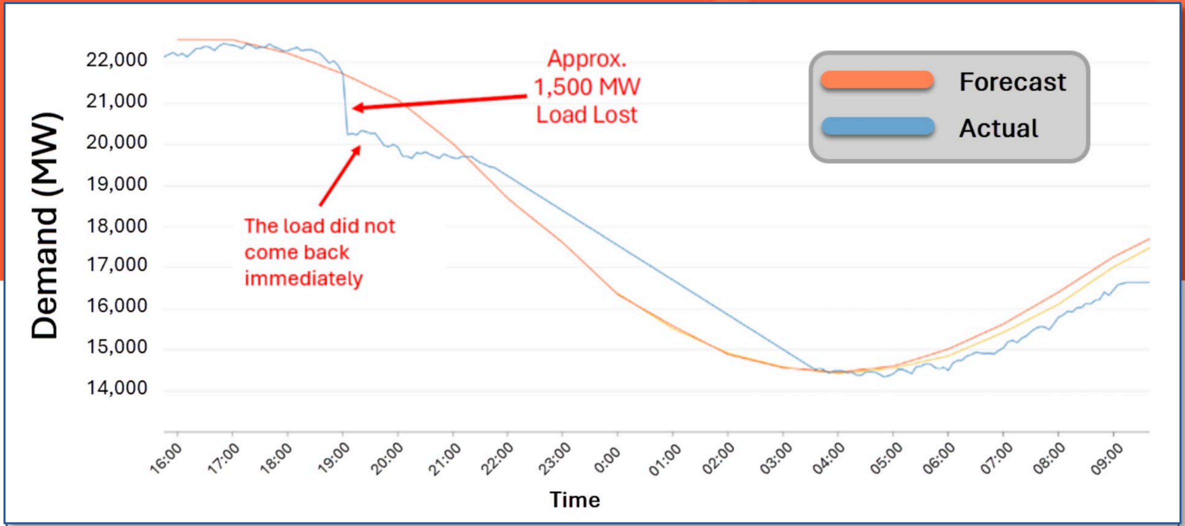


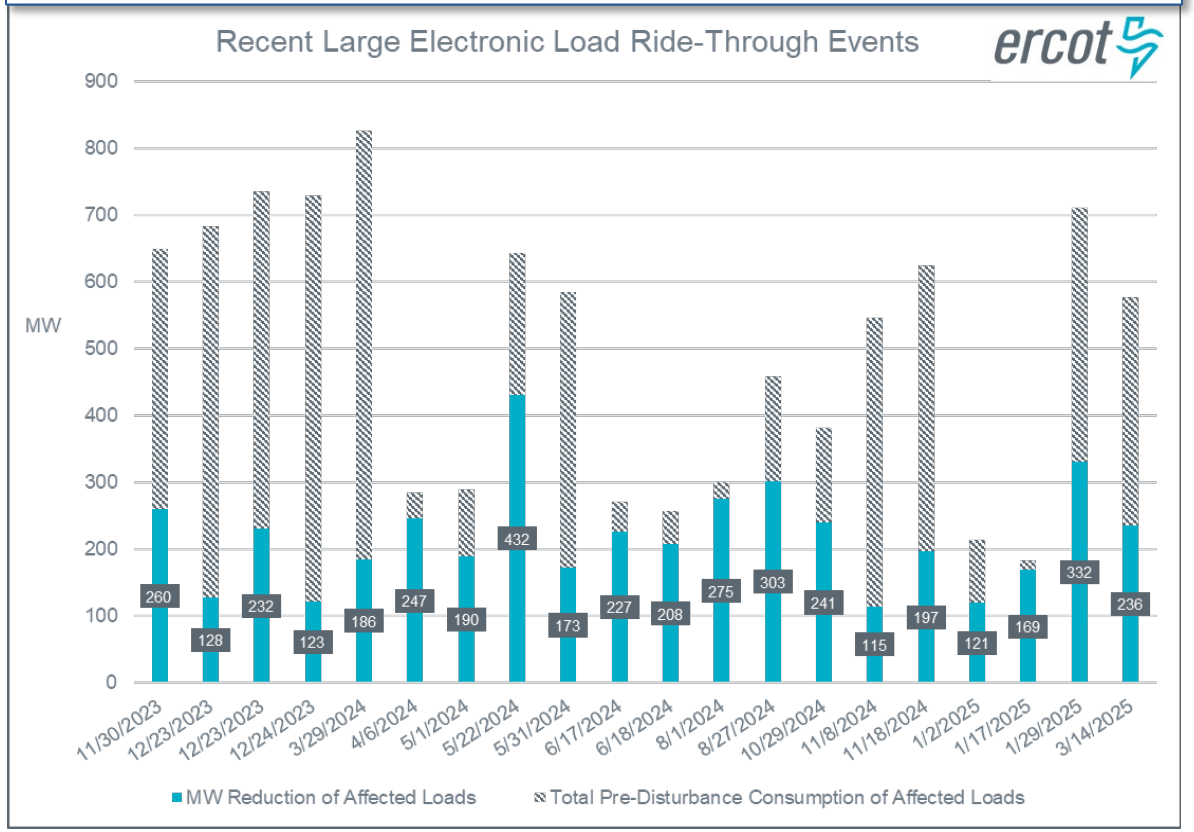
Fewer customers paying for fixed cost of transmission grid drives transmission rates higher

https://energyinstitute.jhu.edu/wp-content/uploads/2025/06/Johns-Hopkins_Datacenters-Playbook_FINAL.pdf

Reliability issues: Fault Ride-Through

- When there is a transmission fault (lightning, animals, trees, equipment failure, etc) some large loads in that region may trip offline, and transfer to their backup power.
- A fast, unexpected drop of 1500 MW of load can have a similar impact as a 1500 MW nuclear plant tripping offline. It can create a reliability event.
- To avoid this, we need to set up interconnection requirements for large loads so that they don't trip offline for minor disturbances. We may also want to control their ramping so that when they do transfer to backup power it is not abrupt.

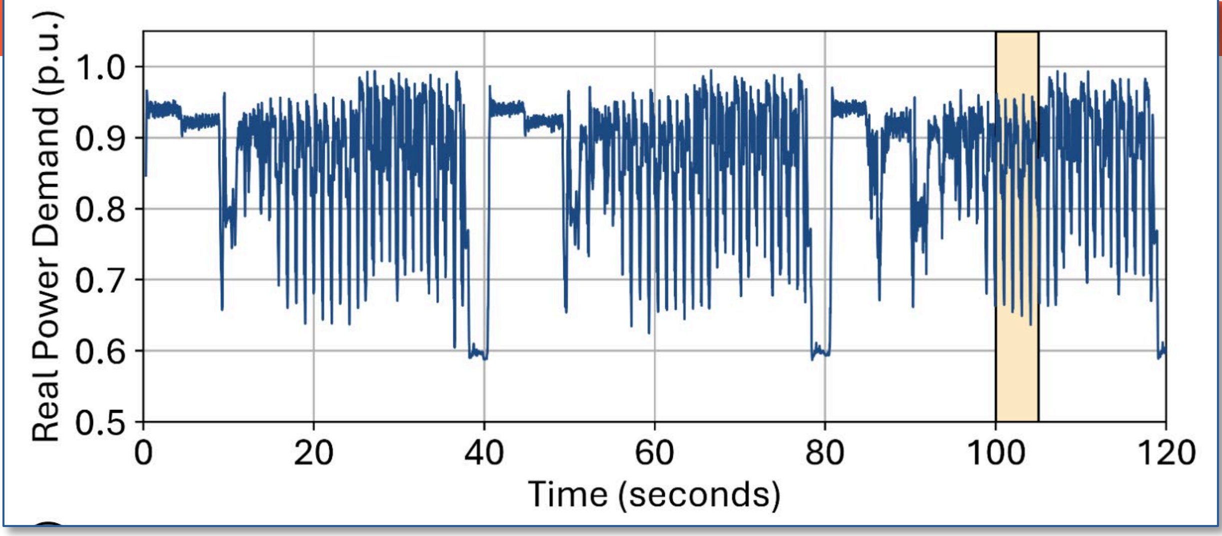




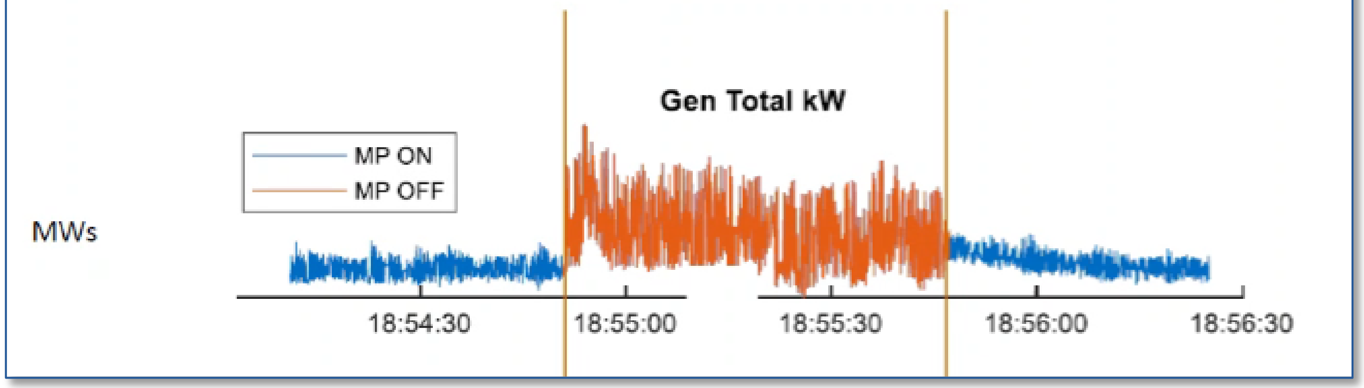
Source: ERCOT Large Load Workshop, June 2025

Reliability Issues: Oscillations

- During AI training, thousands of GPUs can be computing (energy intensive), and then exchanging data (not energy intensive).
- Since they operate in synchronism, it can result in large power fluctuations in which load oscillates rapidly
- If off-grid, the oscillations can damage the generator
- If on-grid, can interact with nearby generators or inter-area oscillations can occur
- Software solutions or battery storage can help to reduce variability
- Even uncontrolled ramping, to chase prices, for example, can create reliability issues.



Real-world results of AI training power load smoothing tested beyond 25 MWs



NERC LLTF 6/18/25; Sean Jones, Tesla, NERC LLTF 4/10/25

Large loads can be resources. Treat large loads like generators.

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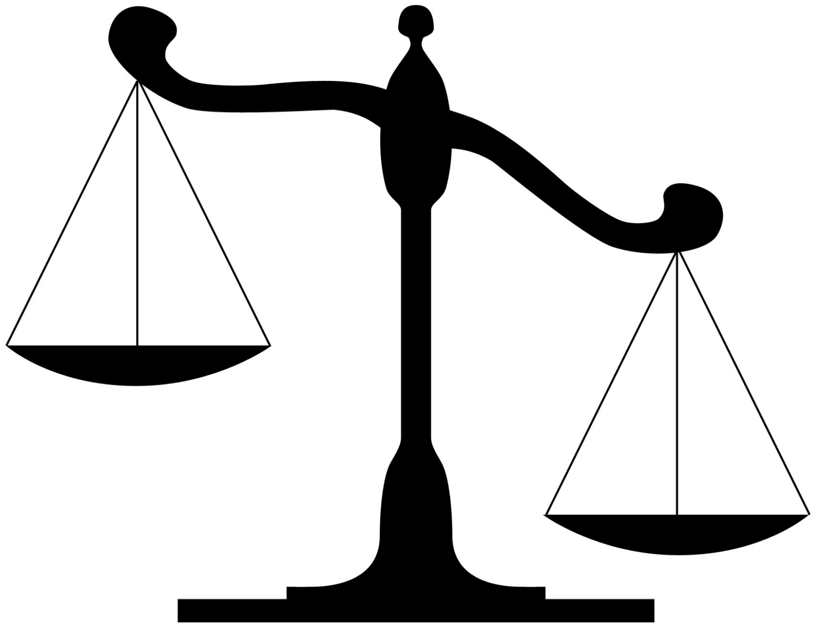
- Large loads and generators can both be resources on the grid.
- They can both have significant reliability impacts and should have interconnection requirements to protect against that.
- We should standardize interconnection processes for loads.
- There should be a higher bar for different steps in the process so that time and money isn't wasted on highly speculative requests.
- We should consider whether socializing large load transmission costs to all ratepayers is fair.
- Large loads should be able to participate in wholesale electricity markets just like generators. This will compensate them for flexibility.
- We need better rules and processes for large loads that provide flexibility during periods of stress or congestion. They may not need generation or transmission built to their nameplate capacity.



Conclusions

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- When you're big, you have an impact!
- Large loads should not be viewed as a burden but rather as a resource to help the grid.
- We need to ensure the planning processes, interconnection requirements, tariffs and market participation models are designed well.
- This is an opportunity to fix our systems. Large loads reveal shortcomings in our processes
- Ultimately we will likely be trading speed for
  - Flexibility and use of backup generation
  - Interconnection requirements
  - Market participation

THANK YOU

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