ESIG Large Loads Task Force: Background Information, Data and Flexibility Needs

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Webinar

ESIG
ENERGY SYSTEMS INTEGRATION GROUP

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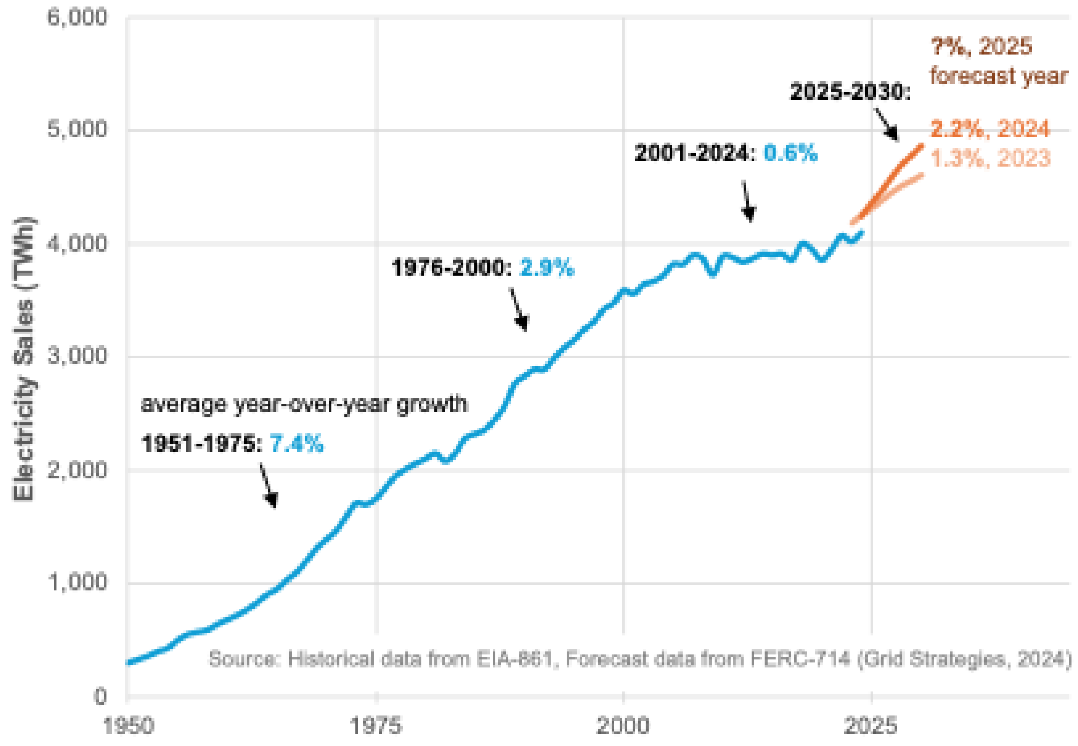
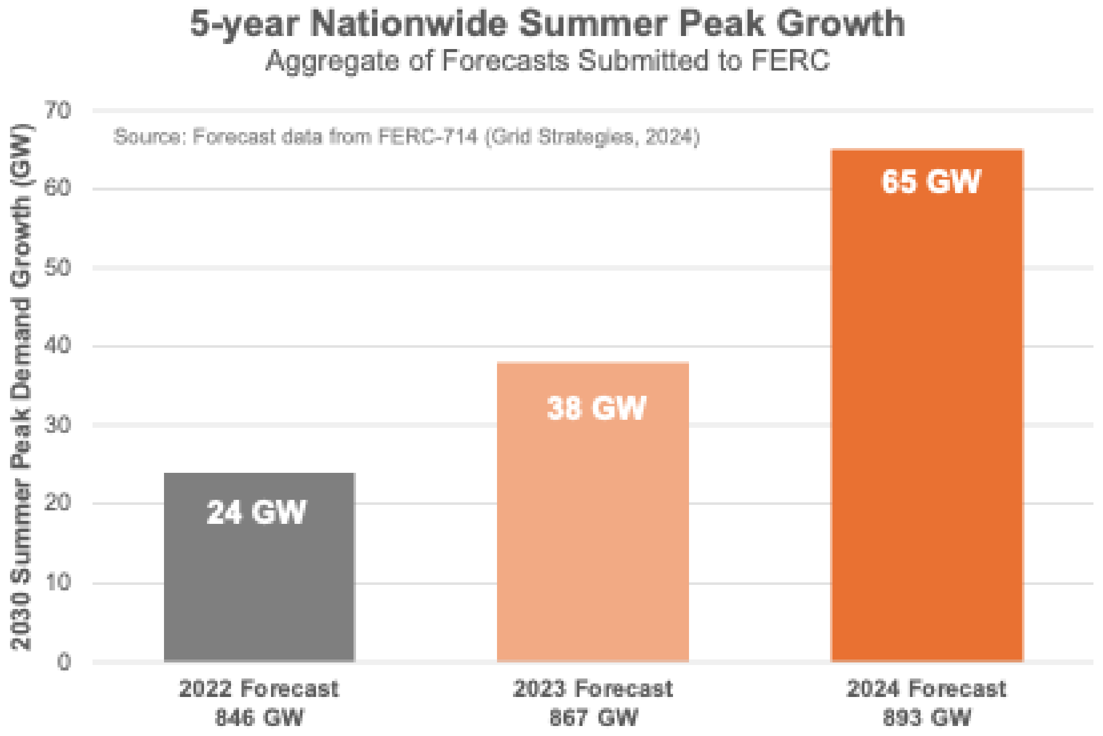
Motivation: Rapidly-Growing Demand and Forecast Uncertainty





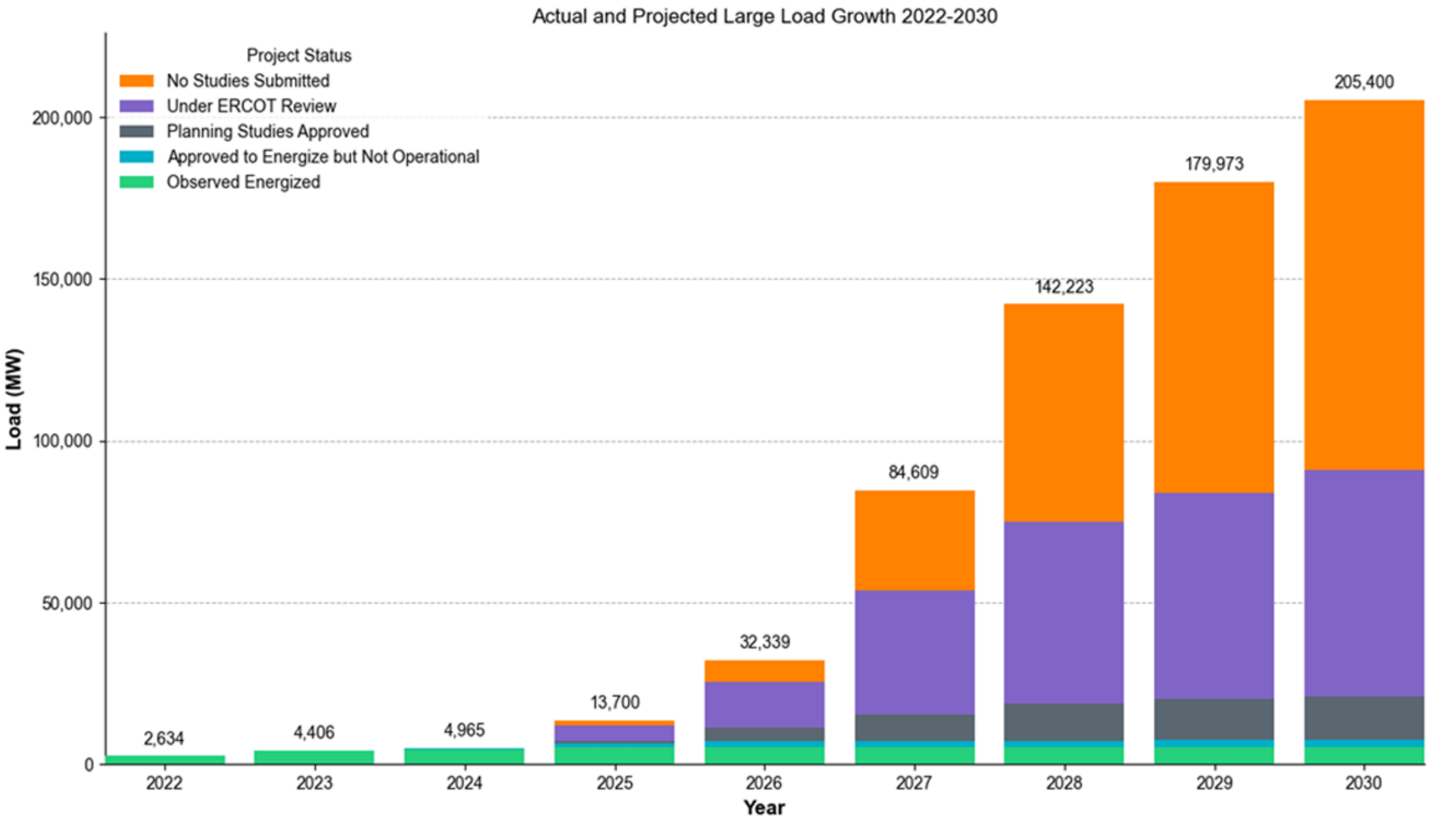
2025 Forecasts will be even more stark ← New report from Grid Strategies planned for publication in November

Source: Grid Strategies, based on aggregate EIA, FERC data

Motivation: Interconnection Queue Challanges

- Many utilities/ISOs have low bars to entry.
  - Load developers file (multiple) 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.
- **Large load interconnection queue data is not public**

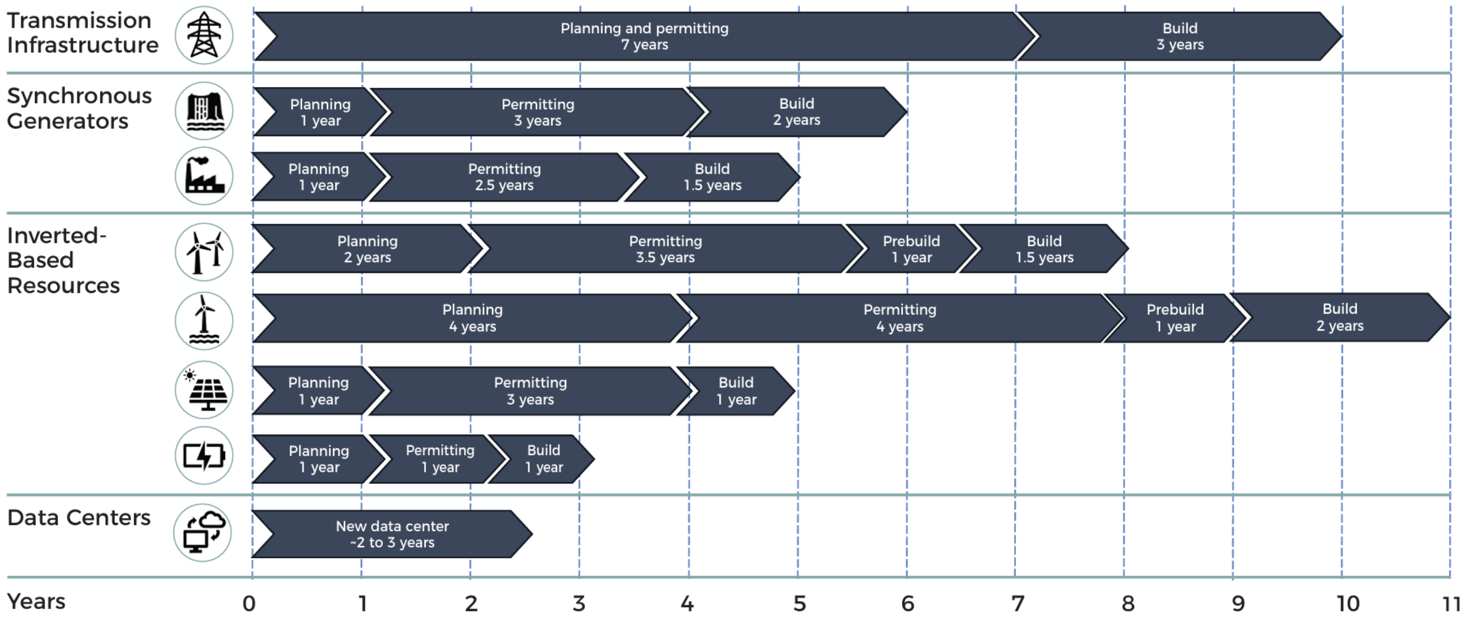
ERCOT Large Load Interconnection Queue (end of July 2025)



Source: ERCOT Monthly Operational Overview, September 2025

Motivation: Planning Generation, Loads, and Transmission

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



Timelines for grid infrastructure are not aligned with those for large load development, creating bottlenecks for grid supply of electricity. SOURCE: ADAPTED FROM S&P GLOBAL.

Source: Practical Guidance and Considerations for Large Load Interconnections GridLab and Elevate Energy, May 2025

ESIG Large Loads Task Force Project Teams

Large Loads Task Force (LLTF)

ESIG Working Groups:
- Reliability
- Systems Operations & Market Design
- Systems Planning

Interconnection Process

- Large load interconnection processes and studies

Interconnection Performance

- Requirements and performance specifications of large loads

Modeling Requirements

- Modeling requirements of large loads for power system studies

Load Forecasting

- Policies and practices for forecasting large loads to inform resource and transmission planning

Transmission Planning

- Consideration of large loads in transmission planning processes

Resource Adequacy

- Practices for evaluating large loads in resource adequacy studies

Markets & Operations

- Market design and operations for large loads and associated co-located resources

ESIG Large Load Task Force Reports and Timelines

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Reports	Final Draft Date	Expected Publication Date
ESIG LLTF Introduction (incl. Data and Flexibility Needs)	End of December 2025	Early May 2026
LL Forecasting: Methodology and Framework	End of November 2025	**Mid-December 2025**
Interconnection Process	Mid-January 2026	End of January 2026
Interconnection Requirements Reports: 1. Interconnection Requirements Recommendations 2. Grid Impacts of LL 3. Behaviors, Capabilities, Limitations of LL 4. LL Disturbance Events	End of December 2025	January 2026
LL Modeling	End of December 2025	Mid- January 2026
Resource Adequacy Assessment with LL	Mid-January 2026	Mid-February
Market Design and Operations with LL	Mid-March 2026	End of March 2026
Transmission Planning with LL	Mid-March 2026	Early April 2026

Introduction Report

- Report Outline
  - Background and Context
    - A New Era of Electricity Demand Growth
    - Drivers of Modern Load Growth
    - What is Different About Modern Large Loads?
    - System Level Impacts of Large Loads
  - Cross-cutting Areas
    - Data Needs and Availability
    - Large Load Flexibility
  - LLTF structure, process, setup
- Draft Report published December 2025
- Final Report published by May 2026

What is Different About Modern Loads

Size & Concentration

- Individual facilities now reach 100s of MW to > 1 GW;
- Clustering in constrained regions drives localized reliability and stability challenges;
- Many now connect directly to HV transmission, changing interconnection and planning processes.

Rapid & Uncertain Growth

- Utilities forecast doubling of peak demand within a few years;
- National projections show tens–hundreds of GW of new load by 2030;
- Forecasts differ by hundreds of TWh, driven by evolving AI and exploratory interconnection requests.

Demand Profiles & Flexibility

- Flat 24/7 profiles giving way to highly dynamic swings (AI training, electrolyzers → tens of MW in seconds).
- Demand response potential exists but hindered by reliability and business constraints.
- Many sites feature co-located or backup generation (diesel, gas turbines, storage, renewables).

Power Electronics Interfaces

- Power electronic interfaces may add stability risks
  - AI/crypto sites may switch over to backup supply during disturbances, aggravating grid events;
  - AI training cycles can introduce oscillatory behavior into the grid
- New standards, models, and screening tools needed

Modern large loads behave less like traditional demand and more like inverter-based resources—requiring new planning, modeling, performance and interconnection frameworks.

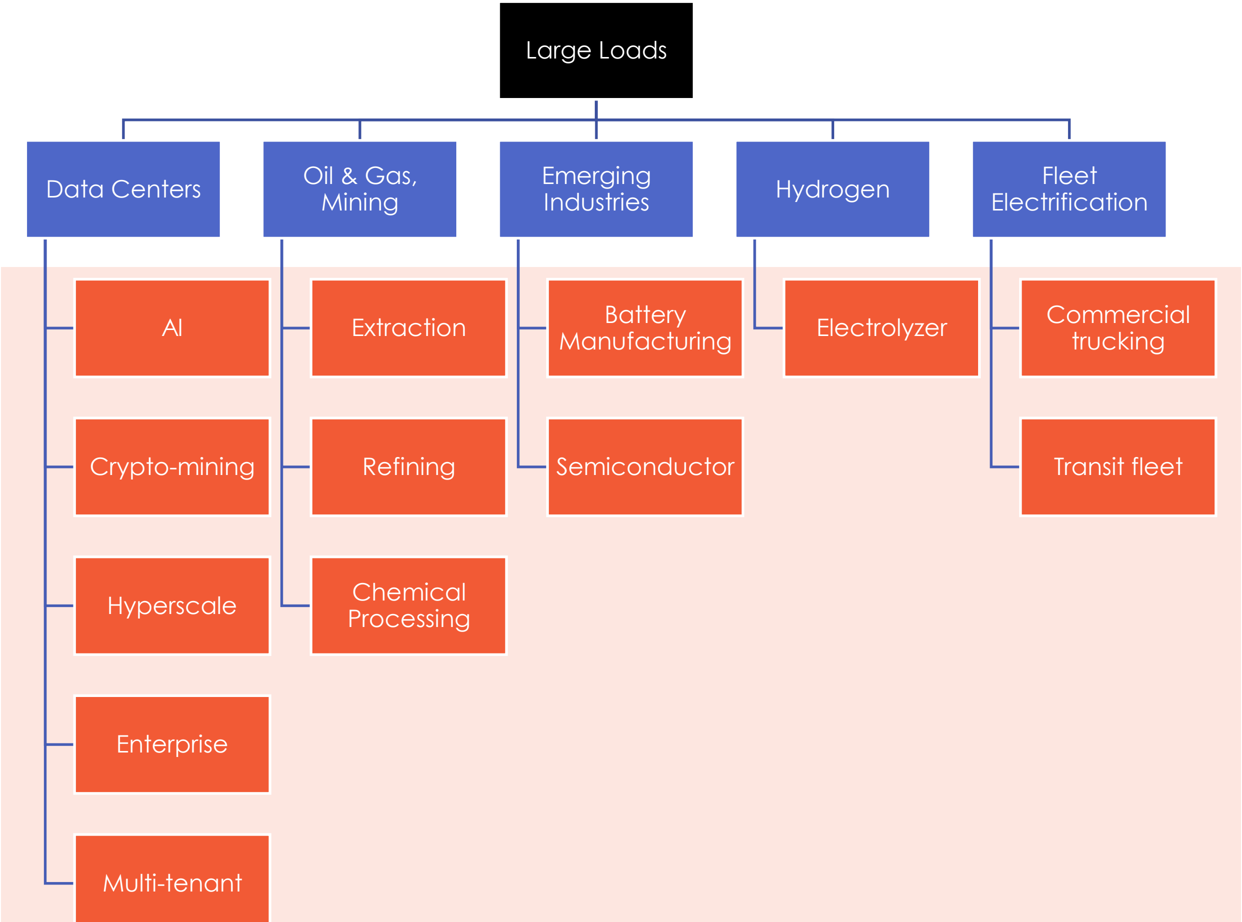
Definition and Types of Large Loads

NERC LLTF Definition of Large Loads:

Commercial or industrial facilities (or site aggregations) that can pose Bulk Power System reliability risks due to their size, operational behavior, or control systems, e.g., data centers, crypto mining, hydrogen electrolyzers, industrial manufacturing.

Different MW-size loads may have a material impact on the system, depending on the power system size and characteristics.

ESIG LLTF adopts a similar high-level definition of Large Load focusing on grid impacts and risks.



Example large load sub-types and end-uses

Integration of Large Loads has Impacts across Grid Planning & Operations

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Large Load Characteristics

Components of Grid Planning & Operations

	Large Facility Size	Geographic Concentration	Development Uncertainty	Profile & Flexibility Uncertainty	Co-located Resources	Power Electronics Interface
Interconnection Process	must consider	keep track	must consider	should consider	may consider	should consider
Load Forecasting	must consider	keep track	must consider	may consider	may consider	keep track
Transmission Planning	must consider	must consider	should consider	should consider	should consider	keep track
Resource Planning & Adequacy	must consider	should consider	should consider	must consider	should consider	keep track
Operations & Markets	must consider	may consider	keep track	must consider	should consider	keep track
Operational Reliability	must consider	should consider	keep track	may consider	should consider	must consider

= must consider
= should consider
= may consider
= keep track

Data Needs

Area of Focus	Data Needs
Load Forecasting	Load type, profile, siting, demand growth trajectories, drivers for adoption
Interconnection Process /Studies	Electrical characteristics, ramp rates, ride-through behavior, redundancy and back up design, models capable of capturing important grid interactions
Interconnection Requirements	Ride-through capabilities, controllability, flexibility to shed or modulate load, and compliance with any voltage/frequency support obligations.
Modeling	Detailed dynamic and steady-state models (incl. representation of power-electronic vs non-power electronic components, UPS, internal protections that impact grid performance, controls and settings, etc.)
Market Operations	Flexibility options (interruptibility, storage coupling, co-located generation, and demand bidding strategies)
Transmission Planning	Geographic concentration / siting, temporal coincidence of demand growth, and likely expansion scenarios
Resource Adequacy	Load forecast uncertainty, coincidence with system peaks, flexibility during scarcity events, and availability of flexibility resources

Data Availability

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- Load developers and industrial customers often treat demand profiles, ramping behavior, and flexibility characteristics as proprietary, which reduces transparency and hinders accurate **forecasting**.
- In the **interconnection process**, utilities frequently receive incomplete or late-stage information, leaving system studies based on assumptions rather than verified design data.
- Standardized **models** of large loads for power system studies are not available, forcing planners to approximate with models that may not capture power electronic behavior or controllability.
- **Market**-relevant data on price sensitivity, operational flexibility, or willingness to curtail is generally anecdotal or pilot-based rather than systematically collected.
- For **transmission planning**, siting information and long-term expansion trajectories are uncertain, often tied to confidential corporate strategies or explorative development pipelines.
- For **resource adequacy**, the most acute gap is in representative, hourly 8760 demand profiles and quantifying the elasticity of large loads during system stress conditions.

Addressing data gaps requires data sharing frameworks, standardization of load modeling, regulatory or market mechanisms that incentivize transparency while balancing commercial sensitivities.

Integration of **flexible** large loads has widespread impacts across grid planning & operations

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● = must consider

◕ = should consider

◑ = may consider

◔ = keep track

A Definition of Load Flexibility

The consumer's capability and/or commitment to temporarily change their net consumption of electricity, to better match the needs of or to provide services to the power grid.

Why? The value of flexibility

The Load Perspective

- Reduces interconnection timelines and costs
- Reduces energy costs for the load
- Creates an additional source of revenue

Broader Societal Impacts

- AI race
- Ratepayer costs
- Emissions
- Supply chains

The Grid Perspective

- Reduces or defers transmission upgrades
- Reduces need for investment in new generation
- Expands options for grid service provision
- Improves reliability
- Reduces electric system costs

Load growth is outpacing supply growth. Can we change demand to make more efficient use of supply?

Why not? Challenges to large load flexibility

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- **Costs**
  - Opportunity cost (e.g., lost revenue from curtailed computations)
  - Capital cost to enable flexibility (e.g., onsite resources)
- **Business models**
  - Non-power contracts and agreements (e.g., multi-tenant data center facilities)
  - Expectations for rapid growth disincentives lower capacity commitments
- **Institutional issues**
  - Dependability and transparency of flexible loads
  - Market participation rules
- **Technical constraints**
  - Examples: back-up gen constraints (fuel supply, emissions permits, ramp rates, RE availability, battery SOC management), disconnectability, telemetry, visibility

Unique flexibility opportunities for large loads

- **Large** and **concentrated**: bigger impact (positive and negative); a few individual facilities or firms can have a large impact; transmission-connected
- **Technical Flexibility**: potentially more flexible than many other types of loads (e.g., through onsite resources, temporal/geographic shifting)
- **Sophistication**: facility owners (e.g., technology firms) have the means to participate in the complex processes
- But could enable transformative change for other (smaller) loads as well

The **4 HOWs** of Load Flexibility

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How **Early**

- Lead time to respond
- Speed of response

How **Long**

- Duration of response

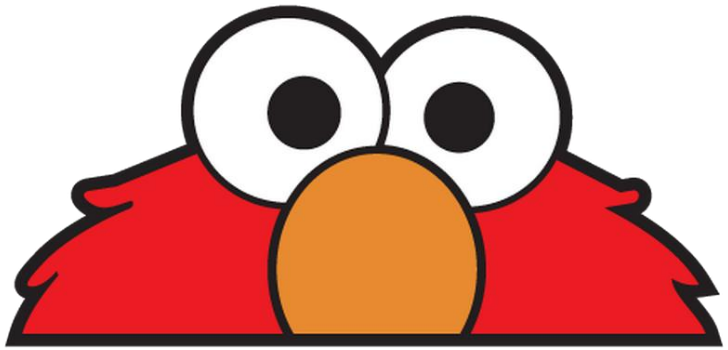
How **Much**

- Magnitude of response
- Direction of response

How **Often**

- Frequency of responses
- Event vs. non-event

Can you help ELMO match large load flexibility capabilities with the needs of the grid?



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Data center flexibility mechanisms

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Challenges and trade-offs

	Mechanism	Challenges and trade-offs
Decreases server uptime	Shift Compute Workload	Opportunity costs; compliance with service level agreements
Maintains server uptime	Shift Non-Compute Workload	Performance or equipment risk; limited duration, frequency, and timing
Maintains server uptime	Use Co-located Resources	Capital expenditures; air pollution permits (fossil back-up); limited duration (batteries)

Dependability and transparency are key challenges for the grid operator/planner

Active exploration of load flexibility mechanisms

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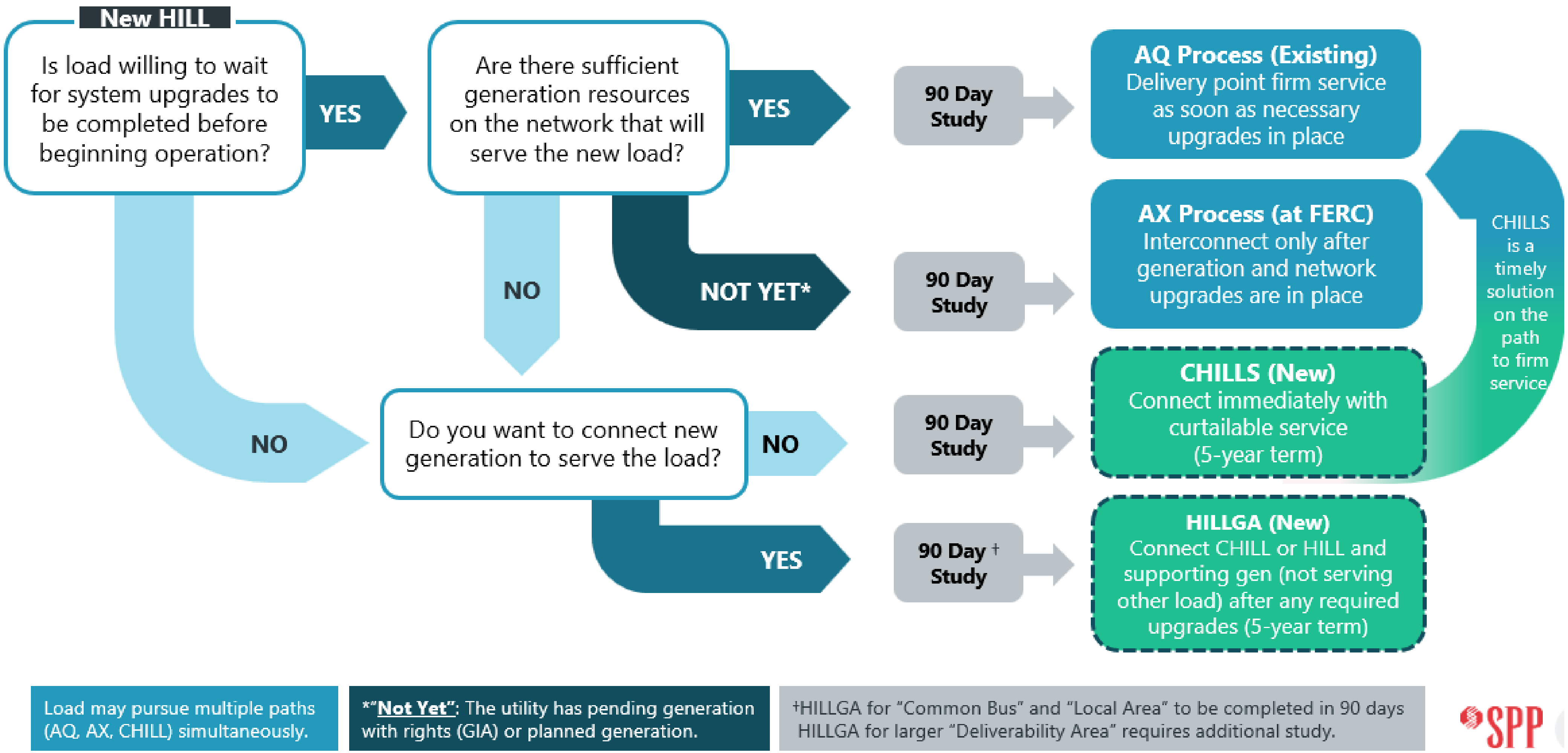
- **DOE Speed to Power Initiative & Letter to FERC**: "the interconnection study of large load that agree to be curtailable and hybrid facilities that agree to be curtailable and dispatchable should be expedited."
- **Texas Senate Bill 6** requires ERCOT to develop a reliability service that procures large load curtailment; also requires protocols for remote disconnection and thresholds for load curtailment or use of on-site generation. Other states are exploring flexibility and its effects on cost allocation
- **Southwest Power Pool** (SPP) proposed Conditional High Impact Large Load Service (**CHILLS**) offers expedited (90-day) interconnection study and ~5 years of non-firm service in exchange for curtailment rights. Also proposing HILLGA and PAL.
- **PJM** is targeting a December 2025 filing of reliability-focused solutions for rapid large load integration without causing resource inadequacy.
- **Agreements between tech firms and utilities**, e.g., Google + I&M/TVA, Microsoft Cheyenne
- **Data center pilots and design innovations**, e.g., Emerald AI, Verrus, Tesla

+ many more examples!

SPP proposed HILL, HILLGA, and CHILL processes



+ PAL (Price Adaptive Load)

Source: Jennifer Swierczek presentation at ESIG Large Loads Workshop on October 30, 2025

Current observations with large load flexibility

- Focus on **speed to power**; direct economic incentives are often insufficient to motivate flexibility
- Flexibility should be **planned upfront** in the large load design
- **Heterogeneity** of large loads, including data centers, leads to heterogeneity in flexibility capabilities
- Load flexibility is rarely (if ever) considered in **load forecasts**; similarly for current modeling of large loads in interconnection and transmission studies
- Need for clear **specifications for flexibility commitments** (e.g., ELMO); flexibility without coordination is worse than no flexibility
- **Carrots** to *incentive* flexibility vs. **sticks** to *require* flexibility vs. “carrot sticks” (service tiers?)

Source: https://premierproduceone.com/carrot-sticks-4-5-lb.html

EPRI DCFlex Initiative

StarFLEX™	Flexibility Tiers (Illustrative)
A	Supports Grid During Disturbances
B	Self Serves During Transmission Outages
C	Supports Grid During Peak Stress
D	Provides Fast or Long Flexible Response
E	Acts Like Dispatchable Capacity

[Under Development]

Source: Anuja Ratnayake, presentation at ESIG Large Load Workshop on October 30, 2025

THANK YOU

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