NPCC Reliability Forum

Thursday, May 15, 2025
9:00 a.m. – 12:00 p.m. EDT
Webex Meeting

Reliability Forum Topics	
9:00 am	**Welcome and Safety Message** Gerry Dunbar – NPCC – Director, Communications and Stakeholder Outreach
9:05 am	**Antitrust Compliance Guidelines, Public Notice, and Meeting Protocols** Ruida Shu – NPCC – Manager of Reliability Standards
9:10 am	**NPCC Reliability Forum Outreach Efforts** Gerry Dunbar – NPCC – Director, Communications and Stakeholder Outreach
9:15 am	**NERC Efforts and Draft Action Plan regarding Large Loads** Jack Gibfried – NERC – Engineer - Power Systems Modeling and Analysis
9:35 am	**Large Load Forecasts: Trends and Challenges to their Use** John D. Wilson – Grid Strategies LLC – Vice President
10:10 am	**Evolving Load Characteristics and Reliability Considerations** Rahul Anilkumar – Quanta Technology – Senior Director, Transmission
10:45 am	**Break**
10:50 am	**Data Centers: Powering the Internet and Our Modern Economy** Morgan Johnson – Data Center Coalition (DCC) – Senior Energy Policy Manager
11:25 am	**ERCOT Large Load Loss/Reduction Events** Patrick Gravois – ERCOT – Lead Operations Engineer
12:00 pm	**Closing Remarks** Gerry Dunbar – NPCC – Director, Communications and Stakeholder Outreach

Meeting Logistics

Participants will be muted upon entry, and you are encouraged to use the “Chat” feature of the Webex if you wish to ask a question. The questions will be answered by the presenter at the end of each presentation. NPCC Reliability Forum will be recorded, the meeting material will be posted on the Reliability Forum section of the NPCC website.
Thank you for your cooperation.

Northeast Power Coordinating Council, Inc. (NPCC)

Antitrust Compliance Guidelines

It is NPCC's policy and practice to obey the antitrust laws and to avoid all conduct that unreasonably restrains competition. The antitrust laws make it important that meeting participants avoid discussion of topics that could result in charges of anti-competitive behavior, including: restraint of trade and conspiracies to monopolize, unfair or deceptive business acts or practices, price discrimination, division of markets, allocation of production, imposition of boycotts, exclusive dealing arrangements, and any other activity that unreasonably restrains competition.

It is the responsibility of every NPCC participant and employee who may in any way affect NPCC's compliance with the antitrust laws to carry out this commitment.

Participants in NPCC activities (including those participating in its committees, task forces and subgroups) should refrain from discussing the following throughout any meeting or during any breaks (including NPCC meetings, conference calls and informal discussions):

- Industry-related topics considered sensitive or market intelligence in nature that are outside of their committee's scope or assignment, or the published agenda for the meeting;
- Their company's prices for products or services, or prices charged by their competitors;
- Costs, discounts, terms of sale, profit margins or anything else that might affect prices;
- The resale prices their customers should charge for products they sell them;
- Allocating markets, customers, territories or products with their competitors;
- Limiting production;
- Whether or not to deal with any company; and
- Any competitively sensitive information concerning their company or a competitor.

Any decisions or actions by NPCC as a result of such meetings will only be taken in the interest of promoting and maintaining the reliability and adequacy of the bulk power system.

Any NPCC meeting participant or employee who is uncertain about the legal ramifications of a particular course of conduct or who has doubts or concerns about whether NPCC's antitrust compliance policy is implicated in any situation should call NPCC's General Counsel and Corporate Secretary, Mr. Damase Hebert at (646) 737-2335 or dhebert@npcc.org.

Reliability Forum Disclaimer Statement

General

Any information presented [at NPCC forums] is for informational purposes only. NPCC accepts no responsibility for the accuracy of such presentations, or for your reliance on any information contained within the content available through such forums. Discussions represent a wide range of views and interests of the participating individuals and organizations. Statements made during discussions do not necessarily reflect those of NPCC.

Vendors

Information presented is for stakeholder informational purposes only and does not imply NPCC's endorsement or approval. NPCC does not promote technology, tools, products, services, or vendors that may be used by entities within the electric industry. Questions or concerns about vendors or the services or products they offer must be directed to the vendor. It is the responsibility of the owner, operator, or the user of the bulk power system to research the services the vendors offer. Those that utilize the services of vendors assume full responsibility for claims directly or indirectly arising thereunder and NPCC is not responsible or liable for any claim or harm, directly or indirectly, that transpires from the use of any information.

Public Announcement

Participants are reminded that this meeting, Webex, and conference call are public. The access number was posted on the NPCC website and widely distributed. Speakers on the call should keep in mind that the listening audience may include members of the press and representatives of various governmental authorities, in addition to the expected participation by industry stakeholders.

NPCC Reliability Forum

NPCC 2025 Outreach Activities

Gerry Dunbar
Director, Communications and Stakeholder Outreach

May 15, 2025

NPCC, Inc.

NPCC Long Term Strategy

To assure effective and efficient reduction of risks to the reliability and security of the grid

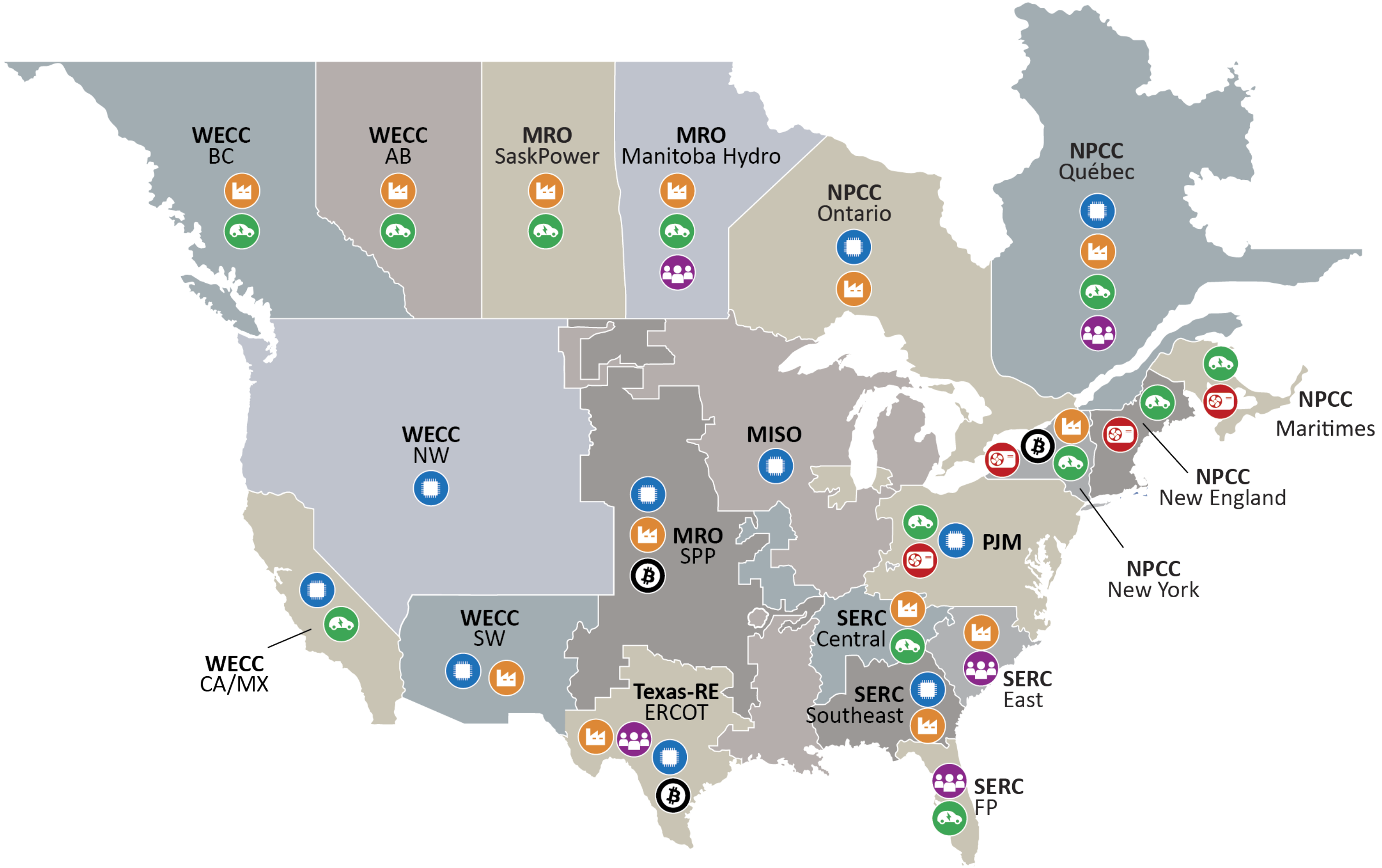
2025 Outreach Activities

- **Reliability Forums - March, May, Aug., Oct.**
  - Various Reliability Topics
  - Electric Vehicles, Energy Storage, Large Loads
- **State and Provincial Outreach Topics**
  - NERC and NPCC Seasonal Reliability Assessments
  - FERC Order 901 (Reliability Standards for Inverter Based Resources)
  - Winterization, Data Centers
- **Regional Webinars/Workshops**
  - Physical and Cyber Security
  - Extreme Weather Preparedness
  - Energy
- **2024 NPCC Northeast Gas-Electric Study**

NERC Efforts and Draft Action Plan regarding Large Loads

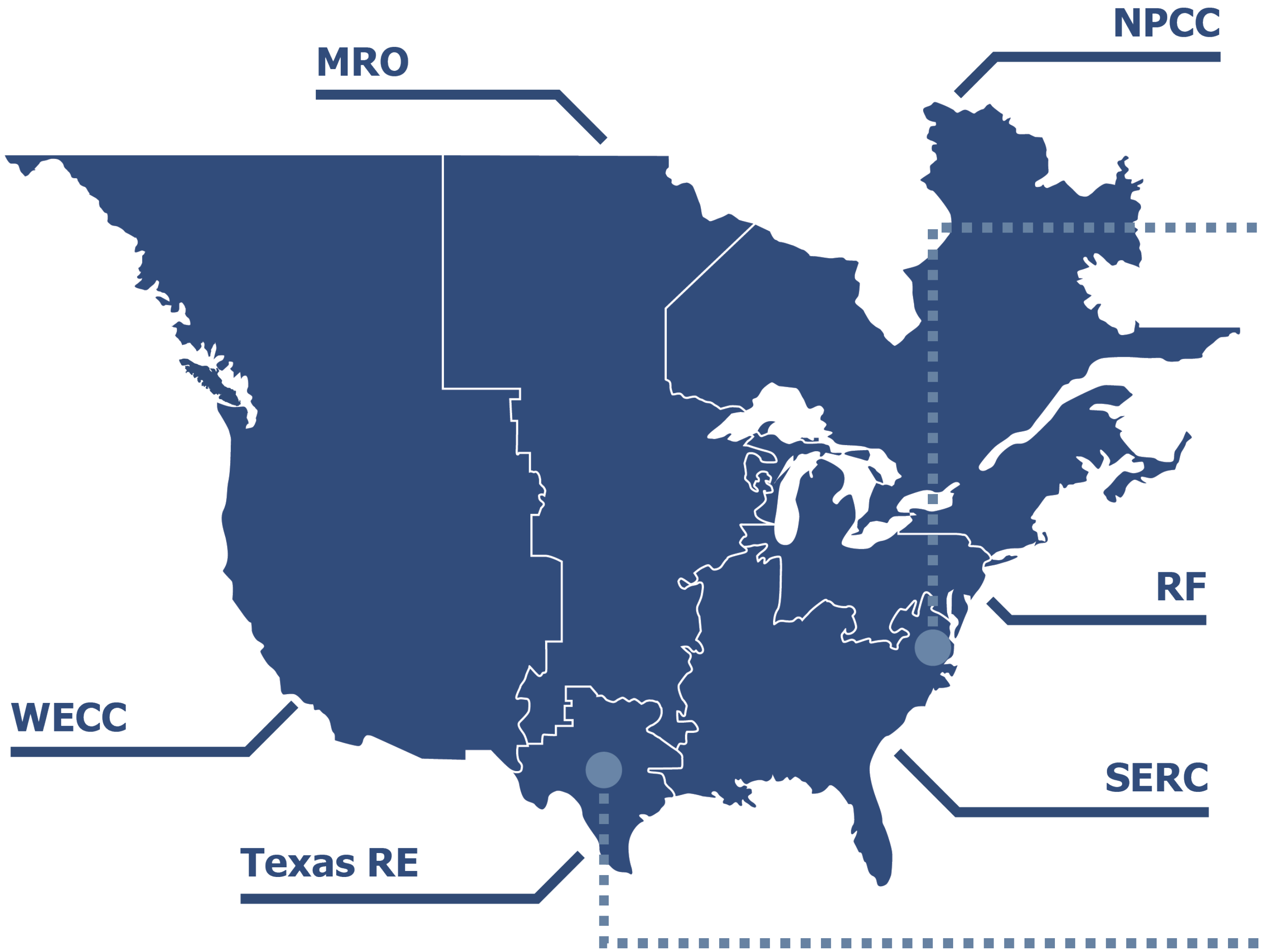
Jack Gibfried, Engineer - Power Systems Modeling and Analysis, NERC
NPCC Reliability Forum
May 15, 2025

Primary Demand Drivers by Assessment Area



- DATA CENTERS
- LARGE INDUSTRIAL LOADS
- TRANSPORTATION ELECTRIFICATION
- CRYPTO
- HEAT PUMPS
- DEMOGRAPHIC CHANGES

Voltage Sensitive Load Loss Events



EI Data Center Load Loss Events

- 1500 MW Load Loss (July 2024)
- 1800 MW Load Loss (February 2025)

ERCOT Crypto Mining Load Loss Events

- 25 Loss Events (November 2023–January 2025)
- 100–400 MW Load Loss

Data Center Load Loss Event

NERC
NORTH AMERICAN ELECTRIC
RELIABILITY CORPORATION

Incident Review

Considering Simultaneous Voltage-Sensitive Load Reductions

Primary Takeaways

Operators and planners of the Bulk Electric System (BES) should be aware of the risks and challenges associated with voltage-sensitive large loads that are rapidly being connected to the power system. Specifically, when considering data centers and cryptocurrency mining facilities, entities should be aware of the potential for large amounts of voltage-sensitive load loss during normally cleared faults on the BES. Voltage-sensitive data center-type loads have increased on the system and are predicted to continue growing rapidly. The 2024 NERC *Long-Term Reliability Assessment* (LTRA) documents and discusses this potential growth of data center-type loads. This vignette highlights this load-loss potential based on analysis of a recent event in the Eastern Interconnection and offers some considerations for BES operators, planners, and regulators concerning identifying and mitigating the potential reliability effects and risks presented by these large voltage-sensitive load losses for future operations.

Summary of Incident

A 230 kV transmission line fault led to customer-initiated simultaneous loss of approximately 1,500 MW of voltage-sensitive load that was not anticipated by the BES operators. The electric grid has not historically experienced simultaneous load losses of this magnitude in response to a fault on the system, which has historically been planned for large generation losses but not for such significant simultaneous load losses. Simultaneous large load losses have two effects on the electric system: First, frequency rises on the system as a result of the imbalance between load and generation; second, voltage rises rapidly because less power is flowing through the system. In this incident, the frequency did not rise to a level high enough to cause concern. The voltage also did not rise to levels that posed a reliability risk, but operators did have to take action to reduce the voltage to within normal operating levels. However, as the potential for this type of load loss increases, the risk for frequency and voltage issues also increases. Operators and planners should be aware of this reliability risk and ensure that these load losses do not reach intolerable levels.

Incident Details

At approximately 7:00 p.m. Eastern on July 10, 2024, a lightning arrestor failed on a 230 kV transmission line in the Eastern Interconnection, resulting in a permanent fault that eventually "locked out" the transmission line. The auto-reclosing control on the transmission line was configured for three auto-reclose attempts staggered at each end of the line. This configuration resulted in 6 successive system faults in an 82-second period. The protection system detected these faults and cleared them properly. The shortest fault duration was the initial fault at 42 milliseconds, and the longest fault duration was 66 milliseconds. The voltage magnitudes during the fault ranged from .25 to .40 per unit in the load-loss area.

RELIABILITY | RESILIENCE | SECURITY

EVENT:

- 1,500 MW Load Loss (exclusively data center load)
- Coincident with 230 kV normal line fault clearing
- Widespread: 60 different load points, 25 substations

CONCLUSIONS:

- Require models for large loads to determine Bulk Electric System risk from coincident large load losses
- Assess need for new or modified standards and if large loads should be registered with NERC

Large Load Task Force Framework to Address Reliability and Security Risks

Risk Identification, Validation, and Prioritization

White Paper (July 2025):
Characteristics and Risks of Emerging Large Loads

Gap Analysis

White Paper (Q3 2025):
Assessment of Gaps in Existing Practices, Requirements, and Reliability Standards for Emerging Large Loads

Risk Mitigation

Reliability Guideline (Q1 2026):
Risk Mitigation for Emerging Large Loads

Standard Authorization Request(s):
Update Reliability Standards as needed

Draft LLTF First White Paper: Prioritization of Risks

HIGH

Long-Term Planning
- Resource Adequacy

Operations/Balancing
- Balancing and Reserves

Resilience
- Automatic UFLS Programs

Stability
- Dynamic Modeling
- Frequency Stability
- Oscillations
- Ride-through
- Voltage Stability

MEDIUM

Long-Term Planning
- Demand Forecasting
- Transmission Adequacy

Operations/Balancing
- Lack of Real-Time Coordination
- Short-Term Demand Forecasting

Resilience
- Load-Shed Obligation Impacts

LOW

Power Quality
- Harmonics
- Voltage Fluctuations

Resilience
- System Restoration

Security Risks
- Cyber Security

Draft LLTF First White Paper: Characteristics and Risks of Emerging Large Loads

Recommendations for Large Load Task Force (#1-3)

- Process and Standard Gap Identification
- Risk Mitigation
- Characteristic Definition and Categorization

Recommendations for Reliability Security Technical Committee (RSTC) Working Groups (#4-6)

- Model Development and Refinement for Large Loads
- Assess Possible Protection System Impacts
- Investigate risks posed to resource adequacy

Recommendation to Utilities (#7)

- Industry should collect data to understand the unique risks associated with connecting a large load.

Target Quarters

2025				2026			
1	2	3	4	1	2	3	4

TASK DESCRIPTION

Reliability Security Technical Committee's Large Load Task Force (LLTF)

NERC-led Collaborative Industry Sessions

Registration Analysis

- Legal basis for registration of large users of the bulk power system
- Consider if Load-Serving Entities (LSE) are accountable for large load performance
- Ability to write Reliability Standards that Large Loads or LSEs would follow

Complementary Activities

- Load Modeling Working Group
- Coordination with EPRI, ESIG, and Large Load Industry Groups
- Industry Communications and Outreach
- Continued Incident Analysis and Lessons Learned

Questions and Answers

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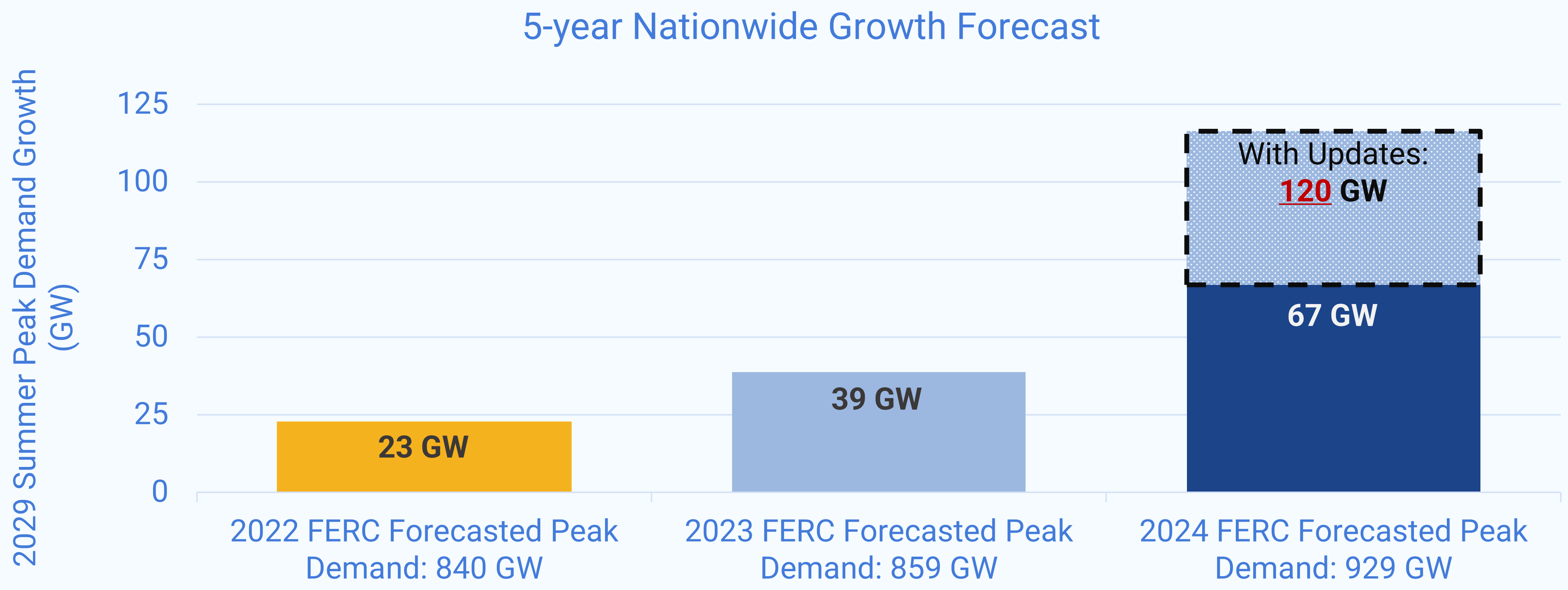
GridStrategies

Strategic Industries Surging – *Presentation to NPCC (May 2025)*

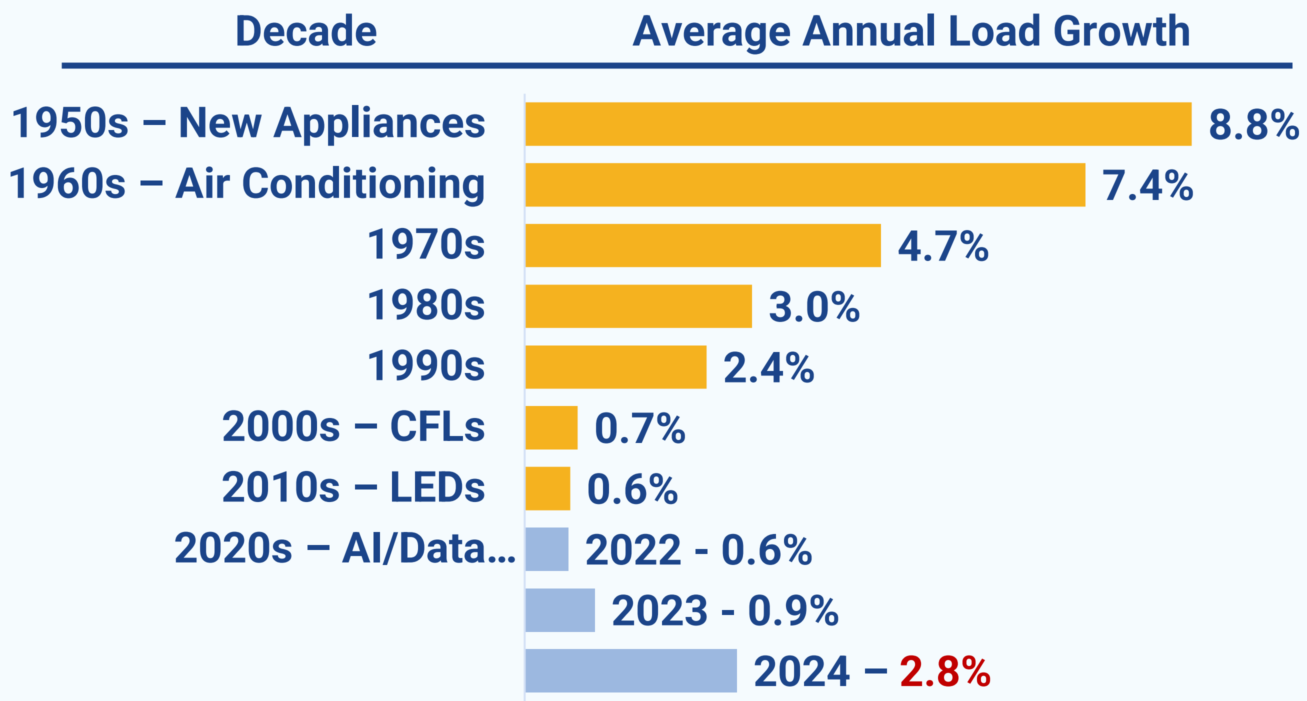
John D. Wilson, Zach Zimmerman, and Rob Gramlich

REPORT PUBLISHED DECEMBER 2024, UPDATED APRIL 2025

Five-Year Load Growth Up Five-Fold to 120 Gigawatts



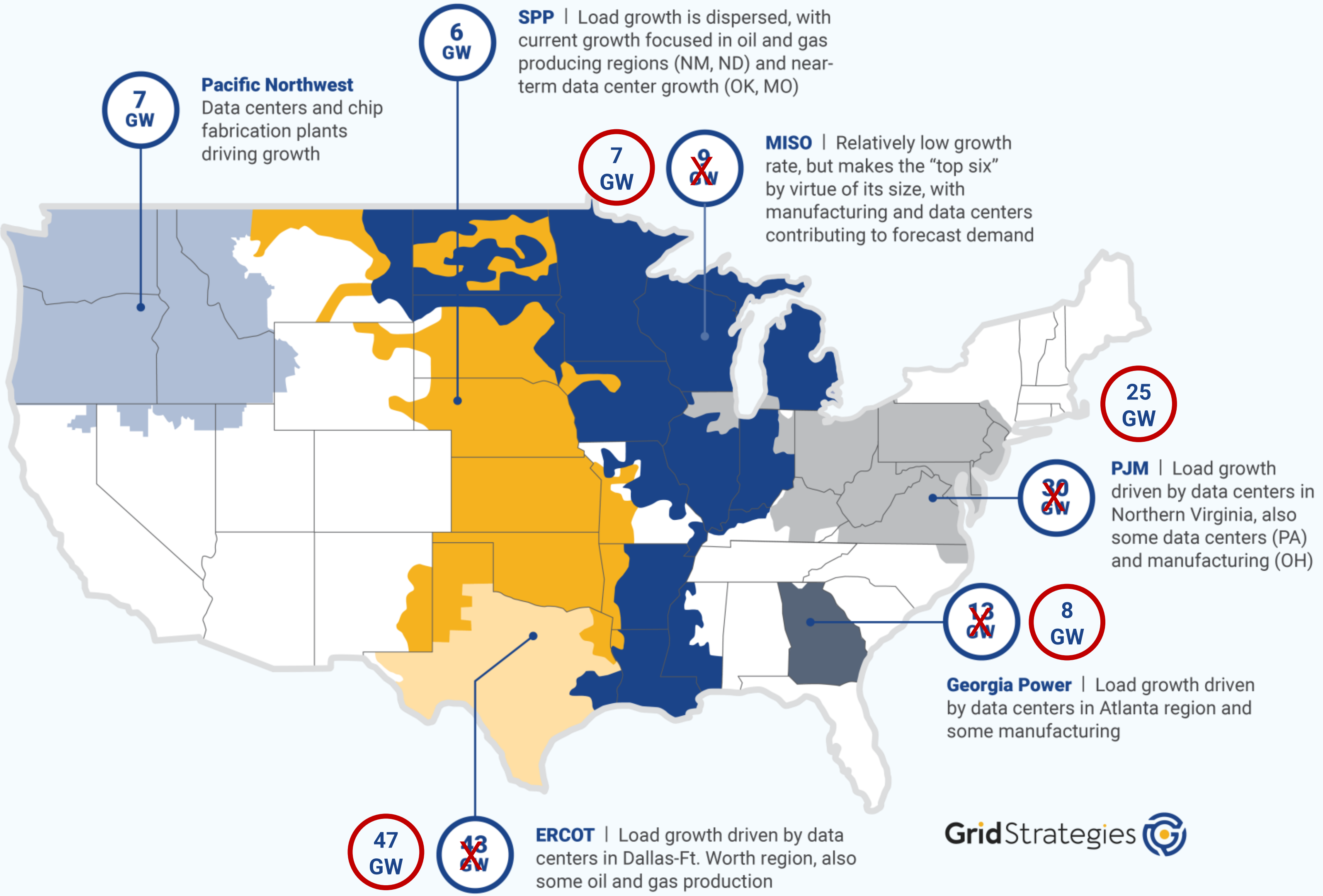
A Scramble to Respond to Growing Load



Strategic Industries Driving Load Growth Across Regions

Near-Term Load Drivers	Data Centers	Manufacturing	Electrification
Arizona Public Service	●		
CAISO	●		●
Duke	●	●	
ERCOT	●	●	
Georgia Power	●	●	
ISO-NE			●
MISO	●		●
NYISO	●	●	●
Pacific Northwest	●	●	
PJM	●	●	●
SPP	●		

Six Regions Driving Load Growth Through 2029



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Planning Areas with Sharpest Increase in 2024 Load Forecast

Updates from published reports:
- ERCOT 2025 update to board increased forecast by 4.0 GW
- PJM 2025 forecast increased by 10.4 GW (not 15.2 GW)
- Georgia Power 2025 IRP forecast increased by 2.2 GW (not 7.3 GW)
- MISO 2024 white paper decreased forecast by 2.0 GW

ISO-NE 2029 Peak Demand Forecast:
- Has not changed much in past three years
- Summer: 27.5 GW
- Winter: 24.9 GW

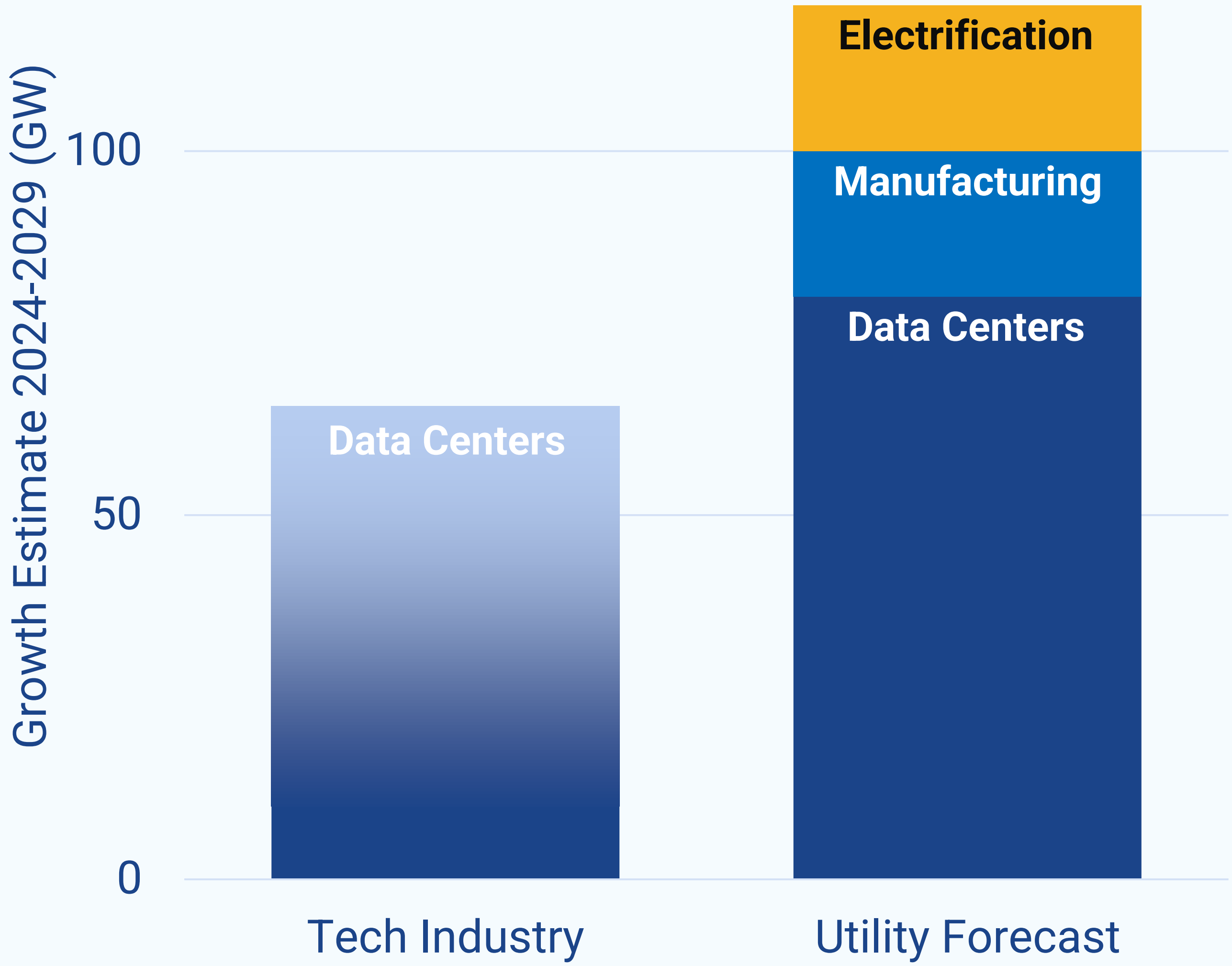
Planning Areas with Greatest Increase in Summer 2029 Peak Demand

Planning Area	2029 Peak Demand: 2022 Forecast (GW)	2029 Peak Demand: 2023 Forecast (GW)	2029 Peak Demand: 2024 Forecast (GW)	2029 Peak Demand: Forecast Updates (GW)	Forecast Increase (GW)	Forecast Increase (Percent)	Total Growth Through 2029 (GW)
ERCOT	84.4	89.6	88.1	+ 40.9	**44.6**	52.8%	**46.8**
PJM	153.3	156.9	165.7	**+ 10.4**	**22.7**	14.8%	**24.8**
Georgia Power	16.3	17.3	22.4	**+ 2.2**	**8.4**	51.6%	**7.9**
MISO	132.4	133.0	138.4	**- 2.2**	**4.1**	3.1%	**7.1**
Pacific Northwest	37.4	38.4	38.5	+ 2.0	**3.1**	8.2%	**7.4**
SPP	56.6	59.5	62.5		**5.9**	10.4%	**6.3**
Duke Energy (North & South Carolina)	33.9	36.2	36.6		**2.7**	7.8%	**2.6**
Arizona Public Service	8.7	9.8	9.9		**1.2**	13.6%	**1.5**
NYISO	31.5	32.3	32.3		**0.9**	2.8%	**0.8**
Tennessee Valley Authority	31.8	32.4	32.5		**0.7**	2.2%	**1.4**
All other planning areas	251.2	250.5	249.5		**-1.7**	-0.7%	**10.0**
Total	**840.5**	**858.9**	**879.8**	**+ 53.5**	**92.8**	**11.0%**	**120.3**

Data Center Forecast: Bottom Up vs Top Down

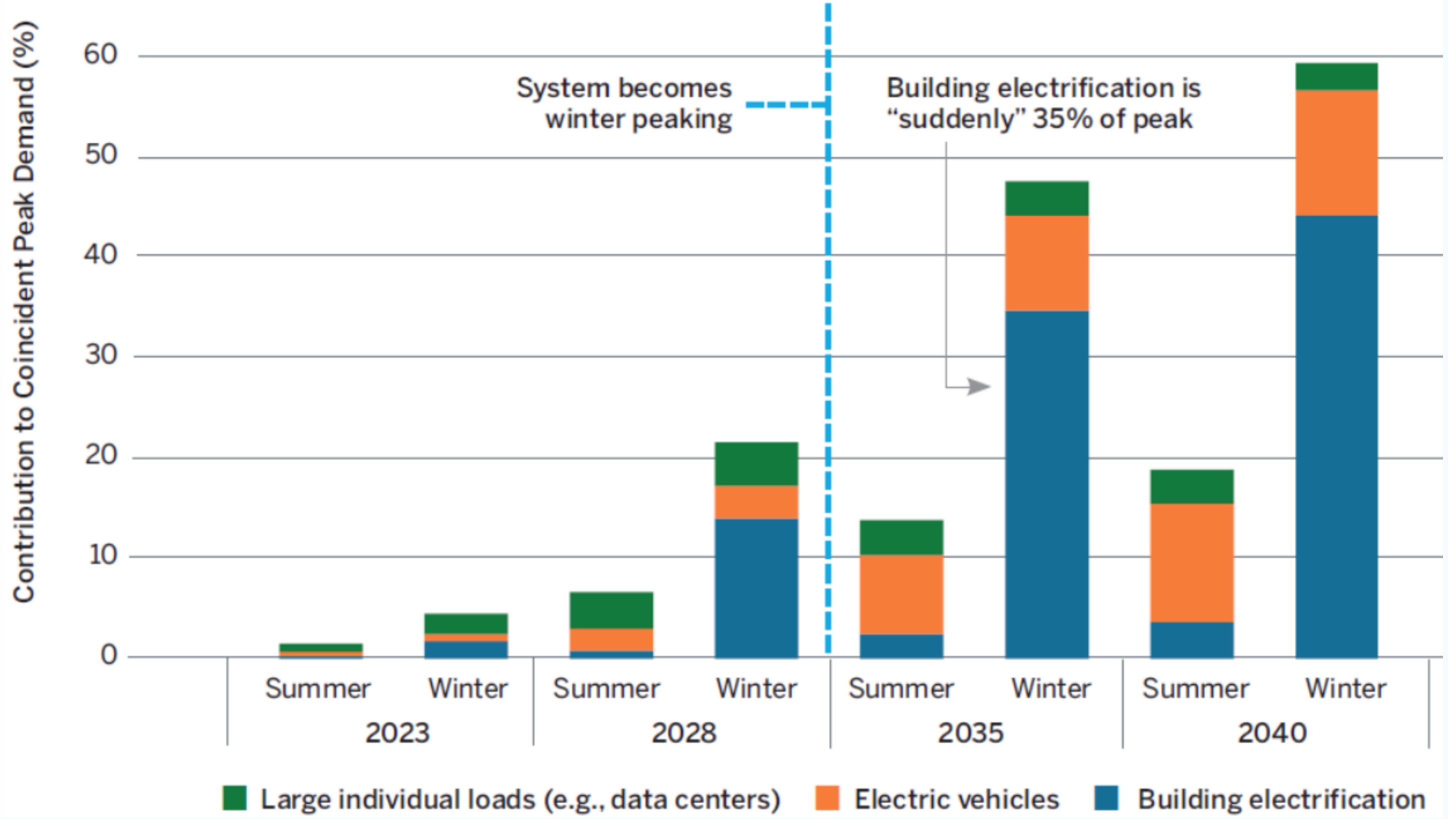
In the aggregate, the power industry does not have access to the data it needs to accurately forecast data center load.

- Industry specialists estimate five-year data center demand growth from as little as 10 GW to as much as 65 GW through 2029.
- Only some utilities break out data centers from other large load drivers. Grid Strategies' rough estimate of aggregate utility data center load forecasts is about **80** GW. Note that this estimate relies on informed speculation for regions with no published breakout or inconsistent category definitions. This is almost 10% of forecast 2029 load of **929** GW.



Building and Transportation Electrification Impacts Coming

Electrification and Large Load Impacts on New York's Peak Power Demand



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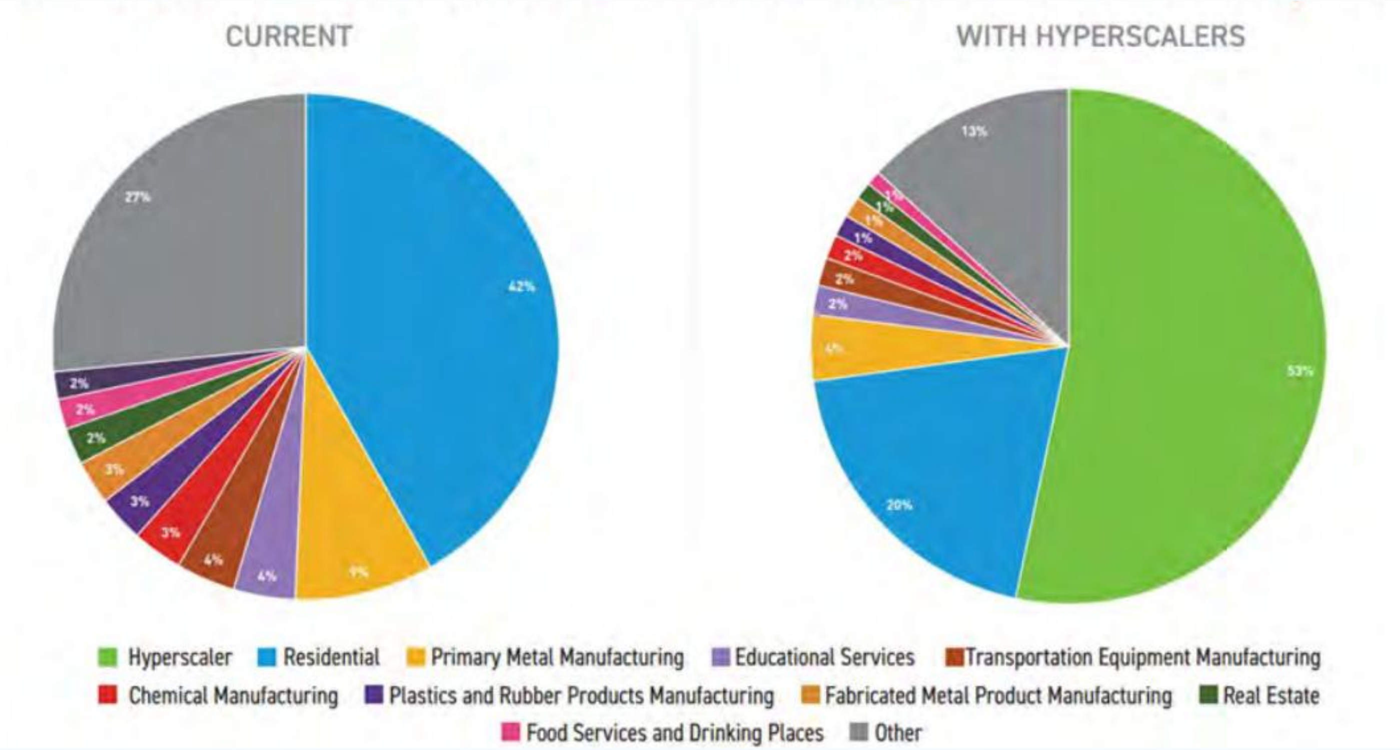
New Large Load Tariffs to Reduce Revenue Risks and Improve Forecasts

New report from Energy Futures Group:
Review of Large Load Tariffs to Identify Safeguards and Protections for Existing Ratepayers

Hyperscale Data Centers Could Represent >50% of Indiana & Michigan Power Revenues



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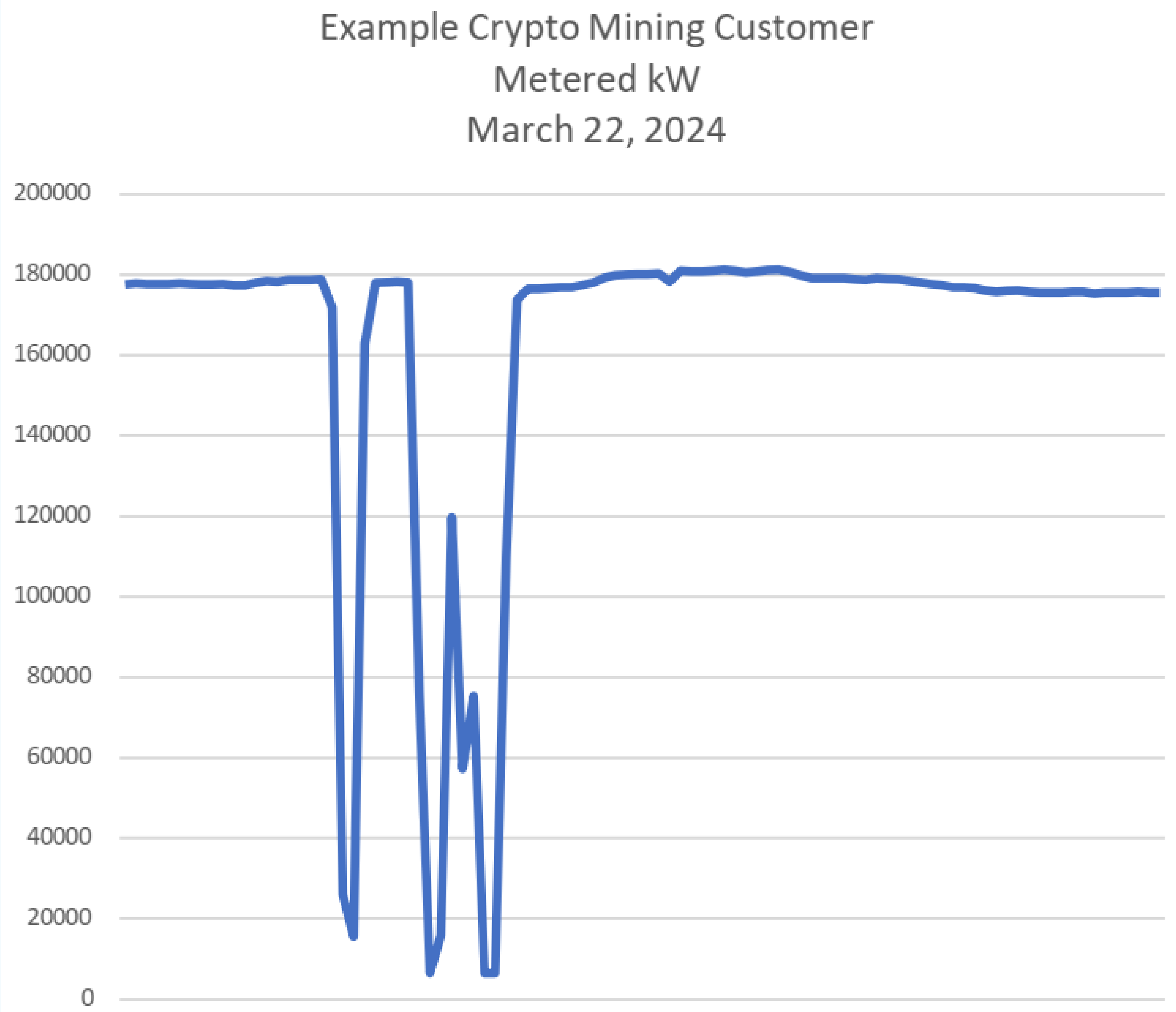
NERC Large Load Reliability Standard

NERC: Large data centers presenting new, unique challenges to grid reliability

- **Price Response** – especially crypto mining
- **“Ride-through”** – backup power systems can remove large loads from the grid
- **Normal operations** – AI “training models” can vary load in just seconds



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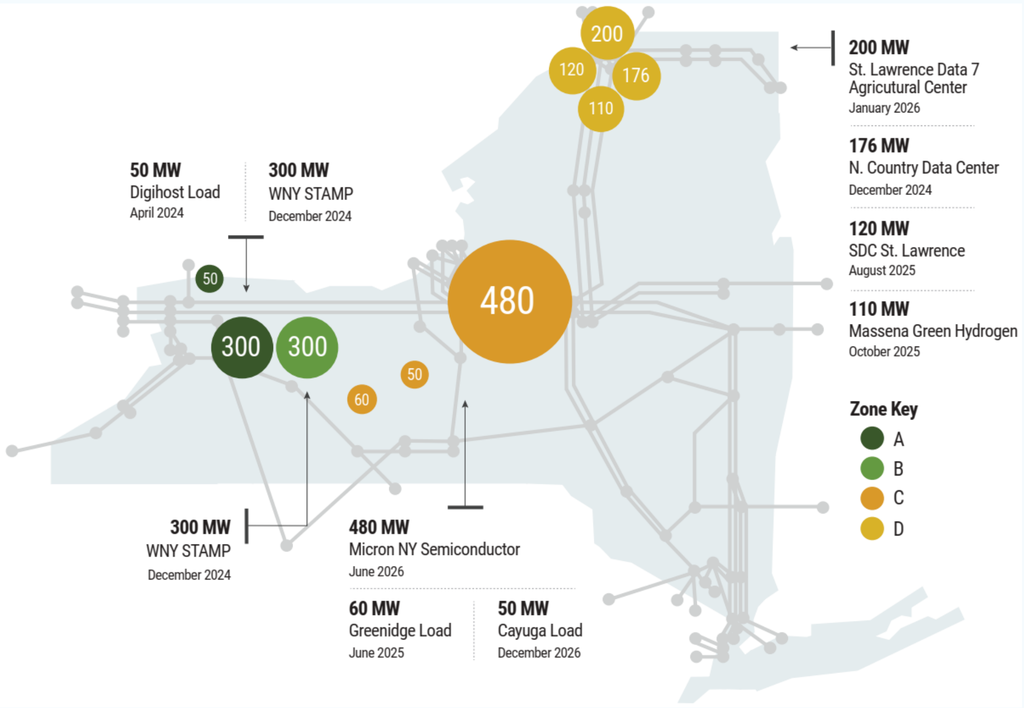
New York (NYISO)

Near-Term Growth Offset by Efficiency

NYISO has received 890 MW of load requests from several data centers and a hydrogen plant with a proposed in-service date prior to 2026.

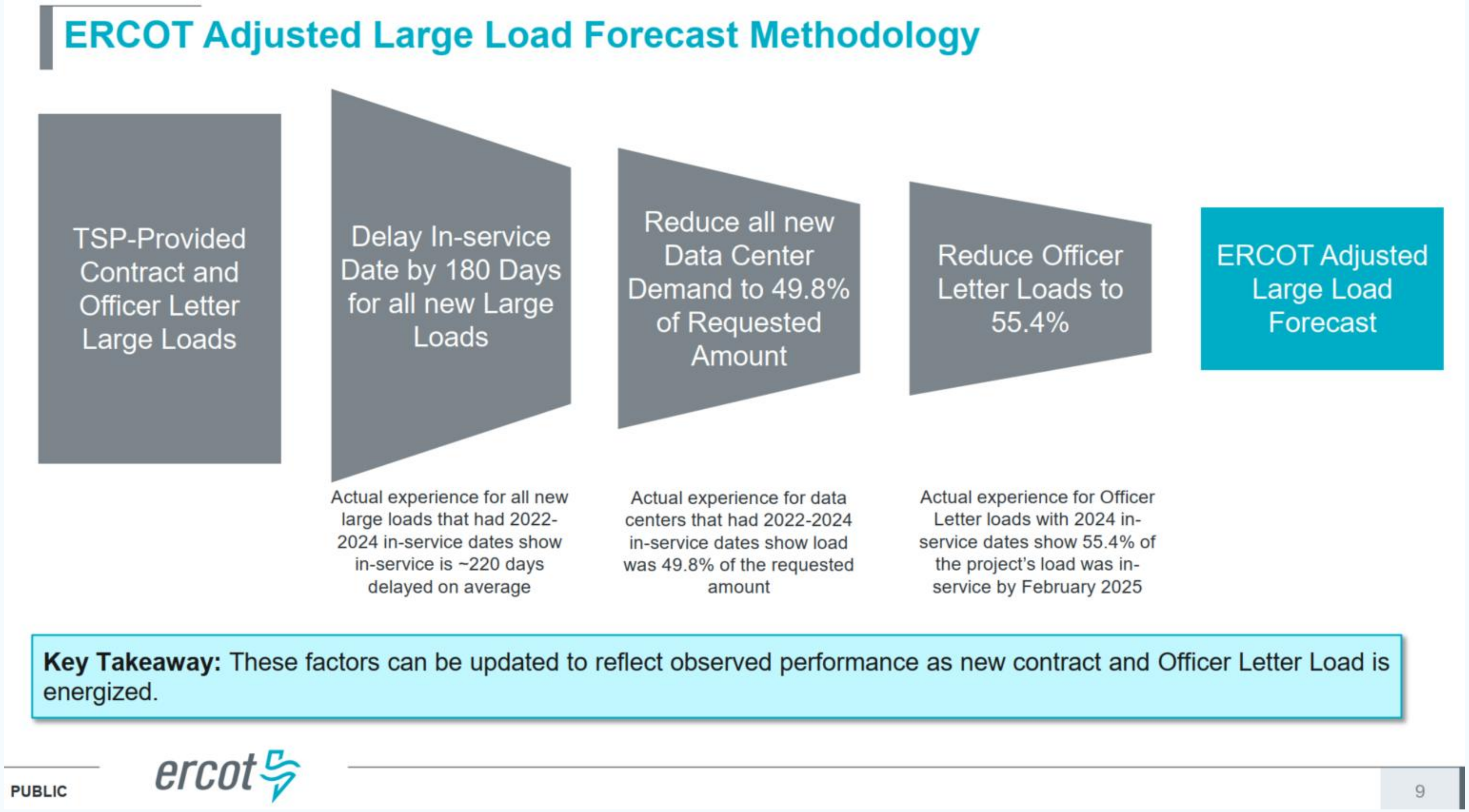
- NYISO 2029 peak load forecast is only 0.8 GW above 2024
- However – 2.8 GW in projected new large loads and electrification
- Energy efficiency impacts are forecast to largely offset projected growth
- By 2035, NYISO expects to shift to winter peaking – building electrification driving shift to winter peak
- So far, no indication of gigawatt-scale data center load growth in NYISO

Large Load Projects Forecast in New York (1.8 GW illustrated)

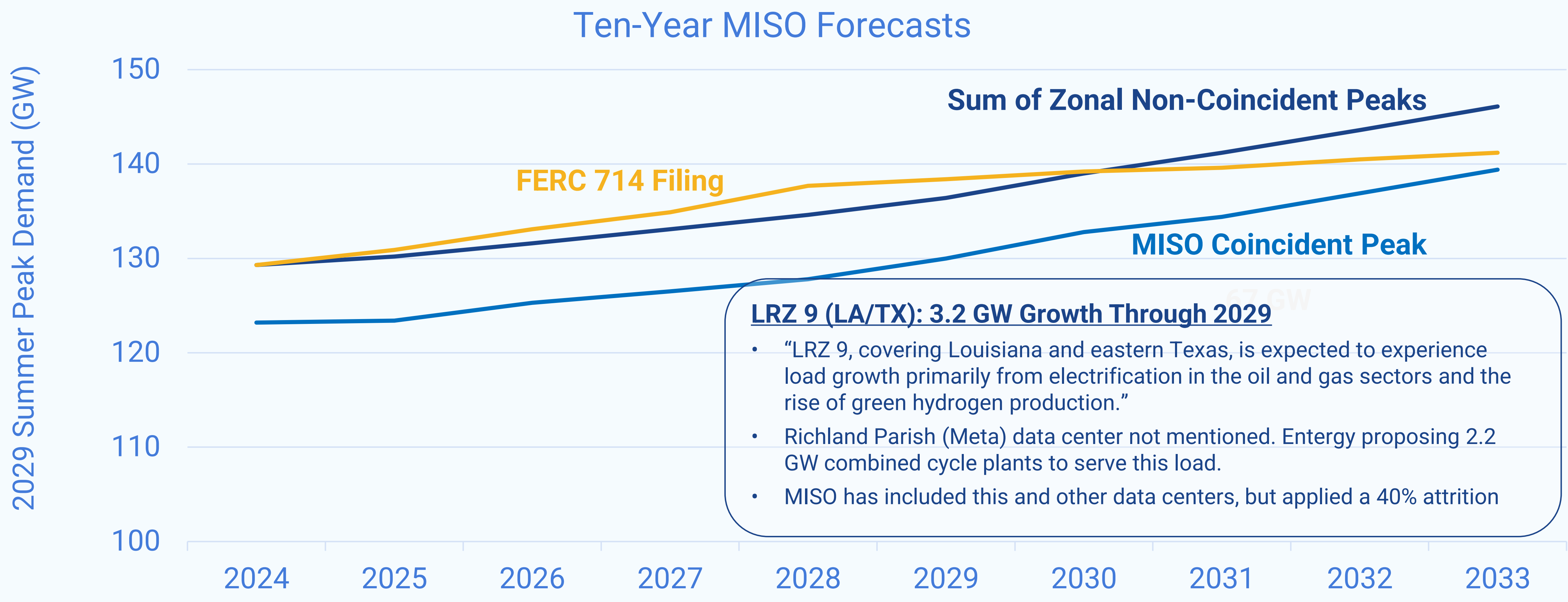


SOURCES | NYISO, 2024 Load & Capacity Data (April 2024).
NYISO, 2024 Power Trends (June 2024).

ERCOT's New Large Load Forecast Method



MISO’s FERC 714 Filing Compared to December 2024 White Paper (Current Trajectory)



LRZ 9 (LA/TX): 3.2 GW Growth Through 2029

- “LRZ 9, covering Louisiana and eastern Texas, is expected to experience load growth primarily from electrification in the oil and gas sectors and the rise of green hydrogen production.”
- Richland Parish (Meta) data center not mentioned. Entergy proposing 2.2 GW combined cycle plants to serve this load.
- MISO has included this and other data centers, but applied a 40% attrition

Energy Systems Integration Group (ESIG): Large Load Task Force

I am leading the Large Load Forecasting team for ESIG's LLTF

- <u>Looking for participants (generally, must join ESIG) and presenters</u>
- Collecting existing large load forecasting practices
- Evaluating methods for considering speculative requests and certainty
- Exploring potential for national aggregation of confidential data
- Studying how to address policy issues, such as impact of demand flexibility
- Develop recommended best practices

Large Load Task Force: Topical Areas / Project Teams

ESIG

- Data collection on characteristics of AI and other data centers and other large loads.
- Load forecasting
- Interconnection process
- Interconnection performance requirements
- Modeling requirements for interconnection
- Wholesale market options for large loads; co-location of generation and load
- Transmission planning with high shares of large loads
- Resource adequacy with high shares of large loads
- Additionally, LBNL will be leading an effort on regulatory and contractual aspects – tariffs, flexible interconnections and curtailment, contracts.

5

Thank you!

John D. Wilson
Vice President
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We offer research and advising on

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- Business & Policy Solutions
- Regulatory Engagement

Founded in 2017, Grid Strategies works on policy to enable decarbonization and an affordable, reliable electricity system.

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Evolving Load Characteristics & Reliability Considerations

Large Loads under the "spotlight"

Power demands are evolving fast, propelled by a wave of new and influential energy consumers.

Simpler (but not 100% accurate) to break into the following categories

Data Centers

Small: 1-5 MW
Medium: 5-100 MW
Large (Hyperscale) – 100+ MW

Size definitions guided by common themes across the data center community.

Commercial & Industrial (C&I)

Hydrogen production, agriculture, Oil & Gas, Semiconductor(& other) manufacturing, electric arc furnaces

Cryptocurrency mining

Vary in size from 1-100+ MW

Crypto Mining: The process of validating and recording transactions on a blockchain by solving complex problems

Crypto Mine: A setup or facility where mining is done (small density), typically <10 MW.

Crypto Farm: Same as Crypto mine, but of a larger scale , > 10 MW

.

Electrification

Transportation and building electrification.

Pathway to decarbonization.

Aggregate impact of consequence

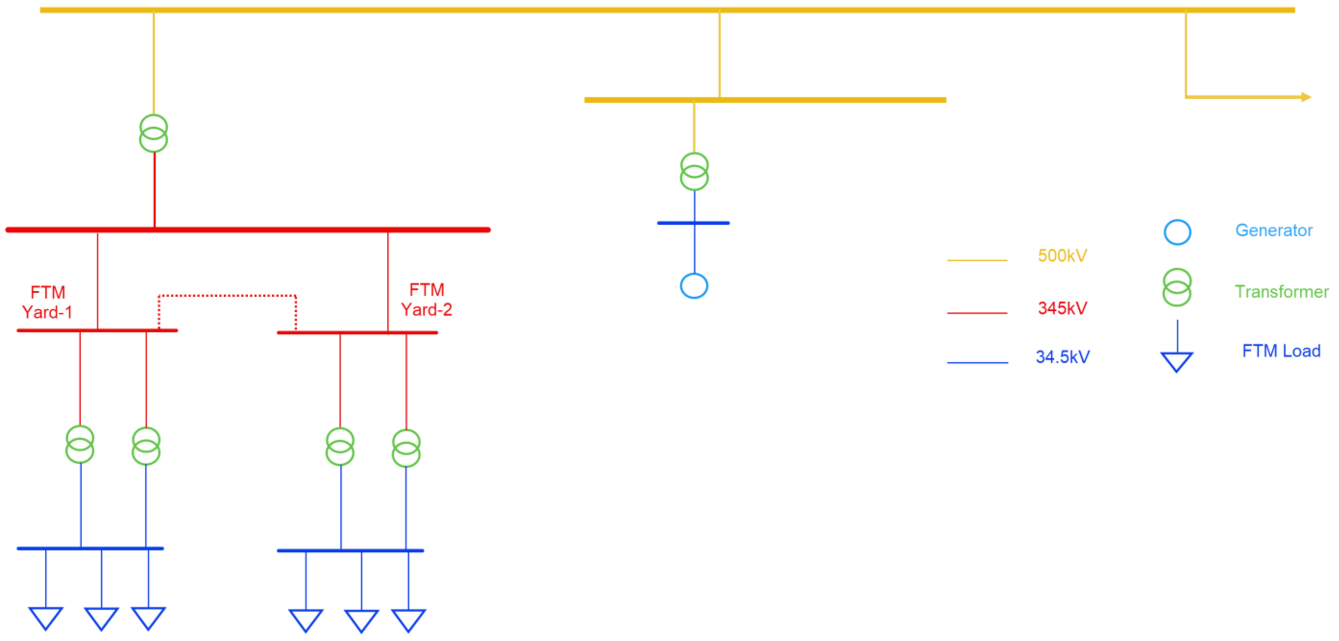
Common themes in the design of large load interconnection requests (1 of Many)

<u>Most common</u>

Grid Interconnected directly to the utility side of the meter

The load is connected directly to the grid and served by the local utility as a network customer

- Subject to standard load interconnection process applicable to the utility.
- Subject to local utility interconnection criteria and broader ISO/BA requirements



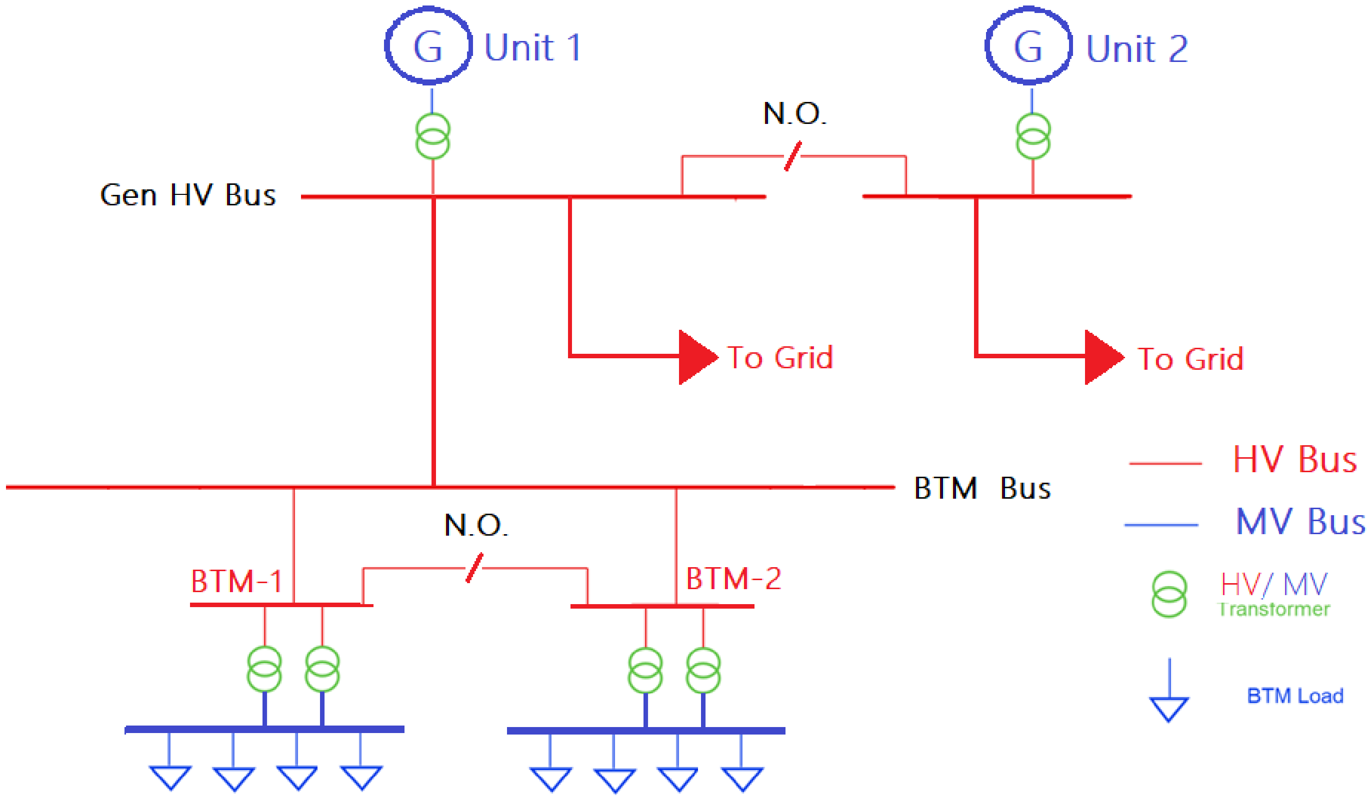
Common themes in the design of large load interconnection requests (2 of Many)

Co-located

Full Behind the meter (BTM) connection

The load is connected Behind the meter to Unit 1 of the plant.

- Designed with BTM backup
  - In the case of Unit 1 outage, the BTM load could be transferred to Unit 2
- Special protection schemes designed to trip the generator/data center out of service if any flows into/out to the grid.



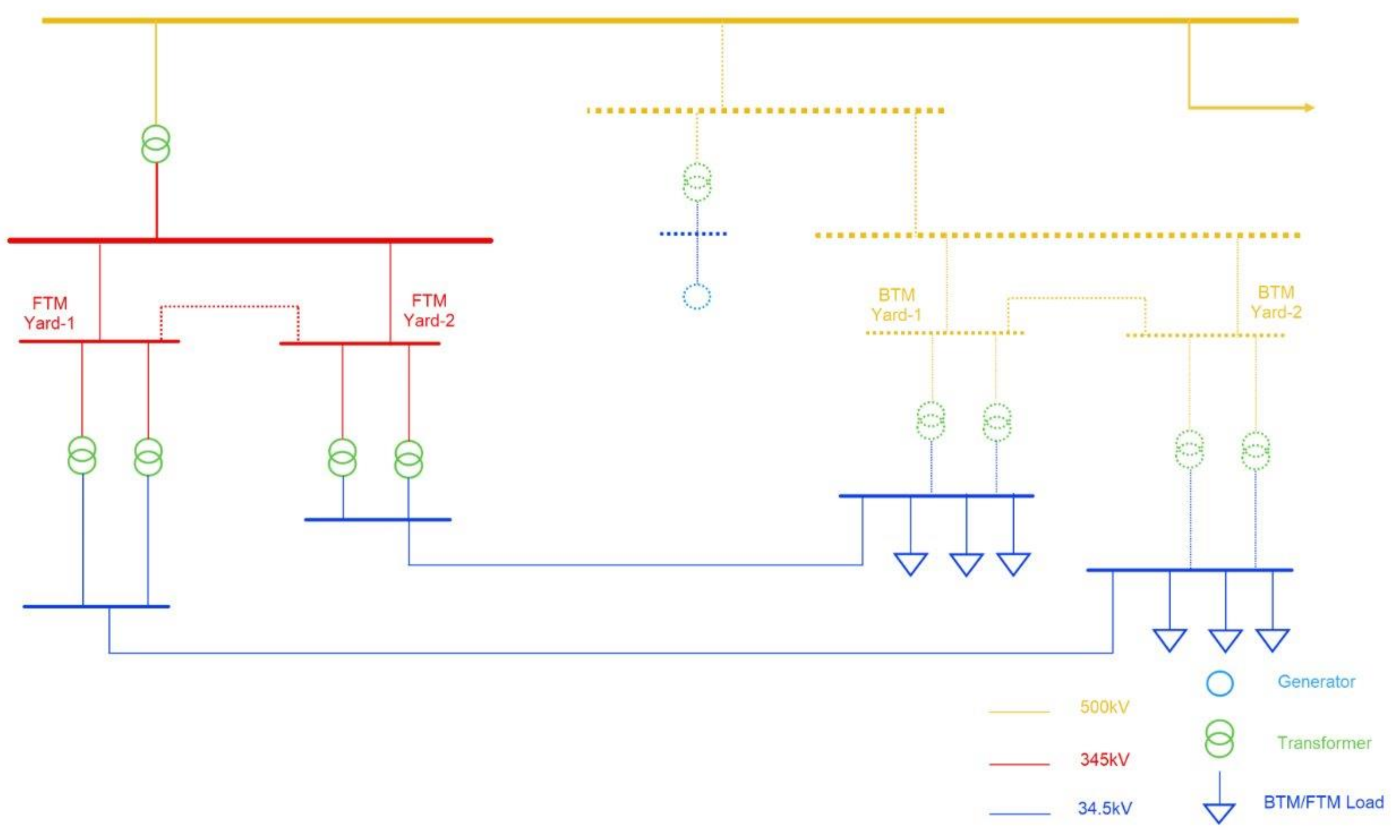
Common themes in the design of large load interconnection requests (3 of Many)

Co-located

BTM with FTM backup

The load is connected as BTM to Unit 1

- Designed with FTM backup
  - In the case of Unit 1 outage, the BTM load is fully transferred to the backup FTM substation.
- Subject to standard load interconnection process applicable to the utility.
- Subject to local utility interconnection criteria and broader ISO/BA requirements



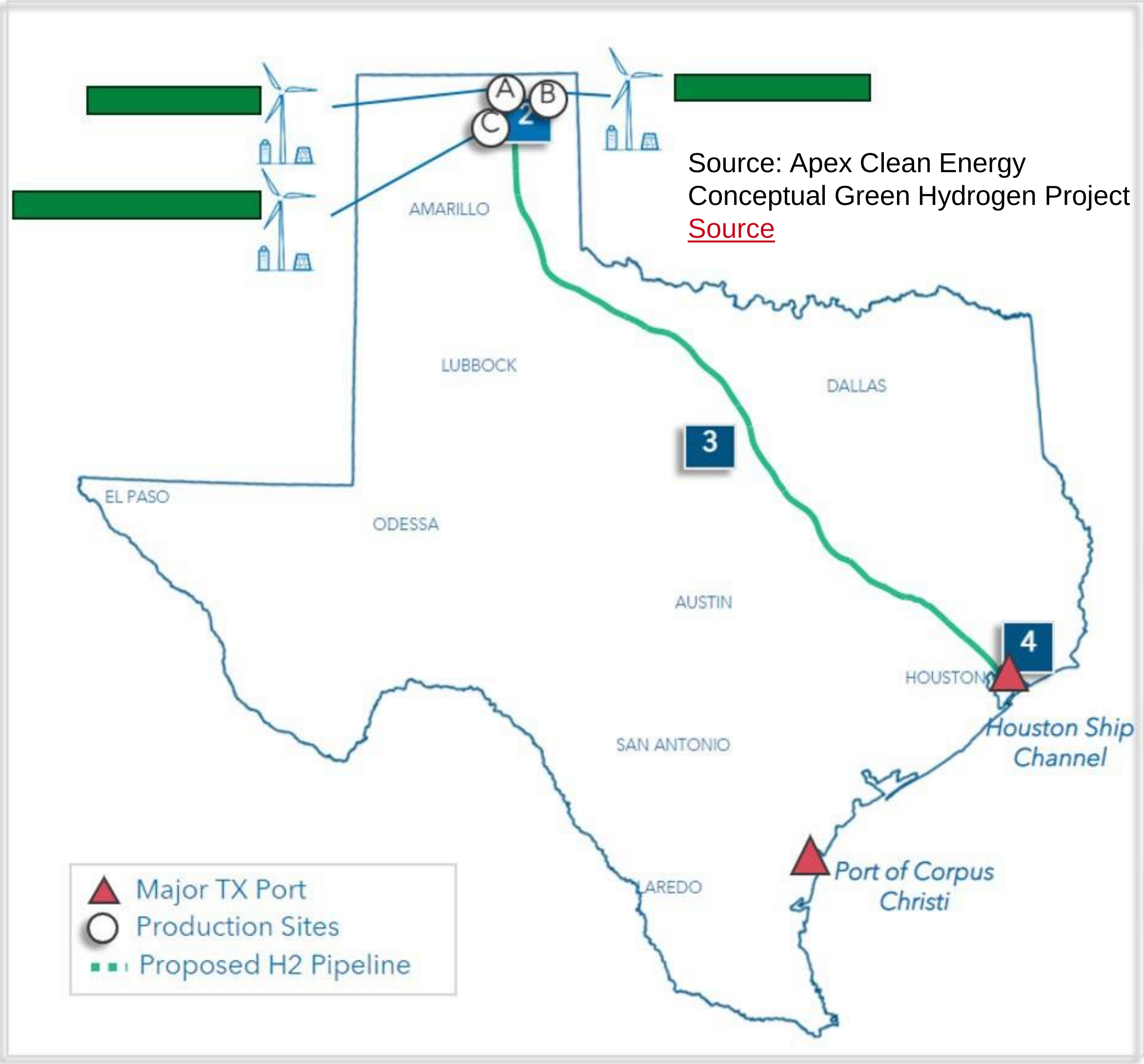
Common themes in the design of large load interconnection requests

What Next? (Conceptual)

Islanded operation

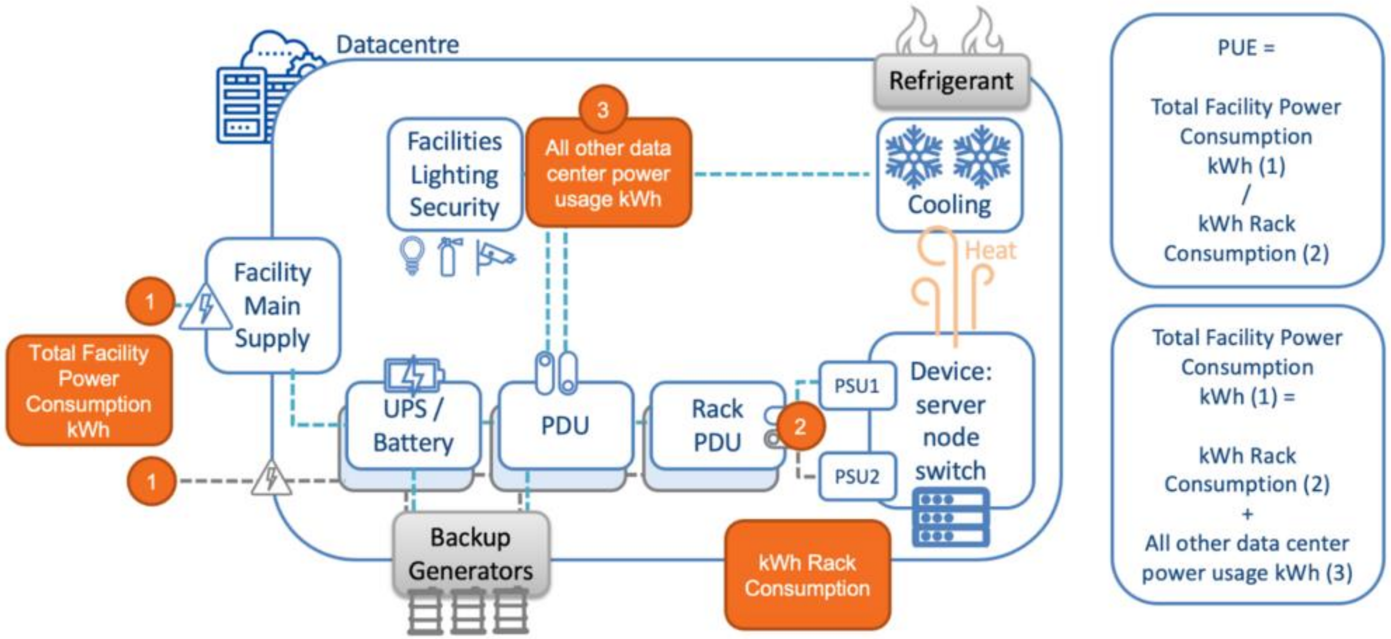
Operate within an islanded configuration

- Several technologies under consideration
  - Grid Forming
  - Small Modular Reactors
- Complemented by synchronous condensers for short circuit ratio
- Reactive power support



Source: Apex Clean Energy Conceptual Green Hydrogen Project
Source

Dive into Data Centers



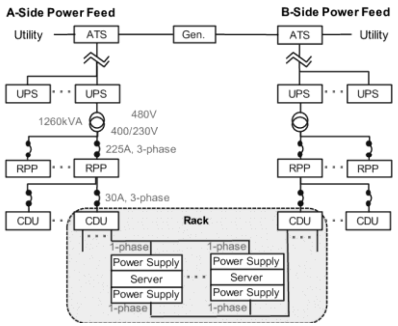
- A data center is a facility that stores critical applications and processes data; it is essential to keep high quality and reliable power supply to electrical loads within the data center to maintain a secure and reliable data storage platform.
- Besides AC grids, conventional diesel generators and uninterruptible power supplies (UPS) supply power during grid outages.

- Considerations in Data Center Power System Design
  - Total electricity cost minimization
  - Bandwidth cost minimization
  - Energy efficiency improvement
  - Workloads allocation
- It is critical to understand the electrical loads in the Data Center

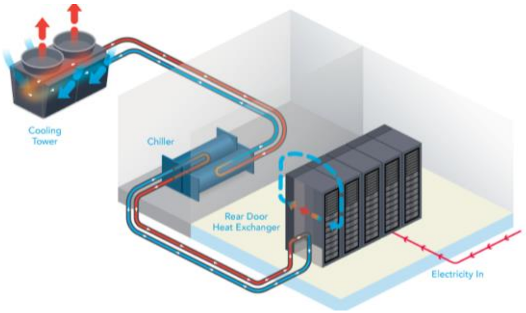
Data Center Power System Breakdown

A data center has three major components:

IT equipment	Power delivery system	Cooling system



Source: https://www.researchgate.net/figure/Example-power-delivery-layout-in-a-data-center_fig1_331258703

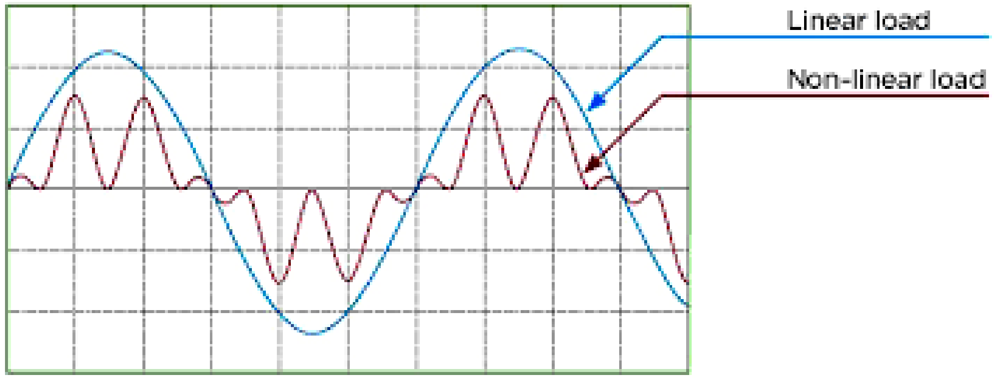


Source: https://www.linkedin.com/pulse/data-center-liquid-cooling-market-trends-growth-drivers-sairam-nagula-nmxic/

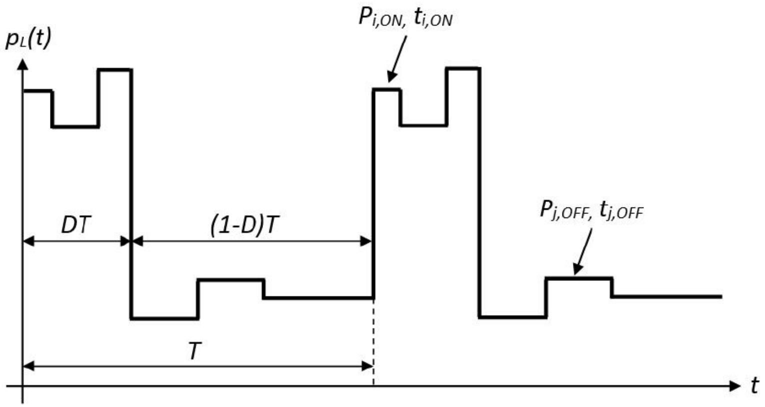
- IT equipment (server, storage device, network equipment) uses half the power entering data center.
- Power from grid is supplied to uninterrupted power supplies (UPS) at data center, converting AC → DC for energy storage, converting back DC → AC and supply IT equipment through power distribution unit (PDU).

Impacts of Data Center Loads

- Data center loads are mostly DC loads
- Data center has many critical loads of nonlinear or pulsed forms
  - Nonlinear loads bring harmonics to the grid, affecting power quality, causes energy losses and interferences to grid-connected apparatus, even resonances in the microgrid
  - Pulsed power loads need high power in short period, affecting grid stability and power quality issues
- The harmonics in AC data centers can be compensated using filters (active, passive, series/parallel resonant filter, etc.) and power conditioners



Non-linear Load



Pulsed Power Load

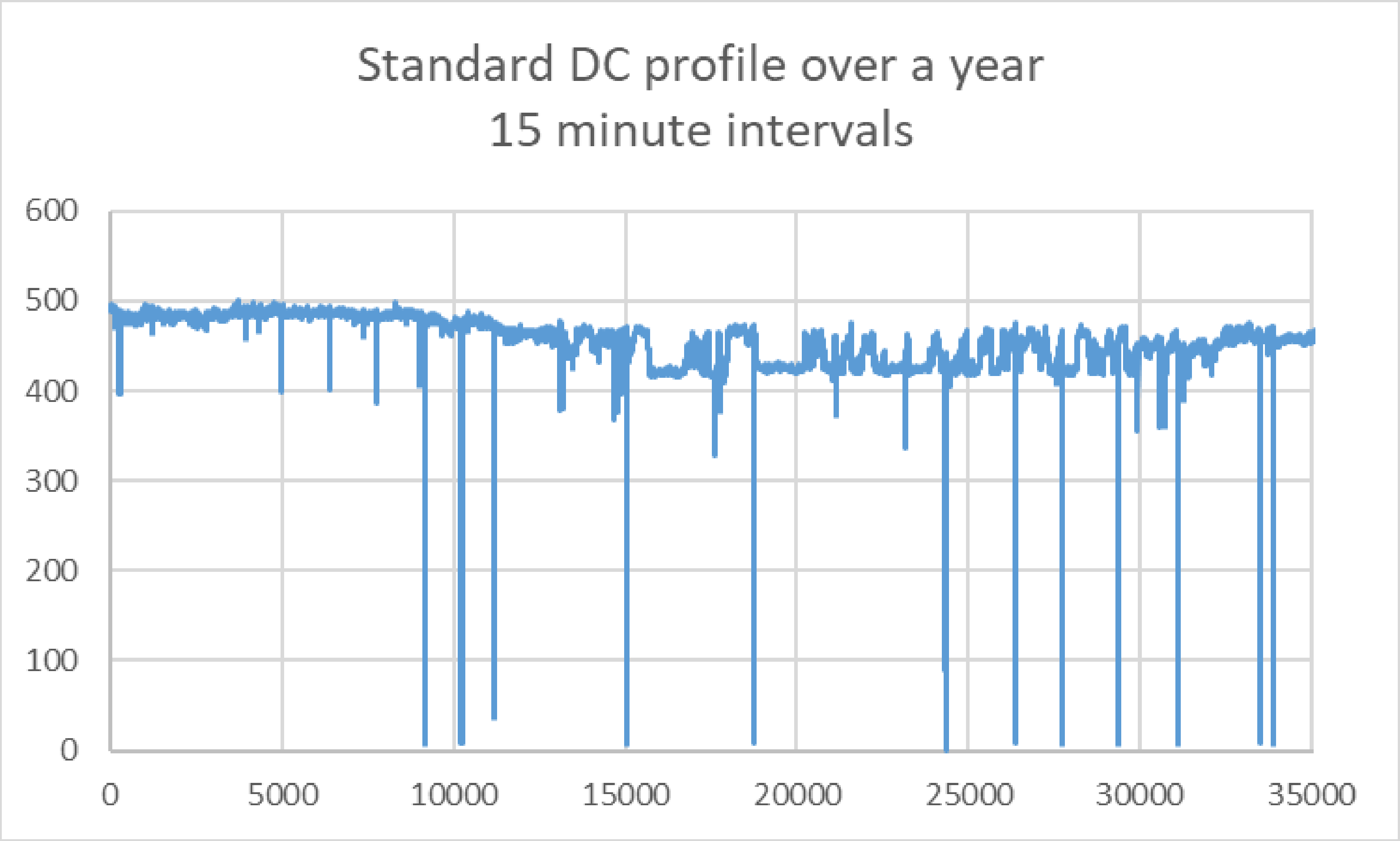
Pulsating Loads in Data Center

- Pulsating loads are a special type of nonlinear loads
  - Large voltage and current signal variations in introduce harmonics and potential instability
  - Instability concerning especially in high-order power electronic systems
  - Pulsed power loads can cause voltage sag or frequency fluctuations in connected power systems, dynamic overvoltage, interruption of other devices
- Pulsative load behavior is a common theme that is expected across different load categories, including crypto mining and hydrogen.

Contributor	Description
High-Performance Computing Tasks	AI, machine learning, batch processing, and data analytics require intensive computations, leading to sharp power spikes.
Dynamic Workload Scaling	Auto-scaling of resources, VM/container management, and resource activation cause rapid increases in power demand.
Server and Hardware Power Management	Power cycling, turbo boosting, and load balancing among servers create fluctuations as demand rises and falls.
Cooling and Environmental Control Systems	Variable cooling needs and environmental control adjustments increase energy usage in response to fluctuating server loads.
High-Density Equipment	Power-intensive GPUs, TPUs, FPGAs, and storage devices consume power in bursts during processing and I/O operations.
Peak Demand Events	Scheduled tasks (e.g., backups) and user-driven surges (e.g., online events) temporarily amplify power usage, creating pulses in load demand.

*Generated using ChatGPT just for kicks.
But I checked important info

Evolution of Data Center profiles (Current)



Averaged over 15-minute interval

Classification of Large Language Model (LLM) Loads

In general, there are three different operation stages for LLM loads:

1 Training

- The model trains on a vast dataset.
- It is the most power-intensive phase with sustained high GPU utilization.
- It may last days, weeks, or even months. As such, uninterrupted power is crucial.

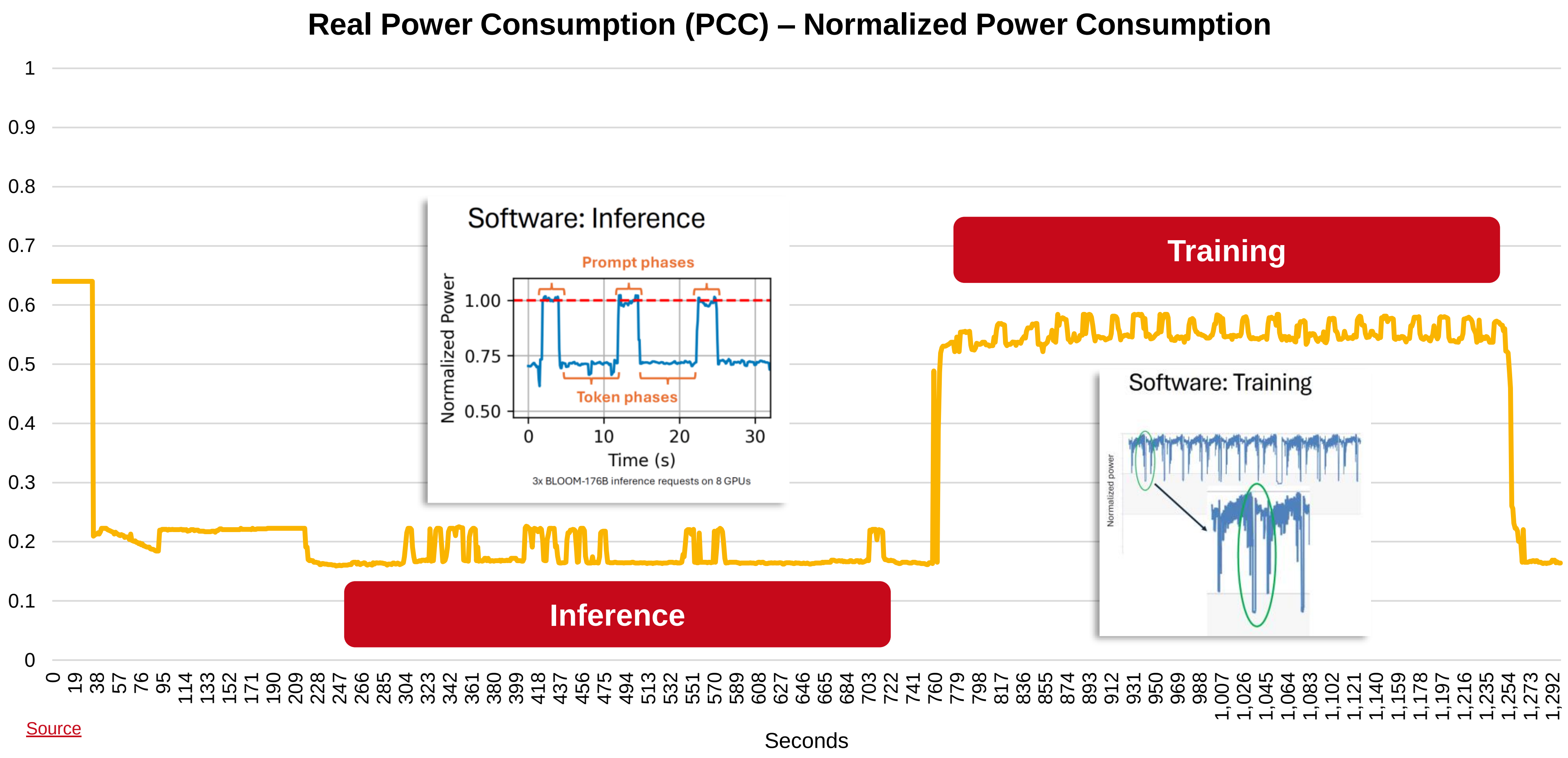
2 Fine-tuning

- It involves adapting a pre-trained model to a specific domain.
- It requires moderate to high power consumption.
- It involves intermittent high GPU utilization, typically for shorter durations than full training.

3 Inference

- It involves the application of trained models to new data.
- It is the least power-intensive phase.
- It requires variable, user-driven power usage.
- The variability leads to short bursts of power consumption

Profile Deep Dive (Training vs. Inference) – Heavily Dependent on the Model's Architecture



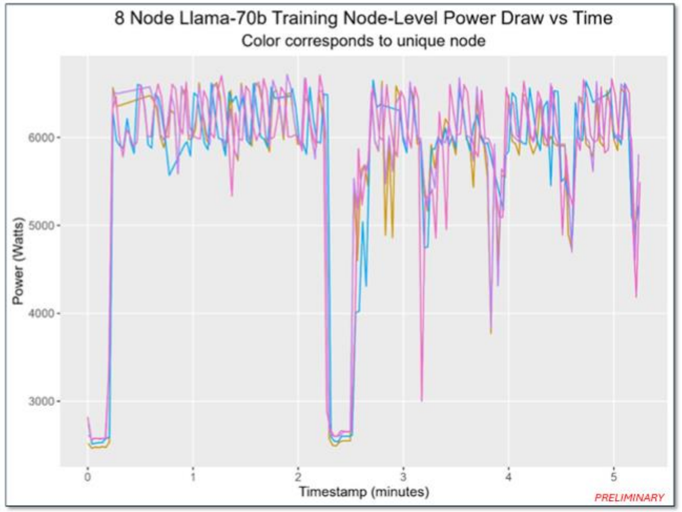
Source

Managing Data center load ramps

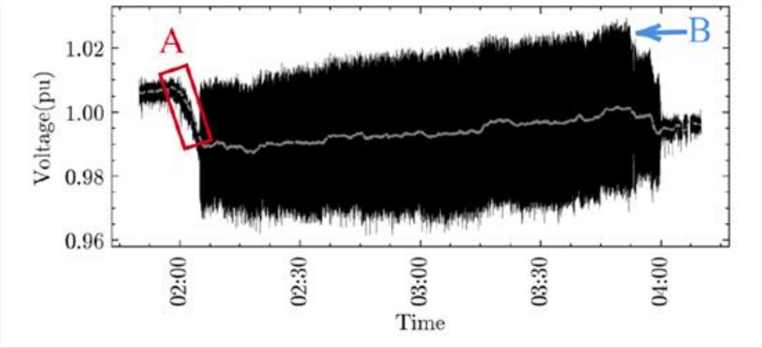
- It is becoming common for utilities to require data center customers to manage and minimize their power quality/grid impacts from large load ramps.
- Some common options under investigation
  - Hardware efficiencies
  - E-STATCOM
  - Generation technologies (including energy storage systems, and other hybrid technologies with gas)
  - Advanced controls and automation within the data center for managing load balancing, generation ramping, and others.

Southern Company Interconnection Requirements Effective January 14, 2025

- ✓ Large loads, >40 kV interconnection voltage, >50 MW (long-term projected demand).
- ✓ Ramp rate limit of 20 MW/minute.
- ✓ Mitigation of forced oscillations with the system by minimizing signal injections at the PCC from 0.01 Hz – 55 Hz.
- ✓ Load information including proposed equipment, control configuration, control parameters, and protection settings.
- ✓ Load models of appropriate detail of above for utility studies (likely EMT models).
- ✓ Simulations of as-planned, as-built, and as-left to demonstrate compliance.
- ✓ Energization, commissioning, and post-commissioning test procedures for large loads.



Power consumption profile



Power system oscillations on the Dominion Energy network, attributed to data center UPS equipment.

Other trends

- Data center loads are trending towards being more capacitive in nature than inductive, resulting in a closer to unity power factor at the interconnection level.
- Several contributing factors:
  - The new generation of power supply units (PSUs) guided by Open Rack specs and design (Open Rack/SpecsAndDesigns – OpenCompute)
  - The newer liquid-cooled sites contribute to the issue.

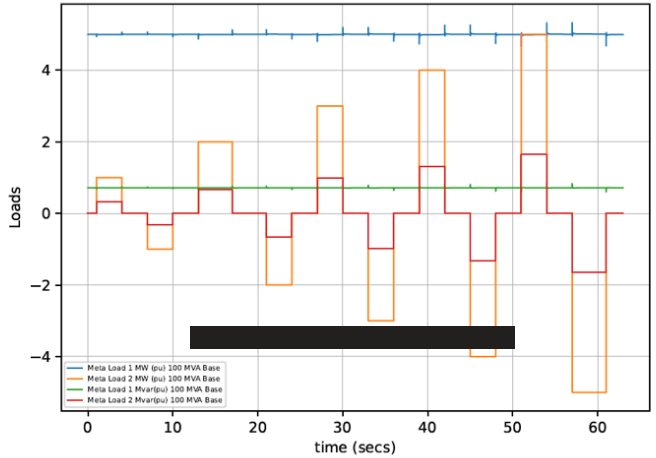
Key Studies and Reliability Considerations
Areas of Collaboration

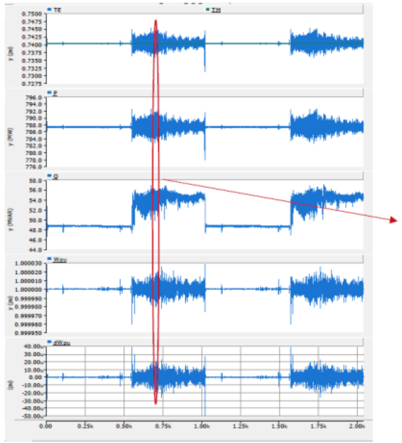
Moving beyond the steady-state studies that are commonly performed:

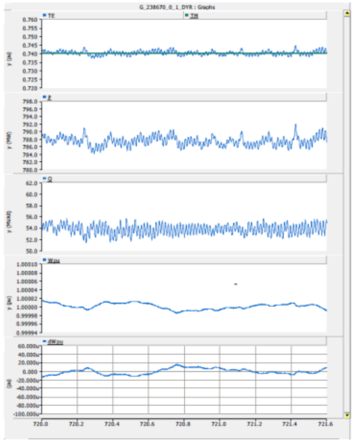
- Transient stability
- Power quality studies
- Ramping evaluations
- Small signal stability
- Ride-through studies
- Sub-synchronous analysis (resonance).

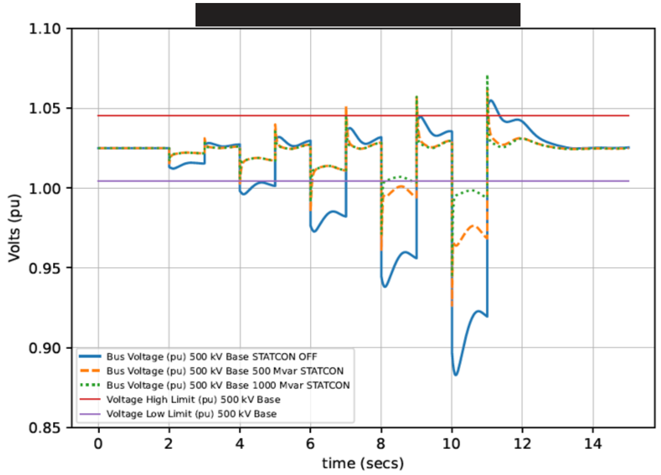
What if we have a configuration that involves BTM generation coupled with FTM? Are the above studies sufficient?

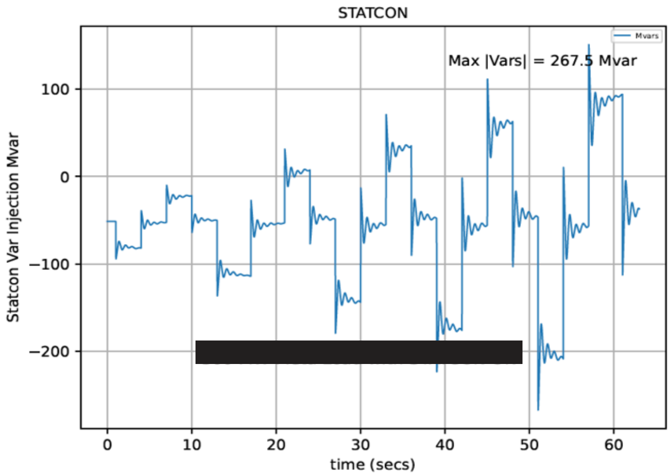
Model quality tests for data center composite load models?











Questions and Discussion

Utility Requirements vs. Data Center Requirements

Point of interconnection

Utility's requirements

- **Facility interconnection requirements** (FAC standards) targeted towards end use customers – e.g., Customer data forms
- **Power quality** (harmonics, voltage fluctuations, flicker)
- **Transient stability** (voltage recovery, frequency)
- **Small signal stability** (forced oscillations at low frequencies)
- **Resonance stability** (Excitation torsional modes of nearby units, etc.)
- **Others** – Ramping rate, ride through, essential reliability services.

Quanta Technology's experience

- **Interconnection strategy, screening/fatal flaw studies**
- **Technology selection** (behind or front of POI)
- **Developing/testing/validating interconnection requirements**
- **System studies and impact assessments** (reliability, steady state, dynamics, transient, small signal, etc.)
- **Facility, equipment and design**
- **Testing, integration, and validation**
- **Interconnection queue and project management**
- **Data center tariff design and review**
- **Co-location design, technical studies and strategy**

Data center's requirements

- **Reliability (enhance uptime)** – achieve 99.999% reliability, availability, maintainability (RAM)
  - Now consider upstream grid events
- **Power quality** (voltage fluctuations/Flickers, harmonics not affect their equipment) – ITIC curve
- **FLISR** (fault location and isolation)
- **Supply chain** (high-quality backup) – multiple vendors
- **Others** (efficiency of DC system, microgrid controllers)
- **Co-location and Backup supply**

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Data Centers:

Powering the Internet and our Modern Economy

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Data Center Coalition:

- **The Voice** of the data center sector
- **Advocates** for a business climate, policies, and investments that support the growth and competitiveness of the industry
- **Information Resource** for elected officials, candidates, community leaders, and other stakeholders

DCC members are leading data center owners and operators, as well as companies that lease large amounts of data center capacity.

Aligned Adaptive Data Centers | aws | CloudHQ Where data lives. | cologix | COMPASS datacenters | CoreWeave | CORSCALE DATA CENTERS

CORESITE An American Tower Company | Crusoe | CyrusOne | DATABANK | DIGITAL REALTY | edgeconnex | EdgeCore Digital Infrastructure

EQUINIX | FLEXENTIAL | Google | IRON MOUNTAIN DATA CENTERS | Meta | Microsoft | NTT

OPPIDAN CONNECT | ORACLE | POWERHOUSE DATA CENTERS | PRIME DATA CENTERS | PROLOGIS | QTS Powered by People | rowan digital infrastructure

SABEY Data Centers | SKYBOX DATACENTERS | STACK INFRASTRUCTURE | STREAM DATA CENTERS | switch | T5 | TA REALTY

VANTAGE DATA CENTERS | VISA | yondr

What Data Centers Are, What They Enable

2 Main Types of Data Centers

Self-Perform/Enterprise

Business owns/controls servers and peripherals, may own facility

Multitenant and Build to Suit

Facility owner leases to one or multiple tenants

Data Center Basics

- Building Shell
- Interior Space
- Security
  - Exterior
  - Interior
  - Cyber
- Servers
- Fiber/Networking Connectivity
- Reliable Power 24/7
- HVAC/Cooling

Why Data Centers?

- Tremendous Capital Investment
- High Wage Jobs, Low Demand on Services
- Substantial Construction Jobs and Activity
- Building and Strengthening Tech Ecosystem
- Catalyst for Renewable Energy
- Driving Tax Revenue in our Communities

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U.S. Data Center Industry

Jobs

- **603,900 direct jobs** in 2023—51% increase from 2017
- **4.7 million in total employment** in 2023—60% increase from 2017
- **$404 billion in total labor income** in 2023—93% increase from 2017

GDP

- **$3.5 trillion in GDP impact** between 2017-2023

Taxes – Federal, State, and Local

- **$162.7 billion in total impact** in 2023 - 146% increase from 2017

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Source: PwC, "Economic Contributions of Data Centers in the United States, 2017-2023," February 2025

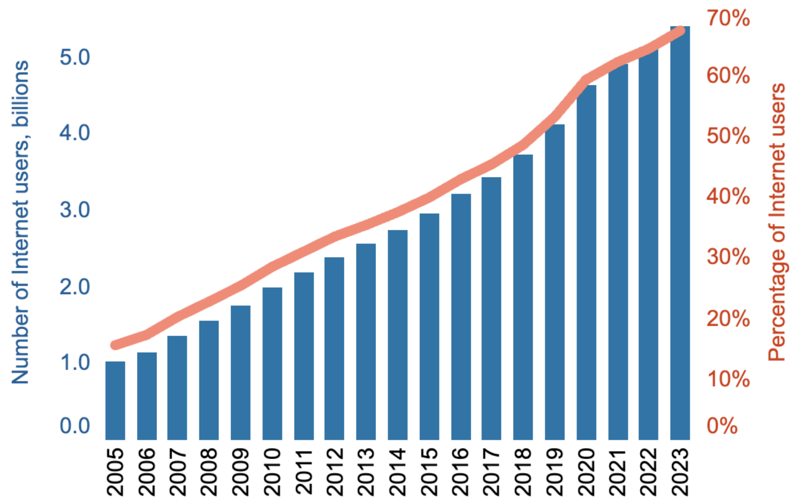
Number of People/Devices Drives Data Center Demand

"The data center industry has experienced explosive growth over the past decade, driven by ever-increasing demand for cloud services and the expanding use of web-enabled devices globally. […] **In the next five years, consumers and businesses will generate twice as much data as all the data created over the past 10 years.**"

-JLL, *Data Centers 2024 Global Outlook*

<u>More People Are Getting Online</u>

- Approximately 5.4 billion people - or 67% of the global population - are online today. This represents an **increase of 45% since 2018**. 2.6 billion people are not yet connected to the internet.
- On average, U.S. households have a total of **22 connected devices**.



Source: ITU

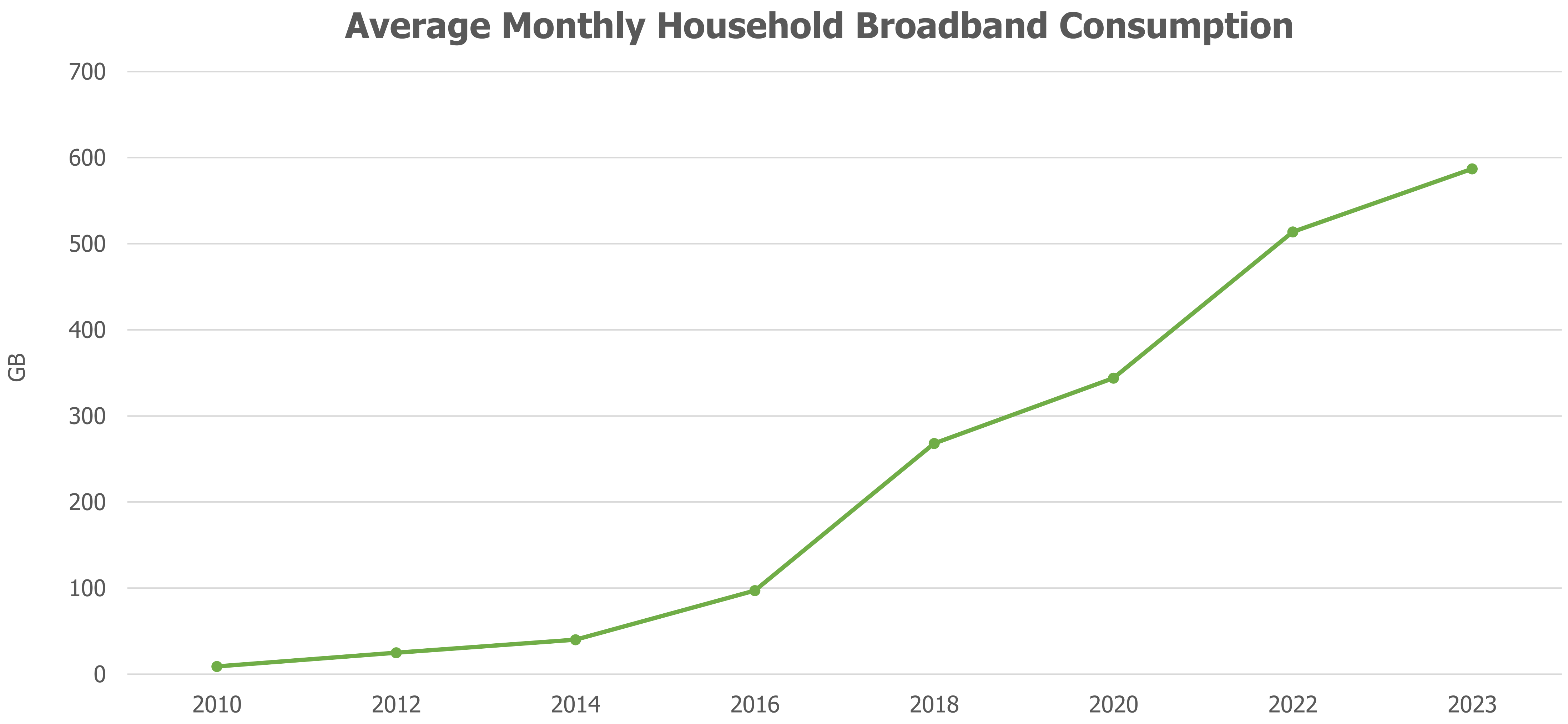
Sources: JLL, Data Centers 2024 Global Outlook, https://www.us.jll.com/content/dam/jll-com/documents/pdf/research/global/jll-data-center-outlook-global-2024.pdf
International Telecommunication Union, https://www.itu.int/en/ITU-D/Statistics/Pages/stat/default.aspx
Deloitte "Shiny new devices may be bringing joy, but who's protecting consumer data?", January 23, 2023 https://www2.deloitte.com/us/en/insights/industry/technology/consumer-data-privacy.html

Driving and Maximizing Energy Efficiency

Maximizing the efficient use of energy in data centers is critical to:

- Competitiveness in the marketplace,
- Individual corporate and collective sustainability goals
- Bottom lines

What Drives Data Center Demand?



Source: OpenVault Broadband Insights Report, OVBI Q4 2022 Report, https://openvault.com/resources/ovbi/

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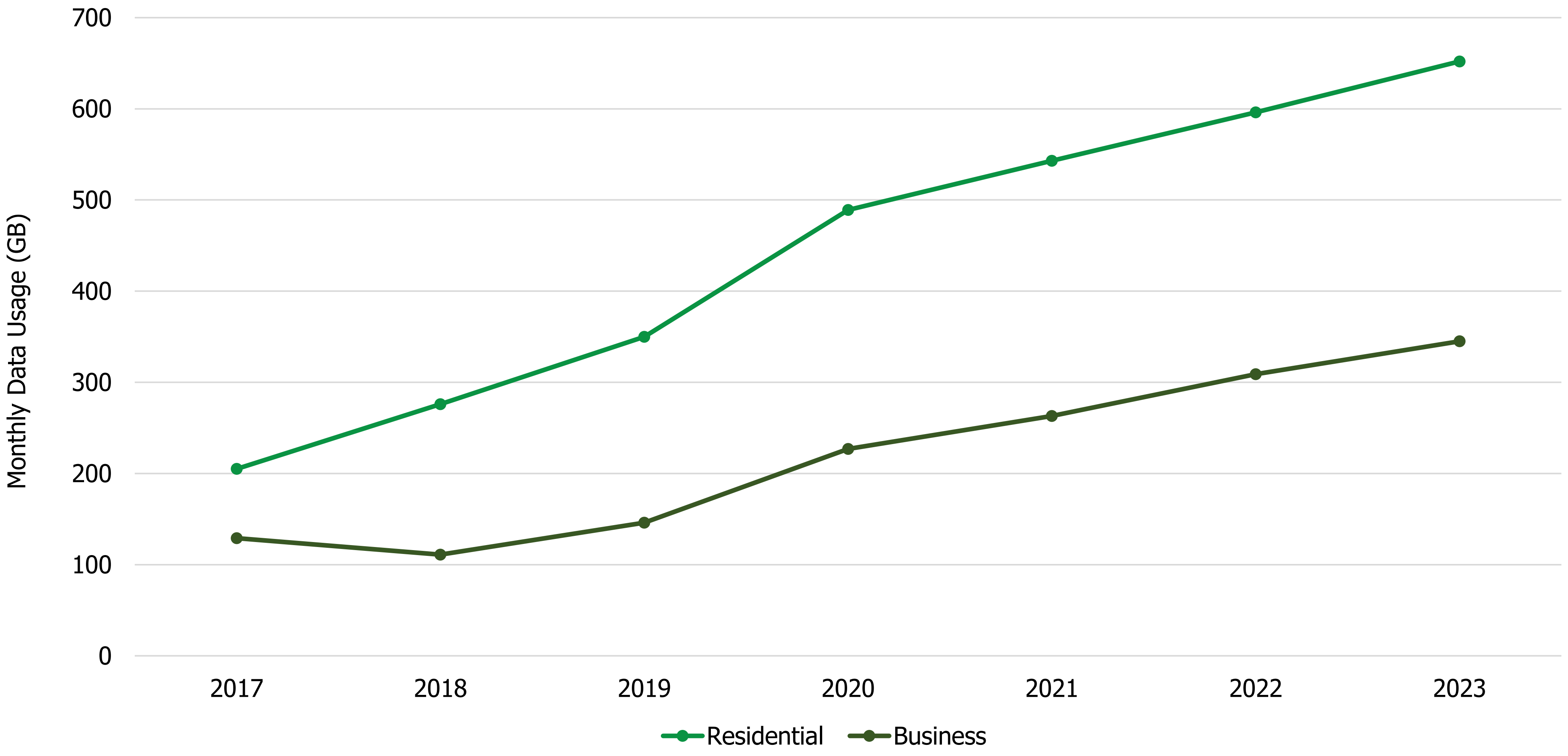
Data Usage Trends: Commercial vs. Residential – 4Q23



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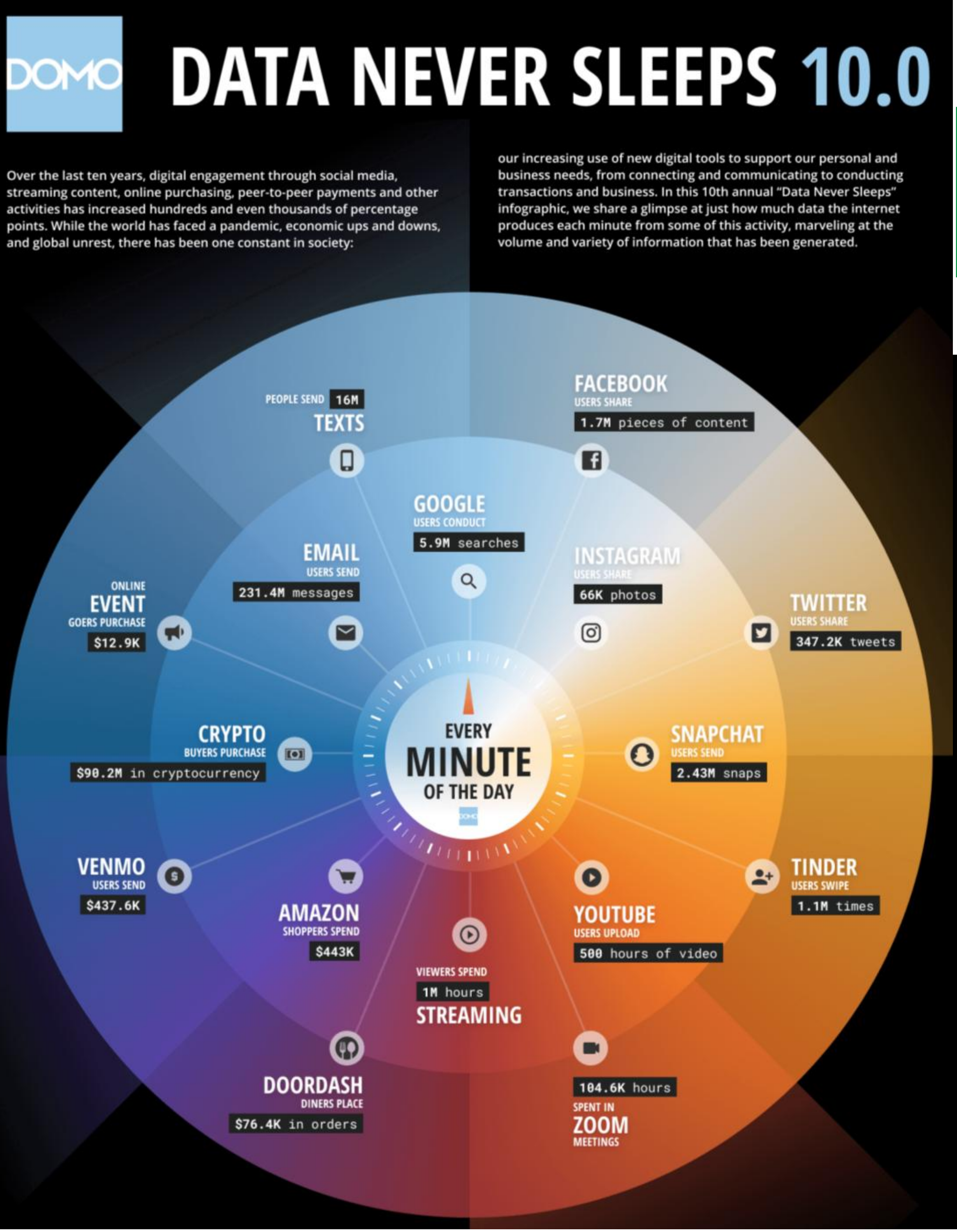
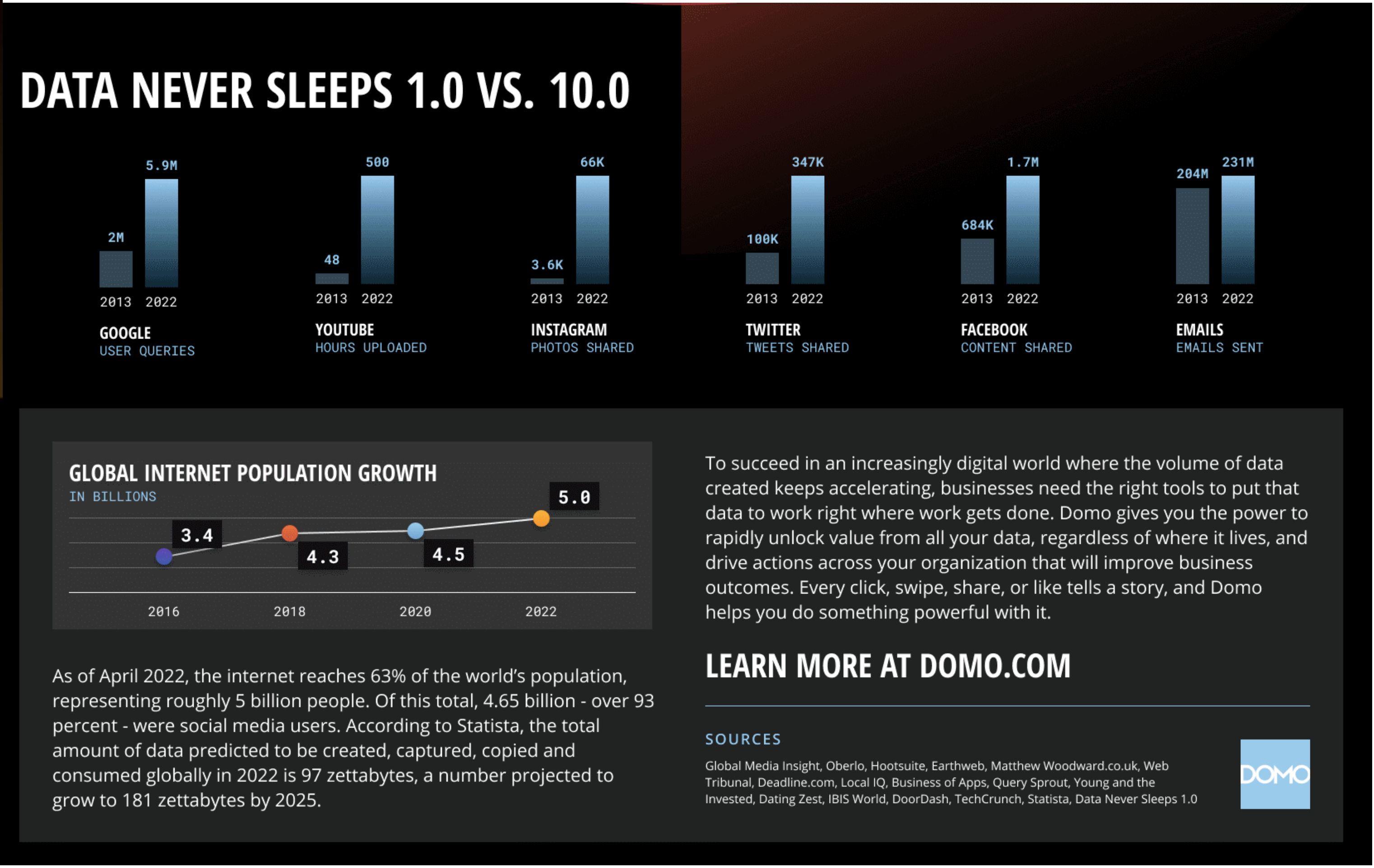
Source: *OpenVault Broadband Insights Report, OVBI Q4 2023 Report, https://openvault.com/resources/ovbi/*

Data and Data Centers NEVER Sleep





Source: Domo, https://web-assets.domo.com/miyagi/images/product/product-feature-22-data-never-sleeps-10.png

New Products/Experiences/Applications Drive Demand

- Cloud
- Business Apps
- Generative AI
- Entertainment and Gaming
- Internet of Things/Connected Devices
- Streaming Video

- Virtual and Augmented Reality
- eCommerce
- Machine Learning
- Payment Processing
- Online Learning
- Connected Vehicles and Autonomous Driving
- Innovation!

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Key Competitiveness Factors for Siting

- Access to Fiber/Connectivity
- Access to Renewable Energy
- Climate and Risk of Natural Disaster
- Construction Workforce
- Energy Rates and Infrastructure
- Land Availability and Cost
- Regulatory Climate
- Ownership/Occupancy Costs
- Time to Market
- Workforce Availability

Relative Size of Largest U.S. Data Center Markets

(MW of Power Capacity-2021)

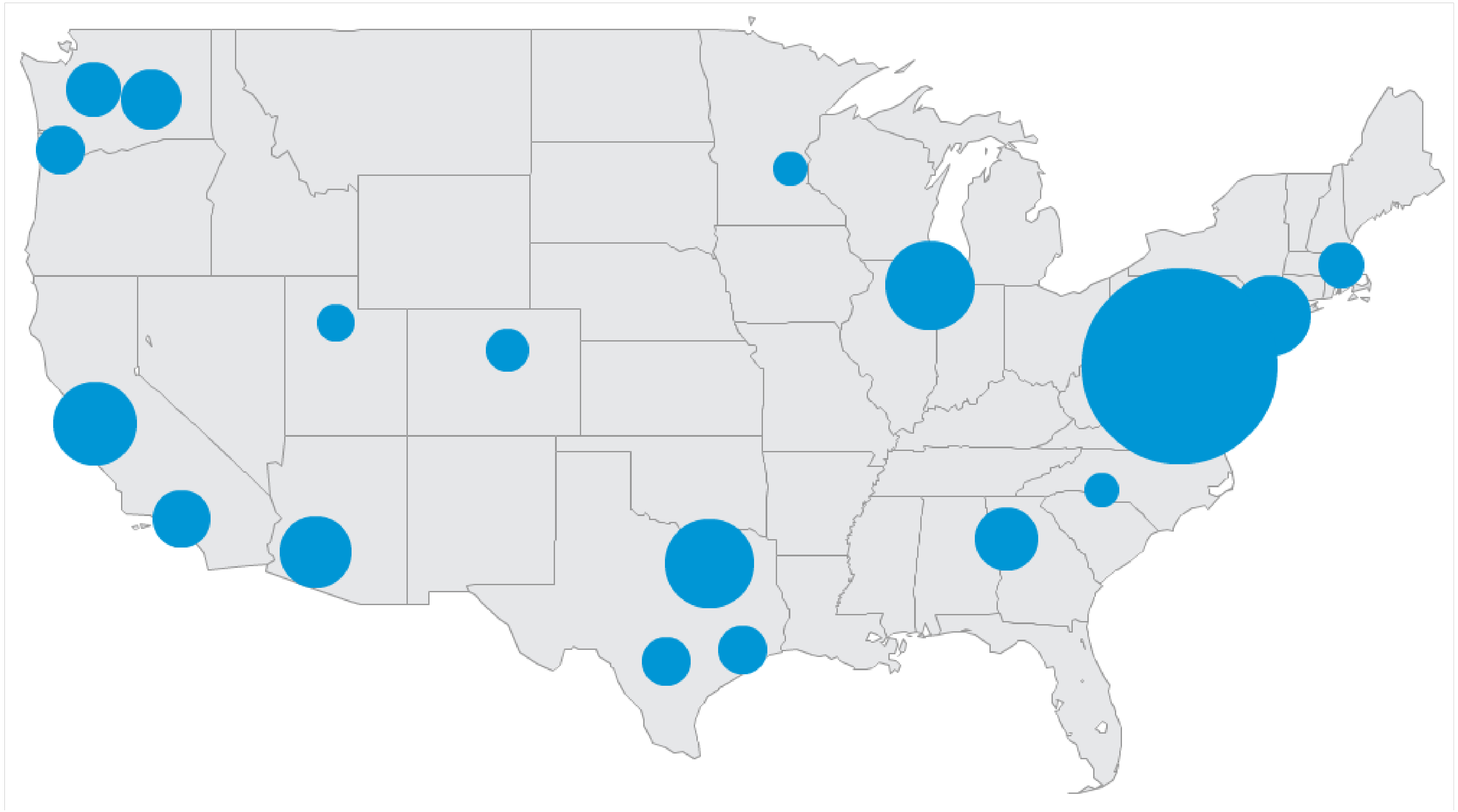

Figure 1 shows the 18 largest data center markets in the United States, as identified by CBRE and JLL. The area of each circle indicates the relative amount of power capacity in each market

In Closing

- Data Centers are proud contributors to our modern economy & way of life
- Energy efficiency is a bottom line
- The industry is no monolith—diverse models and use cases
- Ensuring reliability is hugely important to the industry; advocate for rightsized solutions

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Thank You

ERCOT Large Load Loss/Reduction Events 2020-2024

Patrick Gravois
Operations Engineer – Event Analysis

NPCC Reliability Forum
May 15, 2025

Large Load Growth in ERCOT and Operational Risks

- Since 2022, many large electronic-based loads (cryptocurrency and traditional data centers) have connected to the ERCOT Interconnection
- Additional loads have been approved in Planning studies and will connect over the next few years

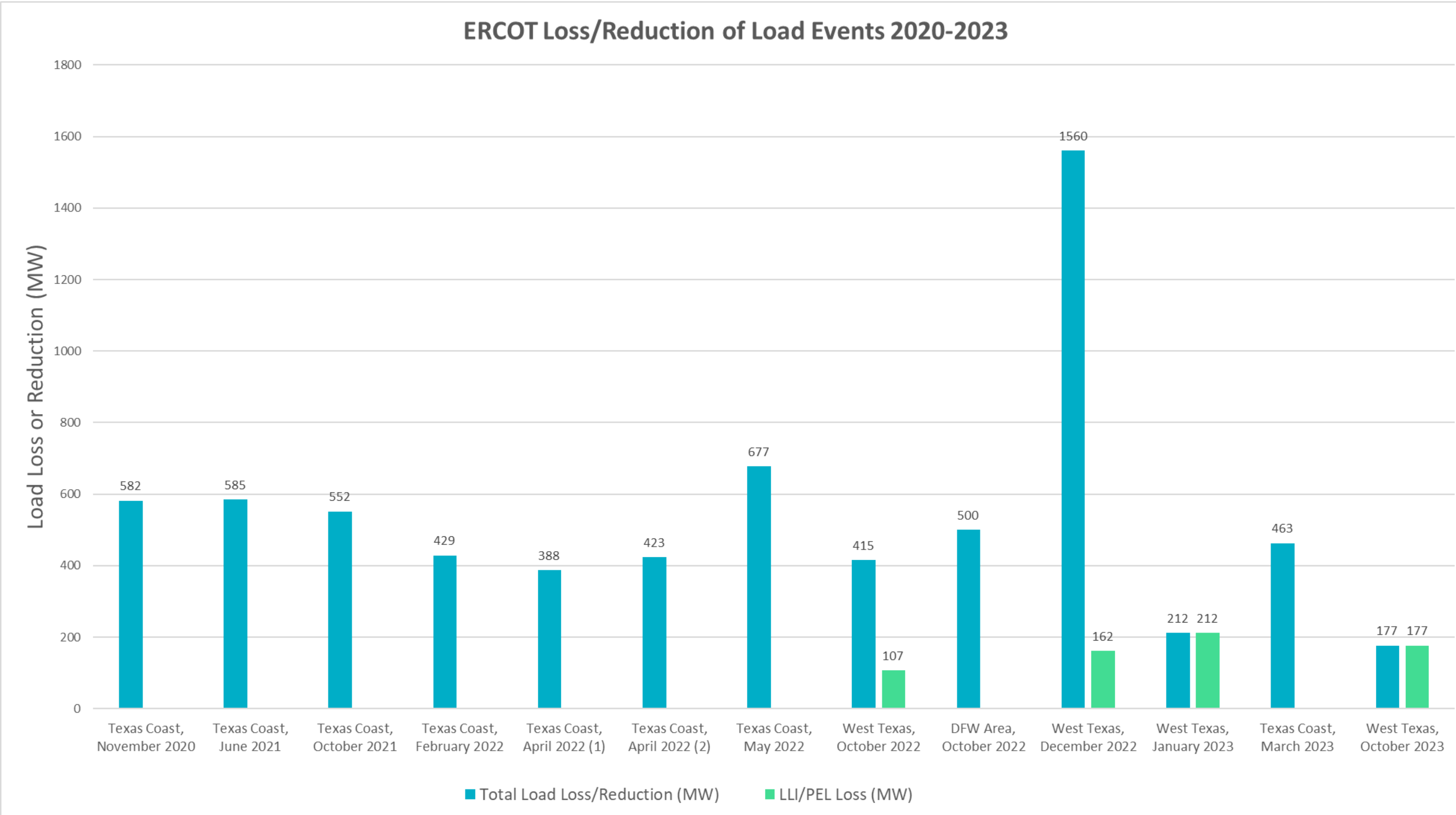
Facility Type	Peak Observed (MW)	Approved to Energize (MW)	Additional Approved (MW)	Total Approved (MW)
Crypto currency	3,126	4,327	4,189	8,516
Data Center	1,130	1,970	9,032	11,002
Combined Large Electronic Load	4,256	6,297	13,221	19,518

- ERCOT has observed these loads exhibit voltage-sensitive behavior and immediately reduce consumption during normal voltage disturbances
- Since generation and load must be balanced to maintain system frequency, sudden large loss of load events could adversely affect grid reliability
- Increase of large electronic-based loads could result in larger events leading to system instability

ERCOT Loss/Reduction of Load Events 2020-2023

- 13 events identified by ERCOT Operations that involved system fault followed by significant reduction of one or more large loads
- Recently reviewed events to distinguish reduction of large loads that have gone through interim Large Load Interconnection (LLI) process since 1/1/2022
  - LLI loads are greater than 25 MW and may include crypto, AI, data center, hydrogen fuel cell loads, or industrial loads and are aggregated into single PI tag for monitoring purposes
  - All LLI loads involved in events are power electronic loads (PEL), and specifically crypto (to our knowledge)
- 8 events involve a single large industrial load on the Texas coast (non-LLI)
- 3 events involve either multiple 3-phase faults or significantly delayed fault clearing
  - Events involve wide-spread reduction of consumption of many load types and sizes
- 2 events involve simultaneous loss of both IBR generation and PELs

ERCOT Loss/Reduction of Load Events 2020-2023



- LLI/PEL Load Loss included in Total Load Loss

ERCOT Loss/Reduction of Load Events 2020-2023

West Texas Event – Dec. 7, 2022 @ 03:50 CT – 1560 MW load reduction

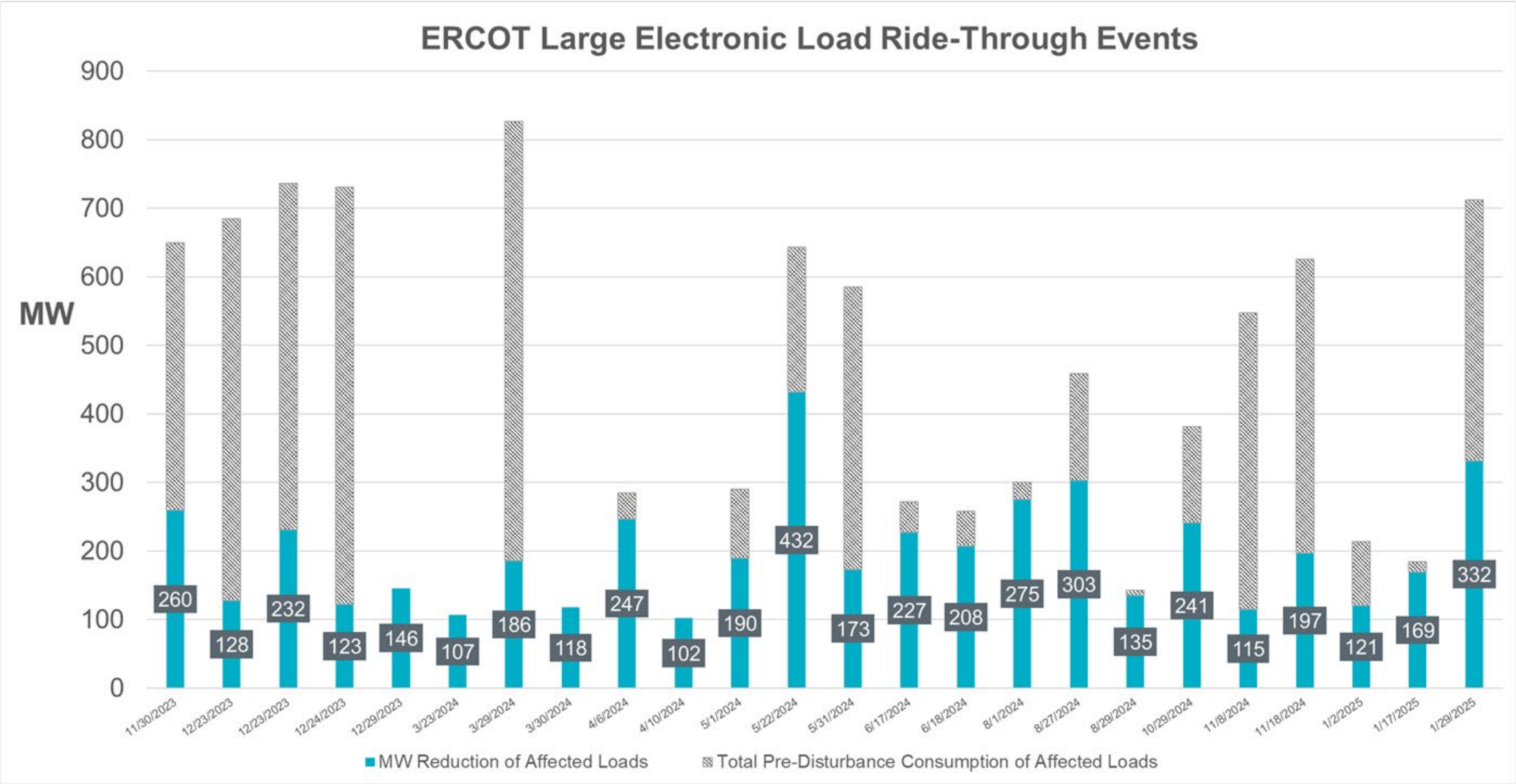
- Multiple Single-Phase Line-to-Ground (SLG) faults and a 3LG ground fault at 138 kV station with delayed 19-cycle clearing due to beaker failure
- Hundreds of loads in Far West Weather zone reduced ~1,560 MW during the event due to extended low voltage period
- 10 large PELs reduced a combined ~162 MW (39% of consumption)
- Largest load reduction from oil and gas production, processing, and delivery facilities (~420 MW from 24 loads)
- System frequency increased to 60.235 Hz and recovered in 12m27s
- 112 MW of thermal generation tripped during event

MW Range of Load Reduction	# of Far West Loads in Range	Total MW Reduction
Greater than 10 MW	41	816
Between 5 MW and 10 MW	46	318
Between 2 and 5 MW	93	314
Between 0 and 2 MW	193	118

Large Power Electronic Load Ride-Through Events November 2023 - Present

- Searched for events in which LLI aggregate tag dropped >100 MW combined with PMU fault flag and system frequency spike
- Collected PMU/DFR data at POIB of large loads from interconnecting TSPs
  - Data availability
  - Confirm fault details and low voltage at POIB during events
  - Confirm MW reduction in consumption of large loads
- 24 events from areas of concentrated large PELs (all crypto loads)
  - 8 events involving 4 loads in Central Texas
    - 890 MW of ERCOT approved consumption
  - 7 events involving 5 loads in 1st pocket in Far West Texas
    - 410 MW of ERCOT approved consumption
  - 4 events involving 3 loads in 2nd pocket in Far West Texas
    - 345 MW of ERCOT approved consumption
    - All consequential loss – loss of line connecting loads during fault
  - 4 events involving 7 loads in multiple pockets in Far West Texas
    - 1,785 MW of ERCOT approved consumption
  - 1 event involving single load in North load zone
    - 264 MW of ERCOT approved consumption

Large Power Electronic Load Ride-Through Events November 2023 - Present



Central Texas Events

Date	Fault Details	Load Zone	Load	Load Type	ERCOT Approved MW	Low Voltage at POI (pu & kV)	Pre-Disturbance Consumption (MW)	Post-Disturbance Consumption (MW)	Total Load Reduction (MW)	% Load Reduction
11/30/2023	345 kV line AG Fault 4 cycle clear	South	LOAD A	Crypto	345	0.489 (138 kV)(Aϕ)	248	125.6	122.4	49.35
			LOAD B	Crypto	390	0.489 (138 kV)(Aϕ)	353.5	239.3	114.2	32.31
			LOAD C	Crypto	65	0.489 (138 kV)(Aϕ)	47.9	24.7	23.2	48.43
			TOTAL		800		649.4		259.8	40.01
12/23/2023	345 kV line AG Fault 4 cycle clear	South	LOAD A	Crypto	345	0.486 (138 kV)(Aϕ)	321.8	169.9	151.9	47.20
			LOAD B	Crypto	390	0.486 (138 kV)(Aϕ)	365.1	305	60.1	16.46
			LOAD C	Crypto	65	0.540 (138 kV)(Aϕ)	49.5	29.9	19.6	39.60
			TOTAL		800		736.4		231.6	31.45
12/23/2023	345 kV line CG Fault 3 cycle clear	South	LOAD A	Crypto	345	0.844 (138 kV)(Cϕ)	281.7	205.8	75.9	26.94
			LOAD B	Crypto	390	0.844 (138 kV)(Cϕ)	354.6	312.3	42.3	11.93
			LOAD C	Crypto	65	0.844 (138 kV)(Cϕ)	48.1	38.5	9.6	19.96
			TOTAL		800		684.4		127.8	18.67
12/24/2023	345 kV line CG Fault 3 cycle clear	South	LOAD A	Crypto	345	0.523 (138 kV)(Cϕ)	314.5	235.3	79.2	25.18
			LOAD B	Crypto	390	0.523 (138 kV)(Cϕ)	367.2	332.4	34.8	9.48
			LOAD C	Crypto	65	0.523 (138 kV)(Cϕ)	48.8	40.1	8.7	17.83
			TOTAL		800		730.5		122.7	16.80
3/29/2024	345 kV line CG Fault 3 cycle clear	South	LOAD A	Crypto	345	0.555 (138 kV)(Cϕ)	319.7	225.8	93.9	29.37
			LOAD B	Crypto	390	0.559 (138 kV)(Cϕ)	364.1	302.8	61.3	16.84
			LOAD C	Crypto	65	0.559 (138 kV)(Cϕ)	47.5	35.9	11.6	24.42
			LOAD D	Crypto	90	0.572 (138 kV)(Cϕ)	95.1	76	19.1	20.08
			TOTAL		890		826.4		185.9	22.50
5/22/2024	345 kV lines & 3LG Faults	South	LOAD A	Crypto	345	0.54 (138 kV)(PS)	230	65.4	164.6	71.57
			LOAD B	Crypto	390	0.54 (138 kV)(PS)	310.2	135.1	175.1	56.45
			LOAD C	Crypto	65	0.54 (138 kV)(PS)	37.4	10.6	26.8	71.66
			LOAD D	Crypto	90	0.00 (138 kV)	65.4	0	65.4	100.00
			TOTAL		890		643		431.9	67.17
5/31/2024	138 kV line AG Fault 4 cycle clear	South	LOAD A	Crypto	345	0.407 (138 kV)(Aϕ)	212.1	117.1	95	44.79
			LOAD B	Crypto	390	0.403 (138 kV)(Aϕ)	337.7	268	69.7	20.64
			LOAD C	Crypto	65	0.401 (138 kV)(Aϕ)	35.1	26.5	8.6	24.50
			TOTAL		800		584.9		173.3	29.63
8/27/2024	138 kV line 3LG Fault 3 cycle clear	South	LOAD A	Crypto	345	0.405 (138 kV)(PS)	91.8	24.3	67.5	73.53
			LOAD B	Crypto	390	0.405 (138 kV)(PS)	367.2	131.9	235.3	64.08
			TOTAL		735		459		302.8	65.97

- Reductions range from 17% - 67% of pre-disturbance consumption
- % reduction larger for 3LG faults than for SLG faults
- 19% reduction seen for shallow voltage dip of 0.844 on single phase

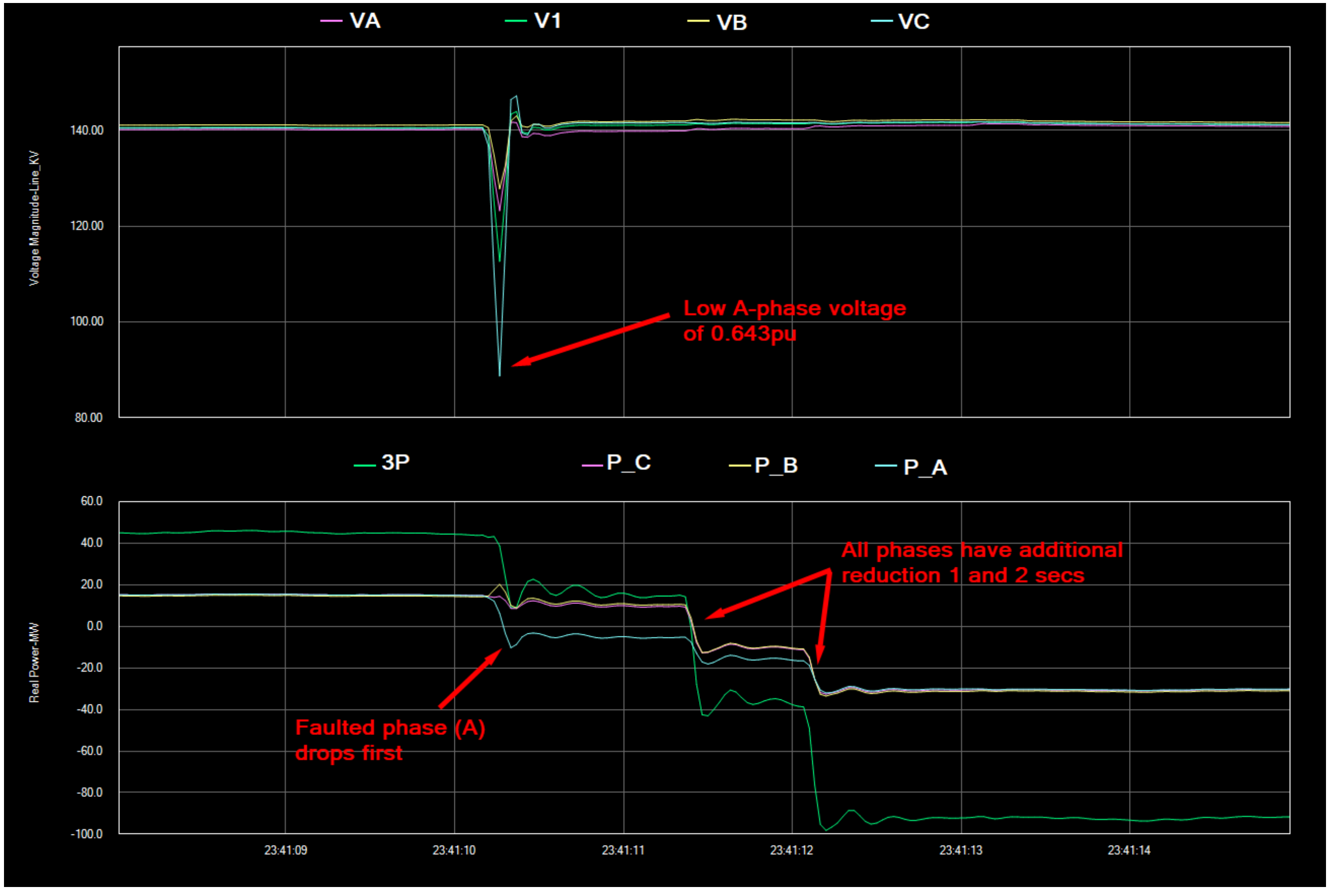
Central Texas LOAD B – 8/27/2024 Event

Far West Texas Events (1st Pocket)

Date	Fault Details	Load Zone	Load	Load Type	ERCOT Approved MW	Low Voltage at POI (pu & kV)	Pre-Disturbance Consumption (MW)	Post-Disturbance Consumption (MW)	Total Load Reduction (MW)	% Load Reduction
12/29/2023	138 kV line Unknown fault type & clearing time	West	LOAD F	Crypto	80	0.00 (138 kV)	72.7	0	72.7	100.00
			LOAD H	Crypto	80	0.00 (138 kV)	73.1	0	73.1	100.00
			TOTAL		160		145.8		145.8	100.00
4/6/2024	138 kV line AG Fault 3 cycle clear	West	LOAD E	Crypto	130	0.356 (138 kV)(Aϕ)	53.4	12	41.4	77.53
			LOAD F	Crypto	80	0.804 (138 kV)(PS)	69.5	0	69.5	100.00
			LOAD G	Crypto	80	0.804 (138 kV)(PS)	65.1	0	65.1	100.00
			LOAD H	Crypto	80	0.804 (138 kV)(PS)	63	0	63	100.00
			LOAD I	Crypto	40	0.804 (138 kV)(PS)	33.4	25.5	7.9	23.65
			TOTAL		410		284.4		246.9	86.81
5/1/2024	138 kV line AG Fault 3 cycle clear	West	LOAD E	Crypto	130	0.398 (138 kV)(Aϕ)	55.5	12.5	43	77.48
			LOAD F	Crypto	80	0.866 (138 kV)(PS)	66.8	61.3	5.5	8.23
			LOAD G	Crypto	80	0.866 (138 kV)(PS)	67.1	0	67.1	100.00
			LOAD H	Crypto	80	0.866 (138 kV)(PS)	67.2	0	67.2	100.00
			LOAD I	Crypto	40	0.866 (138 kV)(PS)	33.5	26.8	6.7	20.00
			TOTAL		410		290.1		189.5	65.32
6/17/2024	138 kV line AG Fault 3 cycle clear	West	LOAD E	Crypto	130	0.384 (138 kV)(Aϕ)	52.9	20	32.9	62.19
			LOAD F	Crypto	80	0.846 (138 kV)(PS)	63.3	0	63.3	100.00
			LOAD G	Crypto	80	0.843 (138 kV)(PS)	60.5	0	60.5	100.00
			LOAD H	Crypto	80	0.846 (138 kV)(PS)	62.7	0	62.7	100.00
			LOAD I	Crypto	40	0.843 (138 kV)(PS)	32.6	25	7.6	23.31
			TOTAL		410		272		227	83.46
6/18/2024	138 kV line BG Fault 3 cycle	West	LOAD E	Crypto	130	0.683 (138 kV)(Bϕ)	31.4	23.9	7.5	23.89
			LOAD F	Crypto	80	0.010 (138 kV)(PS)	62.7	0	62.7	100.00
			LOAD G	Crypto	80	0.717 (138 kV)(PS)	67.2	0	67.2	100.00
			LOAD H	Crypto	80	0.010 (138 kV)(PS)	62.1	0	62.1	100.00
			LOAD I	Crypto	40	0.717 (138 kV)(PS)	34.1	26.1	8	23.46
			TOTAL		410		257.5		207.5	80.58
8/1/2024	138 kV line BG and BC Faults; 3-4 cycle clearing times	West	LOAD E	Crypto	130	0.380 (138kV)(Bϕ)	80.2	0	80.2	100.00
			LOAD F	Crypto	80	0.716 (138 kV)(PS)	63.6	0	63.6	100.00
			LOAD G	Crypto	80	0.756 (138 kV)(PS)	63.2	0	63.2	100.00
			LOAD H	Crypto	80	0.716 (138 kV)(PS)	61.3	0	61.3	100.00
			LOAD I	Crypto	40	0.756 (138 kV)(PS)	31.9	25	6.9	21.63
			TOTAL		410		300.2		275.2	91.67
10/29/2024	138 kV line AG Fault 3 cycle clear	West	LOAD E	Crypto	130	0.305 (138 kV)(Aϕ)	110.8	87.4	23.4	21.12
			LOAD F	Crypto	80	0.643 (138 kV)(Aϕ)	68.7	0	68.7	100.00
			LOAD G	Crypto	80	0.628 (138 kV)(Aϕ)	68.4	0	68.4	100.00
			LOAD H	Crypto	80	0.643 (138 kV)(Aϕ)	67.8	0	67.8	100.00
			LOAD I	Crypto	40	0.628 (138 kV)(Aϕ)	34.4	26.7	7.7	22.38
			LOAD J	Crypto	36	0.490 (138 kV)(Aϕ)	31.5	26.9	4.6	14.60
			TOTAL		446		381.6		240.6	63.05

- All 138 kV SLG faults with exception of one LL fault
- Missing single phase voltage data for several events
- Significant reduction in consumption for shallow positive sequence voltage dips; single phase voltage likely dipping below 0.7 pu at POIs causing reductions

Far West LOAD F and LOAD H – 10/29/2024 Event



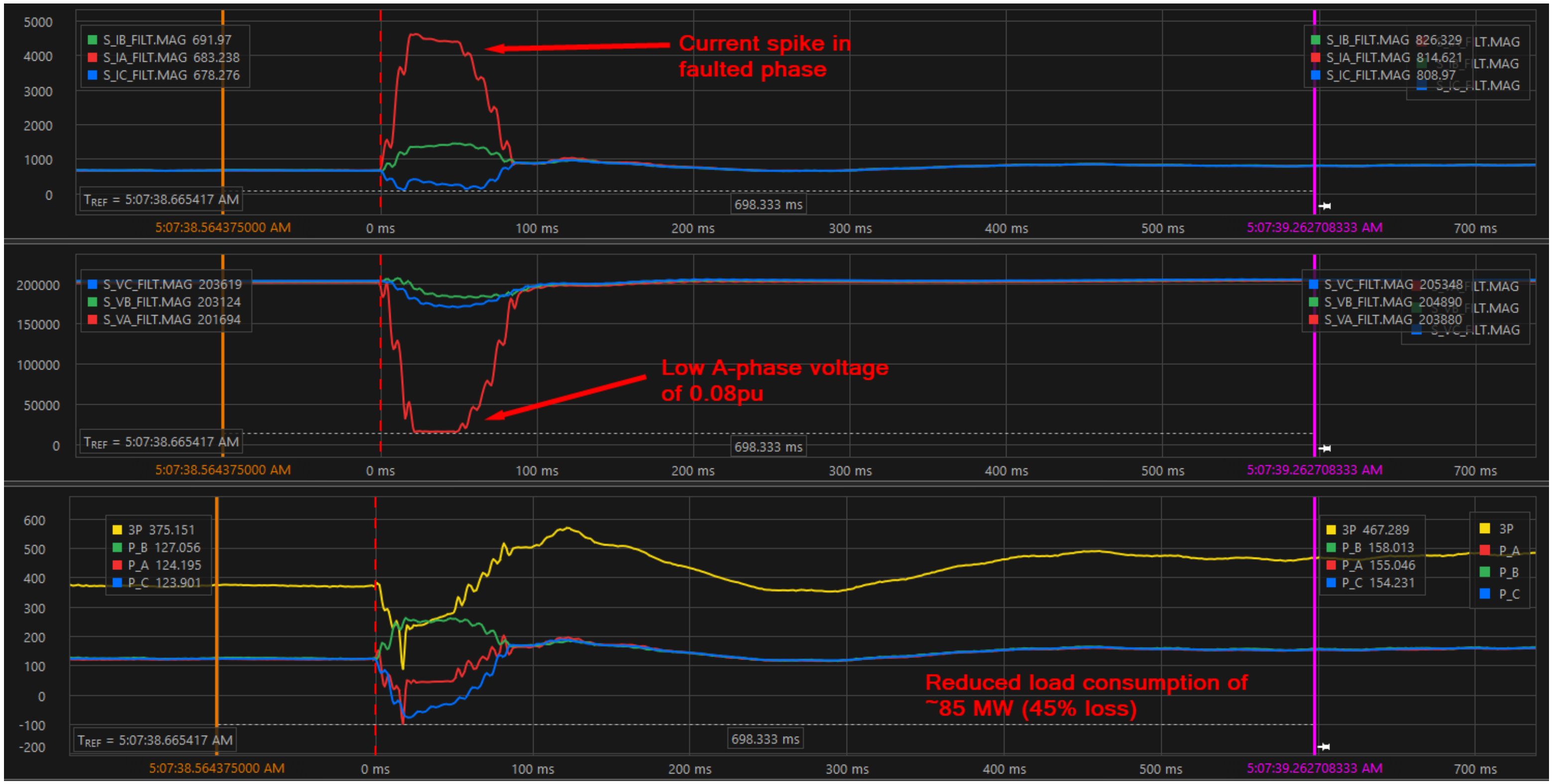
- PMU data at POI towards two co-located sites; Change in line MW flow corresponds to reductions seen in load telemetry (~136 MW and 100% of pre-disturbance consumption)
- Similar performance seen for multiple events for Loads F,G,H, and I
- Possible phase balance protection within facilities?

Far West Texas Events (Multiple Pockets)

Date	Fault Type	Load Zone	Load	Load Type	ERCOT Approved MW	Low Voltage at POI (pu & kV)	Pre-Disturbance Consumption (MW)	Post-Disturbance Consumption (MW)	Total Load Reduction (MW)	% Load Reduction
11/8/2024	345 kV; AG Fault; 4 cycle clear	West	LOAD K	Crypto	207	0.08 (345 kV)(Aϕ)	190.9	105.6	85.3	44.68
			LOAD L	Crypto	345	0.598 (138kV)(Aϕ)	129.7	118.5	11.2	8.64
			LOAD E	Crypto	130	0.663 (138kV)(Aϕ)	110	100.4	9.6	8.73
			LOAD M	Crypto	324	0.627 (138kV)(Aϕ)	80.5	73.4	7.1	8.82
			LOAD N	N/A	10	N/A	8	6.3	1.7	21.25
			LOAD O	Crypto	143	0.589 (138kV)(Aϕ)	27.8	27.4	0.4	1.44
			TOTAL		1159		546.9		115.3	21.08
11/18/2024	345 kV: BG Fault; 4 cycle clear	West	LOAD K	Crypto	207	0.079 (345 kV)(Bϕ)	194	108.5	85.5	44.07
			LOAD G	Crypto	80	0.728 (138kV)(Bϕ)	67.6	0	67.6	100.00
			LOAD L	Crypto	345	0.595 (138kV)(Bϕ)	129.7	107	22.7	17.50
			LOAD E	Crypto	130	0.652 (138kV)(Bϕ)	114	102.4	11.6	10.18
			LOAD M	Crypto	324	0.632 (138kV)(Bϕ)	86.2	79.6	6.6	7.66
			LOAD N	N/A	10	N/A	5.8	4.6	1.2	20.69
			LOAD O	Crypto	143	0.589 (138kV)(Bϕ)	28.2	26.6	1.6	5.67
			TOTAL		1239		625.5		196.8	31.46
1/17/2025	138 kV: AG Fault; 4 cycle clear	West	LOAD M	Crypto	324	0.09 (138 kV)(Aφ)	131.7	0.7	131	99.47
			LOAD R	Crypto		0.11 (138 kV)(Aφ)	23.7	0.1	23.6	99.58
			LOAD S	Crypto		0.11 (138 kV)(Aφ)	13.1	0.8	12.3	93.89
			LOAD P	Crypto	42	N/A	15.4	13.1	2.3	14.94
			TOTAL		366		183.9		169.2	92.01
1/29/2025	345 kV; AG Fault; 4 cycle clear	West	LOAD K	Crypto	207		196.7	125.8	70.9	36.04
			LOAD G	Crypto	80	0.682 (138 kV)(Aϕ)	67.9	0	67.9	100.00
			LOAD F	Crypto	80	0.678 (138kV)(Aϕ)	62.5	0	62.5	100.00
			LOAD H	Crypto	80	0.678 (138kV)(Aϕ)	63.8	0	63.8	100.00
			LOAD Q	Crypto	234	0.631 (138 kV)(Aφ)	155.2	119.4	35.8	23.07
			LOAD L	Crypto	345	0.603 (138 kV)(Aφ)	136.5	111	25.5	18.68
			LOAD P	Crypto	42	0.654 (138 kV)(Aφ)	20.2	16.7	3.5	17.33
			LOAD N	N/A	10		9	7.3	1.7	18.89
			TOTAL		1078		711.8		331.6	46.59

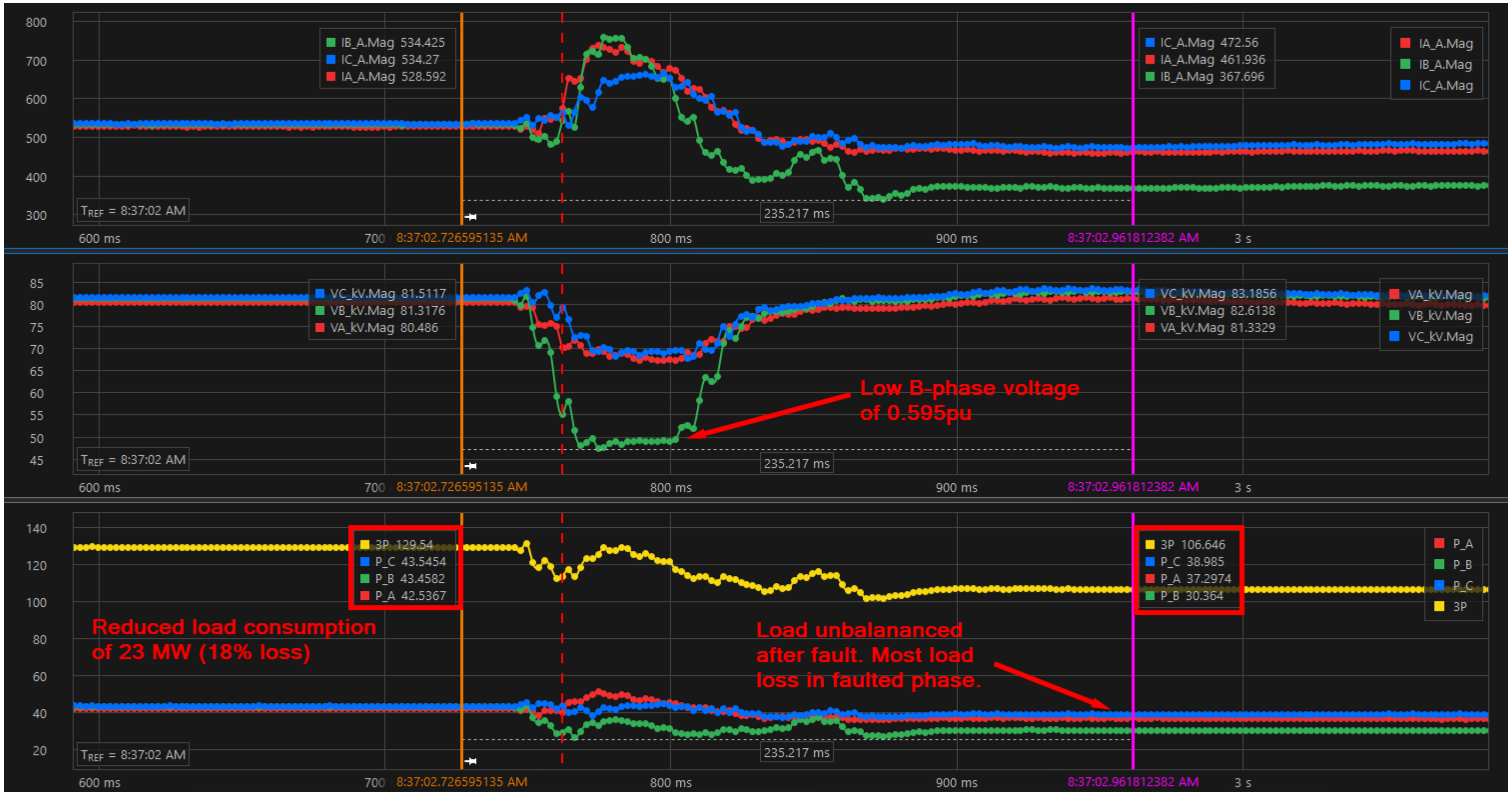
- 345 kV faults in West Texas affecting larger area and number of loads
- Events were all SLG faults; possible larger reductions for 3LG fault
- Multiple loads show reduced active power in faulted phase only
- Some affected loads involved in 2022-2023 events and had larger reductions
- Pre-disturbance load consumption for **all LLI loads in West Texas** was between1,300 and 1,400 MW for all events (table above is just affected loads that reduced consumption)

Far West LOAD K – 11/8/2024 Event



- Co-located with thermal generation. DFR data monitoring line to facility
- Increase in line flow corresponds with load loss in telemetry
- Load balanced between all 3 phases immediately after fault clears

Far West LOAD L – 11/18/2024 Event



- DFR data directly monitoring load
- Load balanced before fault and unbalanced after fault
- Majority of load loss in faulted phase

Key Observations

- Large variance in % of reduction with similar voltage dips at POI
  - Some large PELs more sensitive than others
  - Possible facility protection systems not visible to ERCOT nor included in dynamic models
  - Different facility electrical designs (transformer windings)
- SLG faults causing significant reductions for shallow positive sequence voltage dips as high as 0.85pu
  - Faulted phase likely reducing below ~0.7pu causing load reductions
  - Single-phase high-resolution data required for analysis
- ~1,950 MW of operational large load in Far West Texas weather zone
  - Potential for reductions of ~1000 MW or greater in Far West Texas with 3-phase fault on 345 kV during high consumption
  - Additional ~3,500 MW in Far West Texas has been approved or is in Planning review
- Other weaker grid areas may see similar events with projected large load growth

Key Takeaways and Next Steps

- Working with NERC Event Analysis team on ERCOT events report
- ERCOT Operations to continue monitoring and tracking large load ride-through events
- Operations to continue working with TSPs to retrieve event data and ensure proper Disturbance Monitoring Equipment is in place
- Establish communication between ERCOT, TSPs, and load owners to evaluate ride-through performance of large PELs
- Challenges and issues to be addressed
  - Determine actual ride-through capabilities of each type of large load
  - Verify and validate load models for accurate representation of ride-through capabilities
  - Develop reliability criteria through studies
  - Examine potential ways to mitigate and/or minimize large load loss during fault events
  - Difficulty performing event analysis without formal RFI process for loads

Questions?

NPCC Long Term Strategy

To assure effective and efficient reduction of risks to the reliability and security of the grid

2025 Outreach Activities

- **Reliability Forums - March, May, Aug., Oct.**
  - Various Reliability Topics
  - Electric Vehicles, Energy Storage, Large Loads
- **State and Provincial Outreach Topics**
  - NERC and NPCC Seasonal Reliability Assessments
  - FERC Order 901 (Reliability Standards for Inverter Based Resources)
  - Winterization, Data Centers
- **Regional Webinars/Workshops**
  - Physical and Cyber Security
  - Extreme Weather Preparedness
  - Energy
- **2024 NPCC Northeast Gas-Electric Study**

NPCC Long Term Strategy

To assure effective and efficient reduction of risks to the reliability and security of the grid

Comments/Suggestions:

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[NPCC Reliability Forums]

[NPCC Guidance Document]