EPRI's Headroom Framework

Building Industry Consensus on Robust Data Center Grid Integration Assessment

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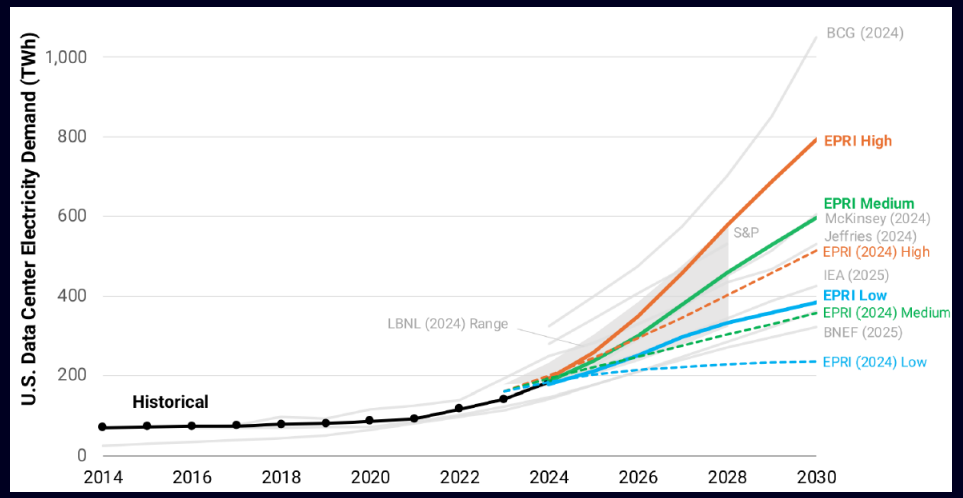
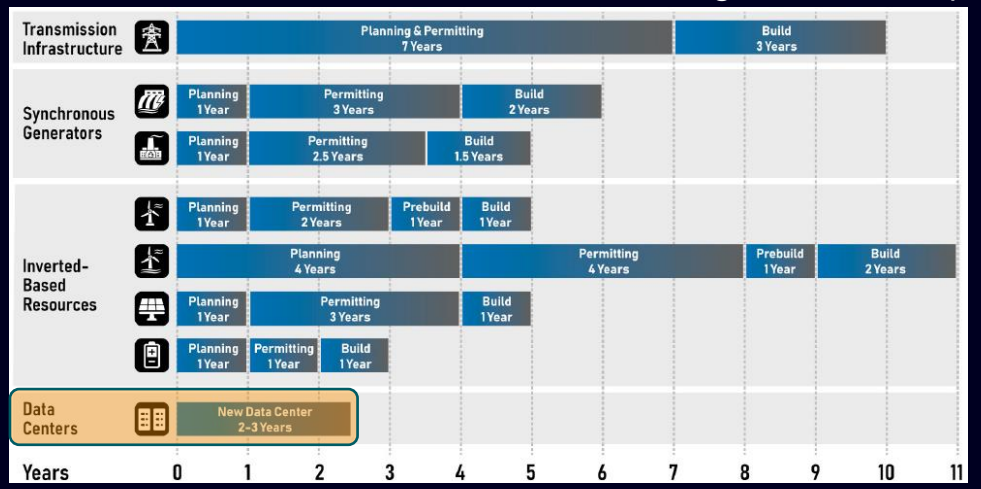
Unprecedented demand growth has potential to challenge system reliability…

Duplicative requests & limited historical data challenge forecasting ability

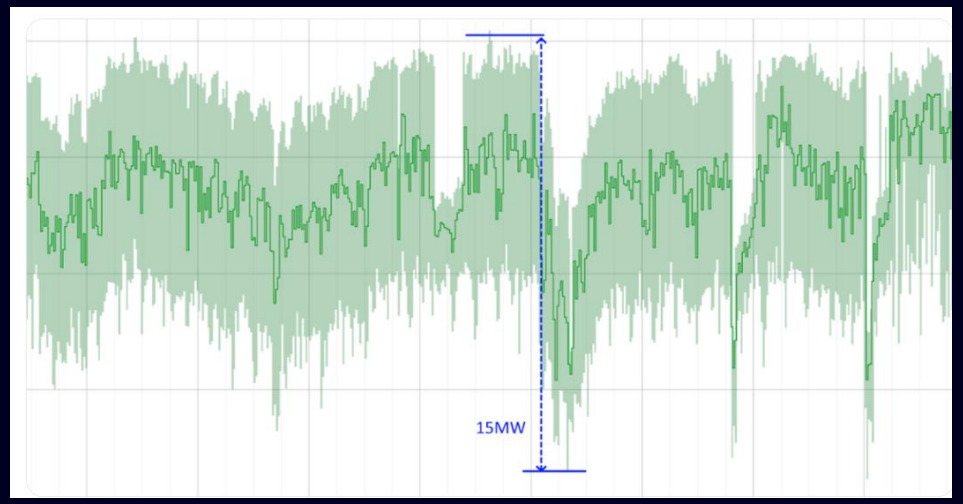


Faster timelines relative to G&T infrastructure challenge resource adequacy

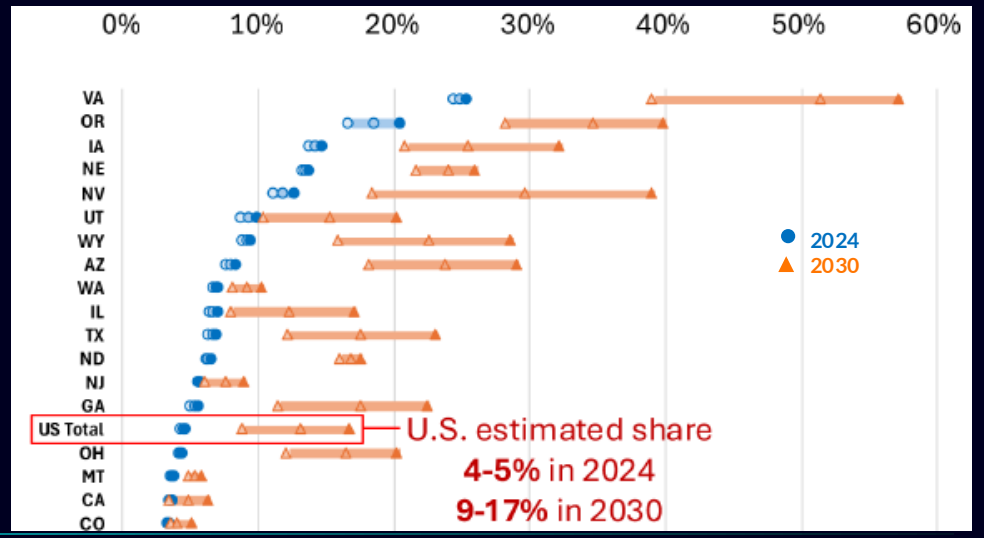


G&T – Generation and Transmission

Nature of the demand challenges system reliability and power quality

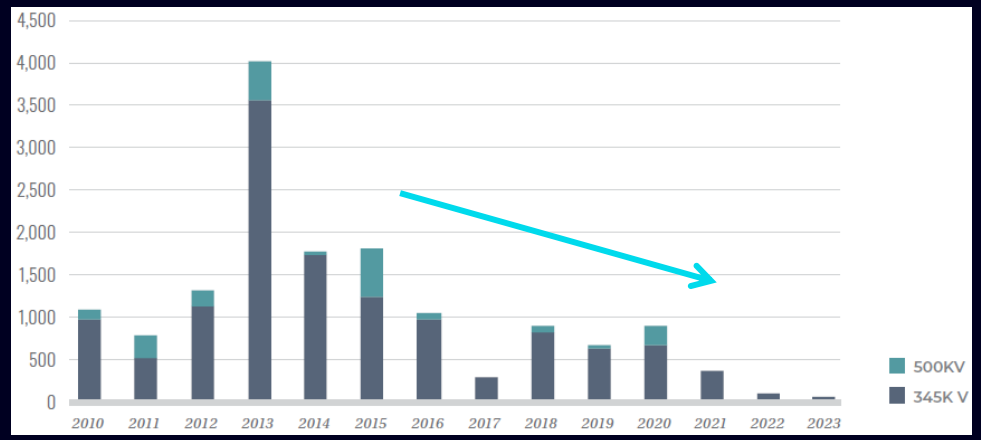


Demand growth is unevenly spread across the region

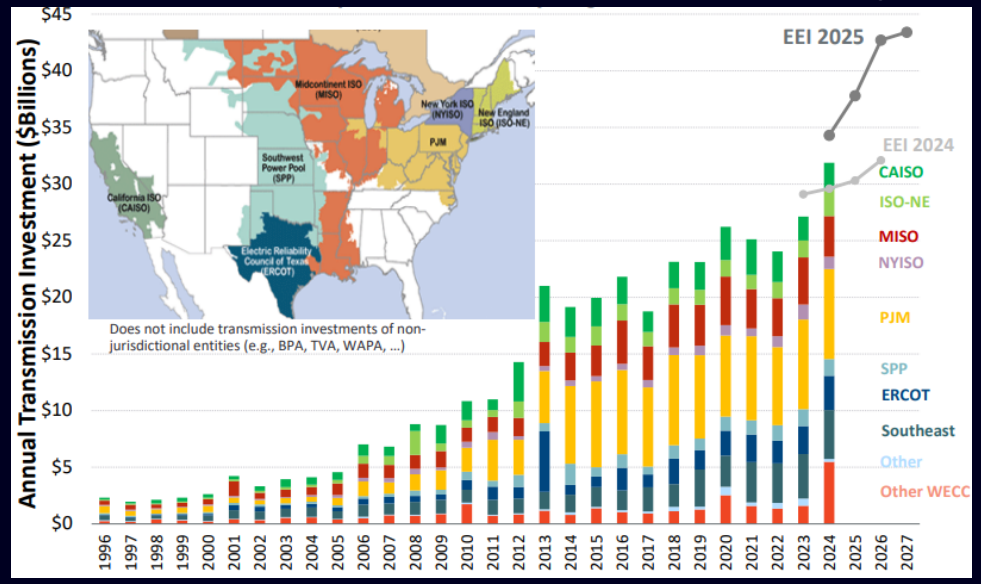


While demand is growing, transmission development has slowed down…

New 345 kV+ transmission lines added each year



Annual transmission investment as reported to FERC by region



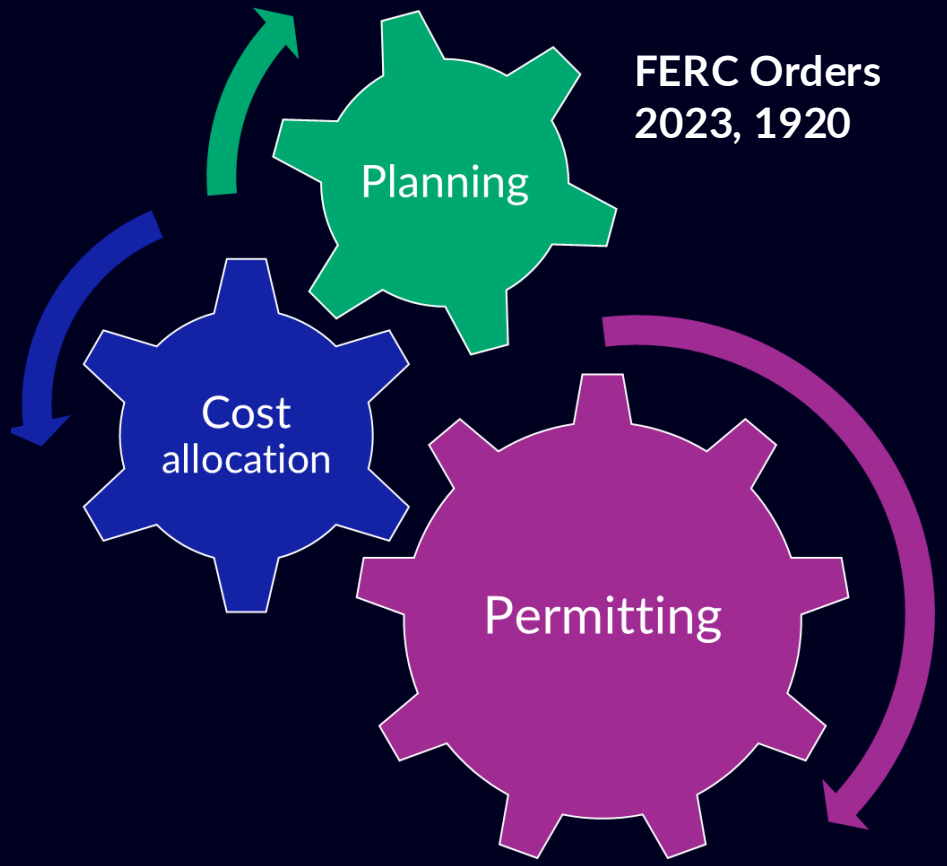
- The U.S. only builds 20% as much new high-voltage (345kV+) transmission in the 2020s as it did a decade ago
  - 1,700 miles per year from 2010 to 2014
  - 350 miles per year from 2020 to 2023
- On the other hand, U.S. transmission investment in 2024 exceeded $30B, up from ~$20B a decade earlier
  - More than 90% was focused on incremental reliability and refurbishment
- Cost per circuit-mile has been increasing, largely due to permitting, supply chain, extreme weather hardening

What are potential solution options?

- Accelerate development of new transmission infrastructure
- Off-grid deployment either as a bridge or permanent solution
- Maximize utilization of existing grid infrastructure

New development while essential may not be timely; off-grid installations are typically more expensive

Key reform areas driving transmission expansion



FERC Orders 2023, 1920

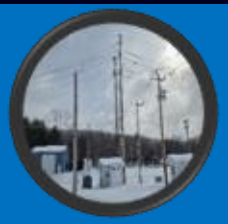
Off-grid installations may provide limited opportunities

So, what does that leave us with?

Maximizing utilization of the existing grid is viable and requires knowledge of existing capacity available on the grid

Additional capacity on the existing grid can be accessed through…

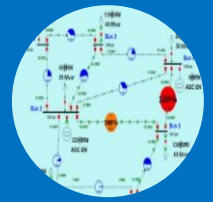
Grid Enhancing Technologies



DLR

Advanced Conductors

APFC



Topology Optimization

Flexible Grid connection

- How much inflexible demand can be accommodated with the existing infrastructure (aka *"Headroom"*)?
- How does that answer change if demand is flexible?
- How do you quantify flexibility?

DLR: Dynamic Line Rating
APFC: Advanced Power Flow Controller

"Headroom" – the amount of new load a system can integrate across all time periods before violating reliability requirements.

Headroom involves more than traditional powerflow analysis and is driven by several factors

Existing Supply- & Demand-Side Resources

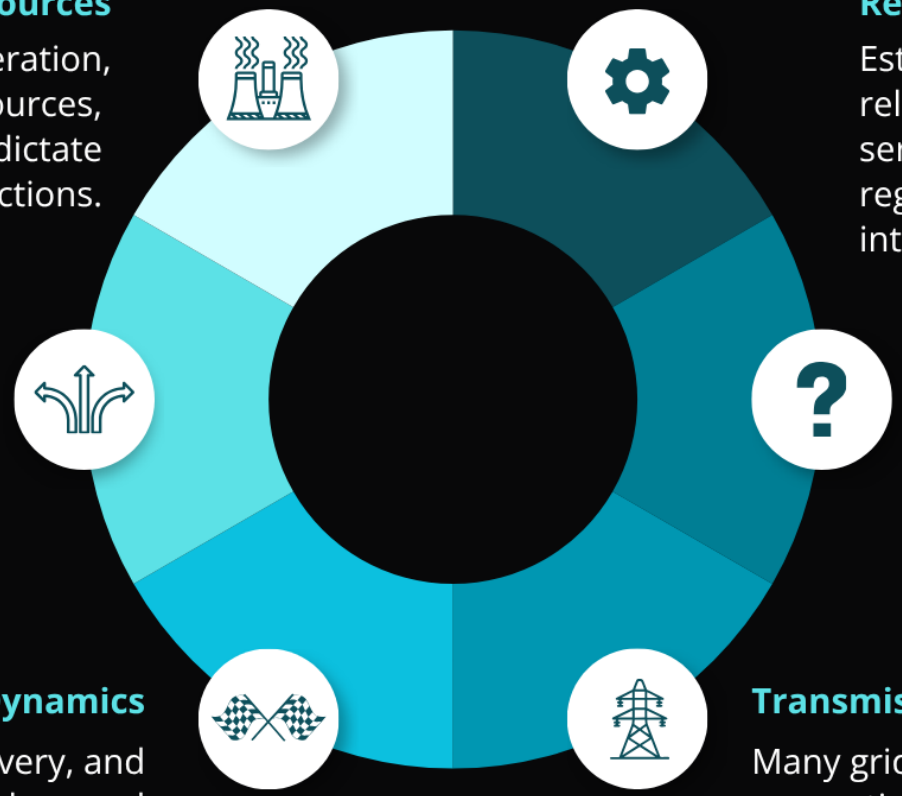
The disposition of existing generation, energy storage, demand-side resources, and loads in a power system dictate many grid interactions.

Data Center Flexibility

While flexible, data centers have critical performance requirements and will seek to maintain minimum deviations and cost-effective load curtailments.

Fast Response System Dynamics

Sub-hourly (~5-10 min) supply, delivery, and end-use interactions introduce real constraints (and opportunity) for systems to use DCs as a grid resource.



Regulation, Standards & Market Rules

Established system adequacy & operational reliabilty standards, energy and ancillary serviced market participation rules, and regulatory constraints can limit absolute integrable DC loads.

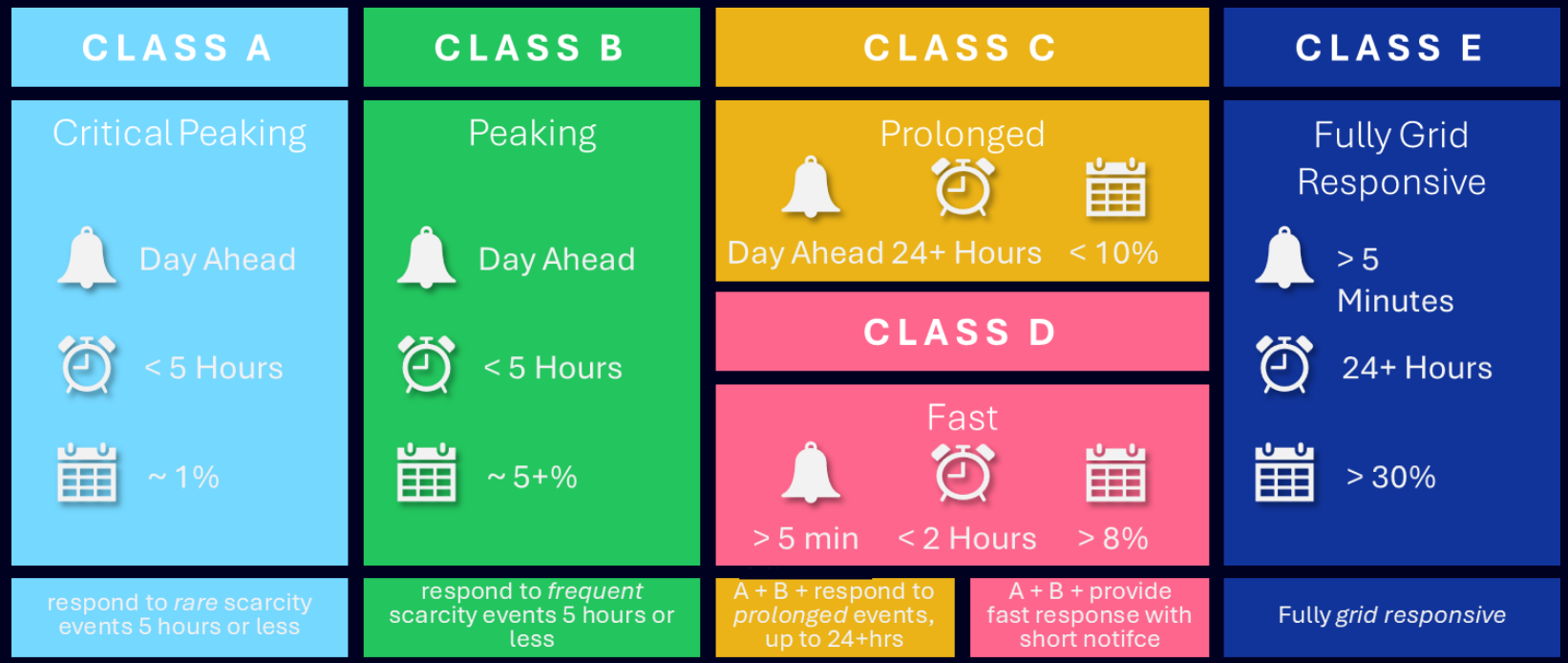
Uncertainty in Grid Conditions

Uncertainty in existing loads, variable generation (e.g., wind, solar), and generator and network outages can drive system contingency events that will limit the amount of integrable new load.

Transmission Limits and Locational Constraints

Many grids are currently experiencing high levels of congestion and already plan around locational constraints. These can limit feasible DC connection locations and offer new opportunities for strategic siting.

To adequately leverage flexibility, we need a common language – introducing Flex MOSAIC™



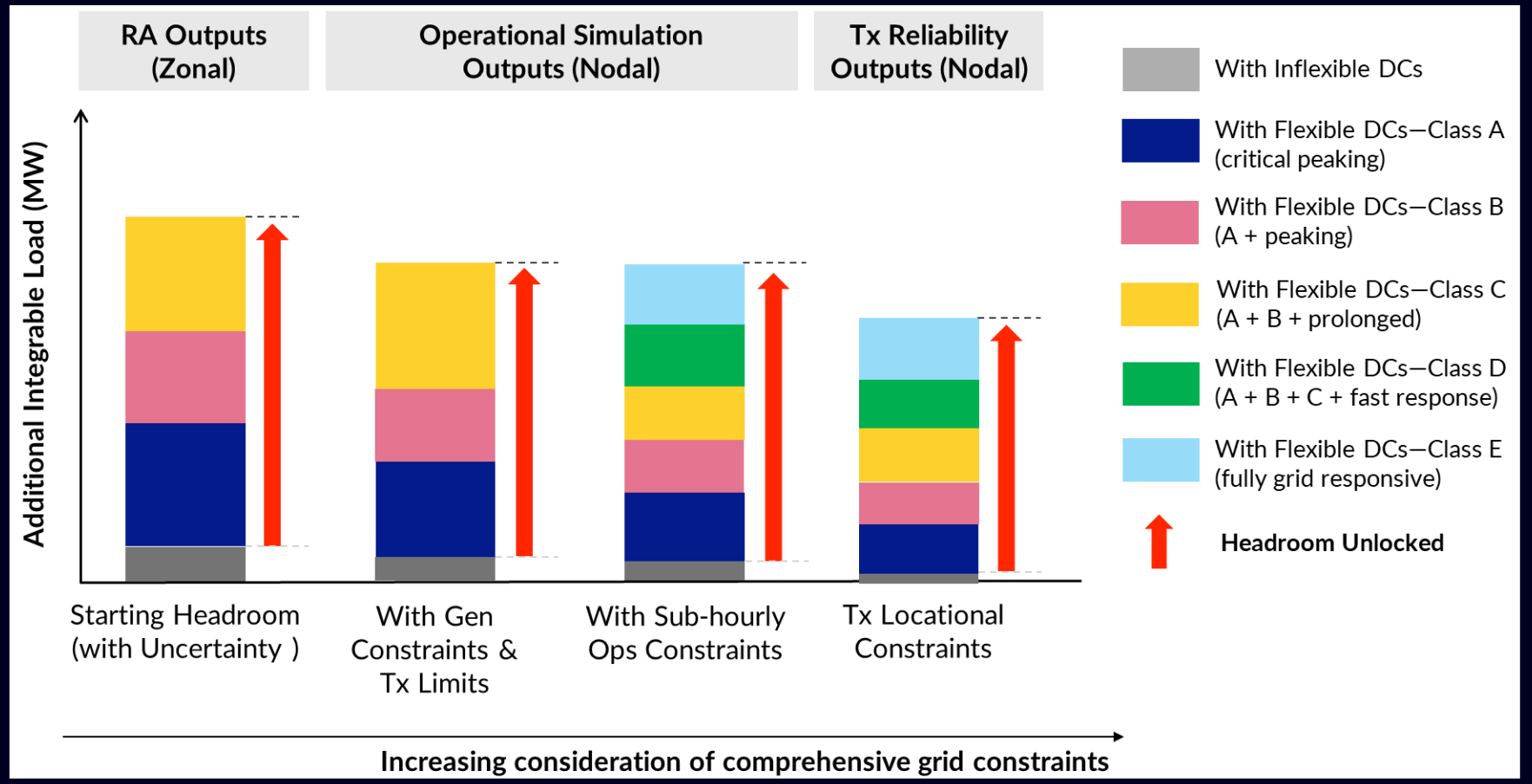
Class	Description
A	Address Critical Peak type: Can respond to *rare* energy scarcity events lasting 5 hours or less with day
B	Can respond to *frequent* energy scarcity events lasting 5 hours or less
C	Can do A and B, and can also respond to *prolonged* energy scarcity events, lasting up to 24 h
D	Can do A and B, and can also provide fast response with short notification times
E	Provides peaking, prolonged and fast response

Notification Window
Activation Period
Annual Utilization

More than 50 industry entities from across the data center and electric system value chain signed an open call to action to build the future of load flexibility on Flex MOSAIC™

Uncovering system headroom requires comprehensive consideration of grid operations and the full range of DC flexibility archetypes

Bringing Flex Mosaic and Headroom concept together



Developing a framework & industry guidance for evaluating DC integration potential in regional power systems

In Summary

- Clear understanding of available Headroom is foundational to reliably accommodating tomorrow's load growth in today's grid.
- **Flexibility**, especially from data centers, is key to unlocking the maximum available headroom.
- By combining probabilistic analysis, operational realities, and transmission constraints into a **unified framework**, EPRI's headroom framework equips the industry to integrate rapidly growing loads reliably, efficiently, and without immediate infrastructure expansion.

Headroom Framework Discussion Paper

Presents a practical framework for system planners to estimate the level of headroom in a power system.

Highlights

- Presented as a “playbook” with step-by-step guidance on comprehensively calculating system headroom
- Considers system adequacy, generator constraints, transmission limits, intra-hour fast response operations, and locational risk and transmission reliability
- Considers range of Flex MOSAIC™ flexibility classes
- Compatible with existing planning and power system modeling tools
- Customizable for system-specific circumstances and planning journey phase
- Presented as a discussion paper to invite industry collaboration over the next few months as we refine the framework

EPRI Report 3002034162

Join EPRI's Headroom Collaborative

Interested in joining a focus group discussion this spring or summer to help EPRI continue to develop our headroom framework?

Take 5 minutes and let us know!

Sign Up Today