Integrating Load Flexibility into Resource Adequacy

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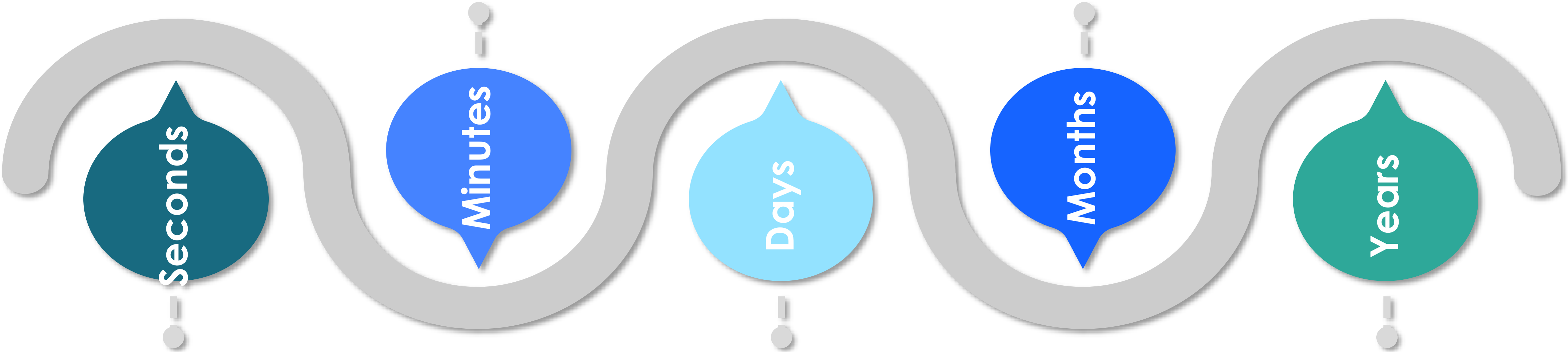
Flexibility comes in many forms depending on when it's needed



Frequency regulation, co-located quick responding batteries

Dynamic line ratings (DLR), advanced power flow controllers

Aggregate load flexibility from DERs, demand response

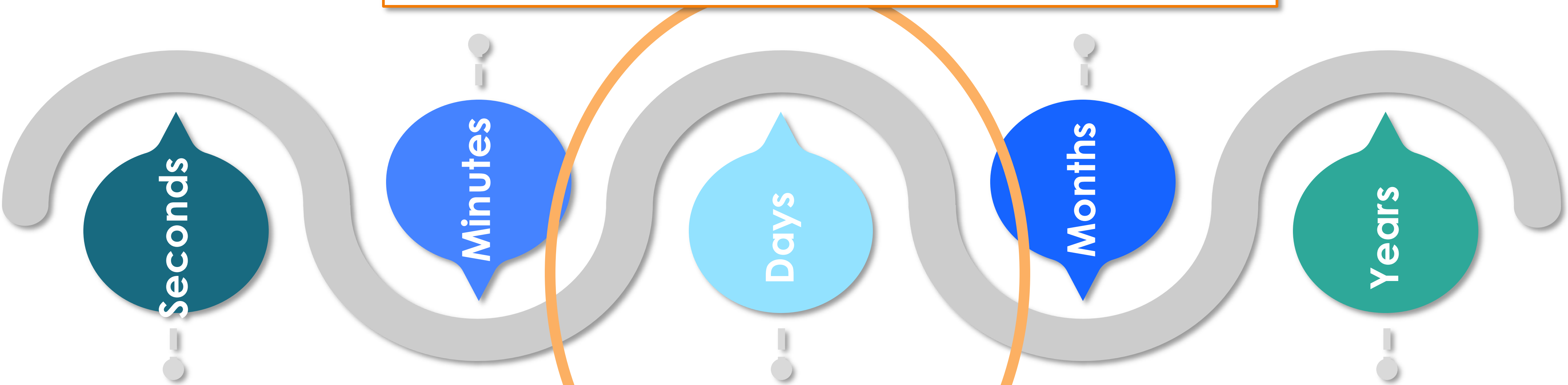
Topology optimization

Non-firm power to enable faster interconnection, non wire alternatives to defer transmission upgrades

Flexibility comes in many forms depending on when it's needed

This flexibility has been studied in Resource Adequacy assessments

What can be learned from these studies for today's large load interconnection needs?



Frequency regulation, co-located quick responding batteries

Aggregate load flexibility from DERs, demand response

Non-firm power to enable faster interconnection, non wire alternatives to defer transmission upgrades

DERs bring a set of key differences and similarities with respect to traditional generation resources

Similarities

- Ability to provide capacity, energy, and ancillary services
- Have operational constraints
- Have outages and availability rates

Differences

Certain differences may be neutral, others bring opportunities to support power system planning:

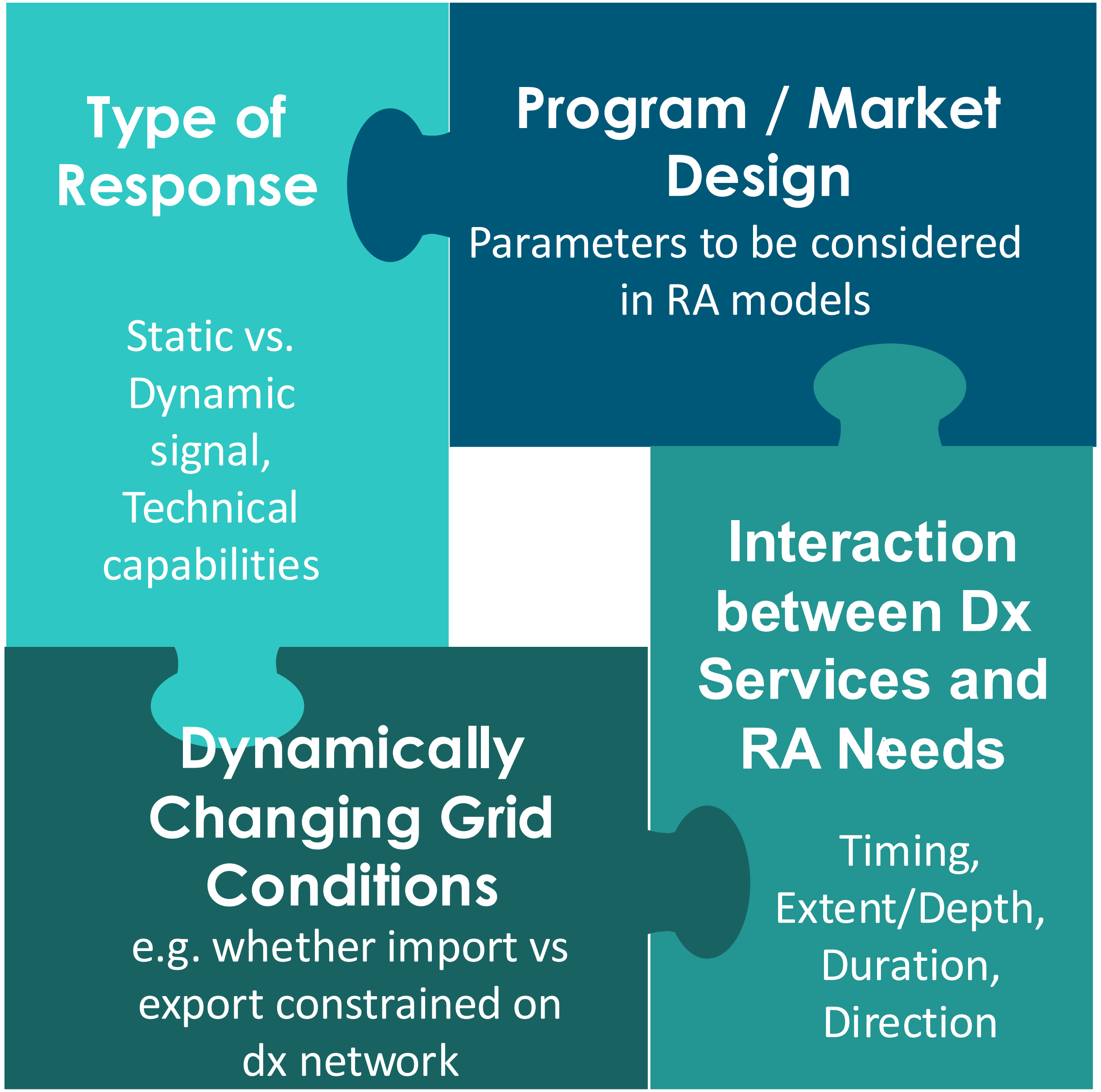
- Traditional generation resources take years or even decades to deploy, DERs may begin service in weeks to months.
- DERs often require aggregation for operational (i.e., market participation) and modeling purposes, while traditional resources can often be operated and modeled individually.

Other differences bring new challenges for planning:

- Traditional generation resource construction is planned for, resources operate for decades and may require permission to retire. DER connection to the power system is not as predictable, and certain DERs may disconnect from the grid and stop participating in grid services with little or no warning.
- Traditional generation resource response is highly predictable, DER response can be less so, although aggregate values may increase in predictability as DER shares grow.
- Traditional generation resources have generally been connected to the transmission network, while **DERs are connected to the distribution grid. This requires consideration of distribution-level operational constraints to ensure resource deliverability.**
- Traditional generation resources are exclusively used to provide services to the bulk power system, **DERs can value stack across various bulk system and distribution services.** Preventing double counting and ensuring that the range of services provided are compatible is required.

Adapted from *Demand Flexibility for Grid Reliability and Resilience: Planning Tool Integration of Demand Flexibility*. EPRI, Palo Alto, CA: 2023. 3002025443

EPRI developed a framework to determine the value of DER load flexibility in resource adequacy studies



Goal: Capture with the greatest level of accuracy the availability and probability of materialization of assets contributing to resource adequacy under times of system stress.

Signal Types for DERs: Static vs Dynamic

Static signal

DERs are not responsive to real-time (or near-real-time) system conditions

Includes firm load but also demand flexibility achieved through long-term signals (TOU, energy efficiency), and changes to net-load due to BTM PV and energy storage uptake

Modeling response through timeseries that captures technical parameters is most appropriate.

Dynamic signal

DERs are responsive to real time (or near real time) system conditions

Includes load reduction, real time pricing, reliability dispatch, and critical peak pricing programs, as well as DER participation in wholesale market products responding to RA needs.

Modeling requires consideration of program/market design *and* technical parameters

Adapted from *Demand Flexibility for Grid Reliability and Resilience: Planning Tool Integration of Demand Flexibility – Phase II*. EPRI, Palo Alto, CA: 2023. 3002028252.

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Program or market design considerations impact the utilization of DERs in RA constructs

Dynamic Signals and Response Considerations

- Dispatch trigger (could be load level, system marginal cost or other)
- Time-varying maximum power available for load reduction
- Constraint on number of dispatches
- Constraint on dispatch duration
- Response persistence/customer fatigue
- Weather-dependent customer response
- Equipment availability to enable flexible demand (such as EV charging equipment for EVs)

- Daily/weekly energy requirements
- Shifted energy constraints (are there periods when consumption cannot be shifted to?)
- Shifted energy compounding rate (is shifted consumption greater than baseline consumption?)

Specific to shiftable loads: consumption is shifted from one period to another rather than solely increased or decreased

Adapted from *Demand Flexibility for Grid Reliability and Resilience: Planning Tool Integration of Demand Flexibility – Phase II*. EPRI, Palo Alto, CA: 2023. 3002028252.

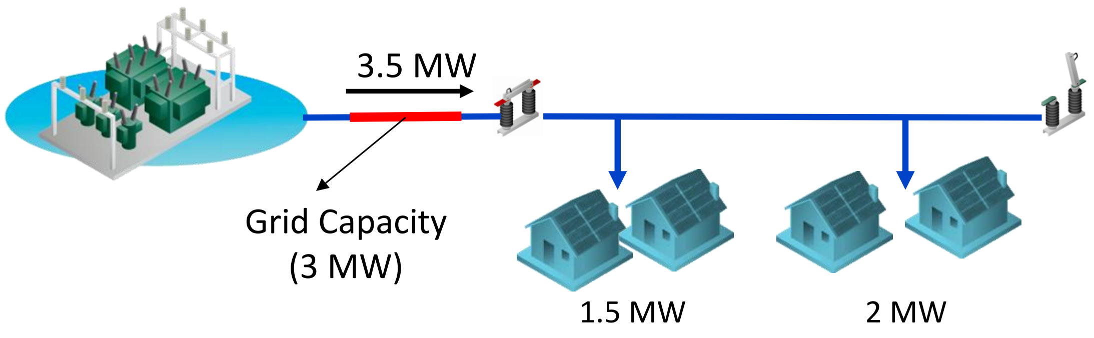
Distribution services and RA needs can create conflicting priorities

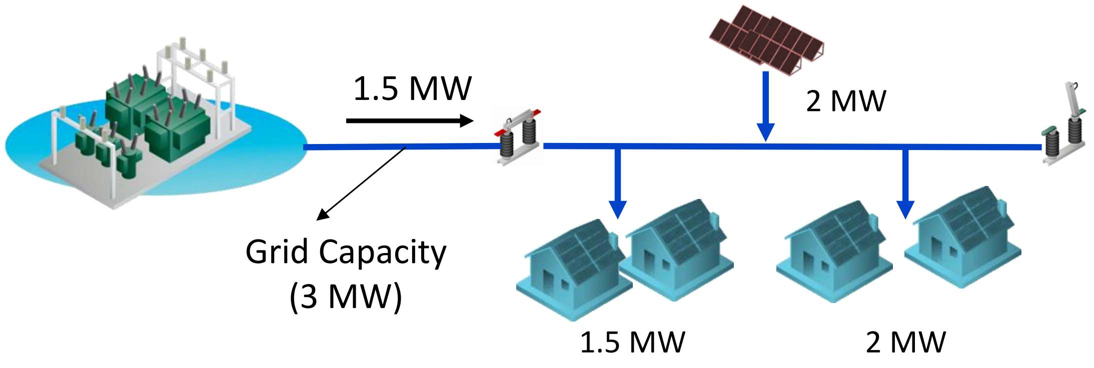
Type Of DER Service	Congestion Management and Grid Capacity Deferral	Voltage Support	Reliability Services	Resiliency Services
The drivers for services – *and how they align/conflict with RA needs*	Congestion management is mainly activated during relatively rare events such as annual peak loading conditions but may also be leveraged during high distribution-connected generation output scenarios, or during maintenance periods. It is activated to respond to *planned* but *infrequent* conditions. Grid capacity deferral flexibility is leveraged on a much more frequent basis (could be to respond to daily/weekly events), in response to *planned* grid conditions.	Activated to support *planned* grid conditions, often to correct net load forecast errors at a local level. Flexible DER assets can provide voltage support through active and reactive power management.	Activated in response to *unplanned* but (generally) expected conditions, often single-fault issues, e.g., a line or a component failure in the network due to old age or insufficient maintenance. These are generally highly localized and uncorrelated grid issues.	Activated in response to *unplanned*, high impact low frequency events, generally involving extreme climate events, e.g., storms, causing damage to distribution infrastructure. These could also involve cyber security breaches compromising the operability of the distribution network.

Grid conditions affect the RA benefits

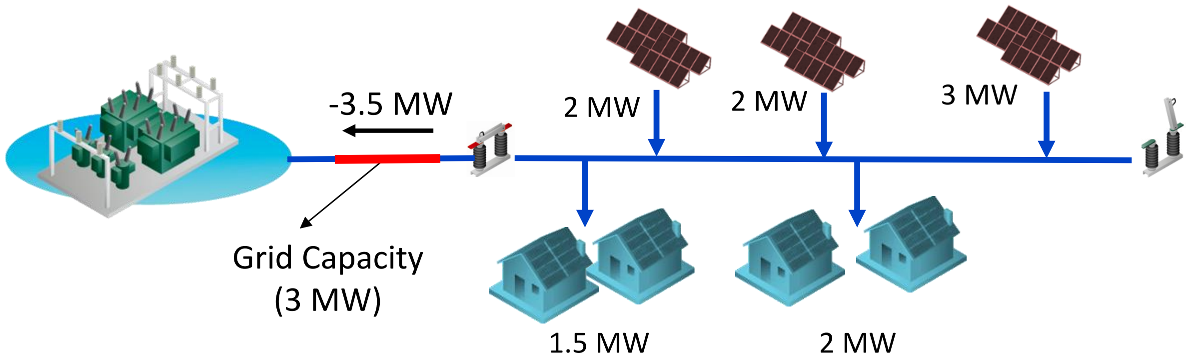
Bi-directional distribution network congestion affects DER stacking

Distribution network congestion scenario 1: Import-constrained network





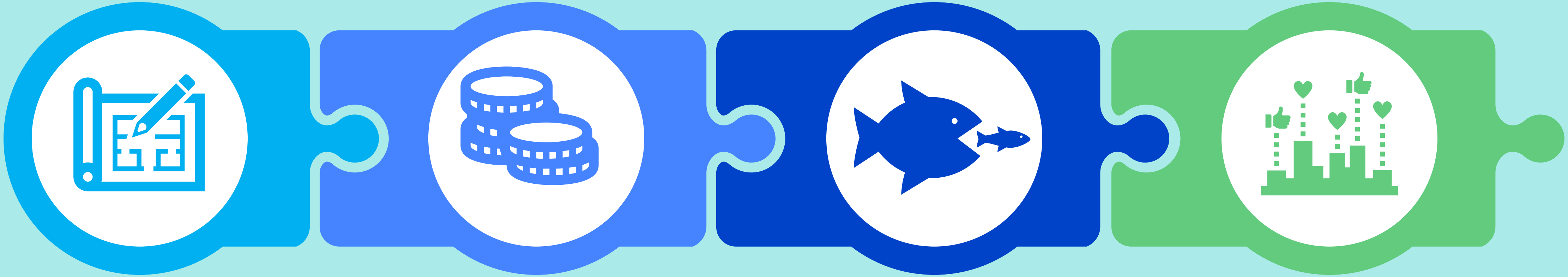
Distribution network congestion scenario 2: Export-constrained network



The services and congestion inform the compatibility of DER distribution service provision with resource adequacy support

Factor	Resource Adequacy	Distribution System Operations	Compatibility
Trigger (Timing)	High net load conditions, regardless of cause	Local forecasting errors, peak load conditions, construction work impacting the distribution network, distribution network topology leading to voltage sags, and extreme weather events damaging distribution infrastructure,	Sometimes
Extent/ depth of events	Events either impacting large enough areas (adding up to sufficient load or generation impact) or large enough generators or loads to make a substantial difference at the system level	Event correlation over large geographical areas is immaterial to the operation at the feeder level. All events affecting local network operations are material to distribution network operations	Minimal
Duration of events	Any event lasting more than several minutes	Any event lasting more than several minutes – distribution network operations are not concerned with frequency control or sub-minute grid balancing	Most of the time
Mitigation Response (Direction)	Reduction of demand and/or increase in generator power output	▪ Reduction of demand and/or increase in generation/storage power output ▪ Increase in demand and/or reduction of generation/storage power outputs ▪ Changes to reactive power outputs	The first response is always in line with RA needs, the second and third may be in line or conflicting.

Lessons for Dx Connected Load Interconnections



Understand technical capability and temporal dynamics (type of flexibility)

e.g. data center design, flexibility operations, system dynamics

Understand incentive structures

e.g. market design, program design, standards, regulation

Understand competing needs between systems

e.g. grid conditions vs data center conditions, areas of uncertainty, locational considerations/directionality of flows

Find ways to integrate into fungible dimensions and find complementarities

e.g. timing, extent/depth, duration, direction, speed

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Next Steps – EPRI is integrating these lessons into the DC Flex headroom studies

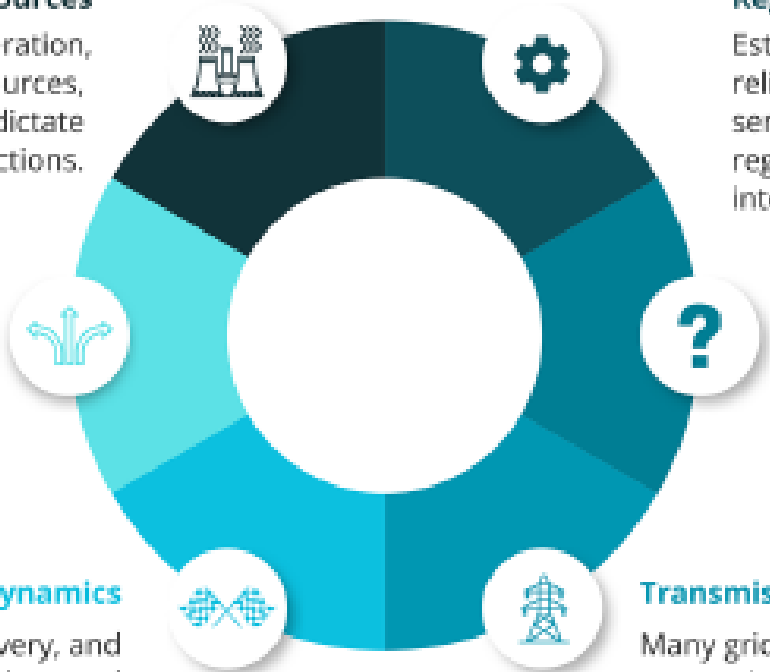
REALISTIC CONSTRAINTS TO SYSTEM HEADROOM

DCs can be grid assets, but many constraints may limit their absolute deployment in the near-term

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 Operations
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.

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