

# Interconnection Implementation Review Group (IIRG) Flexible Interconnection Workshop

MARCH 3-4, 2026 – DAY 1



GridLAB

ADVANCED  
ENERGY UNITED™

RMI

# Background & Context



## ► Interconnection Implementation Review Group (IIRG) Background

- Established to make recommendations to the DPU regarding DG interconnection processes
- Established a Flexible Interconnection subgroup in May 2025 co-chaired by National Grid, the AGO and Blue Wave
- Working since August 2025 to develop a Draft Flexible Interconnection Guidelines & Implementation Plan with the goal of submitting such plan to the DPU in 2026

## ► DPU Flexible Interconnection Directives

- **DERs within existing system:** D.P.U 25-20 directed proposal as soon as practicable in the first quarter of 2026
- **DERs within LTSP proactive upgrades:** D.P.U 25-20 directed development of consensus proposal that incorporates FI process into the Long-term System Planning Process (LTSP) upon completion of first proposal
- **Electric Vehicles/EV Charging Infrastructure:** D.P.U 24-10/11/12 directs development and inclusion of an EV flexible interconnection offering in the next Electric sector Modernization Plan (ESMP) Filings

} Workshop Scope\*

# What is CHARGED



CHARGED is a multi-stakeholder initiative that aims to develop solutions to address distribution system-related barriers to the electrification of buildings and transportation nationwide.

We believe that by developing solutions with broad buy-in/acceptance in advance and outside of formal regulatory proceedings can help drive efficient outcomes that are beneficial to all stakeholders.

## Three components:

**Develop innovative solutions**, crafted through generative work with diverse stakeholders (e.g., utilities, public interest organizations, advanced energy companies).

**Drive implementation through project participants**, testing and improving solutions' applicability across the US.

**Education & dissemination to support scaled adoption in high-impact states**, e.g., where existing policy is already creating momentum for electrification.

# Workshop Objectives



## ► Objectives

- Build shared understanding of how different DER flexible interconnection offerings work within the existing electric power system (EPS)
- Discuss and solicit feedback on the implementation of a ***Dynamic Flexible Interconnection offering via a Distributed Energy Resource Management System (DERMS)***

## ► Out of scope (Addressed in subsequent phases)

- Flexible Interconnection in the context of the Long-term System Planning Process (LTSP)
- Flexible Interconnection for electric vehicles (EVs) and electric vehicle supply equipment (EVSE)

# Agenda – Day 1



**9:00 - 9:50 Welcome**

**9:50 - 10:45 Session 1: Flexible Interconnection Overview and Existing Offerings**

**10:45 - 11:00 Break**

**11:00 - 11:30 Session 2: State of Play**

**11:30 - 12:00 Session 3: Curtailment Overview**

**12:00 - 1:00 Lunch**

**1:00 - 1:55 Session 4: Breakout on Curtailment % and Allocation Methodology**

**1:55 - 2:25 Session 5: Curtailment Study**

**2:25 - 2:40 Break**

**2:40 - 3:30 Session 6: Breakout on Curtailment Study Requirements**

**3:30 - 4:30 Session 7: Interconnection Process/Queue Management**

**4:30 - 4:45 Close Out**

**5:30 - 7:00 Happy Hour**

# Agenda – Day 2



**9:00 - 9:30 Welcome & Recap**

**9:30 - 10:15 Session 8: IX Agreement**

**10:15 - 10:30 Break**

**10:30 - 11:30 Session 9: Financing Breakout**

**11:30 - 12:15 Session 10: Technical & Operational Requirements + Breakout Session**

**12:15 - 1:15 Lunch**

**1:15 - 2:15 Session 11: Implementation Process + Breakout Session**

**2:15 - 2:30 Break**

**2:30 - 3:00 Session 12: Technology Specific Considerations**

**3:00 - 3:30 Session 13: Tariff & Regulatory Approval**

**3:30 – 4:00 Review bike rack**

**4:00 - 4:15 Close Out**

# Ground Rules



## Be present

- Refrain from using laptops, phones, tablets during activities

## Consider new possibilities

- Park assumptions and engage constructively

## Take space, make space

## Keep confidences

- Modified Chatham house rules: you can say what was said, who was here, but not who said what

## “Bike Rack”



Place to identify topics we want to discuss that are not necessarily in scope for our numbered session

We will plan to cover bike rack topics at the end of day 2

# Panel Discussion

## Check In



In small groups of 6, introduce yourselves.

Each person please share your name, organization and respond to the following prompt:

***What are you hoping to walk away with after this workshop?***

# Session 1: Flexible Interconnection Overview and Existing Offerings

# Definition & Objectives (DERs)



## Definition:

- ▶ Flexible interconnection is the ability to leverage several different DER control approaches to more quickly and/or cost-effectively connect some or all the desired DER capacity that would otherwise not be able to connect under a traditional firm interconnection provided these connections remain with the physical and operational limits of the distribution system.
- ▶ Flexible interconnection would be applicable to a broad set of DERs (i.e solar, solar + storage and standalone storage) and includes DER control approaches that range from static controls to time-based dynamic controls to adjust generation output based on pre-determined schedules or real time conditions.

## Objectives:

Flexible interconnection can achieve several objectives depending on the specific approach and use case:

- ▶ Reducing timeframes to connect some or all of capacity
- ▶ Avoid or delay/defer significant distribution system upgrades otherwise required to safely connect
- ▶ Maximize DER penetration and system utilization on existing infrastructure and/or future upgrades

# Flex IX Options



Flex IX Approach	Description	Example (5 MW facility)
<b>Import/Export Limits</b>	DG facility agrees to temporary fixed limits while capacity is built or is permanently de-rated.	Developer exports 2MW today & additional 3MW when upgrades are complete
<b>Dispatch Limiting Schedule Connections</b>	DG facility connects full nameplate capacity but agrees to pre-defined schedules based on time of day, month, season	Developer can export 5MW throughout the year except in April-September (30% of full output) and May to August (0% of full output).
<b>Dynamic Connections</b>	<p>DG facility connects full nameplate capacity agrees to be curtailed entirely or partially at a given time, up to a certain percentage of annual kWh/MWh based on real-time or near real-time system needs</p> <p>Common technical capabilities to leverage resources for distribution grid services as part of Grid Compensation Fund. Flex IX + grid services could be bundled upfront*</p>	Developer agrees to be curtailed up to 5% of their annual MWh.

# Flex IX Scenarios: Permanent vs. Bridge to Wires

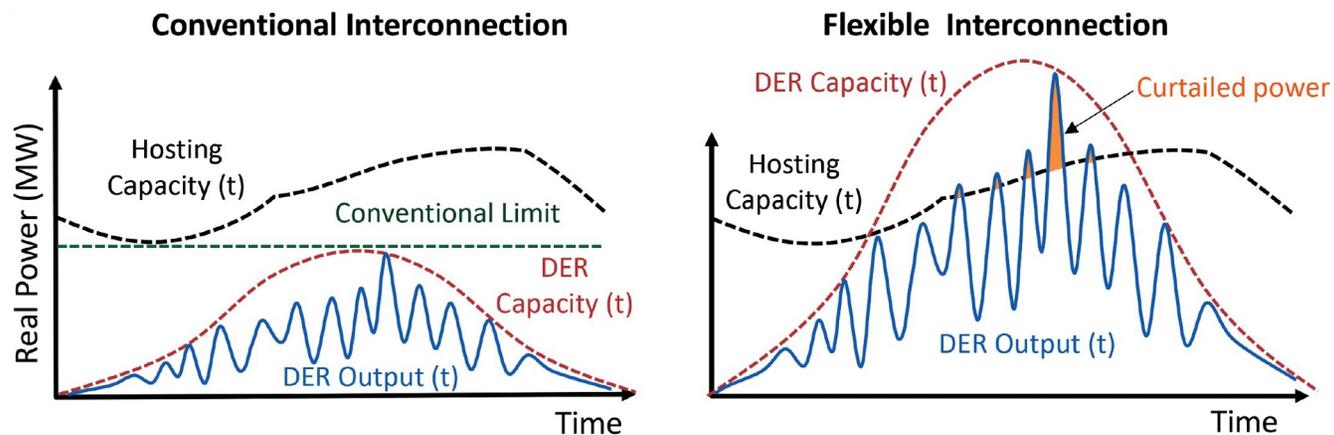


Flex IX Approach	Description	Permanent	Bridge to Wires
<b>Import/Export Limits</b>	DG facility agrees to temporary fixed limits while capacity is built	Applicable	Applicable
<b>Dispatch Limiting Schedule Connections</b>	DG facility connects full nameplate capacity but agrees to pre-defined schedules based on time of day, month, season	Applicable	Applicable
<b>Dynamic Connections</b>	DG facility connects full nameplate capacity agrees to be curtailed up to a certain percentage	Applicable (e.g accepts 5% curtailment risk)	Applicable for temporary high-level of curtailment (ex: 30% curtailment)  Applicable for facilities with lower curtailment (e.g 5%) but more unlikely to elect to pay for upgrades.

# Static vs. Dynamic Hosting Capacity



Type of HC Analysis	Static HC	Dynamic HC
Assumption	Assumes HC is the same over time (worst case scenario)	Assumes HC changes over time (true system conditions)
Impact on HC Output	Underestimates HC	More accurately reflects true HC which is greater than Static HC



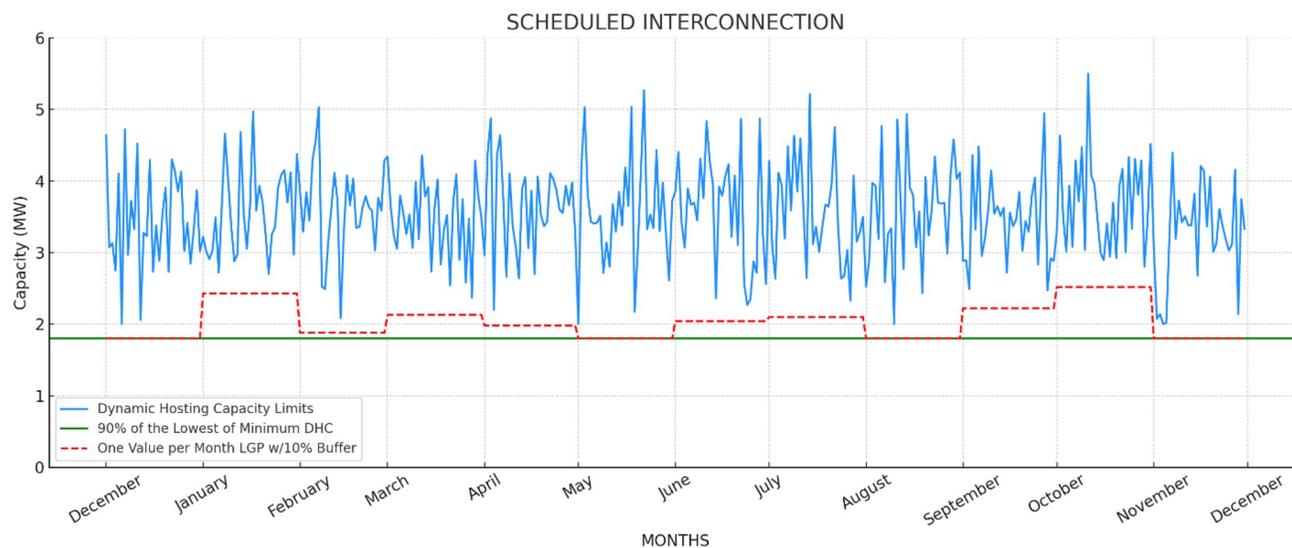
[Adopted from EPRI: Understanding Flexible Interconnection](#)

# Dispatch Limiting Scheduled Connections



Scheduled Connections are less complex but under utilizes system capacity

- **Analysis:** Relies on historical data to develop schedules and doesn't reflect real-time conditions
- **Risk management:** Buffers are usually added (e.g 10-20%) to historical dynamic hosting capacity to minimize risk that schedule deviates from real-time conditions
- **DER Control System:** DER operator owned power control system which is pre-programmed to schedule (set & forget) + utility side equipment (relay, gateway etc.)

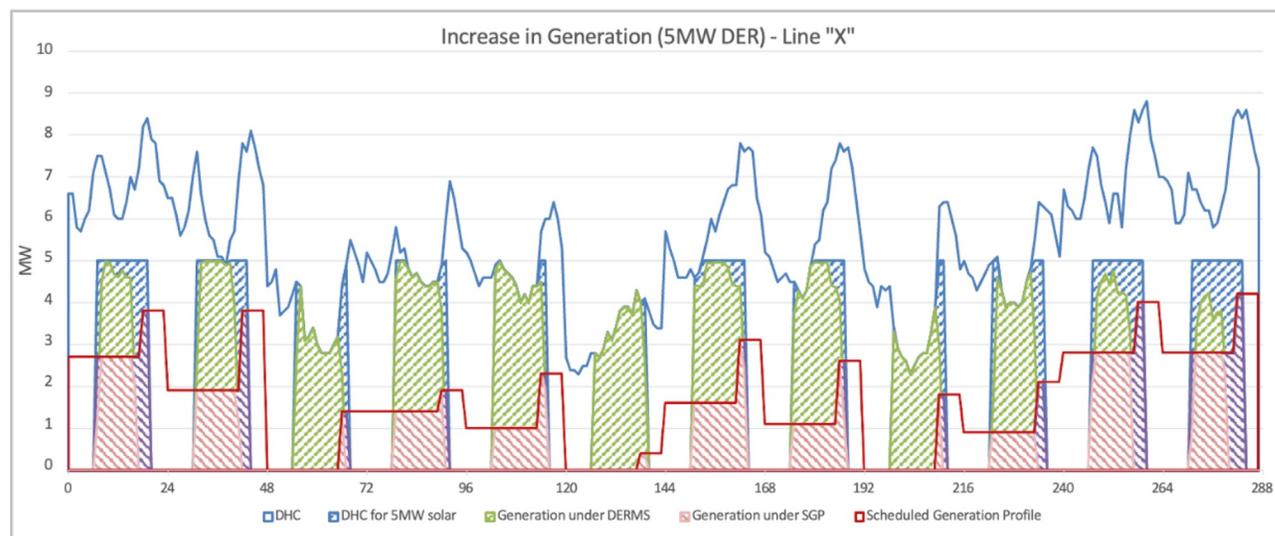


# Dynamic Connections



Dynamic Connections are more complex but maximizes system utilization

- **Analysis:** Relies on real-time or near-real-time monitoring and forecasting of dynamic hosting capacity
- **Risk management:** No buffer needed as curtailment is based on real-time dynamic hosting capacity
  - Schedules may also become stale after a certain period
- **DER Control System:** Utility operated Distributed Energy Resource Management System (DERMS) which directly integrates with and curtails DER facility



Source: [ComEd](#)

# Flex IX Approach Attributes



Flex IX Approach	Hosting Capacity & Study Analysis	DER Control Approach	DER Penetration & System Utilization	Complexity & Cost
Import/Export Limits	Static	Utility Or Facility owned Device at site	Low	Low
Operating Schedule Connections	Static	Utility Or Facility owned Device at site	Medium	Medium
Dynamic Connections	Dynamic	DERMS + Utility Or Facility owned Device at site	High	High (upfront)
Real-time	Dynamic Coordinated with ISO-NE market participation & distribution grid services*			
Day Ahead	Dynamic Coordinated with ISO-NE market participation & distribution grid services*			

# Workshop Focus & Prioritization



- ▶ **IIRG subgroup prioritized the development of a dynamic connection offering for several reasons:**
  - Greatest potential to maximize DER penetration and system utilization
  - Ongoing DERMS deployments by EDCs
  - Growing national precedent and lessons learned (Illinois, New York & United Kingdom)
    - ComEd commits to 240+ MW and has unlocked 52 MW at 2 substations
    - National Grid NY proposed up to 7 substations with 30-60MW per substation
- ▶ **IIRG subgroup will address both scenarios with an initial focus on the permanent scenario**
  - **Permanent:** Integrate additional DERs in constrained areas (e.g constrained stations, defer CIPs, fully subscribed CIPs etc.)
  - **Bridge to Wires:** Integrate additional DERs in constrained areas while waiting for upgrades (e.g individual projects w/ small upgrades, in-construction Capital Investment Proposals etc.)

# Workshop Assumptions & Structure



- ▶ **Financing and Regulatory/Tariff considerations are overarching topics**
  - Stakeholders should consider the impacts of these topics across each of the individual topic discussions
  - IIRG & CHARGED will consolidate these insights to inform dedicated sessions on Day 2 to holistically address each topic
- ▶ **Standalone storage has additional complexities to participate in Dynamic Flex IX vs. Solar & solar + storage**
  - Stakeholders should consider the impacts of standalone storage but work to align on solutions that address solar & solar + storage
  - IIRG & CHARGED will consolidate these insights to inform a dedicated session on Day 2 to holistically address standalone storage

**Questions?**

# Flex IX Options: EDC Availability



Flex IX Approach	National Grid	Eversource
<b>Import/Export Limits</b>	Permanent derating of DG facilities is a currently available option	Yes
<b>Dispatch Limiting Schedule Connections</b>	Dispatch Limiting Schedules is a currently available option for ESS facilities	Yes, enabled by DER Gateway (new technologies under assessment to optimize cost effectiveness)
<b>Dynamic Connections</b>	Available as a pilot opportunity, requiring DERMS platform integration for scalable offering	Prerequisite DER Gateway, ADMS & DERMS in service <ul style="list-style-type: none"><li>• Repowering opportunities</li><li>• Grid services</li></ul>

**Questions?**

# Current Offerings Discussion

Please use the stickies at your table to respond to the following:

*What are challenges with current programs that you hope to see addressed in future offerings? (Write on **pink** sticky color)*

*What is working well with current programs that you hope to see implemented in future offerings? (Write on **green** sticky color)*

**Break**  
**Please return at**  
**11:00 AM**

## Session 2: State of Play

# Financing Discussion

What are the most important considerations for industry in the financing process?

What needs to be true for industry to consider pursuing dynamic flexible interconnection?

# Group Discussion

# **Session 3: Curtailment Overview, % & Allocation Methodology**

# A Complementary Approach: Flex IX



Strategy Overview

Flexible interconnection through DERMS can enable DER integration with minimal curtailment and reduce the need for immediate capital investment.



	Tool	What It Does
	<b>Managed DER Curtailment</b> Primary Mitigation	Temporarily reduce DER output during the few hours when grid limits are hit.
	<b>Battery Energy Storage Dispatch</b> Load Shifting	Absorb excess generation and shift it to hours when the grid can handle it.
	<b>Inverter-Based Reactive Power Support</b> Voltage Management	Use smart inverters to manage voltage without new equipment.
	<b>Strategic Outcome</b>	These strategies allow utilities to accommodate <b>higher DER penetration</b> within existing infrastructure. The trade-off is a modest, well-characterized reduction in annual energy production during the relatively small number of hours when constraints are binding.

# Why Curtailment Can Be Orders of Magnitude Cheaper



 Cost Efficiency

## The Economic Analysis

### Limited Temporal Exposure

Distribution systems are typically thermally constrained for only a **limited number of hours per year**.

### Asymmetric Costs

The cost of curtailing a small percentage of annual DER energy may be **orders of magnitude lower** than upgrading infrastructure to eliminate the constraint entirely.

### Core Insight

Assume a transformer overloaded for 200 hours/year (2.3% of time). Compare: Curtailing output during those hours costs thousands; replacing the transformer costs millions.

## What Analysis Quantifies

### Curtailment Analysis Makes Visible:

 **Spatial & Temporal Distribution**  
Where and when constraint violations occur

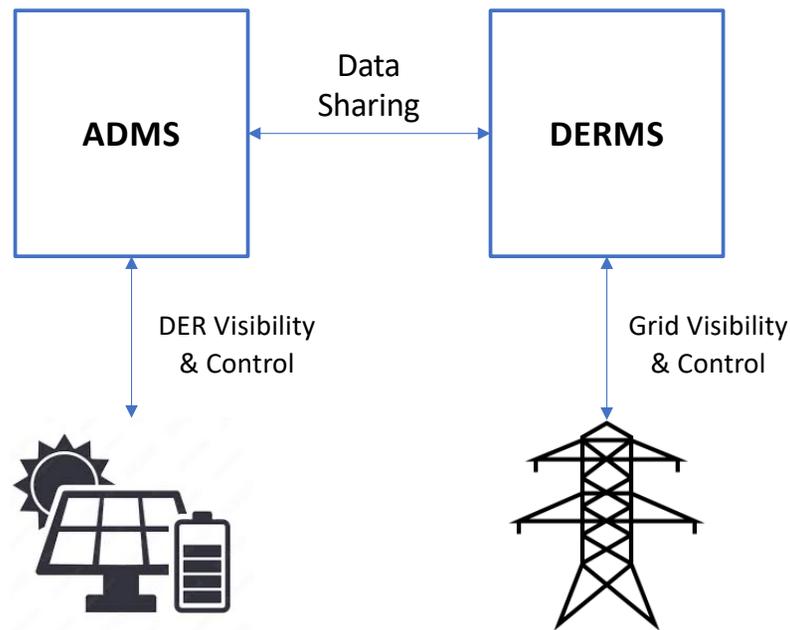
 **Energy Volumes at Risk**  
Total MWh potentially lost to curtailment

 **Flexibility Potential**  
Degree to which measures (e.g., storage) reduce upgrades

### Benefit-Cost Comparison

**\$\$\$** Capital Upgrade >> **\$** Operational Fix

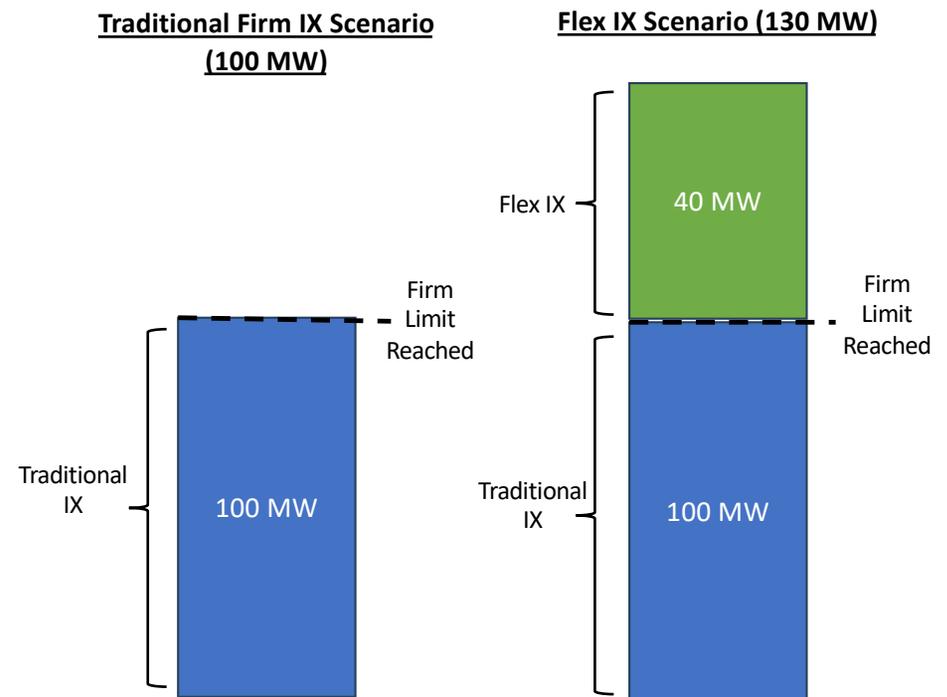
## DERMS enabled real-time curtailment of DERs



- Advanced Distribution Management System (ADMS) monitors and controls grid infrastructure
- DERMS integrates with both the ADMS and individual DERs
- DERMS will leverage data from both the ADMS and individual DERs to model and identify grid constraints and send dispatch signals to curtail DERs in real-time during periods of ***thermal constraints***
  - Address DERMS voltage use case

## Curtailment in Practice

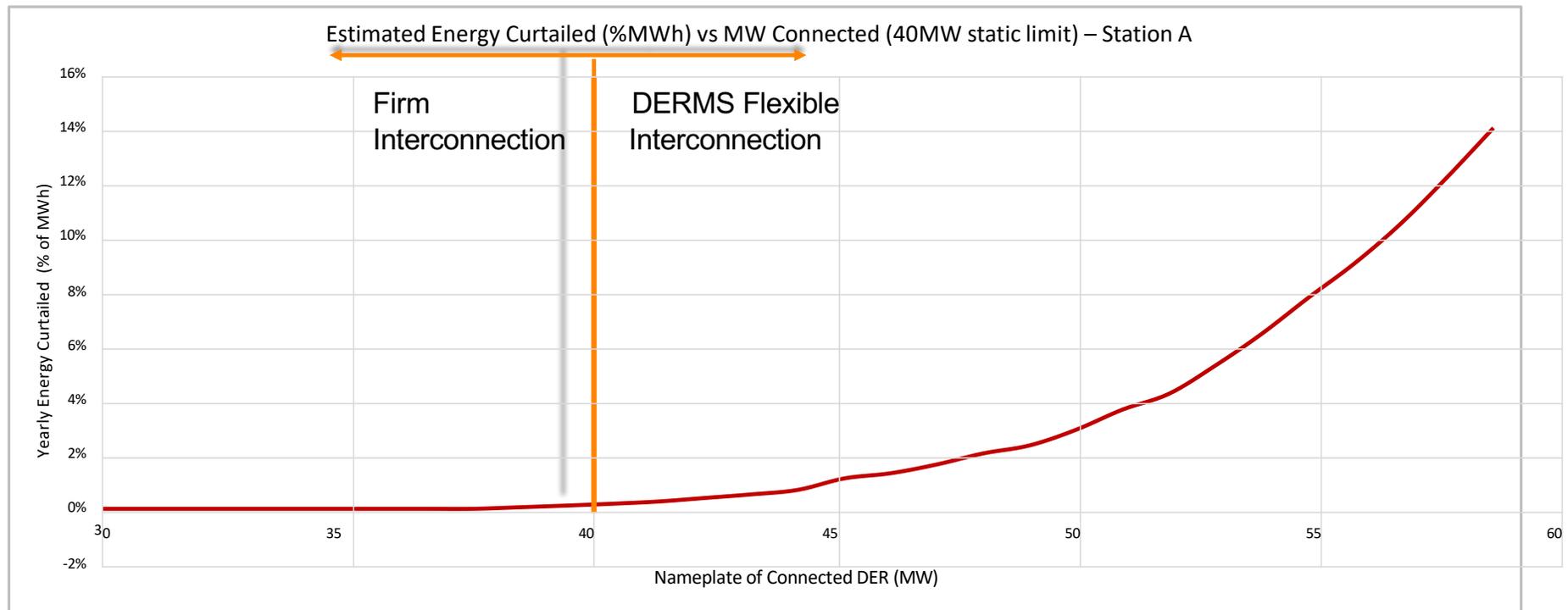
- Under Dynamic Flex IX, an individual DER facility can interconnect its full nameplate capacity provided they are willing to curtail their system a limited percentage of their **annual megawatt-hours (“MWh”)**
  - For example, a 5 MW DER facility may agree to be curtailed up to 5 percent of their annual MWh.
- This requires an **involuntary reduction** in DER active power output required to maintain distribution equipment within operational limits.
- Depending on the specific location and parameters of the grid, a utility may be able to connect multiple facilities under dynamic flex IX at a given location
  - Provided the level of curtailment is economically viable



# Curtailment % in relation to DERs Connected

% MWh curtailment increases with increase in DER penetration

Establishment maximum annual curtailment % that is economically viable for industry is critical to success

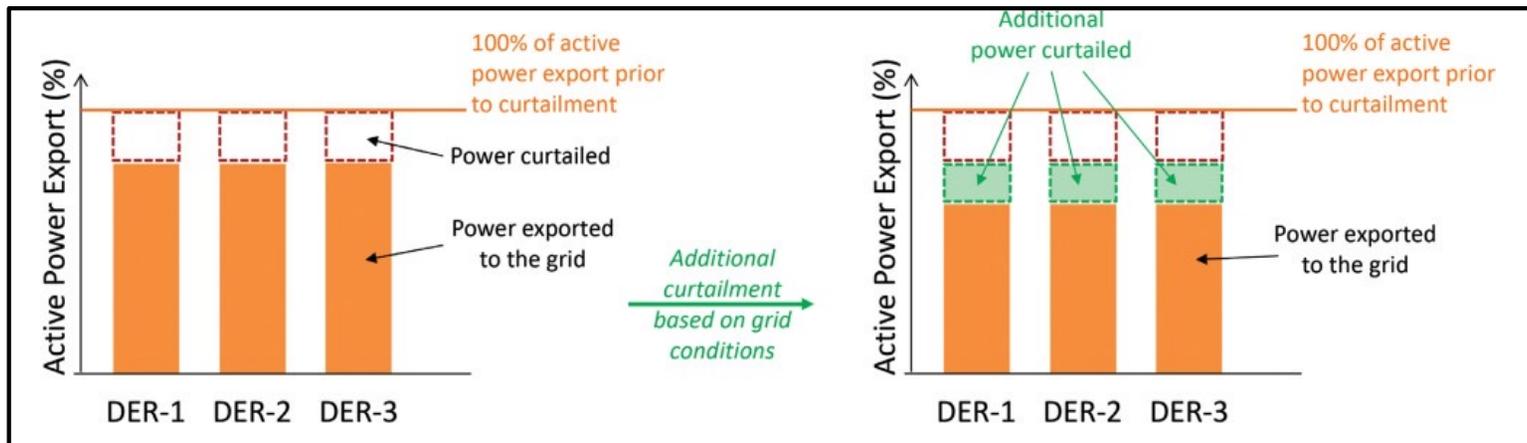


## Curtailment Allocation Methodology

- The curtailment allocation methodology determines **how much each facility is curtailed and in what order**
  - There are generally two methodologies under consideration to implement a dynamic connection offering:
    - **Last in First Out (LIFO)**
    - **Pro-rata**
-

## Last in First Out (LIFO)

- **Curtailment Logic:** DER facilities are individually curtailed based on the order in which they interconnect



### Pros

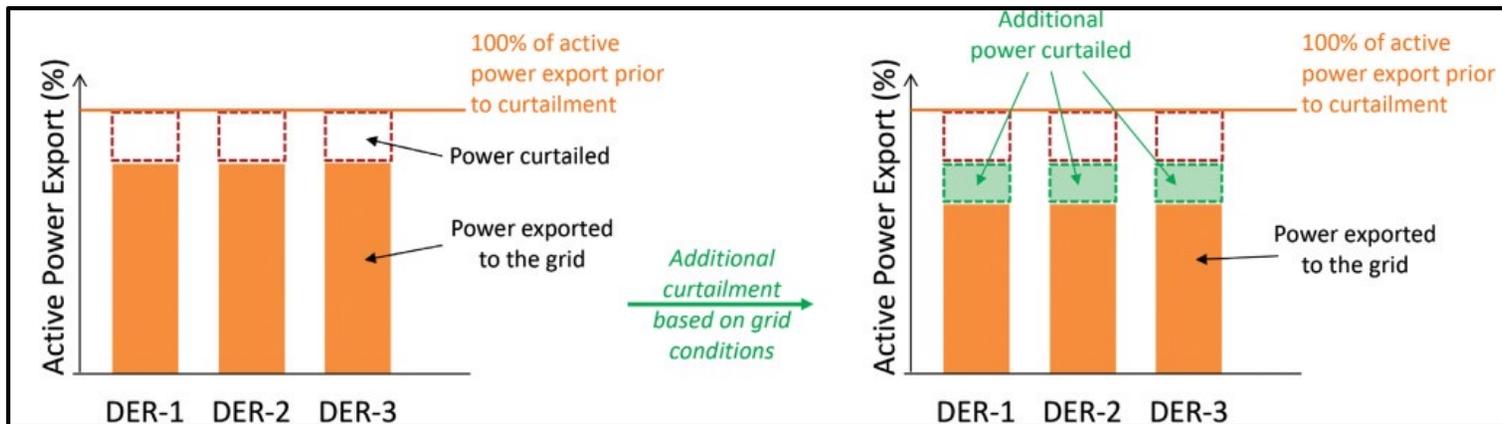
- Encourages more participation since no individual DER is disproportionately affected
- Unlocks the most capacity and allows for most efficient use of grid assets

### Cons

- Curtailment risk/uncertainty is significant because the curtailment can increase as more flexible capacity is added
- Can be more difficult to trace curtailment than LIFO but still a demonstrated approach

# Pro-rata

- **Curtailment Logic:** DER facilities are curtailed equally as part of a group



## Pros

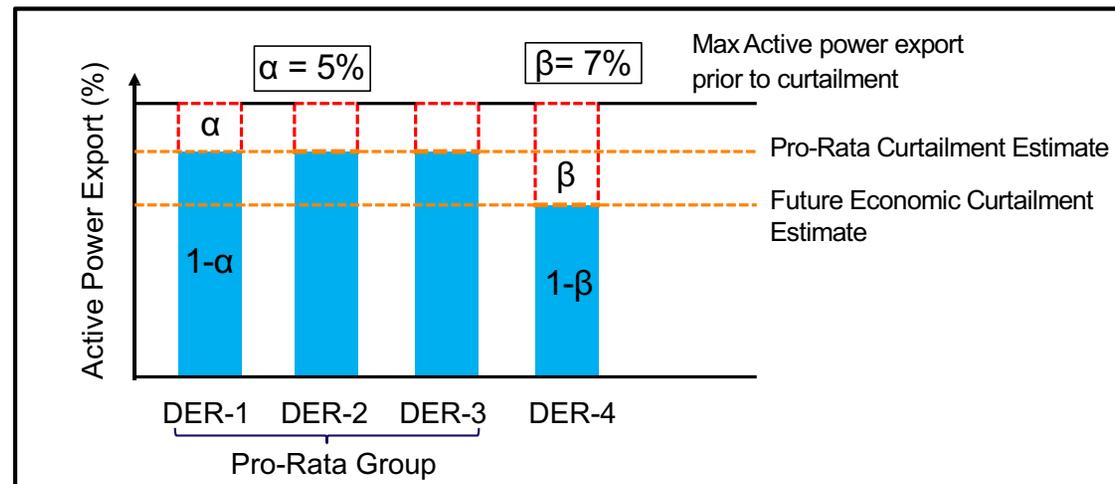
- Encourages more participation since no individual DER is disproportionately affected
- Enables the most additional DERs and allows for most efficient use of grid assets

## Cons

- Curtailment risk/uncertainty is significant if pro-rata group is not capped because the curtailment can increase as more flexible capacity is added
- Can be more difficult to trace curtailment compared to LIFO

## Scenario 1: Hybrid (Pro-rata + LIFO)

- **Curtailment Logic:** DER facilities are first curtailed equally as part of a capped pro-rata group and then subsequent facilities will be curtailed under LIFO.



### Pros

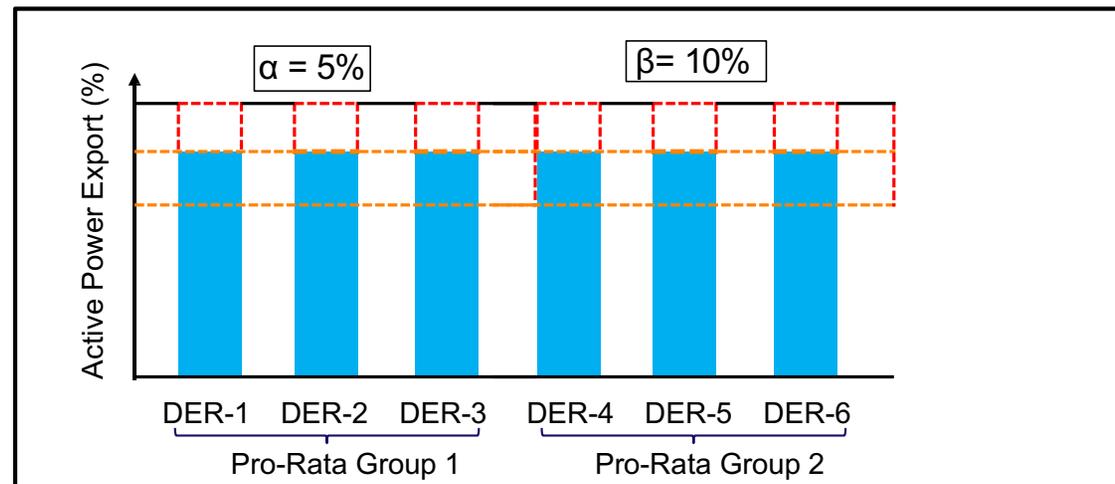
- Encourages more participation since no individual DER is disproportionately affected & provides certainty by capping the pro-rata group
- Enables individual DERs with higher curtailment tolerance to interconnect beyond pro-rata group

### Cons

- LIFO may limit the amount of additional DERs with a higher curtailment tolerance from interconnecting

## Scenario 2: Pro-rata Buckets

- **Curtailment Logic:** DER facilities are curtailed equally as part of multiple, capped pro-rata groups



### Pros

- Enables more DERs to interconnect after the first pro-rata group provided its economically feasible

### Cons

- Subsequent pro rata buckets curtailment limit may be too high preventing any DERs from connecting
-

**Questions?**

**Lunch**  
**Please return at**  
**1:00 PM**

# Session 4: Breakout on Curtailment % and Allocation Methodology

# Breakout Group Assignments



Table 1	Table 2	Table 3	Table 4	Table 5
Daniel Passarello	Kevin Dunn	Elio Torres	Joshua Briggs	Nachum Sadan
Kavita Ravi	Silas Bauer	Sean Burke	Ed Brolin	Pauravi
Chris Modlish	Samantha Meserve	Gerry Bingham	Carson Bullock	Courtney Feeley Karp
Melissa Liazos	William Kern	Michael Porcaro	Andrew Schneller	Josh Tom
Daniel Yung	Nick Watson	Paul Krell	Emily Slack	Kevin Reardon
Syed Ali	Naera Hagnazarian	Juan Martinez	Muhammad Khan	Farzam Nejabatkhah
Daniel McDonough		Annemarie Belle (Observer)		Vlad Zaiets (Observer)

Table 6	Table 7	Table 8	Table 9
Haskell Werlin	Shikhar	Dexter Hendricks	Ryan McGlothlin
Emma Hillman	Kate Tome	Ami Vyas	Christian Bilcheck
Rachele Marshall	Kayla Burns	Nikhil	Julia Fox
Randy Armstrong	Nancy Israel	Laura Townsend	Claudia Rosen
John Bonazoli	Manuel Saadallah	Cole Wheeler	Arnaldo Arnal
Jill Duplessis	Gerhard Walker	Michael Taniwha	Zach Tedford
	Robert Fitzpatrick (Observer)	Michael Hershberg	Justin Woodard

# Curtailment Allocation Discussion

In your breakout group, please review the worksheets you have been given and fill them out as a group. After filling them out, discuss the following:

- 1. What is the max curtailment target that is financially viable for industry? 2.5%, 5%, 10%, 20%, 40%? Does this vary for solar vs. solar + storage?*
- 2. What are the key attributes stakeholders should consider when selecting a curtailment allocation methodology? (predictable, equitable, ease of implementation etc.)*
- 3. How does each methodology compare in regards to each of these attributes?*
- 4. What are the pros and cons of each methodology for individual developers vs developers as a whole?*
- 5. What additional questions are necessary to answer before an allocation methodology is chosen?*

# **Session 5: Curtailment Study Methodology & Template**



Section 02 ●

# Analytical Foundation

Inputs, constraint locations, and the overall data-to-analysis workflow.



Scope



Analysis

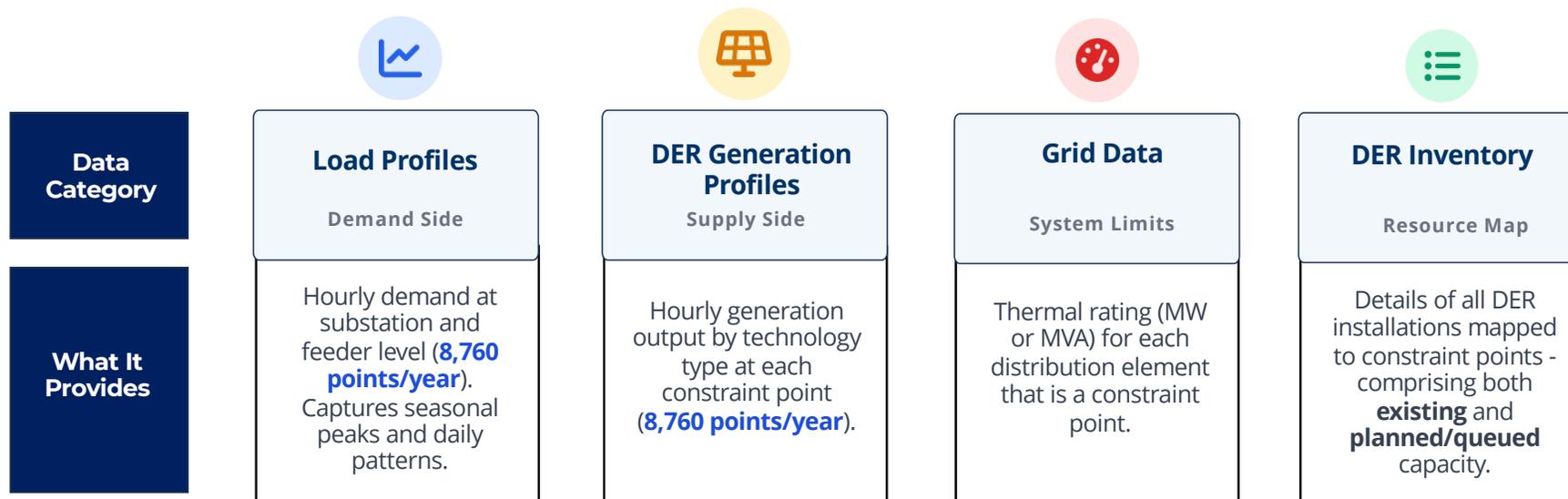


Logic

# Four Categories of Input Data



The curtailment methodology requires **four distinct categories of data** to accurately model system conditions and identify potential constraints.



**Data Source :** Where utility-metered operational data is available, it should be used directly. In the absence of operational data, representative synthetic profiles based on regional characteristics may be substituted.

# Load Profiles: What the Grid "Sees"



## 8,760 Hourly Data Points

Full-year hourly demand data required at both substation and individual feeder levels to capture all operating conditions.

## Temporal Variation Capture

Profiles must reflect seasonal peaks (summer A/C, winter heating) and daily usage patterns (morning ramp, evening peak).

## Forward-Looking Trends

Adjustments for expected load growth and electrification impacts (EVs, heat pumps) over the planning horizon.

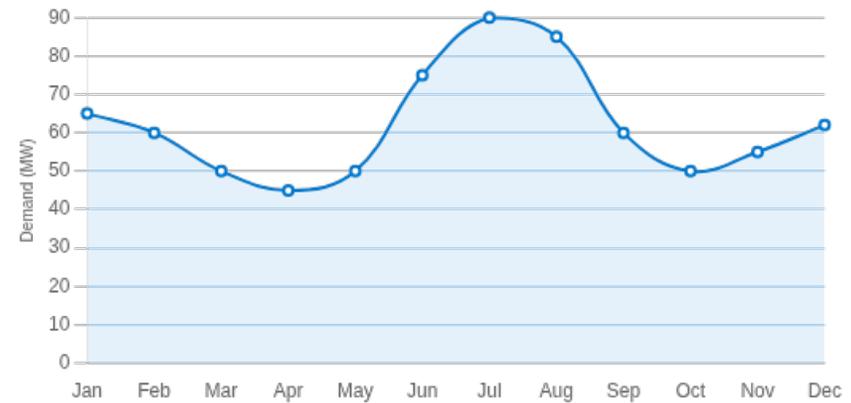
### Data Sources Hierarchy:

**Preferred:** Utility SCADA / Metered Data

**Fallback:** Representative Synthetic Profiles

## Sample Annual Load Profile Concept

8,760 Hours



### Summer Peak

High A/C load, often coincident with solar.



### Winter Peak

Heating load, early evening constraints.



### Daily Patterns

Morning ramp-up & evening residential peaks.



### Feeder Specifics

Unique mix of residential vs. commercial.

# DER Generation & Equipment Data



## Solar PV Adjustments

Irradiance data is refined to account for panel orientation, inverter efficiency curves, and clipping losses.

### Existing Capacity

Currently interconnected resources

### Incremental Capacity

Planned/queued projects

## Ratings & Inventory

### Equipment Ratings

#### Substation Transformers

#### Feeder Conductors

*Defines thermal capacity limits*

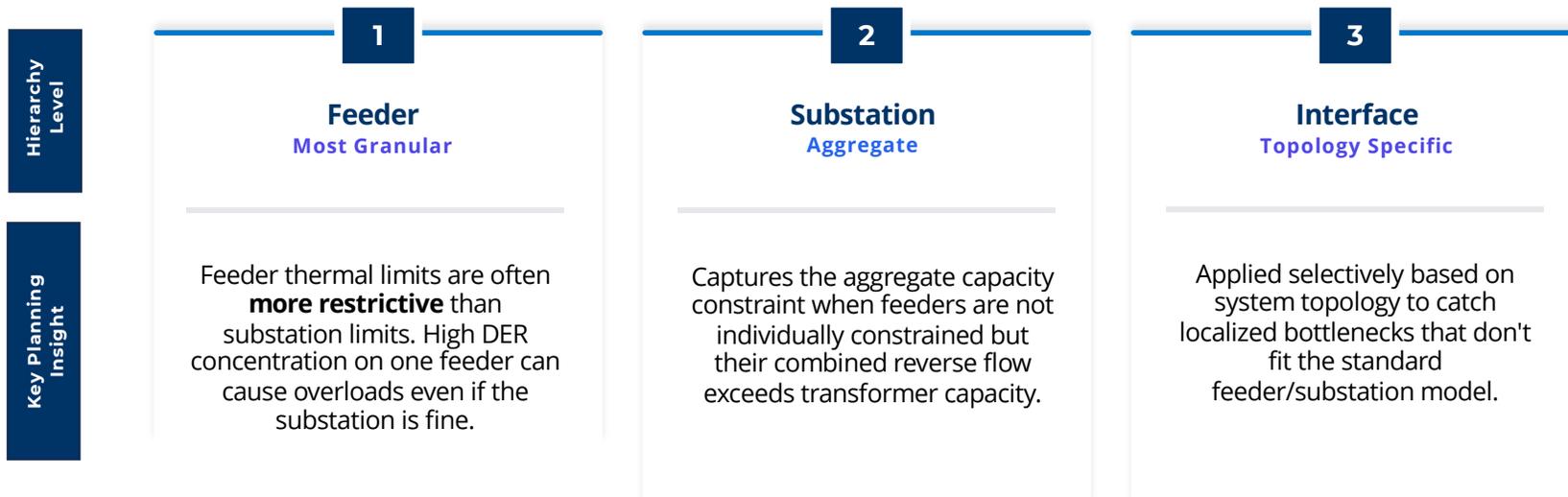
## Total Generation Exposure

**Existing** + Queued = Curtailment Risk Baseline

# Constraint Points?



Curtailment is evaluated at **three hierarchical levels**, applied sequentially from the most granular (feeder) to the most aggregated (substation) to ensure the true binding constraint is identified.



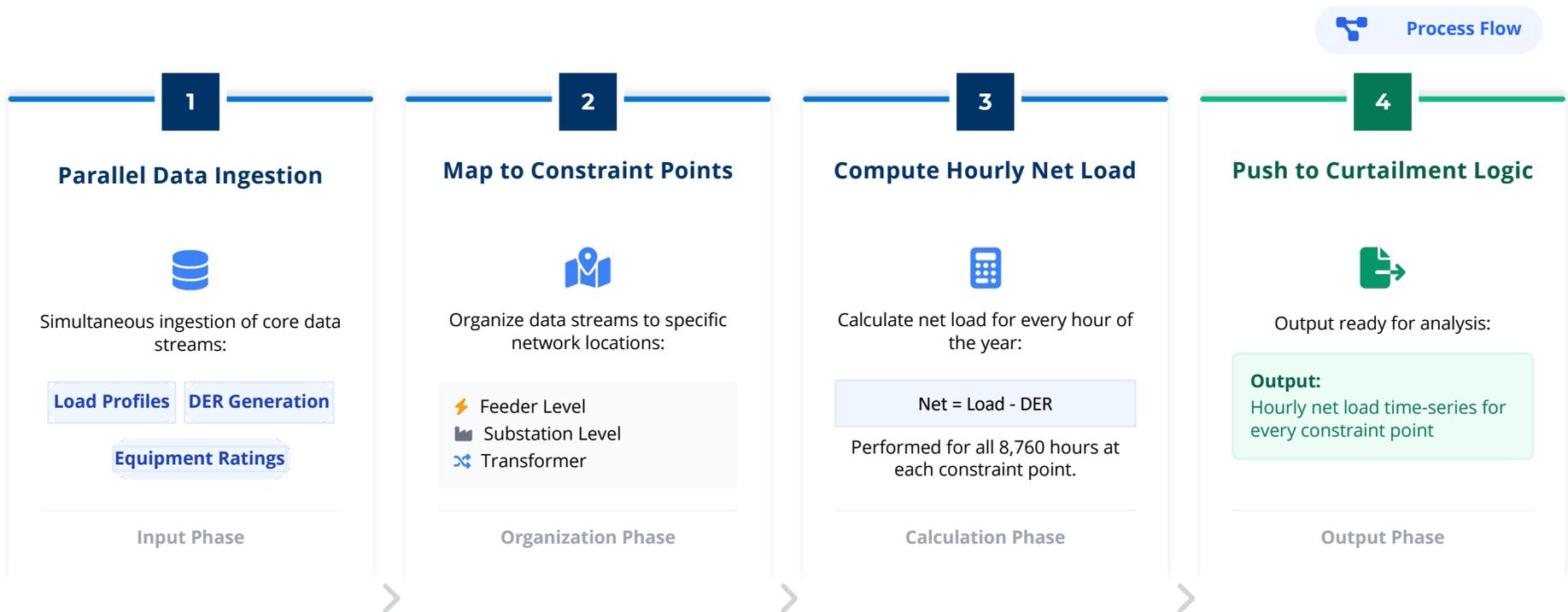
## Crucial Planning Logic: Feeder-First Evaluation

This one-directional pipeline ensures data is fully prepared before any curtailment calculations begin. The parallel ingestion minimizes processing bottlenecks, while the hierarchical mapping ensures no constraint point is overlooked.

# Data Ingestion & Constraint Mapping Workflow



 Process Flow





Section 03 ●

# Curtailment Logic

Algorithm and how thermal constraints differ from voltage considerations.



Scope



Analysis



Logic

# Curtailement Logic: Central Rule & Method

Algorithm



## The Central Rule

"If reverse power flow at any constraint point exceeds the thermal rating during any hour, DER output must be curtailed just enough to bring flow within limits."

## The Four-Step Calculation Method

### Step 1: Reverse Power Flow

Determine Excess

$$P_{\text{reverse } i(t)} = \max(0, P_{\text{DER } i(t)} - P_{\text{load } i(t)})$$

Calculates net backfeed for each constraint  $i$  and each hour  $t$ . Minimum value is zero.

### Step 2: Curtailment Trigger

Decision Point

IF  $P_{\text{reverse } i(t)} > \text{Rating}_i \Rightarrow \text{CURTAILMENT REQUIRED}$

Check against equipment thermal rating (MW/MVA).

### Step 3: Hourly Volume

Calculate Reduction

$$C_{i(t)} = P_{\text{reverse } i(t)} - \text{Rating}_i, \text{ when } P_{\text{reverse } i(t)} > \text{Rating}_i$$

$$C_{i(t)} = 0, \text{ otherwise}$$

Only trim the excess amount needed to restore safety.

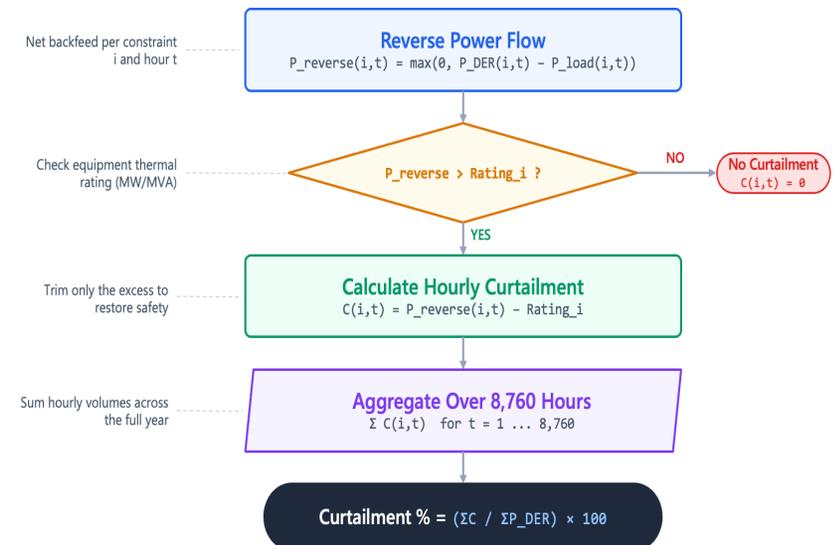
### Step 4: Compute Annual Curtailment Metrics

Aggregation

$$\text{Curtailment \%} = (\Sigma C_{i(t)} / \Sigma P_{\text{DER}}(t)) \times 100$$

Sum hourly volumes across full year (8,760 hours).

## Flow Chart



# Thermal vs. Voltage Constraints



The framework focuses exclusively on **thermal constraints** because they are structural limits requiring expensive upgrades or curtailment. **Voltage issues** are real but can typically be resolved through low-cost operational measures without new infrastructure.

[Constraint Comparison](#)

## Operational Tools That Resolve Voltage (Low Cost / Near Term)



### Volt/VAR Optimization (VVO)

Coordinated regulation via caps, regulators, LTCs



### LTC Re-coordination

Update setpoints for bidirectional flow



### Smart Inverter Support

IEEE 1547-2018 volt-watt/volt-VAR modes

## Constraint Comparison Snapshot

Attribute	Thermal Constraints	Voltage Constraints
Nature of Problem	Equipment (conductors, transformers) carrying current beyond rated capacity	Voltage at points on the feeder rising above or falling below acceptable limits
Primary Trigger	Reverse power flow > equipment rating	High DER output on lightly loaded feeders; reactive power imbalances
Operational Fix?	Requires curtailment/storage or physical upgrade	VVO, LTC re-coordination, smart inverters
Cost & Timeframe	<b>High Cost / Long Lead Time</b> Months to years for infrastructure upgrades	<b>Low Cost / Short Term</b> Weeks to months for operational measures
Curtailment Trigger?	YES	NO

**Questions?**



Section 04 ●

# Scenario Analysis

Scope: Compare substation-only vs feeder+substation screening and evaluate battery storage as a flexibility resource.



Scope



Analysis



Logic



Scenarios



Context



Framework



Limits

# Scenario 1 vs. Scenario 2: Granularity as needed



Granularity Impact

Comparing the traditional aggregate approach against granular feeder-level analysis reveals why localized constraints are often masked in planning studies.

 Scenario 1: Substation-Only	 Scenario 2: Feeder + Substation
<b>Evaluation Scope</b> Substation transformer level only	<b>Evaluation Scope</b> Feeder-level first, then substation level
<b>Treatment of DER/Load</b> All feeder loads and generation aggregated into a single net flow	<b>Treatment of DER/Load</b> Each feeder evaluated individually; passing feeders then aggregated at substation
<b>What It Catches</b> <input checked="" type="checkbox"/> Aggregate capacity constraint at the substation interface	<b>What It Catches</b> <input checked="" type="checkbox"/> Both feeder-level bottlenecks AND substation-level constraints
<b>What It Misses</b> <input checked="" type="checkbox"/> Feeder-level constraints, may incorrectly conclude DER can be accommodated when specific feeders are already at thermal limits	<b>What It Misses</b> <input checked="" type="checkbox"/> Nothing, the most binding constraint is always identified
<b>Curtailment Result</b> Generally lower for specific feeders (localized stress is masked by aggregation)	<b>Curtailment Result</b> Higher curtailment % on constrained feeders, even when system-level aggregates appear comparable

## Critical Planning Implication

When curtailment is driven by feeder-level constraints, the response must be at the feeder level. **Upgrading the substation transformer will not relieve a thermally constrained feeder.** Deploying feeder-level flexibility (co-located battery, managed curtailment) can potentially resolve the bottleneck without expensive substation investment.

# Battery Storage as a Flexibility Resource



Storage Sensitivity

## Case Comparison

### Base Case

No Storage

#### Full Curtailment Exposure

All reverse flow exceeding equipment rating must be curtailed. This is the infrastructure upgrade trigger under traditional planning.



### Storage Sensitivity

4-hr Battery

#### Co-located at Constraint Point

Reduced curtailment energy and hours. Batteries absorb excess DER generation at midday and discharge during evening peak load.

## How Batteries Reduce Curtailment



### Load Shifting

Absorb excess solar during peak output (midday) and discharge during peak load (late afternoon/evening).



### Peak Reduction

Reduce both the **magnitude** and **duration** of reverse flow exceedances.



### Duration Match

4-hour duration selected to match MA SMART program incentive structures and prevailing commercial deployment profile.



### Key Insight

Instead of curtailing solar output or building a transformer, deploy a battery at the constrained feeder. It soaks up the midday excess and releases it in the evening when demand peaks.



Section 05 ●

# Curtailment Scenarios & Planning Context

How contingency planning apply to DER, and what risk tolerance should utilities adopt... These choices affect how much infrastructure is deemed necessary.



Scope



Analysis



Logic



Scenarios



Planning



Flexibility

# N-1 Contingency: The DER Challenge



## Traditional N-1

The loss of any single element (transformer, feeder) must not result in load curtailment or equipment overloading. Well-established for load-serving reliability.

## N-1 Applied to DER

If one element is lost, remaining infrastructure must absorb full DER output or curtailment is assumed. This **significantly reduces** computed hosting capacity.

## Key Planning Implications

### Conservative Estimates

Applying load-transfer timelines to fast-acting generation produces unnecessarily conservative hosting capacity estimates.

### Risk-Informed Standard

Relaxing N-1 for DER to a risk-informed standard would increase effective hosting capacity and reduce upgrades.

# Weighted Planning Criteria



The choice between planning criteria determines the baseline for infrastructure investment. A risk-informed approach accepts modest curtailment in exchange for higher hosting capacity.



Approach	Risk-Informed	Conservative
Description	Plan infrastructure for the <b>95th percentile</b> of expected operating conditions. Accept curtailment during the remaining 5% of hours (extreme/atypical conditions).	Full contingency compliance at <b>all operating hours</b> . System must accommodate DER output even with loss of one major element, with no reliance on real-time curtailment.
Planning Implication	Allows <b>higher DER penetration</b> with a small curtailment tail.  <b>Modest curtailment accepted in exchange for avoided/deferred investment.</b>	Lower hosting capacity estimates, higher projected curtailment %.  <b>Most conservative posture - may drive significant infrastructure investment.</b>

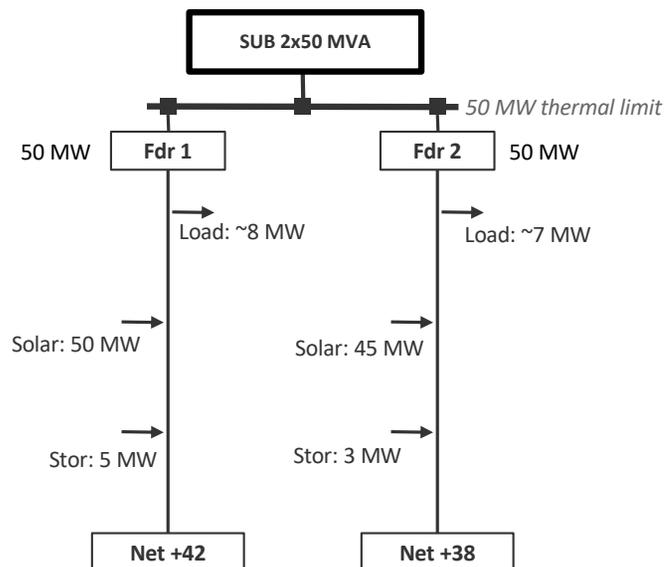
## This Study's Basis

The **N-1** context is provided for planning interpretation so stakeholders understand how stricter criteria would affect results.

# Curtailment Study Scenarios - 1



## Scenario A: 95 MW Solar



Solar: 95 MW | Coincident Load: ~15 MW

Solar: 95 MW | Coincident Load: ~15 MW  
Reverse Flow: ~80 MW typical / 89 MW max

### Base case -- current interconnection queue.

- Two feeders serve 33 MW peak load with 95 MW of solar DER and 8 MW storage.
- Solar peaks midday when load is only ~15 MW, creating up to 89 MW of reverse flow through the substation.

**N-0 (both transformers in service):** Substation limit is 100 MW. Peak reverse of 89 MW clears comfortably. No curtailment.

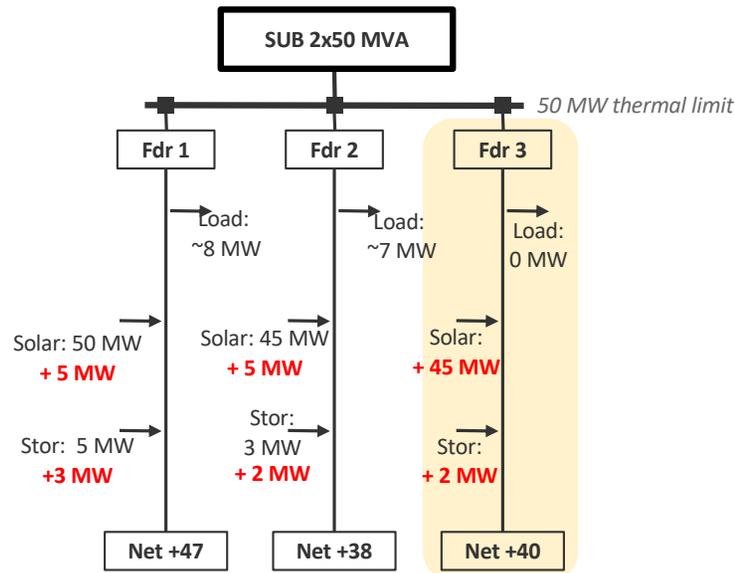
### • N-1 (single transformer out):

- Limit drops to 50 MW. Exceeded 520 hours/year,
- Feeder limits (50 MW each) are not violated.
- **The substation N-1 constraint is the only binding limit.**

# Curtailment Study Scenarios - 2



## Scenario B: 150 MW Solar (Incremental)



Solar: 150 MW | Coincident Load: ~15 MW  
Reverse Flow: ~135 MW typical / 142 MW max

**Incremental growth.** +5 MW solar and additional storage added to each existing feeder. A third feeder (F3) comes online with 45 MW solar - no local load to offset.

**N-0:** Reverse flow now reaches 142 MW, exceeding the 100 MW substation limit. Curtailment begins even with both transformers: 3,020 MWh (1.4%), 256 hours.

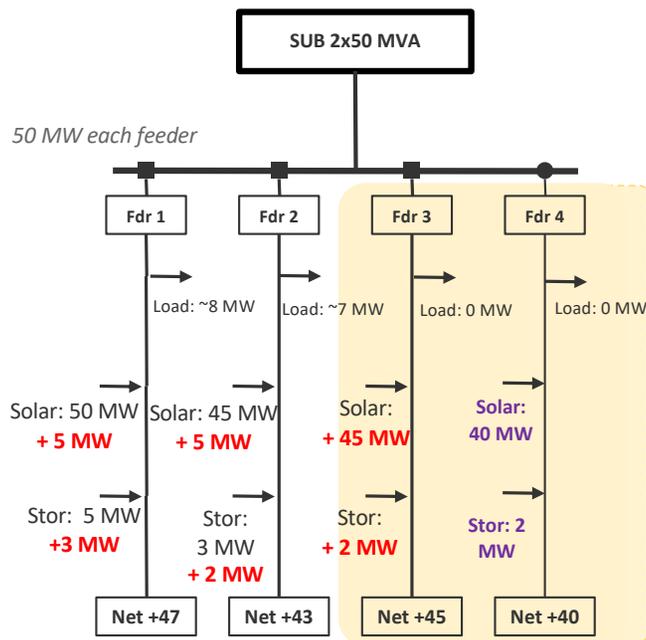
**N-1:** 19.6% of annual generation curtailed -42,674 MWh across 1,518 hours.

**Weighted (95% N-0, 5% N-1):** Expected curtailment is 2.3%.

# Curtailment Study Scenarios - 3



## Scenario C: 190 MW Solar (4 feeders)



**Solar: 190 MW | Coincident Load: ~15 MW**  
**Reverse Flow: ~175 MW typical / 182 MW max**

**Fourth feeder added.** Developer adds F4 at 40 MW, properly sized within the 50 MW feeder limit. Every feeder respects its thermal rating – no feeder violations across all 8,784 hours.

**N-0:** 6.2% curtailment (17,208 MWh). Even with full substation capacity, 702 hours/year exceed the 100 MW limit.

**N-1:** 30.0% of annual generation curtailed -- 82,677 MWh across 2,041 hours. Nearly a third of all solar production is wasted.

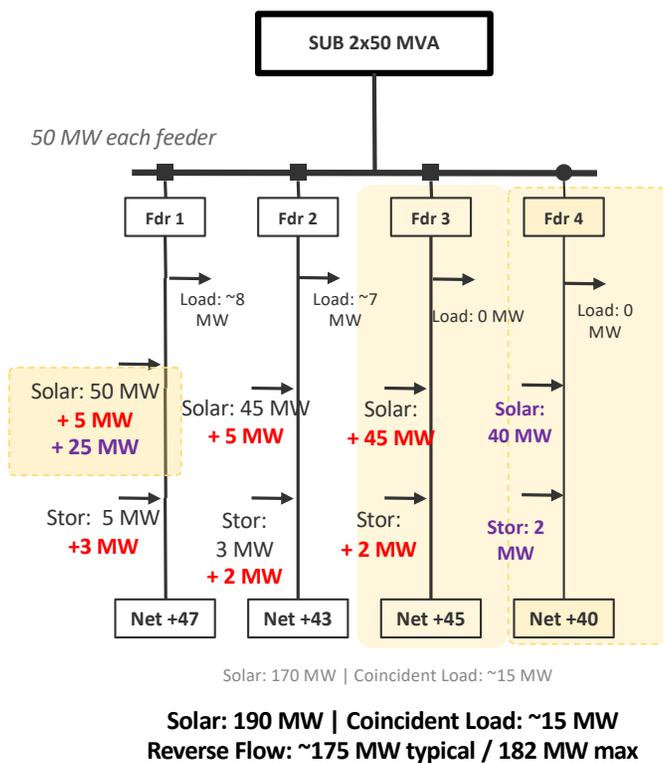
**Weighted (95:5):** 7.4% expected curtailment.

**The substation is the constraint - feeders are fine, but the bottleneck is entirely upstream.**

# Curtailment Study Scenarios - 4



## Scenario D: 190 MW Solar (4 feeders) + 25 MW on F1



**New interconnection request on existing feeder.** A developer proposes +25 MW on F1, pushing it to 80 MW nameplate on a 50 MW-rated feeder. This triggers cascading curtailment analysis: feeder first, then substation.

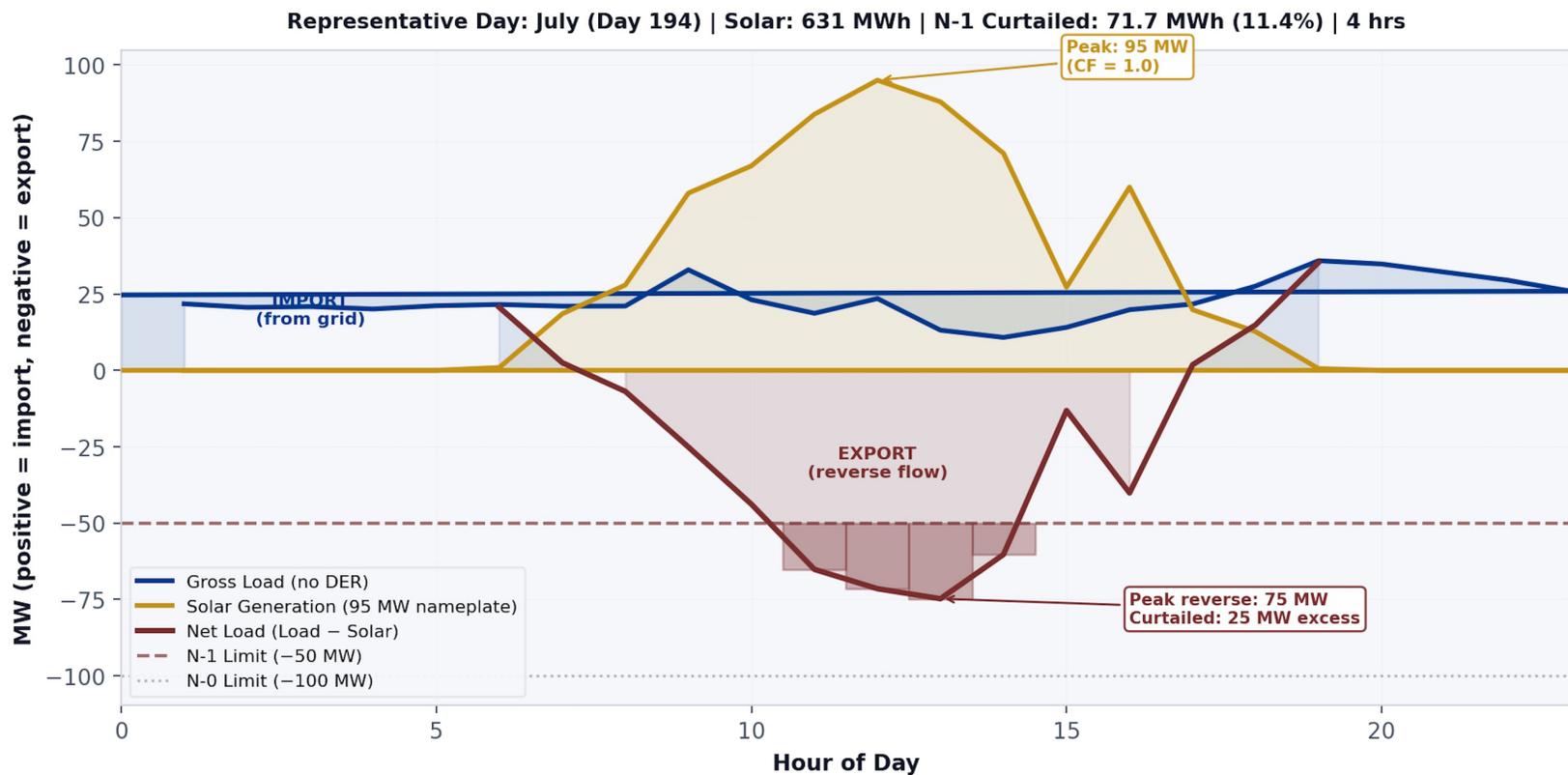
- **Step 1 - Feeder curtailment:** F1 reverse flow is clipped at 50 MW for 353 hours/year. 2,591 MWh lost at the feeder breaker before power even reaches the substation bus.
- **Step 2 - Substation curtailment:** The clipped profile still pushes 182 MW through a 100 MW (N-0) / 50 MW (N-1) substation. An additional 108,296 MWh curtailed at substation level under N-1.

**Key insight:** F1's developer faces curtailment at two levels - first clipped at the feeder, then proportionally curtailed again at the substation. *(Should do coordinated feeder + substation hosting capacity analysis)*

# Representative Day: Load, Solar, and Net Load



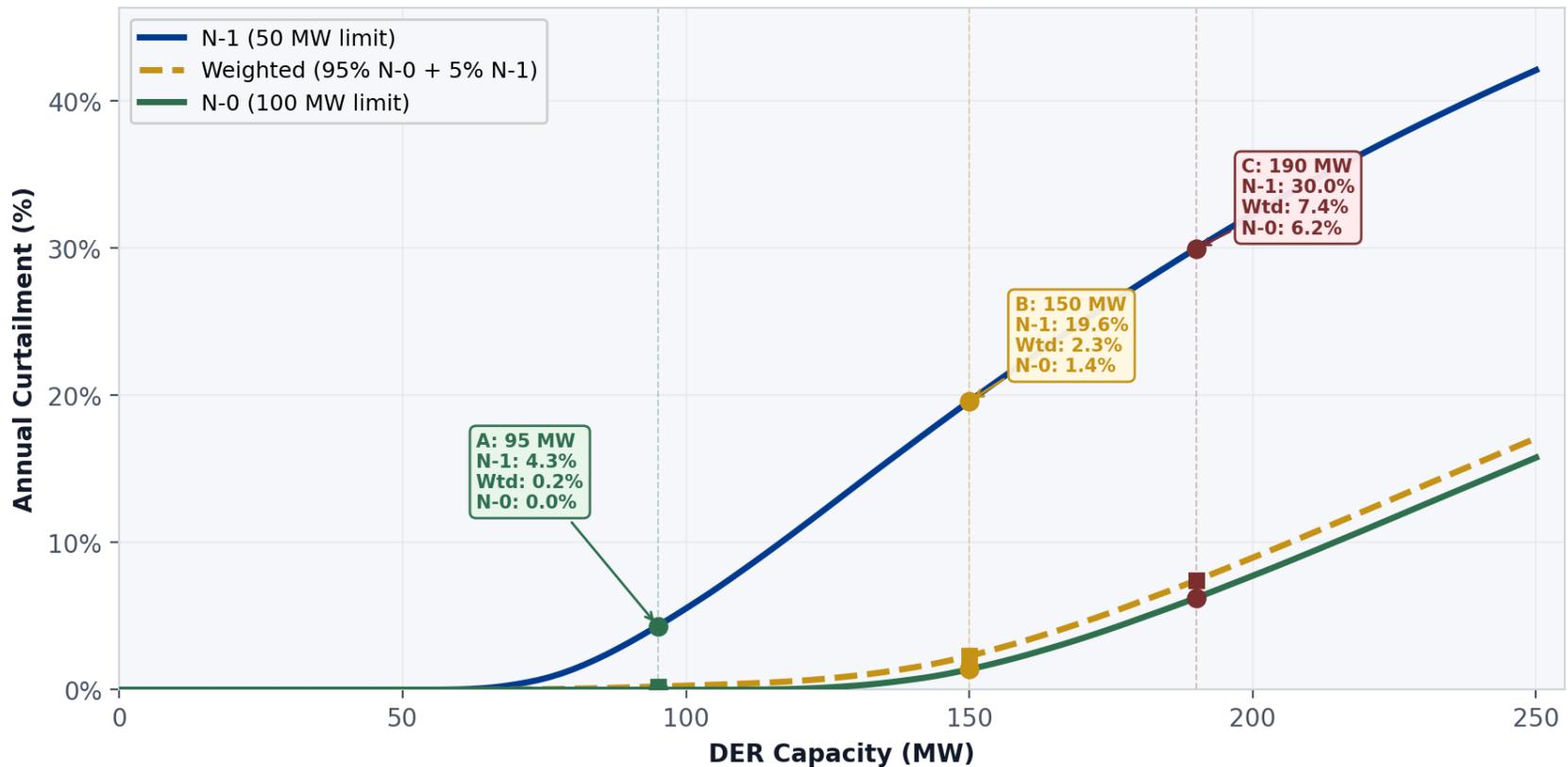
Peak solar day in July, Scenario A. Net load drops below -50 MW for 4 hours.



# Curtailment Curves: N-0 vs N-1 by DER Penetration



Three constraint regimes shown. The weighted (95:5) curve reflects expected curtailment under realistic contingency probability. At 190 MW, expected loss is 7.4%



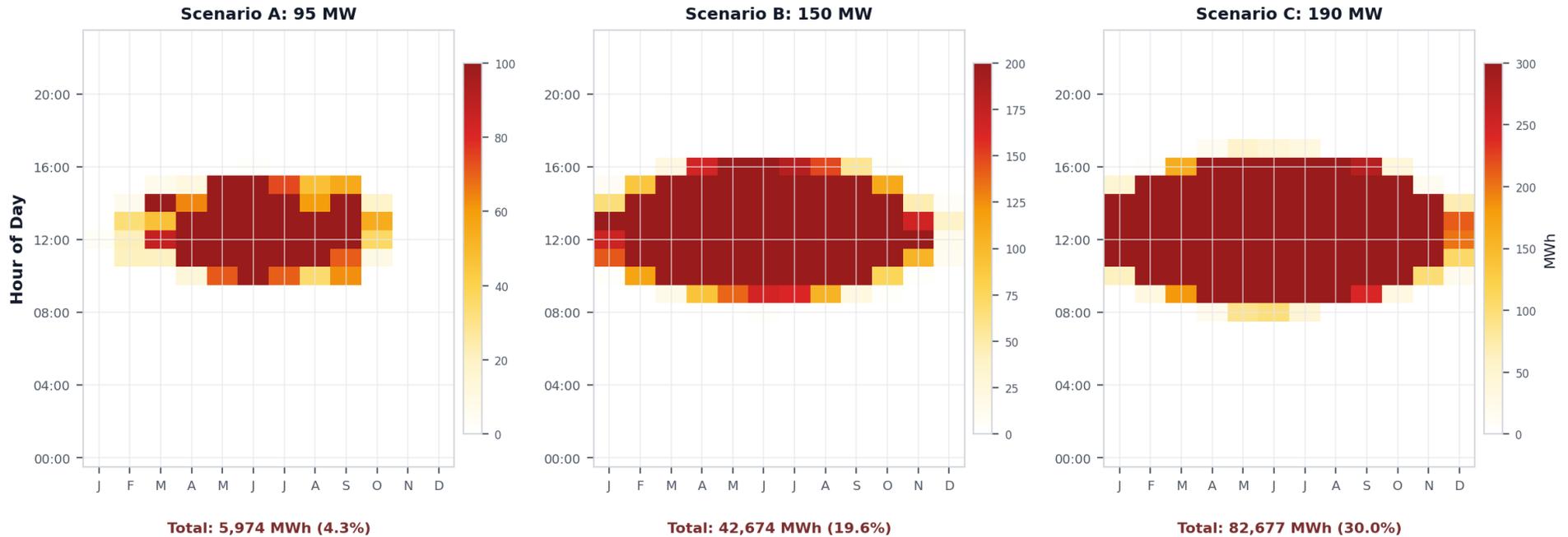
# N-1 Curtailment Heatmap by Scenario



Curtailment footprint expands from narrow midday band (A: 5,974 MWh) to near year-round 8am-5pm coverage (C: 82,677 MWh). The 14x increase from A to C shows curtailment scales nonlinearly - each incremental MW of solar faces steeper constraints.



**N-1 Curtailment Heatmap by Scenario (Hour x Month)**



# Five Strategic Considerations for Stakeholders



## 1 Prioritize Feeder-Level Visibility

Substation-level screening alone misses critical feeder-level bottlenecks. Utilities must incorporate feeder-level thermal evaluation as standard practice to avoid misdirecting flexibility investments.

## 4 Re-Examine N-1 Criteria for DER

Sub-second DER curtailment is fundamentally different from minutes-long load transfer. Identical contingency margins may be overly conservative and drive avoidable investment.

## 2 Distinguish Constraint Types

Don't bundle distinct constraints. Thermal issues are structural (requiring upgrades/curtailment), while voltage issues are often operational (resolvable via VVO, LTCs, smart inverters at a fraction of CIP cost).

## 5 Align Planning Proceedings

Integrate curtailment analysis into screening to identify where flexibility is more cost-effective than capital upgrades. Ensure flexibility options are evaluated on equal footing with traditional poles-and-wires solutions.

## 3 Value Storage Holistically

Benefit-cost frameworks for storage at constrained locations should explicitly account for the **avoided capital cost** of the infrastructure upgrade it displaces, not just energy arbitrage or capacity value.

### The Strategic Pivot



Move from "upgrade-by-default" to "quantify flexibility first." These considerations provide actionable guidance to align planning practices with state clean energy goals while minimizing ratepayer costs.

**Questions?**



Section 07 ●

# Key Assumptions and Limitations

Scope and modeling assumptions for this planning-grade screening framework.



Scope



Analysis



Logic



**Assumptions**

# Key Assumptions and Limitations



▲ Methodology Constraints

This framework is designed as a **planning-grade screening tool**. The following simplifications are appropriate for screening but should be refined in detailed engineering studies.

Category	What to Know
 <b>Methodology Scope</b>	<p><b>Planning-grade screening only.</b> Not a substitute for operational dispatch simulation, full AC power flow study, or protection coordination analysis.</p> <p>Operates in the <b>steady-state thermal domain</b>; transient phenomena, dynamic stability, and electromagnetic interference are not modeled. Results are indicative of curtailment risk, not precise operational forecasts.</p>
 <b>Data Assumptions</b>	<p><b>Use of representative profiles.</b> Where utility-specific data is unavailable, illustrative profiles are constructed from regional load shapes.</p> <p>DER generation profiles based on typical solar irradiance, adjusted for system orientation, inverter sizing, and module degradation. Actual profiles vary with weather, shading, and equipment performance. <i>Input data quality directly affects curtailment result accuracy.</i></p>
 <b>Modeling Choices</b>	<p><b>Thermal constraints only.</b> Voltage, protection coordination, and power quality are excluded.</p> <p><b>Curtailment Allocation:</b> Pro-rata basis (no economic dispatch priority or contractual ordering).</p> <p><b>Battery Storage:</b> Simplified charge-discharge cycle (fixed duration, no degradation, no round-trip efficiency losses, no optimization).</p>
 <b>Strategic Context</b>	<p>The framework tells you <b>where to look</b> (screening); a detailed engineering study tells you exactly <b>what to do</b> (implementation). These limitations are intentional to ensure broad applicability across diverse distribution systems.</p>

# What This Framework Is and Is Not



Setting clear expectations for the analysis: this is a screening tool designed to inform planning decisions, not a real-time operational simulation.



## It IS

- ✓ A **planning-grade screening** methodology
- ✓ Based on **steady-state thermal analysis**
- ✓ Uses **hourly resolution data** across a full calendar year (8,760 hours)
- ✓ Intended to **inform planning decisions** and regulatory discussions
- ✓ Designed to **identify candidate locations** for flexibility interventions



## It Is NOT

- ✗ An operational dispatch simulation
- ✗ A full AC power flow study
- ✗ A protection coordination analysis
- ✗ A precise operational forecast
- ✗ A substitute for detailed engineering studies



### Key Application

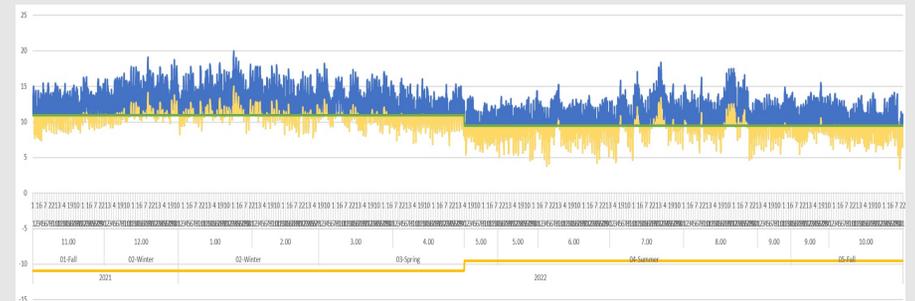
Supports development of **benefit-cost frameworks** comparing operational flexibility against traditional capital upgrades. Acts as a "planning compass" to quantify trade-offs before commitments.

# Curtailment Analysis Approach

## National Grid

The following outlines National Grid study approach to date, through the pilot period of its dynamic DER management, known as Active Resource Integration ([ARI](#))

- Uses **8,760-hour analysis** to establish transparent, upfront curtailment expectations
- Evaluates multiple interconnection pathways, including:
  - Full nameplate capacity
  - Derated nameplate capacity
  - Dispatch-limiting schedules
  - Dynamic flexibility
- Aligns to curtailment targets – studying at **75% EPS limits**, operationally curtailing at **95% EPS limits**
- Accounts for **energy storage complexity**, recognizing that charging constraints may be driven by upstream system limits, while discharge constraints can be site-specific
- Applies a **pro-rata curtailment methodology** to improve clarity and predictability by directly linking incremental DER capacity to expected curtailment levels



**Questions?**

## Flex Interconnection 101: Overclocking the Site

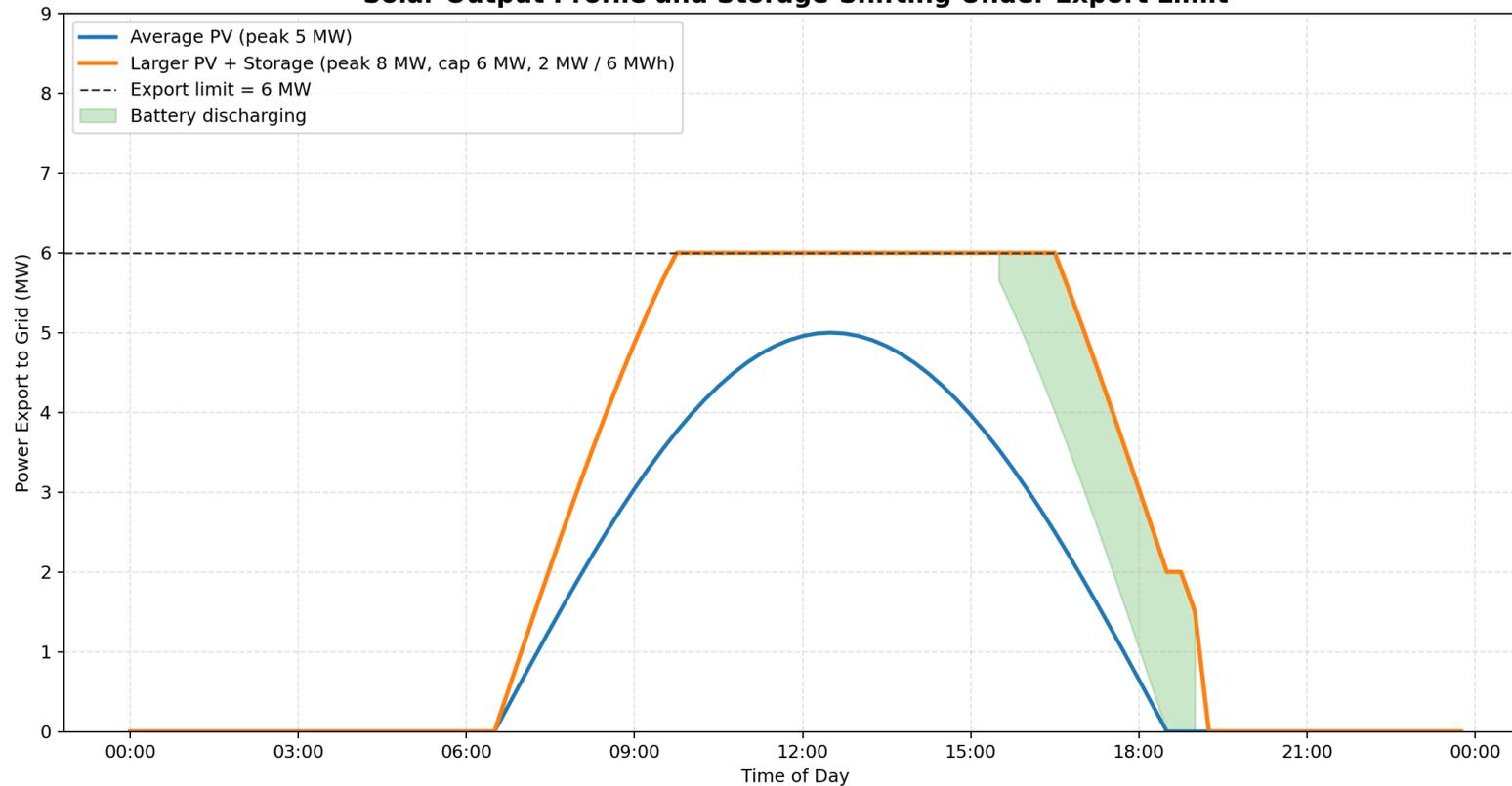
*“Overclocking defines the customers approach off placing more capacity at a site than they request to import or export”*

- **Example A:** In the current CIPs the largest DC capacity is 23 MW requesting a maximum export of 5MW and 0MW import capacity. On average, large scale solar overclocks with a ratio 1.3-1.5
- **Example B:** A load customer connecting 6 x 350 MW chargers at a site reworked their request to 500 MW import maximum while managing 1000 MW of storage behind the meter.

In the Context of Flexible Interconnection “Overclocking” the site represents a permanent curtailment to avoid major system modifications. The customer makes an economic optimization decision. For other flexibility services, this may limit future capabilities as a service point may already be saturated as a customer is managing significantly more behind the meter.

# Flex Interconnection 101: Overclocking the Site

Solar Output Profile and Storage-Shifting Under Export Limit



# Dynamic Flex Interconnection (DFI) - Adding Critical Context

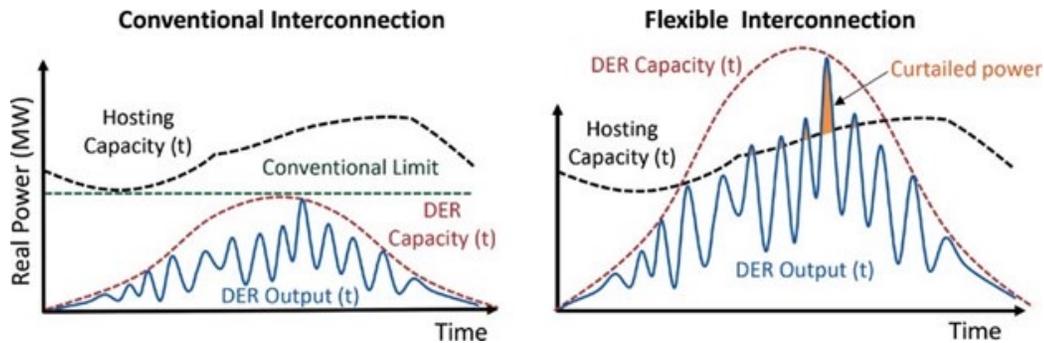


Diagram from Interconnection Implementation Review Group (IIRG)  
Flexible Interconnection Workshop, March 3-4, 2026, Boston, MA

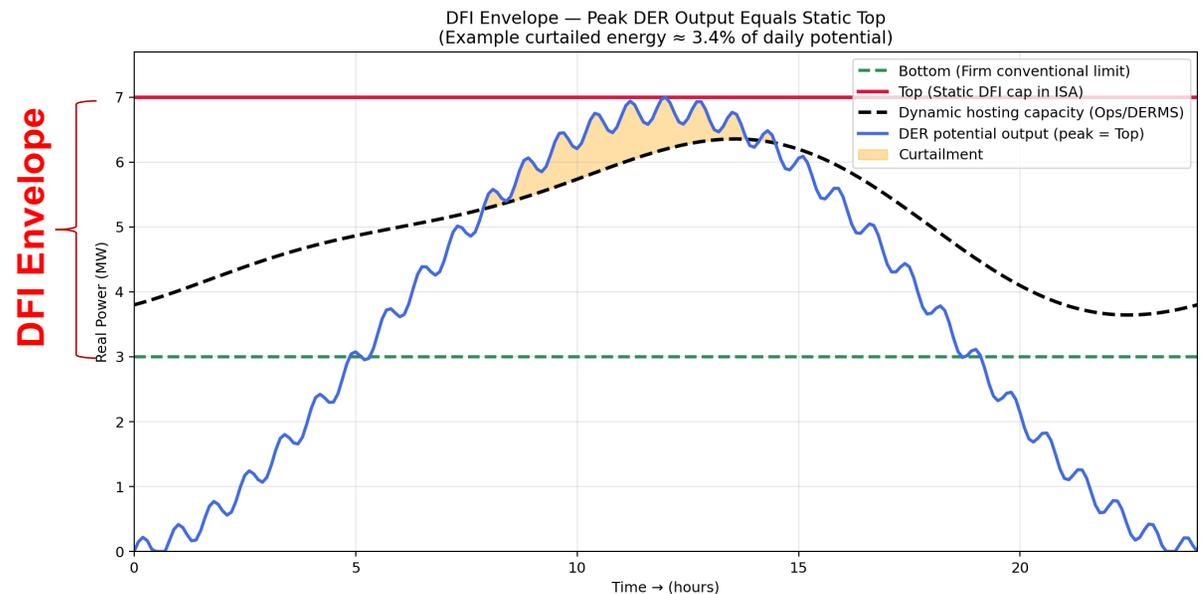
- DFI makes the case that additional hosting capacity exists above the static limit
- The static (conventional) limit becomes the bottom of the dynamic flex envelope – an operating band
- DER Planners must define and calculate the DFI static limit (MW), i.e., the top of the envelope (not shown)
- The diagrams illustrate the aggregate DER output
- One could assume that the peak of the aggregate DER output (red dashed curve) represents the height of the static horizontal envelope top.
- This assumption only holds if the resulting curtailment (any output above the black-dashed curve) remains below 5% annually

## Dynamic Flex Interconnection (DFI) Envelope Illustration

### DEFINING THE TOP OF THE ENVELOPE

(how much dynamic flex capacity – “headroom” – is available)

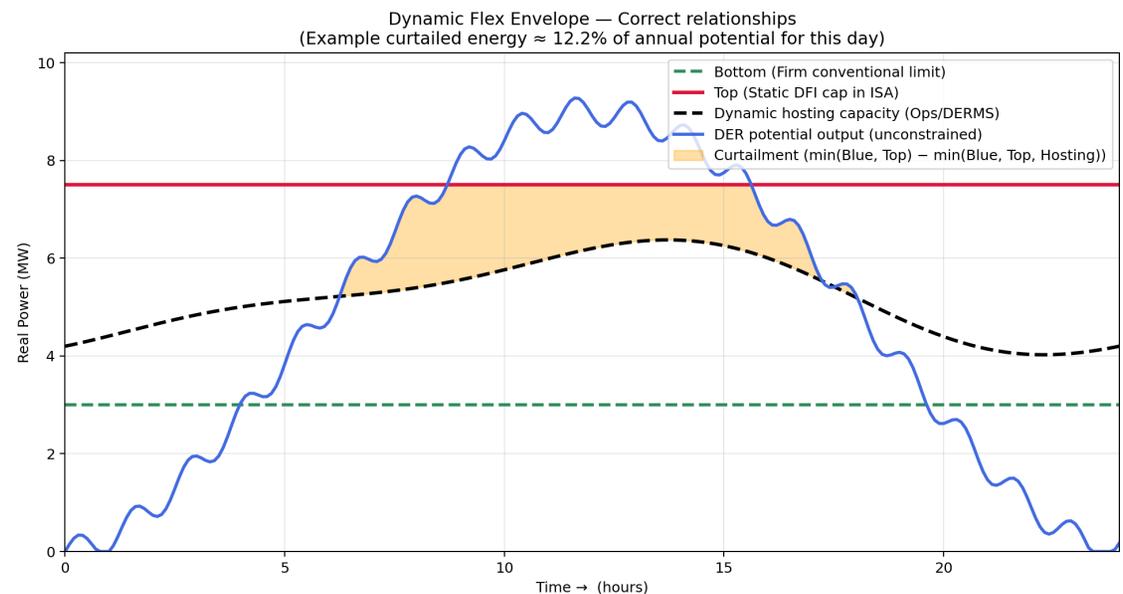
- At the Substation:
  - Used only as a gatekeeping screen (whether a DFI study is warranted).
  - Preferably evaluated at the substation transformer level
- At the Point of Interconnection (POI):
  - Necessary – e.g., the project may be nearby the substation or at the end of a very long feeder
  - Since curtailment only solves thermal violations (and, in cases, steady-state voltage violations), a project must be studied at the top of the envelope to determine ROI, LROV, GFOV, and other violations that must be corrected prior to DFI interconnection



## Overclocking Influence

- Overclocking lengthens the hours injecting into the Grid at peak export, and lengthens the total hours injecting into the Grid, in general
- As a result, DFI top envelope must move lower towards the bottom envelope (to limit curtailment %), compressing headroom.
- Recommendation: Apply a 'de-rating' factor to the DFI top envelope where overclocking is present in an area. For example:
  - For overclocked PV (1.3–1.5 DC/AC), dynamic flex interconnection supports only ~40–60%\* as much incremental DER capacity as it would for non-overclocked systems.
    - If overclocking  $> 1.3 \times$  → reduce expected marginal DER enabled by 40%\*
    - If overclocking =  $1.5 \times$  → reduce expected marginal DER enabled by 50–60%\*

\* Example only



## Overclocking is not going anywhere

- Overclocking lets a project harvest more energy from the same interconnection capacity, increasing revenue more than it increases cost.
- You capture energy during the “shoulder hours” when the inverter would otherwise be under-utilized; even with clipping at the mid-day peak, the annual net kWh increases.
  - The value of extra annual production outweighs the clipping losses.
- Overclocking increases profit because it extracts more energy (and value) from the same inverter and interconnection (i.e., the most expensive parts), with very modest incremental costs.

**Questions?**

**Break**  
**Please return at**  
**2:55 PM**

# Session 6: Breakout on Curtailment Study Requirements

# Curtailment Study Requirements Discussion

In your breakouts, introduce yourselves and discuss the following:

## Curtailment Study

1. What study assumption scenario do you prefer?
  - a) EDC chooses what percent they do the study at (e.g. 75%), at discretion → Less MW connected, lower risk of curtailment
  - b) EDC studies at the percent they expect to operate at (e.g. 95%), same every time → Higher MW connected, higher risk of curtailment
2. What preferred generation profiles should be used? Should it be standardized, or should the developer provide the input?
3. What curtailment study assumptions could help alleviate concerns about overclocking?

## Data Sharing

4. What types of data (other than customer generation profiles) do the EDCs need to conduct the study? What data can be provided from industry?
5. What data should EDCs provide to support independent analysis and financing?

# Breakout Group Assignments



Table 1	Table 2	Table 3	Table 4	Table 5
Daniel Passarello	Kevin Dunn	Elio Torres	Joshua Briggs	Nachum Sadan
Kavita Ravi	Silas Bauer	Sean Burke	Ed Brolin	Pauravi
Chris Modlish	Samantha Meserve	Gerry Bingham	Carson Bullock	Courtney Feeley Karp
Melissa Liazos	William Kern	Michael Porcaro	Andrew Schneller	Josh Tom
Daniel Yung	Nick Watson	Paul Krell	Emily Slack	Kevin Reardon
Syed Ali	Naera Hagnazarian	Juan Martinez	Muhammad Khan	Farzam Nejabatkhah
Daniel McDonough		Annemarie Belle (Observer)		Vlad Zaiets (Observer)

Table 6	Table 7	Table 8	Table 9
Haskell Werlin	Shikhar	Dexter Hendricks	Ryan McGlothlin
Emma Hillman	Kate Tome	Ami Vyas	Christian Bilcheck
Rachele Marshall	Kayla Burns	Nikhil	Julia Fox
Randy Armstrong	Nancy Israel	Laura Townsend	Claudia Rosen
John Bonazoli	Manuel Saadallah	Cole Wheeler	Arnaldo Arnal
Jill Duplessis	Gerhard Walker	Michael Taniwha	Zach Tedford
	Robert Fitzpatrick (Observer)	Michael Hershberg	Justin Woodard

# Session 7: Interconnection Process/Queue Management

# Interconnection Process Considerations



- ▶ Implementing Dynamic Flex IX requires integrating this offering into Massachusetts' interconnection process and rules.
- ▶ There are several key considerations to do so:

Key Scenarios	Incorporation vs. Modification of Interconnection Rules
Determine what are the additional <b>scenarios under which Dynamic Flex IX would be implemented</b> and how this would be offered to existing and new queues	Assess whether each scenario <b>can be integrated into the existing interconnection process</b> or whether modifications are required

# Interconnection Scenarios



The IIRG identified three scenarios in which Dynamic Flex IX could be offered:

## 1. Existing projects in queue that were already studied for firm interconnection and/or upgrades

- Restudies anticipated

## 2. New projects that seek to interconnect after firm limits are reached

## 3. Existing projects seeking a bridge to wires solution while waiting for an upgrade

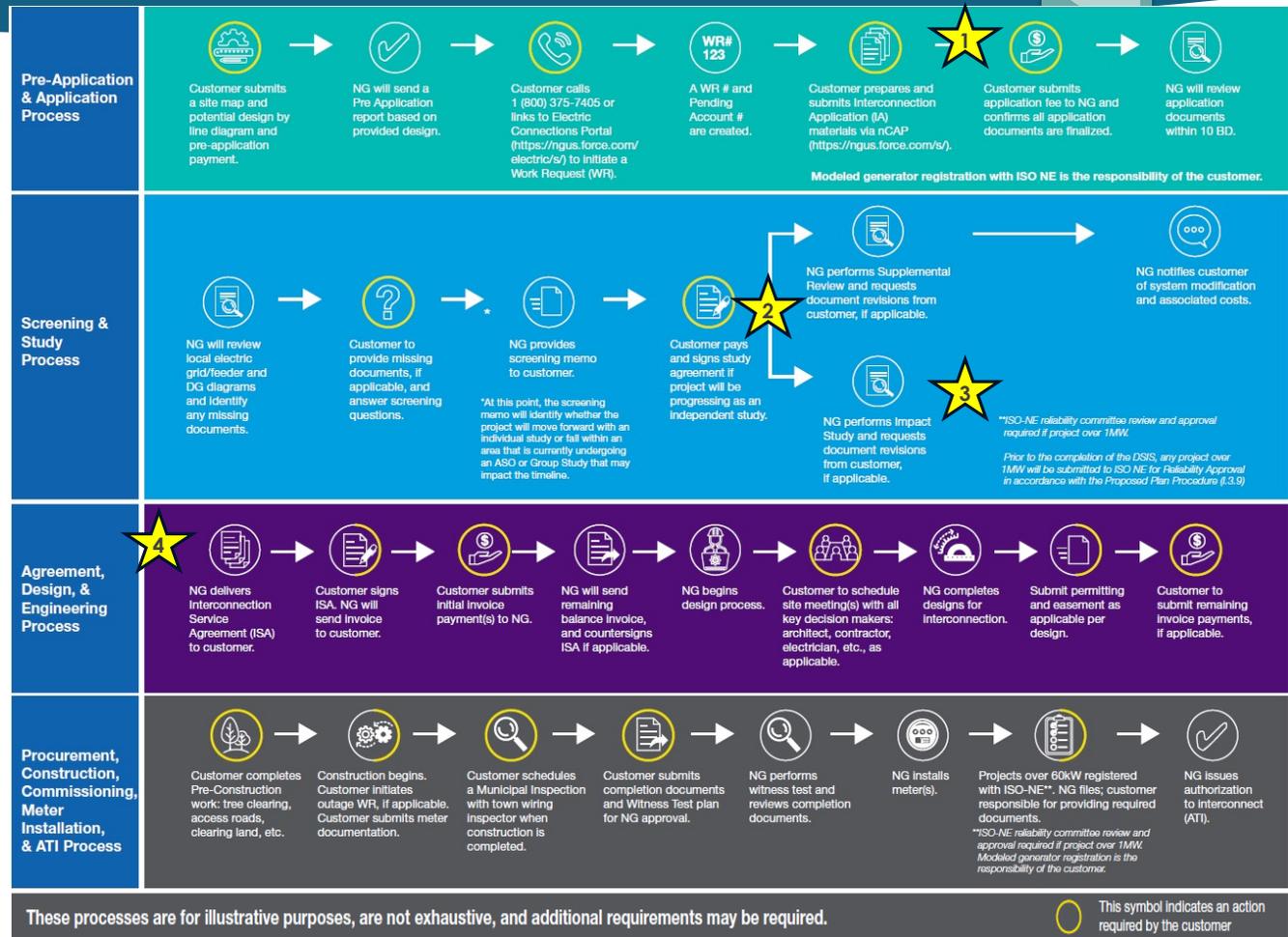
- Could also be considered as upgrade timelines are being monitored to receive ITC

# Interconnection Process



The following are draft points of the DG Interconnection Process for Flex IX decisions:

1. Application Submission
2. Study Start
3. Preliminary Assessment
4. ISA Delivery (Phased/Temp Flex only)



These processes are for illustrative purposes, are not exhaustive, and additional requirements may be required.

This symbol indicates an action required by the customer

**Questions?**

# Interconnection Process Discussion



In **new** breakout groups, introduce yourselves and fill out the worksheet at your tables together.

## Check Out



What is one new thing you learned today or a new perspective you heard that you appreciated?