System Planning with High-Fidelity Adequacy

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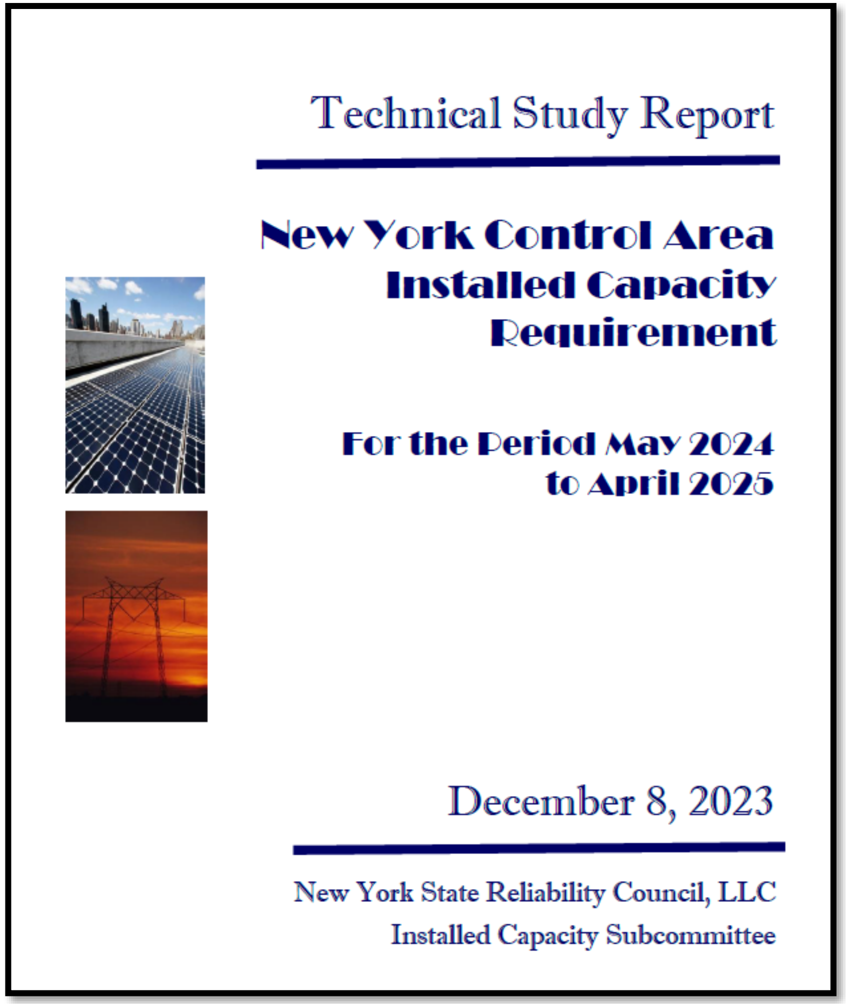
Outline

- Traditional versus High-Fidelity Reliability Analysis
- Why should we care about Nodal Analysis and Operational Details?
- Re-studying NYCA 2024 IRM Study using both the zonal and nodal configurations of the same model using ENELYTIX® powered by PSO
- Goals:
  1. What can we learn from the nodal assessment compared to the zonal representation?
  2. How can the nodal information be used in planning?



Technical Study Report

New York Control Area Installed Capacity Requirement

For the Period May 2024 to April 2025

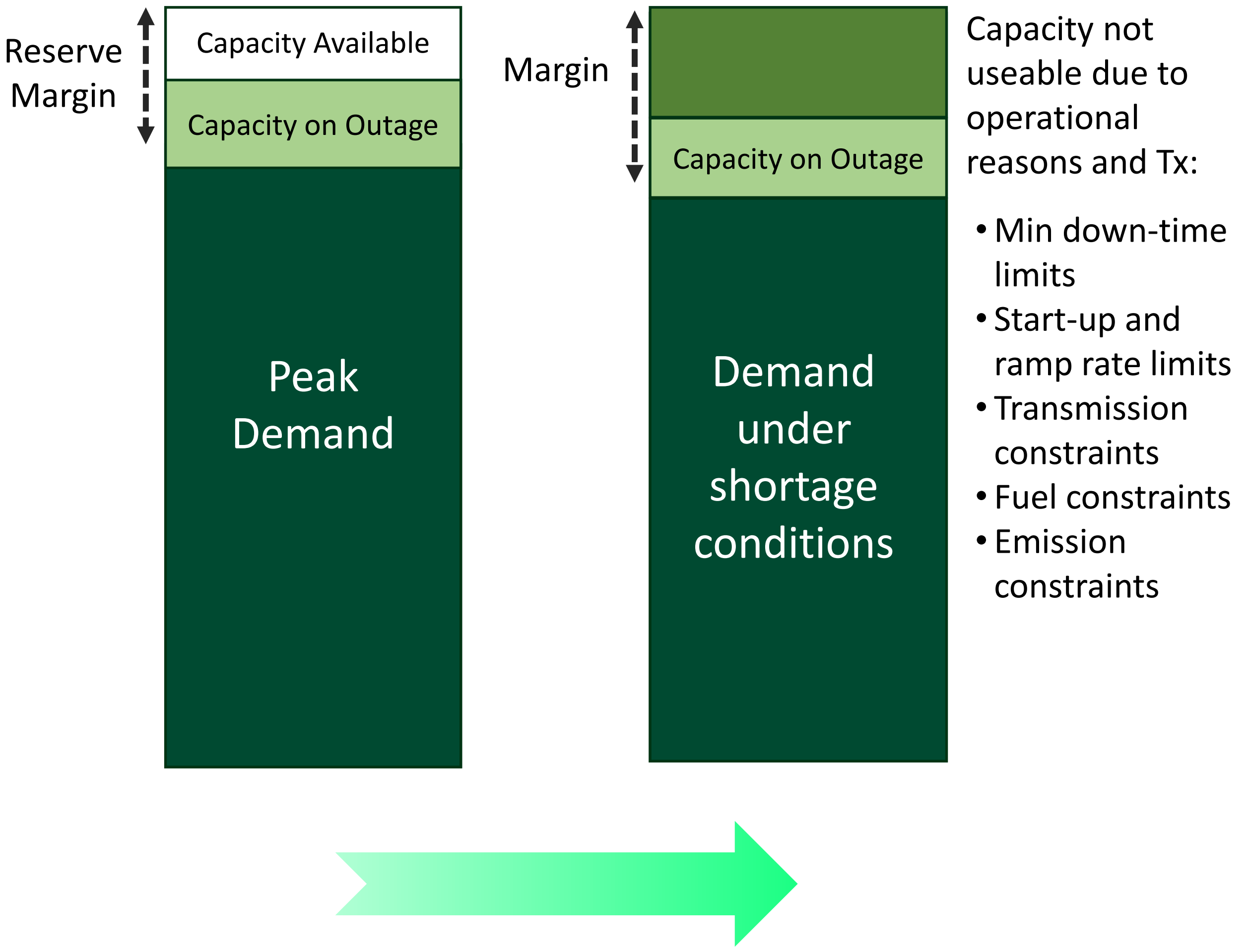
December 8, 2023

New York State Reliability Council, LLC
Installed Capacity Subcommittee

New York Control Area Installed Capacity Requirement, New York State Reliability Council, LLC Installed Capacity Subcommittee, December 8, 2023.

Why Should We Care About Tx and Operational Details?

- **Zonal is not necessarily easier:** Zonal models require defining zones with no or low congestion within them and limits between zones
- **Generation & Transmission:** Poorly coordinated generation and transmission expansion lead to suboptimal decisions
- **Capturing true system risk:** Shortages can occur even when capacity is available system-wide or elsewhere because of other operational limitations (e.g. ramping constraints)
- **Capturing deliverability:** Accreditation should reflect the deliverability of capacity at a location



Planning reserve margin is no longer a safe margin

Zonal versus Nodal Reliability Analysis

	Zonal	Nodal
Modeling effort	Requires defining zones and transfer limits	Physical system model already exists
Accuracy	Violates Kirchhoff's Law; relies on transfer limit approximations	Reflects physical system; adapts to changing topology and generation
Performance	Fast; especially without operational details	Comparable runtimes with scenario reduction
Outcomes	No locational investment signals, inefficient investments, excessive costs, high epistemic risk	Locational investment signals for generation, transmission and demand resources, optimal investment costs, lower epistemic risk

Where Nodal Risk Metrics Plug In

Planning

Identification of:

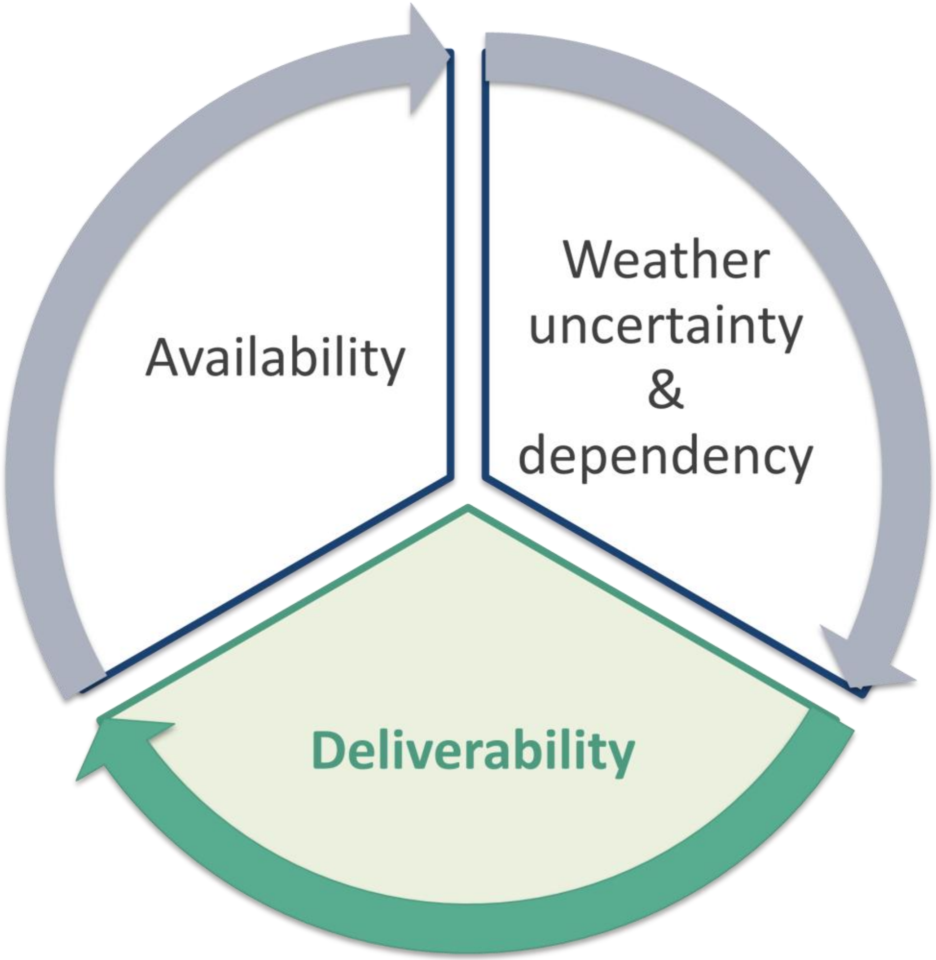
- Locational needs for capacity additions
- **Locational reliability contribution**
- Load pockets
- Reliability limiting constraints and efficiency of transmission investments, both conventional and GETs

Visibility into locational risk at the planning stage

Operational

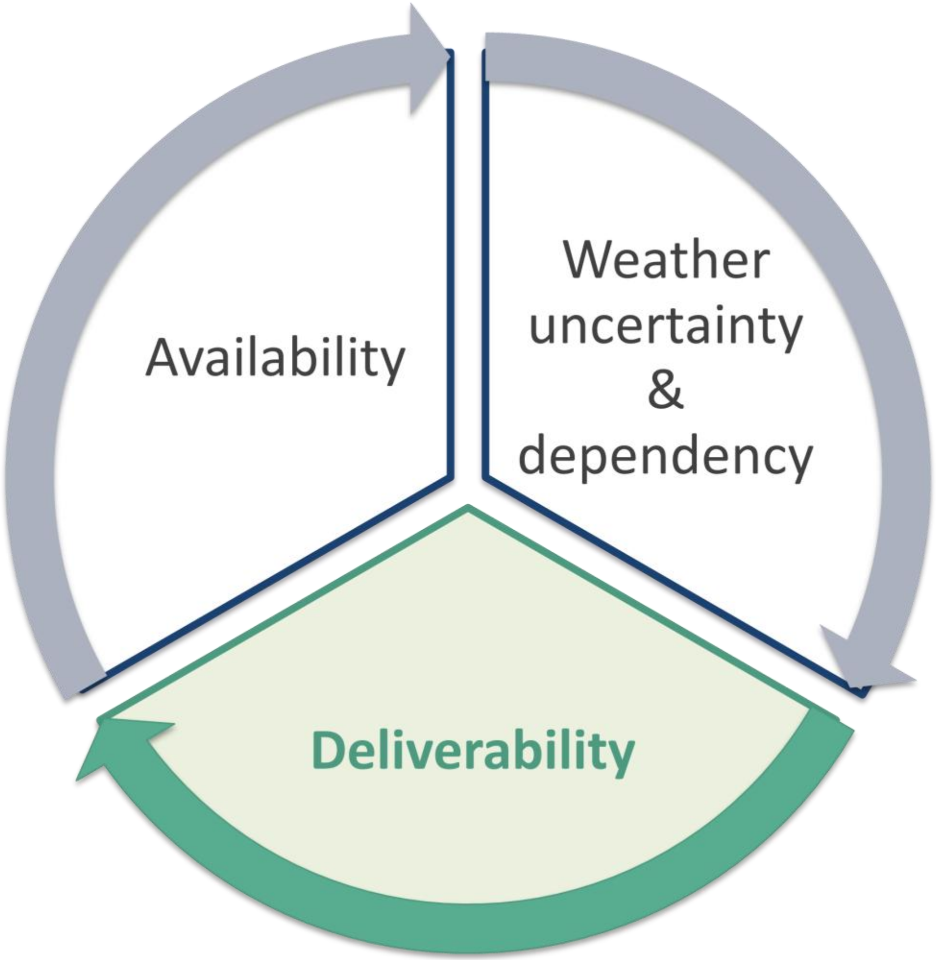
1. NYISO runs short-term (4-5 days ahead) probabilistic analysis
2. Operators see the locational reliability risk in the system
3. Operators take locational actions such as
   - Reschedule maintenance
   - Start long-lead time units
   - Relax Tx constraints

Resource Reliability Contribution



- From today's accreditation metrics, location aspect is missing
- **Marginal reliability contribution** using nodal models capture deliverability in assessing capacity value of resources
- Interpretation: Level of perfect capacity that 1-kw of an existing or future unit in question can replace without changing the system-wide EUE over time

Resource Reliability Contribution

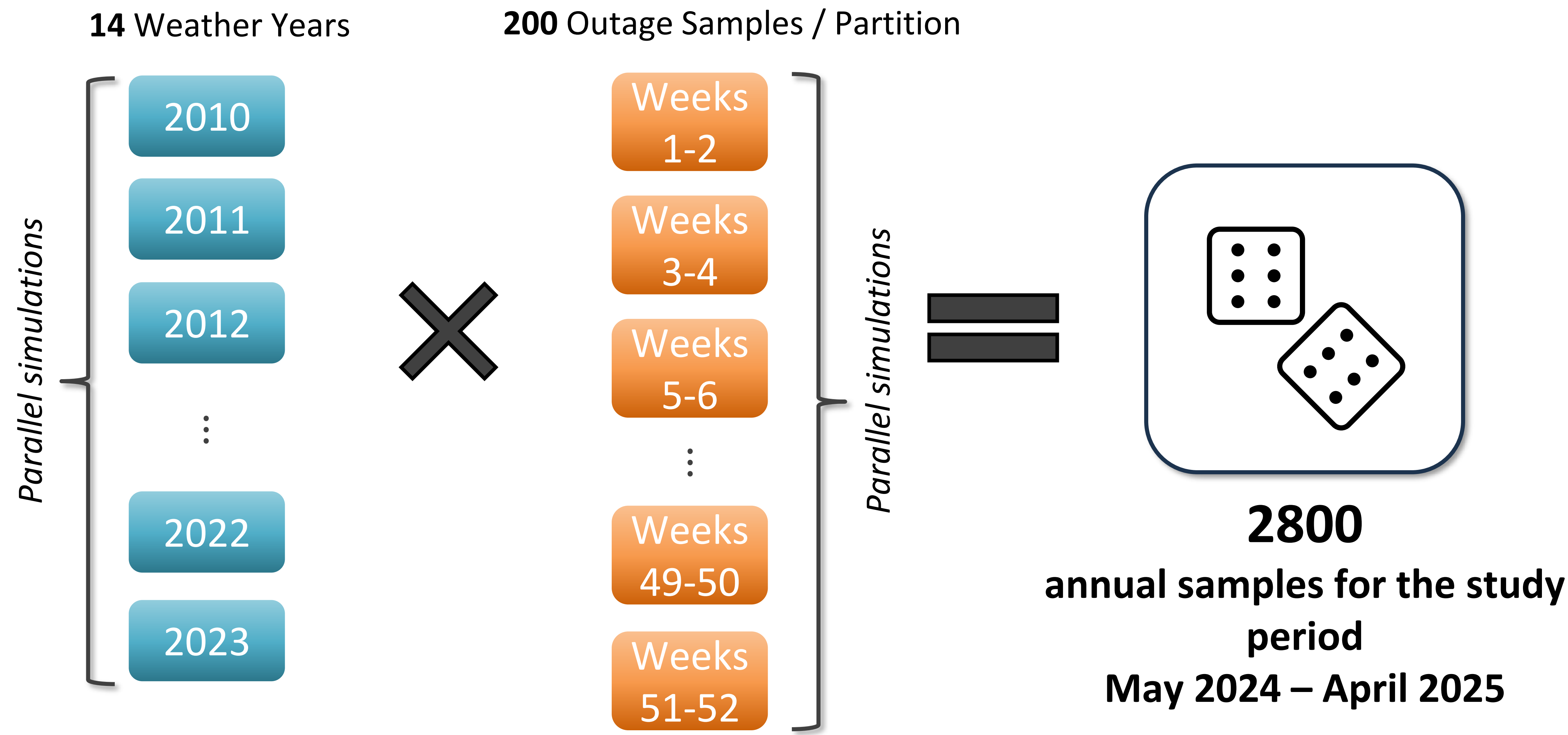


- Improved siting decisions
- Improved Transmission and Generation coordination and assessment of trade-offs between solutions
- Improved assessment of firm capacity value of DERs
- Accreditation as a compensation mechanism to provide the right incentive
- Nodal capacity market
- Improved ELCCs in capacity planning

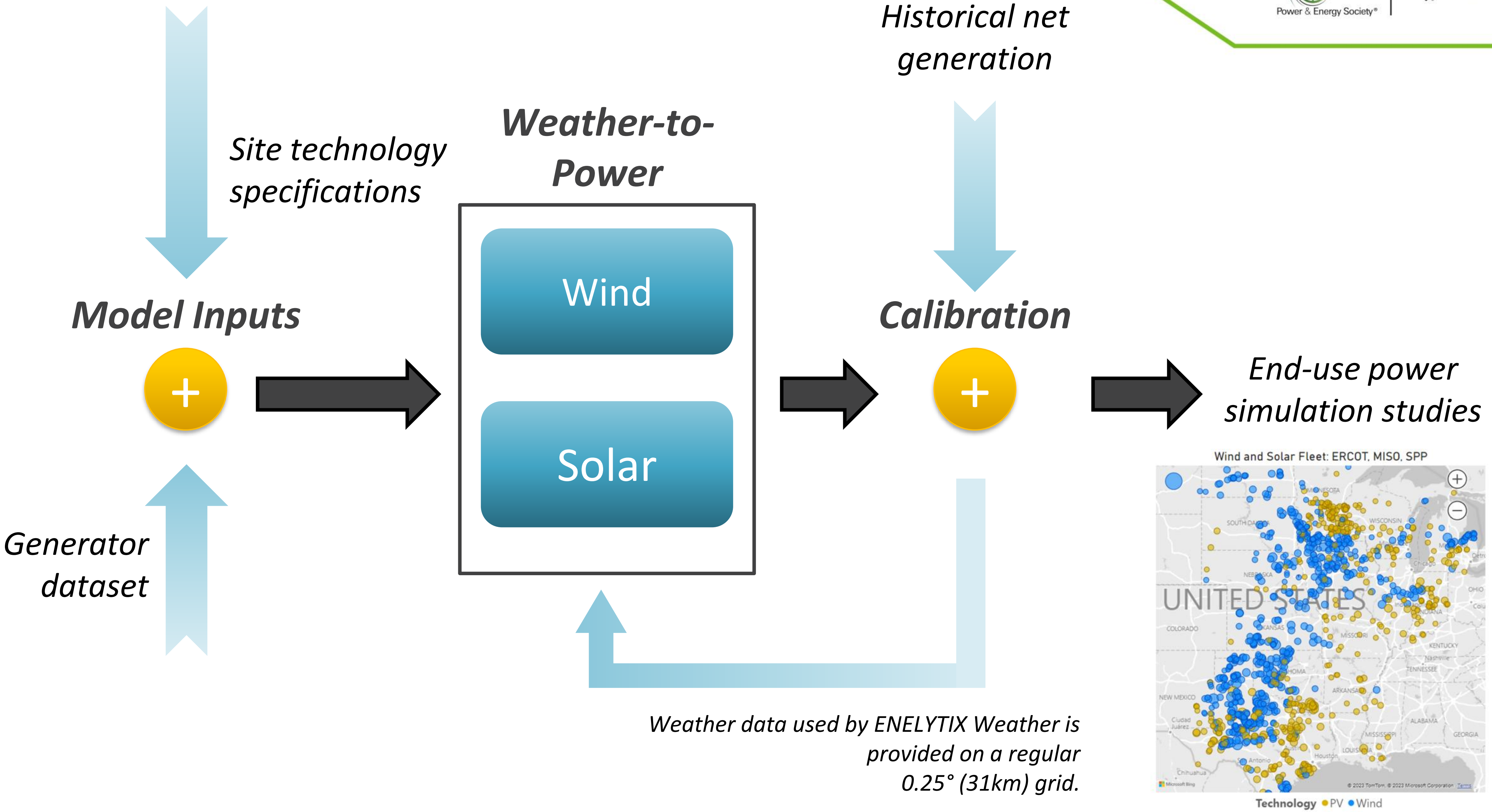
ENELYTIX NYCA IRM Study Sources

	Zonal	Nodal
Peak load forecast	NYCA IRM Study	NYCA IRM Study
Energy forecast	Goldbook	Goldbook
Thermal and renewable generation capacity	NYCA IRM Study	NYCA IRM Study
Load and fixed interchange shapes	ENELYTIX® Weather (2010-2023)	ENELYTIX® Weather (2010-2023)
Wind and solar shapes	ENELYTIX® Weather (2010-2023)	ENELYTIX® Weather (2010-2023)
Zonal transfer limits	NYCA IRM Study	
Power-flow		MMWG 2022
Contingency and interface constraint definitions		NYISO Operating Studies ENELYTIX N-1 analysis
Emergency Operating Procedure (EOP) limits	NYCA IRM Study	NYCA IRM Study

NYISO Probabilistic Reliability Study

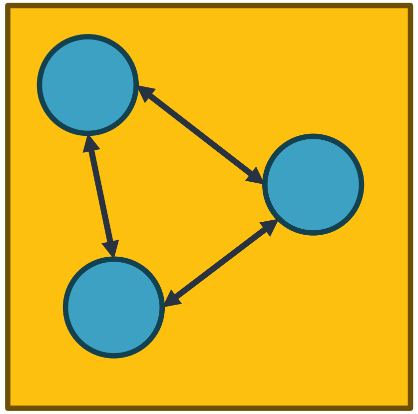


ENELYTIX WEATHER USED IN THE STUDY

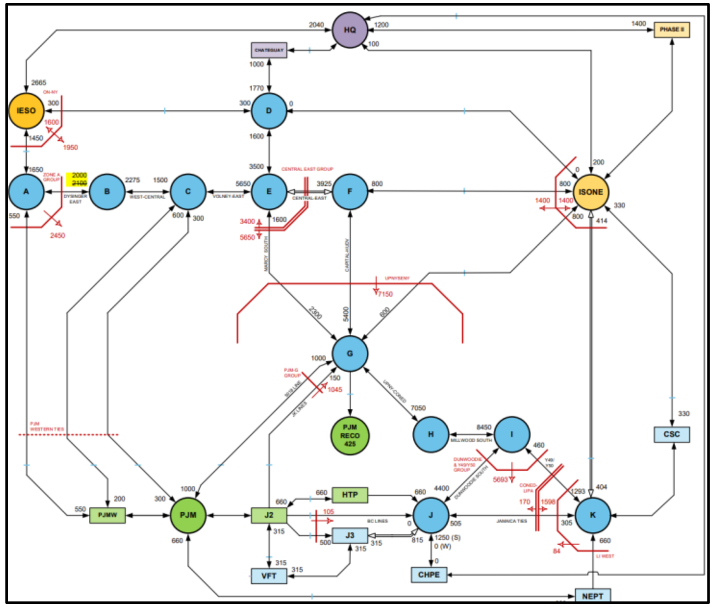


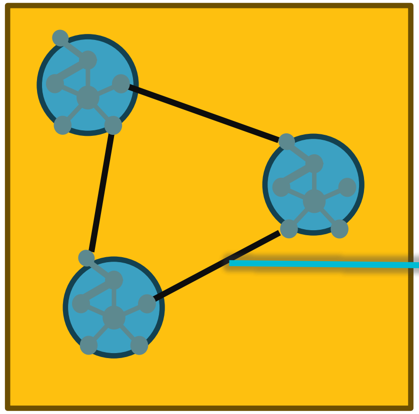
Weather data used by ENELYTIX Weather is provided on a regular 0.25° (31km) grid.

Types of Studies Performed



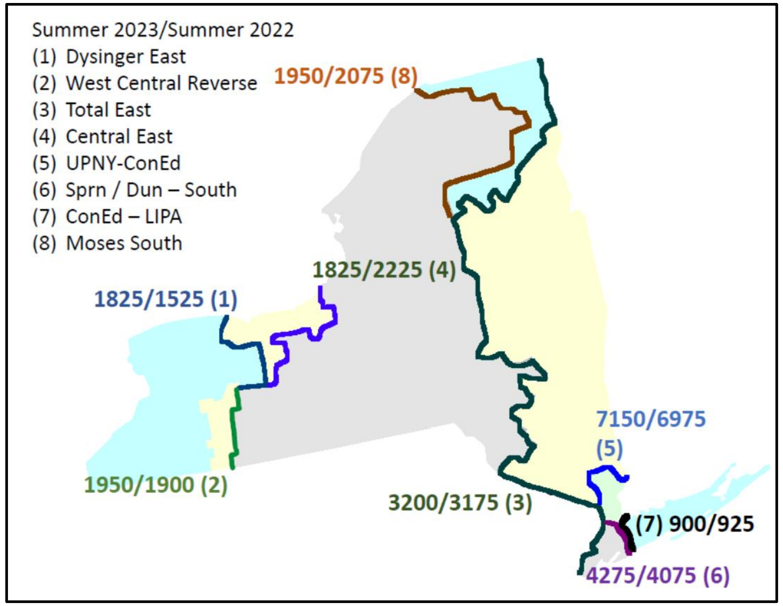
Zonal with transfer limits
- As used in the IRM study

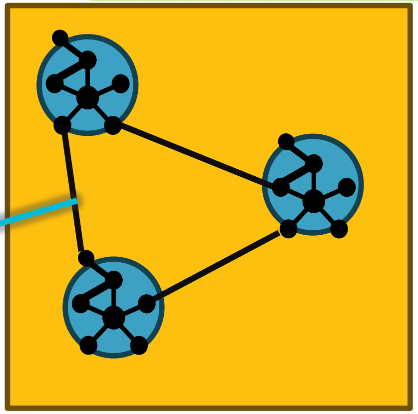




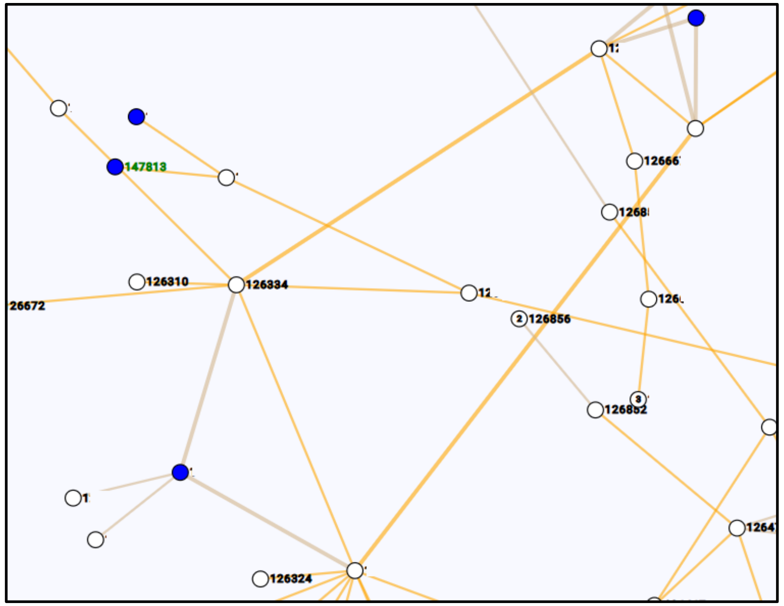
Interfaces
(physical ties)

Nodal with major interfaces
(Reduced nodal)





Full nodal with internal transmission limits



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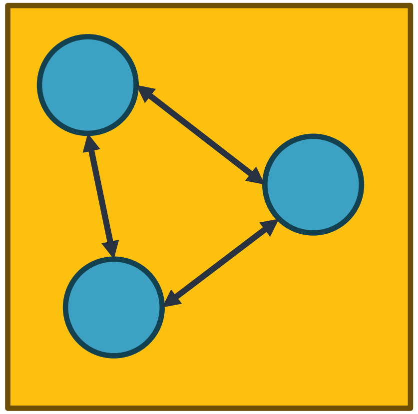
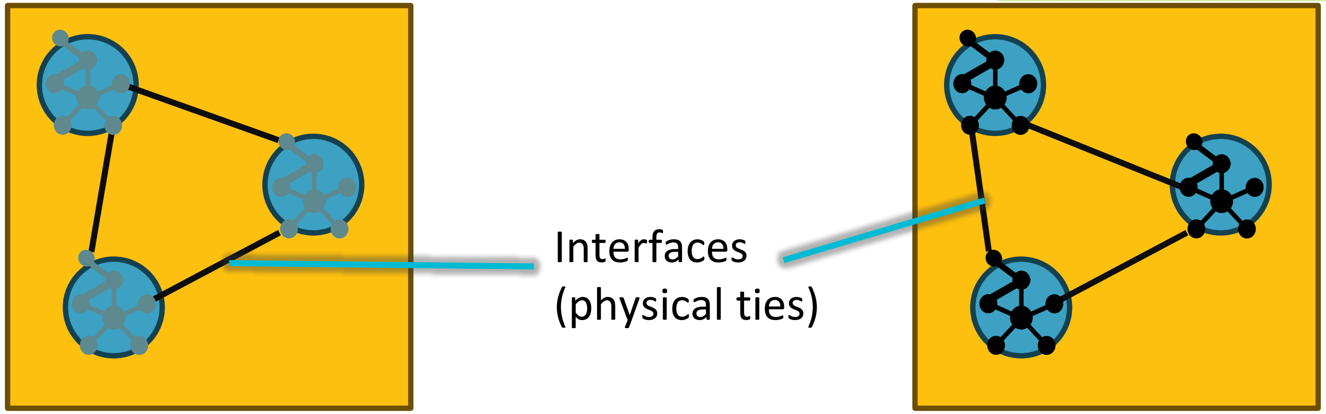


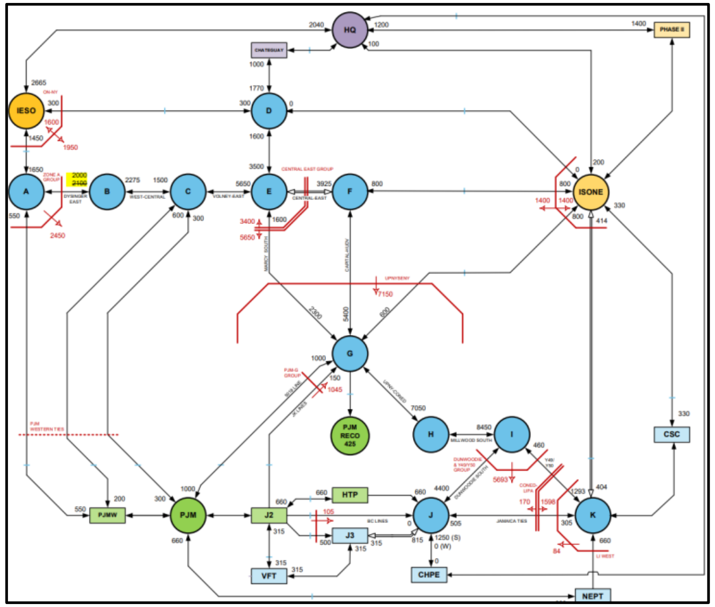


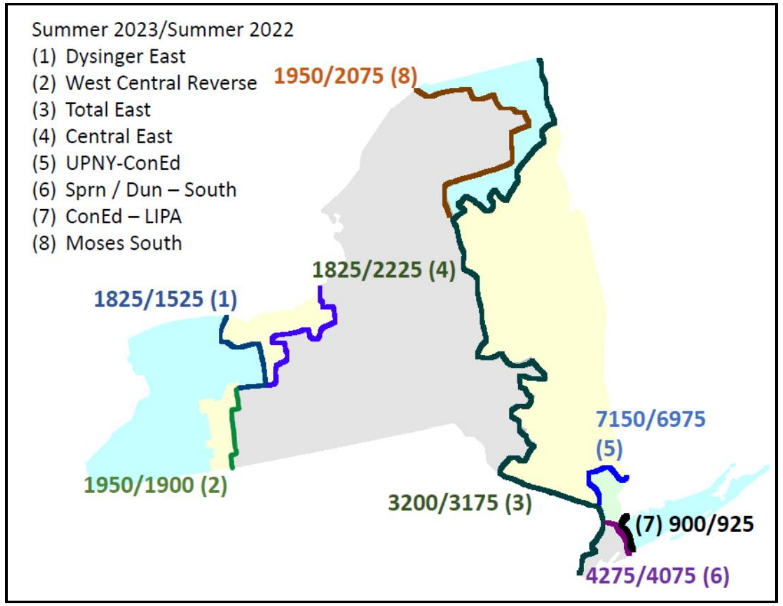
Zonal with transfer limits

- As used in the IRM study

Nodal with major interfaces (Reduced nodal)

Full nodal with internal transmission limits





Study 1: Use internal transmission constraint violations to resolve local issues before load shed

Study 2: Resolve shortages through load shed before violation of transmission constraints

HOW DOES SYSTEM RISK COMPARE BETWEEN ZONAL AND NODAL MODELS?

NYISO-Wide Metrics

	NYCA IRM Study	Zonal	Nodal with Major Interfaces	Full Nodal Low Tx Penalty	Full Nodal High Tx Penalty
LOLH (hours/year)	0.337	0.338	0.773	0.862	3.583
LOLH CI 95	No data	[0.29,0.39]	[0.69, 0.85]	[0.78, 0.95]	[3.41,3.75]
EUE (MWh)	181	109	192	231	1290
LOLH + EOPH[1]	No data	8.62	9.53	12.11	34.95
EUE + EEOP[2] (MWh)	No data	6,150	6,678	8,313	24,188
Total computational time	No data	131 hours[3]	189 hours[3]	470 hours[3]	600 hours[3,4] $79 AWS cost
Turn-around time	No data	0.67 hours	0.87 hours	2.5 hours	4 hours[4]

[1] EOPH = Hours where any Emergency Operating Procedure is used (e.g., *demand response*)

[2] EEOP = Expected dispatch of all Emergency Operating Procedures

[3] On 364 Virtual Machines

[4] Stratified sampling applied

- Simulations are brought to criteria by scaling load in each zone by the same factor
- More than two-fold differences between zonal and nodal reliability metrics are observed even with a nodal model that only includes physical interface limits
- Full Nodal model results in a 10 times higher LOLH than the zonal model due to locational issues

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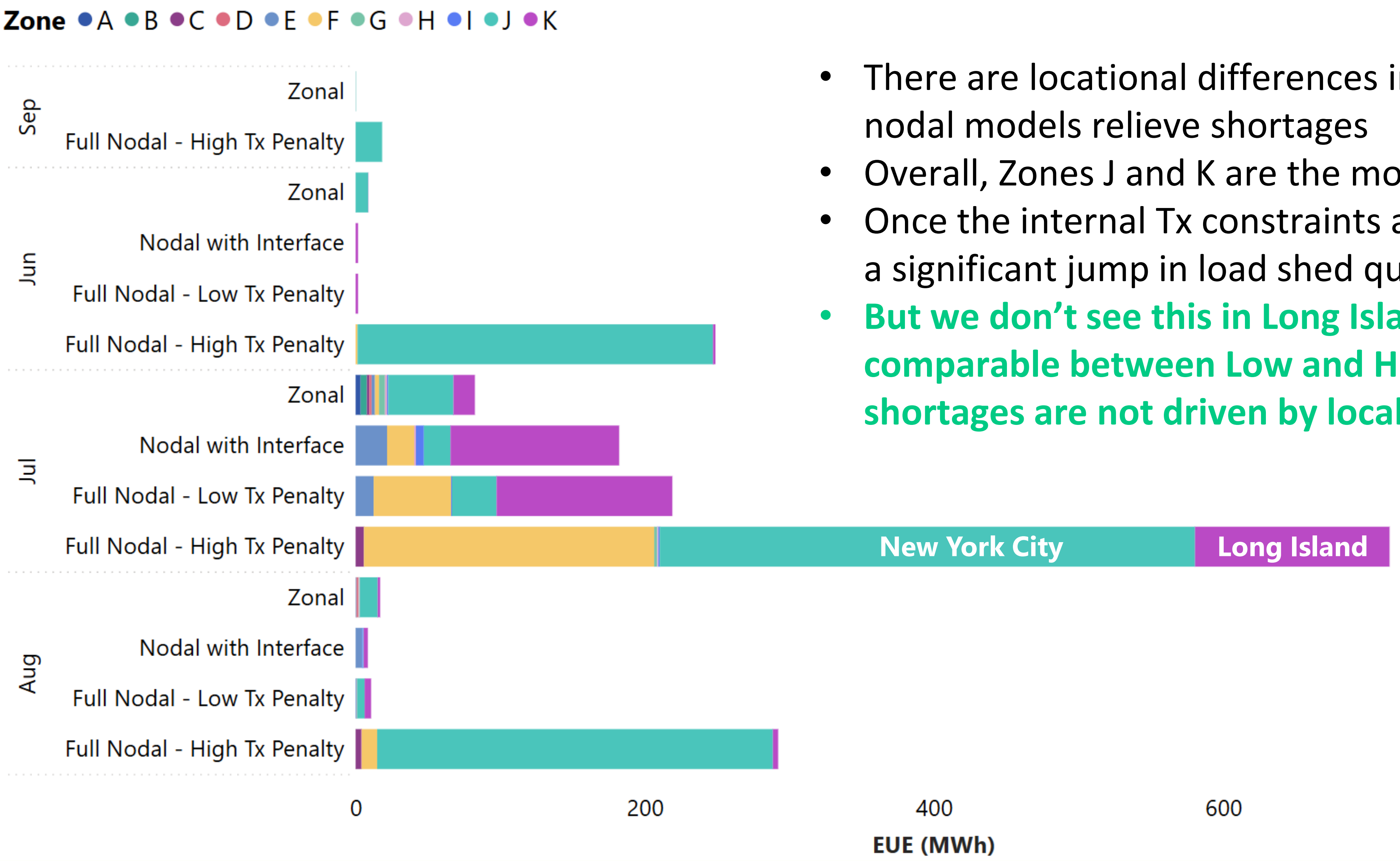
When and Where Does Unserved Energy Occur?



- There are locational differences in how zonal and nodal models relieve shortages
- Overall, Zones J and K are the most problematic zones
- Once the internal Tx constraints are enforced, we see a significant jump in load shed quantity in NYC
- **But we don't see this in Long Island – EUE is still comparable between Low and High Tx penalty since shortages are not driven by local constraints**

HOW TO MEASURE LOCATIONAL RISK and EFFICIENCY OF LOCAL ACTIONS?

How to Assess Locational Risk

Marginal Reliability Metrics

- What metrics can we use to assess locational risk?
- A marginal metric reflect the response of the system to a small variation applied to its element
  - A change in system-wide production cost in response to incremental demand (LMP);
  - A change in system-wide level of Expected Unserved Energy in response to an increment of ideal capacity (LOLP)
- *Marginal Reliability Metric:* **Expected unserved energy reduction in the system per 1 kW of added ideal capacity at a given location and time**
- In addition to traditional metrics (LOLH, LOLE, EUE), optimization-based RA tools can provide dual variables that directly generate *Marginal Reliability Metrics*

Recognition of Marginal Metrics from ISOs

- **ISO-NE and MISO:** Marginal Reliability Impact (MRI) adopted to measure a resource's reliability contribution as reduction in EUE in response to adding a unit of ideal capacity
- **NYISO:** Marginal Accreditation methodology uses the concept of MRI as reduction in EUE as well as reduction in LOLE in response to incremental capacity
- **PJM:** Replacement of average ELCC capacity accreditation method with marginal ELCC approved by FERC in early 2024
- **ERCOT**: Using LOLP (= MRI, see next slide) in ORDC-based pricing of operating reserves

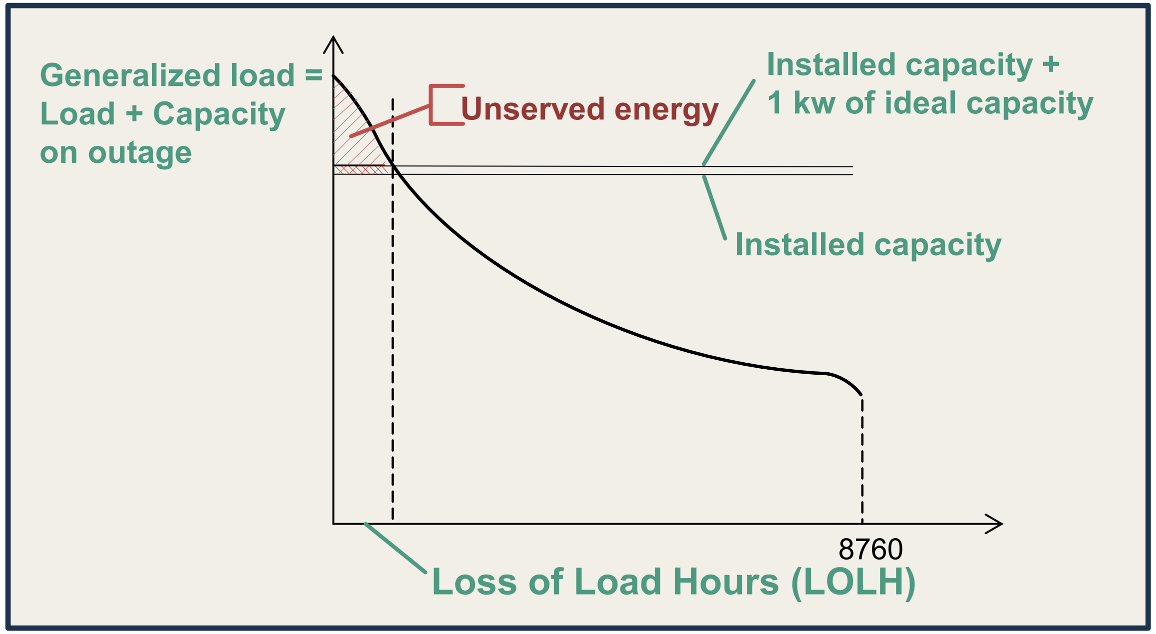
Why Are Marginal Metrics Important?

- Marginal metrics measure the effect (or efficacy) of applied change
- In that sense they are more than just the benchmarks
- By definition, marginal metrics are locational (or location ready)
- Marginal metrics can be used to assess the impact of locational actions on adequacy:
  - Where to add capacity
  - Impact of transmission solutions on adequacy

Marginal Reliability Metrics are "Location Ready"

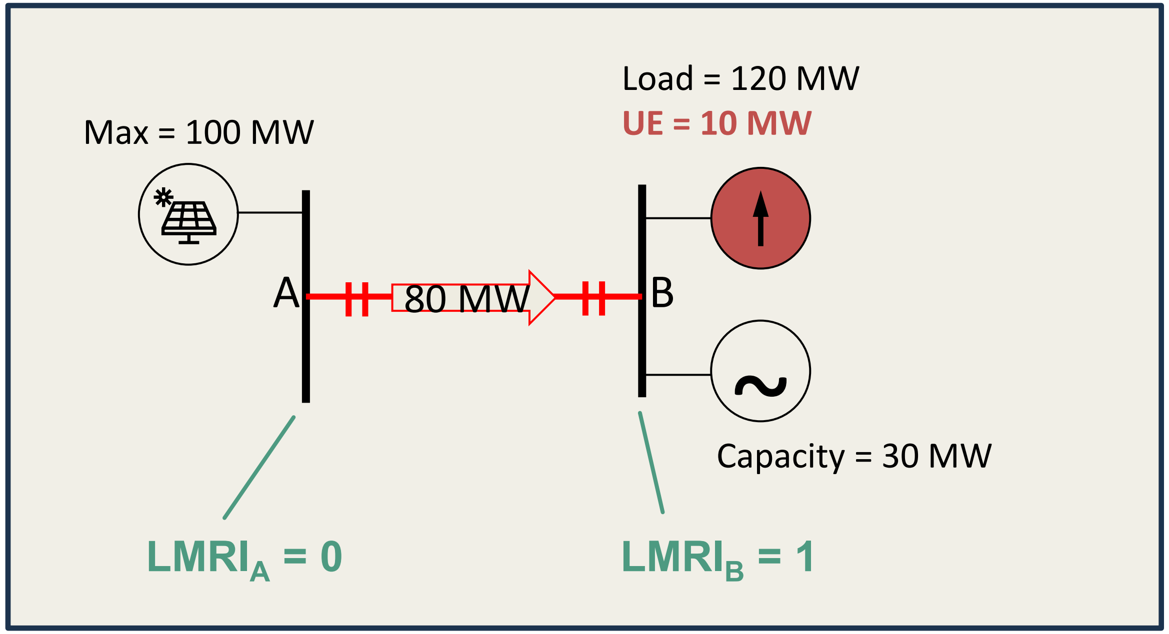
Copper Plate System

***LOLP*(t)** = kW of EUE(t)/hr reduction per 1 kW of added ideal capacity **in an unconstrained system at a given point in time**



Constrained System

$LMRI_{node}$(t) = kW of EUE/hr reduction system-wide per 1 kW of added ideal capacity **at a given location at a given point in time** → **Locational Marginal Reliability Impact**



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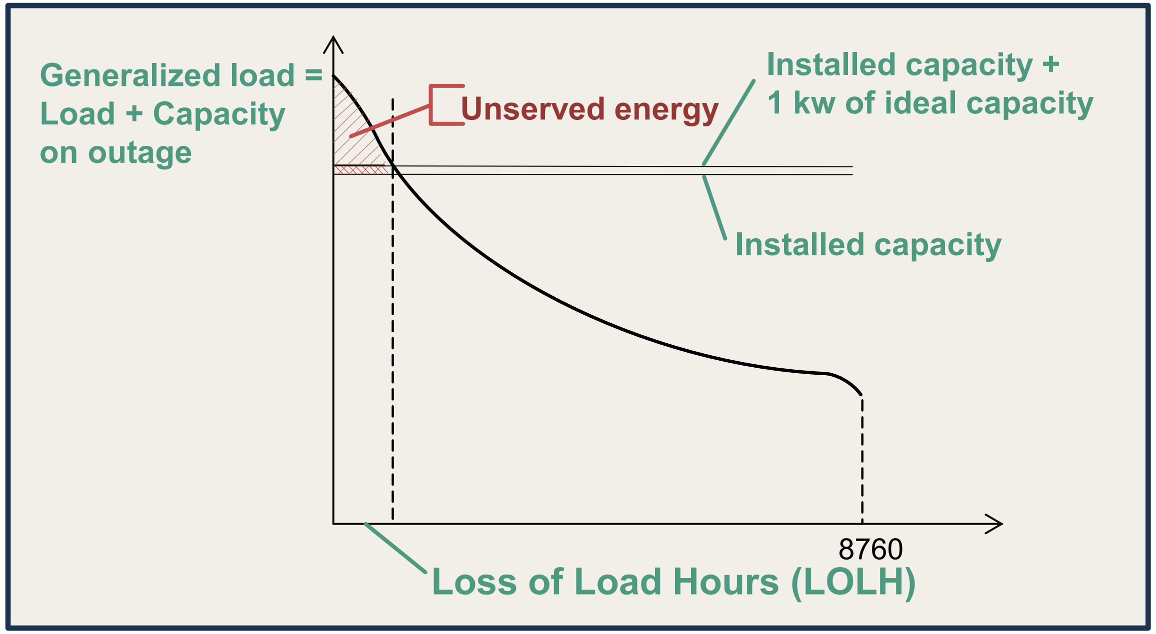

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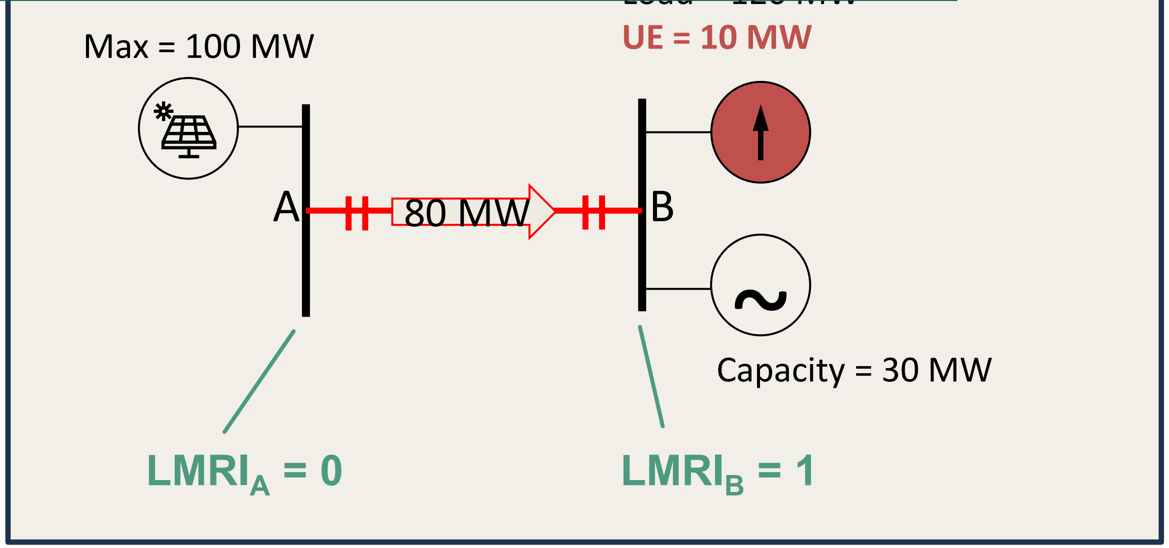
Marginal metrics are directly obtained as dual variables from optimization-based RA methods (no iterative calculations are necessary)

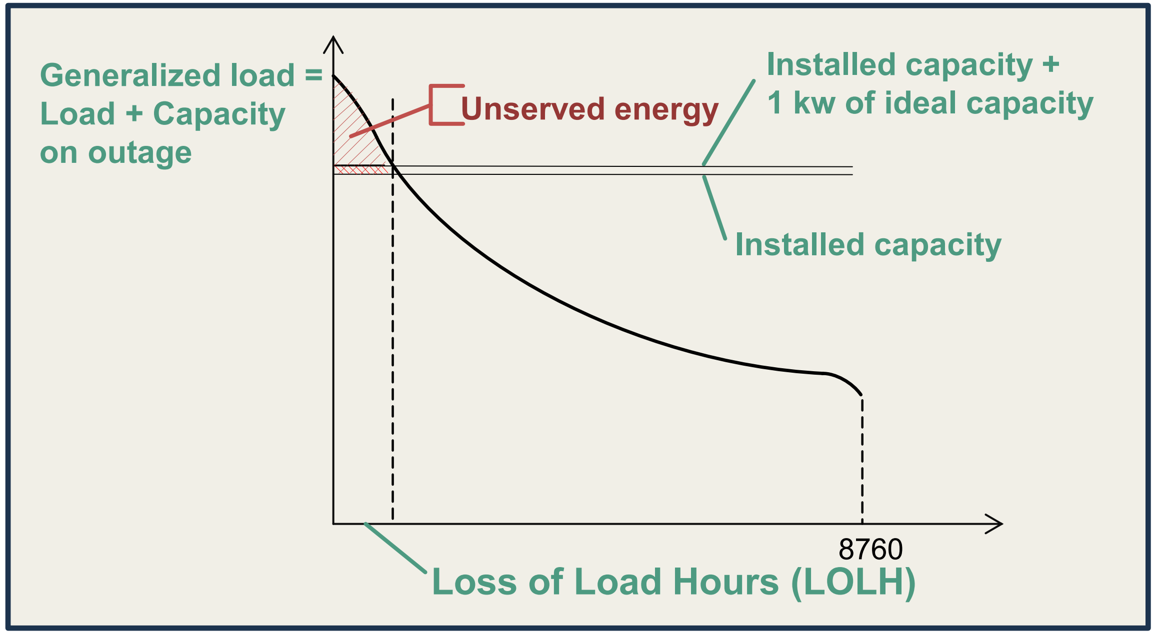


Marginal Reliability Metrics are "Location Ready"

Copper Plate System

LOLH = kWh of EUE reduction per 1 kW of added ideal capacity **in an unconstrained system over a year**

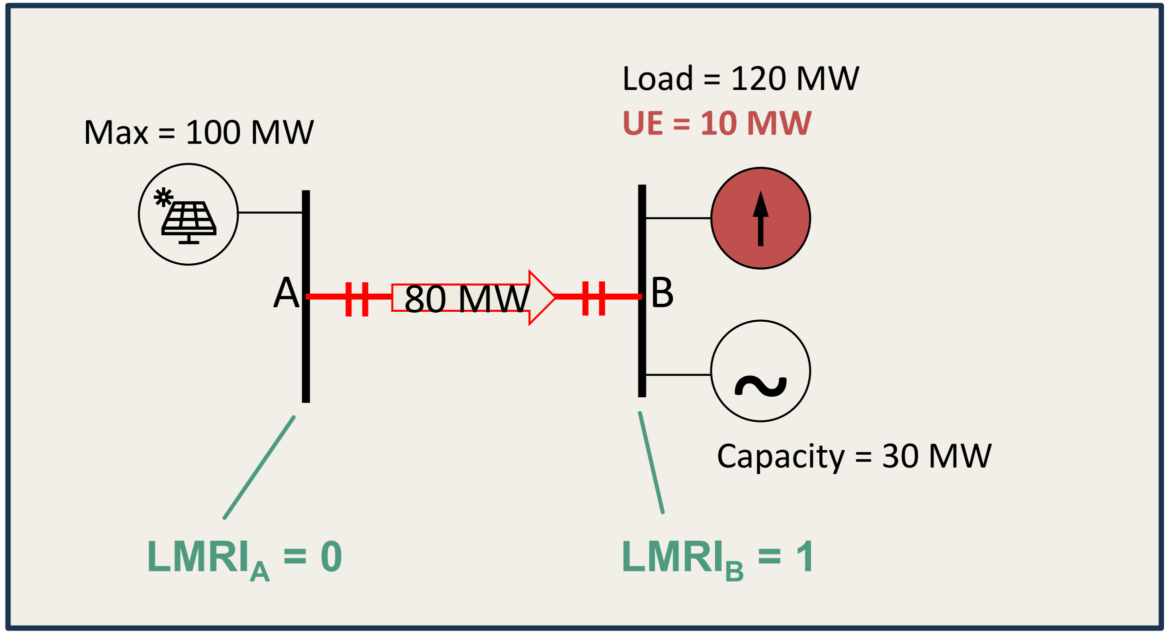
$$LOLH = \sum_{t=0}^{8760} LOLP(t)$$



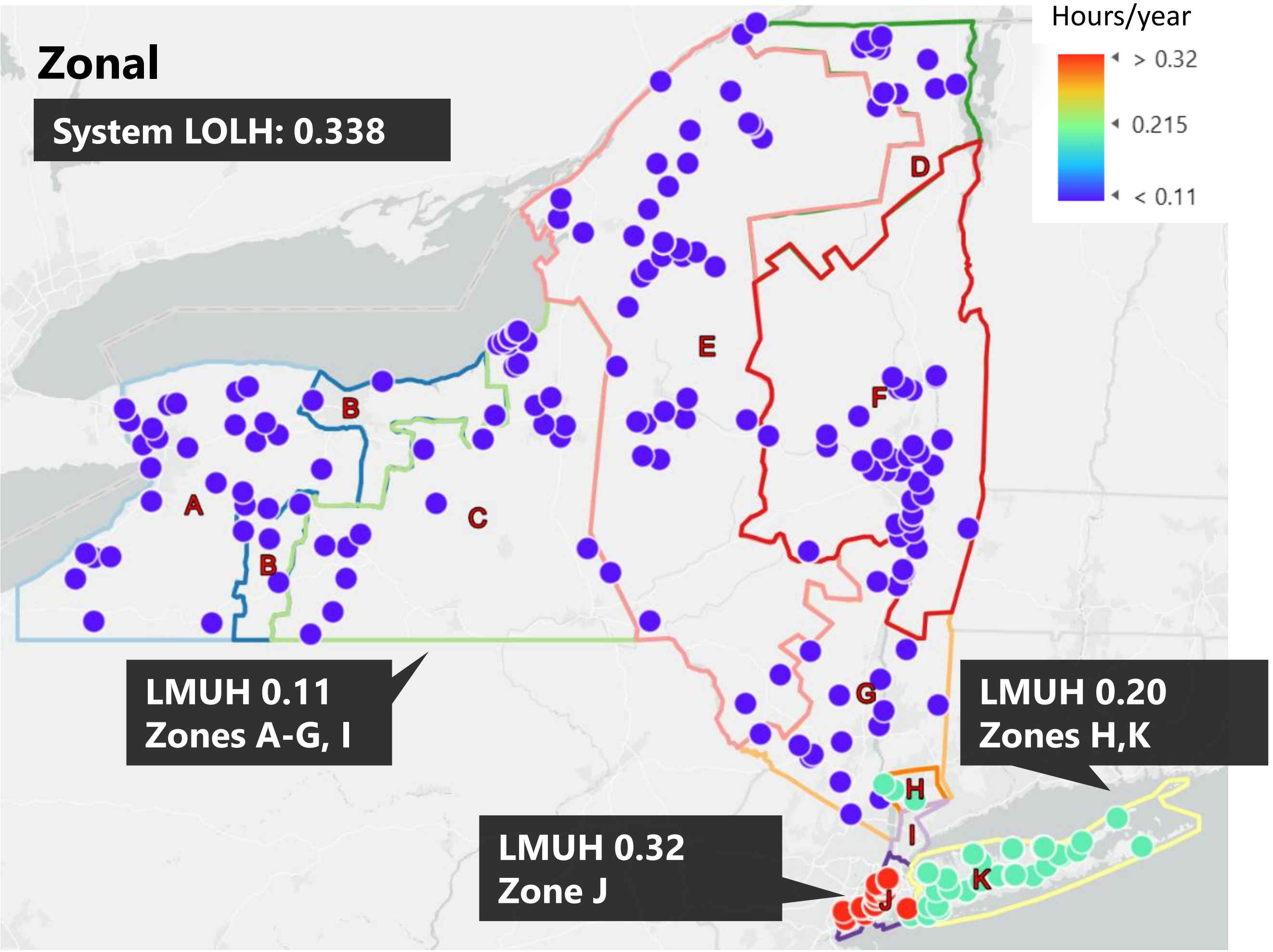
Constrained System

LMUH $_{node}$ = kWh of system-wide EUE reduction per 1 kW of added ideal capacity **at a given location over a year** → **Locational Marginal Unserved Hours**

$$LMUH_{node} = \sum_{t=0}^{8760} LMRI_{node}(t)$$



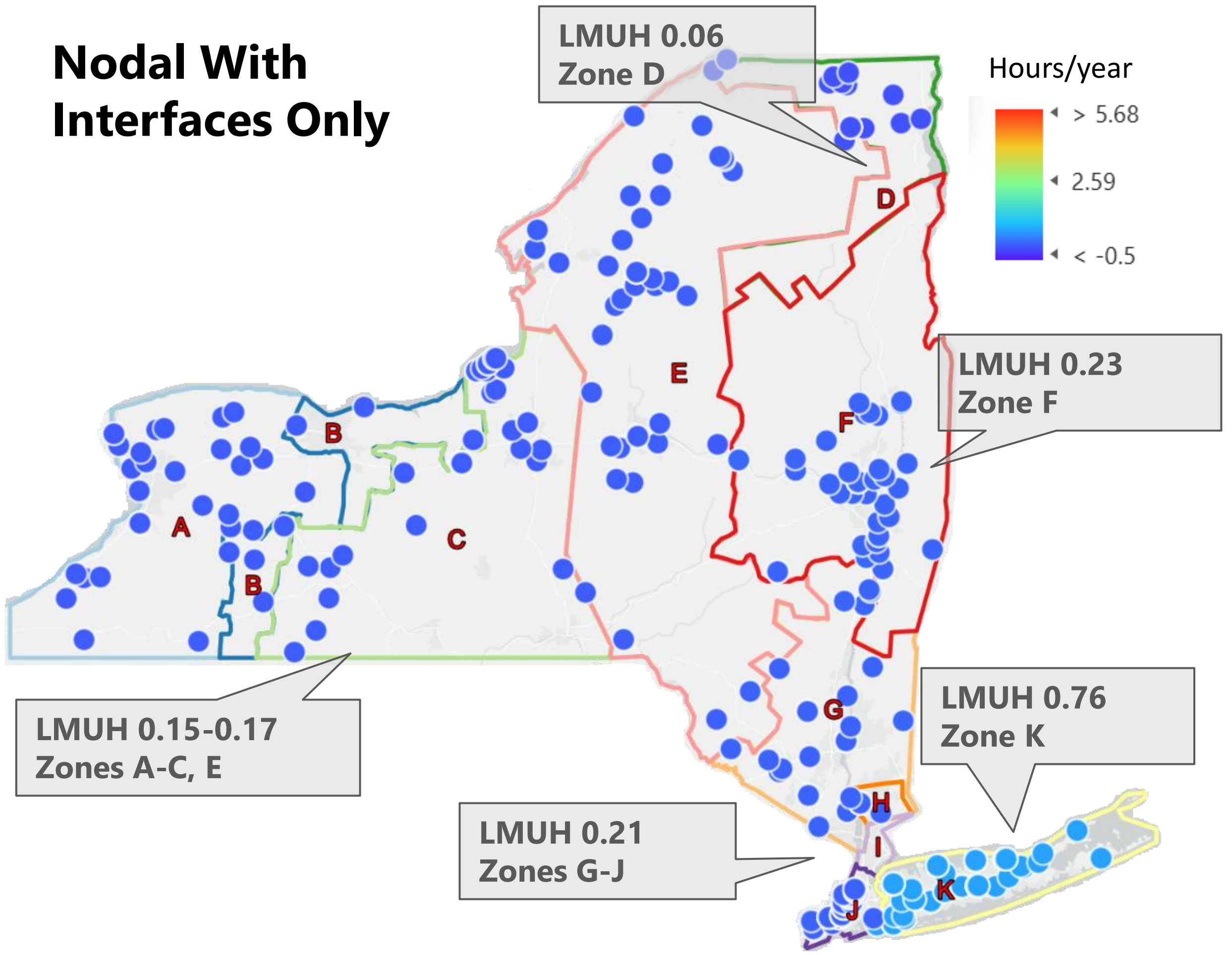
Locational (Zonal) Marginal Unserved Hours

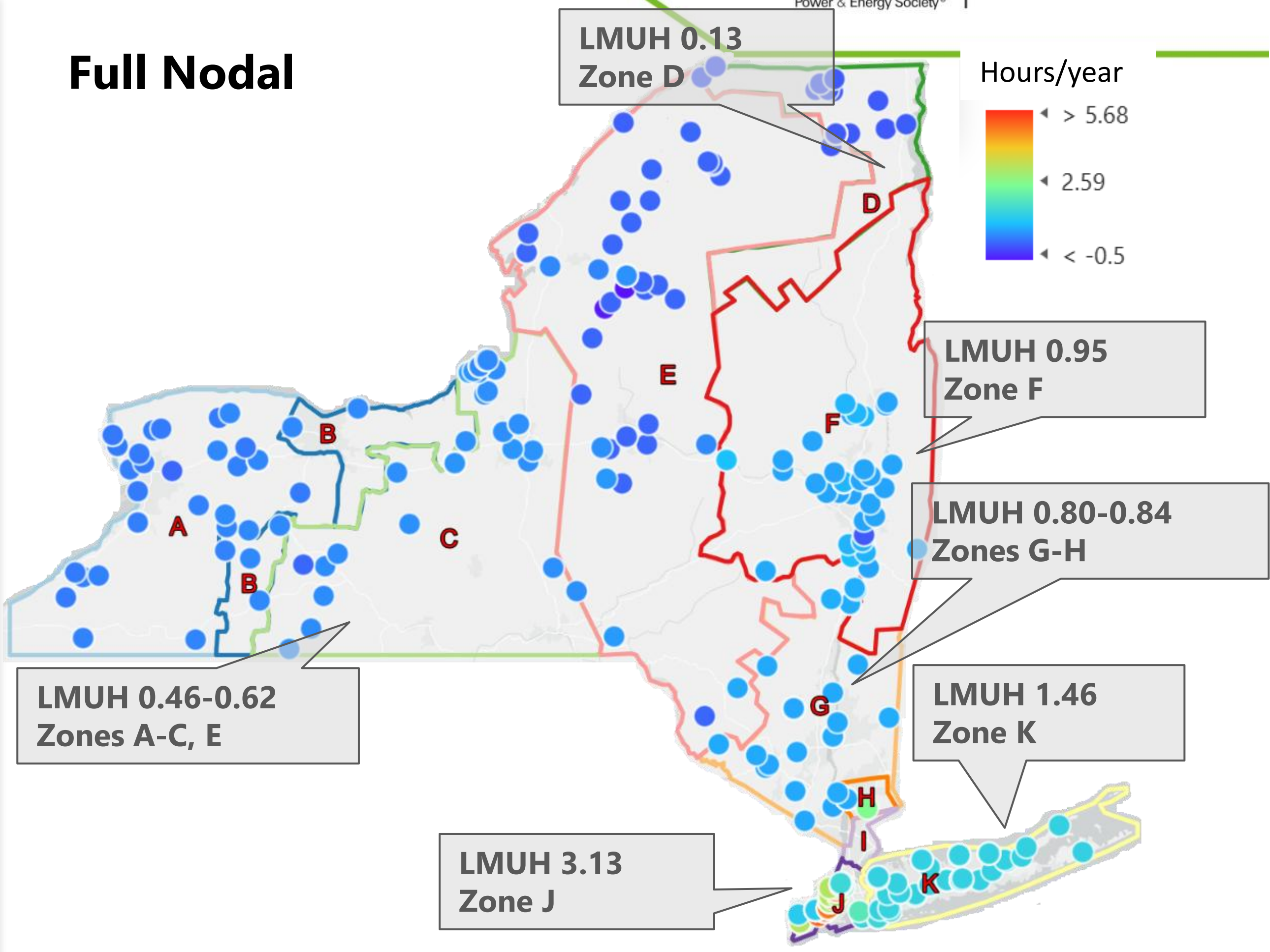


Map powered by Esri
Source for NYISO Load Zone shape file: GISSaturnPower

- Zone J has the highest Zonal Marginal Unserved Hours
- We can't distinguish between individual resources' contribution to reliability in the zonal model
- Note that **LMUH by zone do not add up to LOLH for the system**
- In a constrained system, LOLH and LOLE do not have a meaningful interpretation as a measure of the impact of any specific locational action

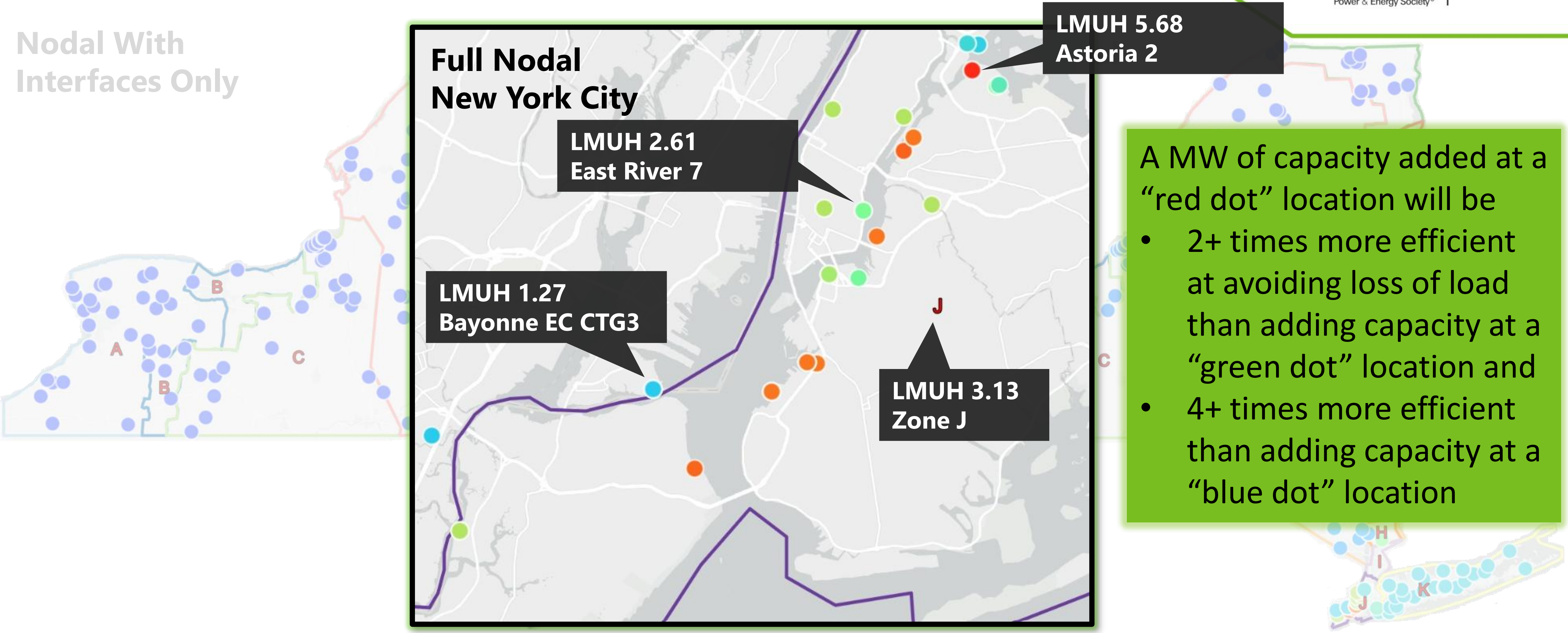
Locational Marginal Unserved Hours – Nodal





- In the zonal model, each zone has an LMUH value whereas in the nodal models we can see the locational variation within the same zone
- Especially under the internal transmission constraints, contribution to reliability massively varies within New York City by location, and some within other zones (e.g., Zone E)

Locational Marginal Unserved Hours in NYC



A MW of capacity added at a "red dot" location will be

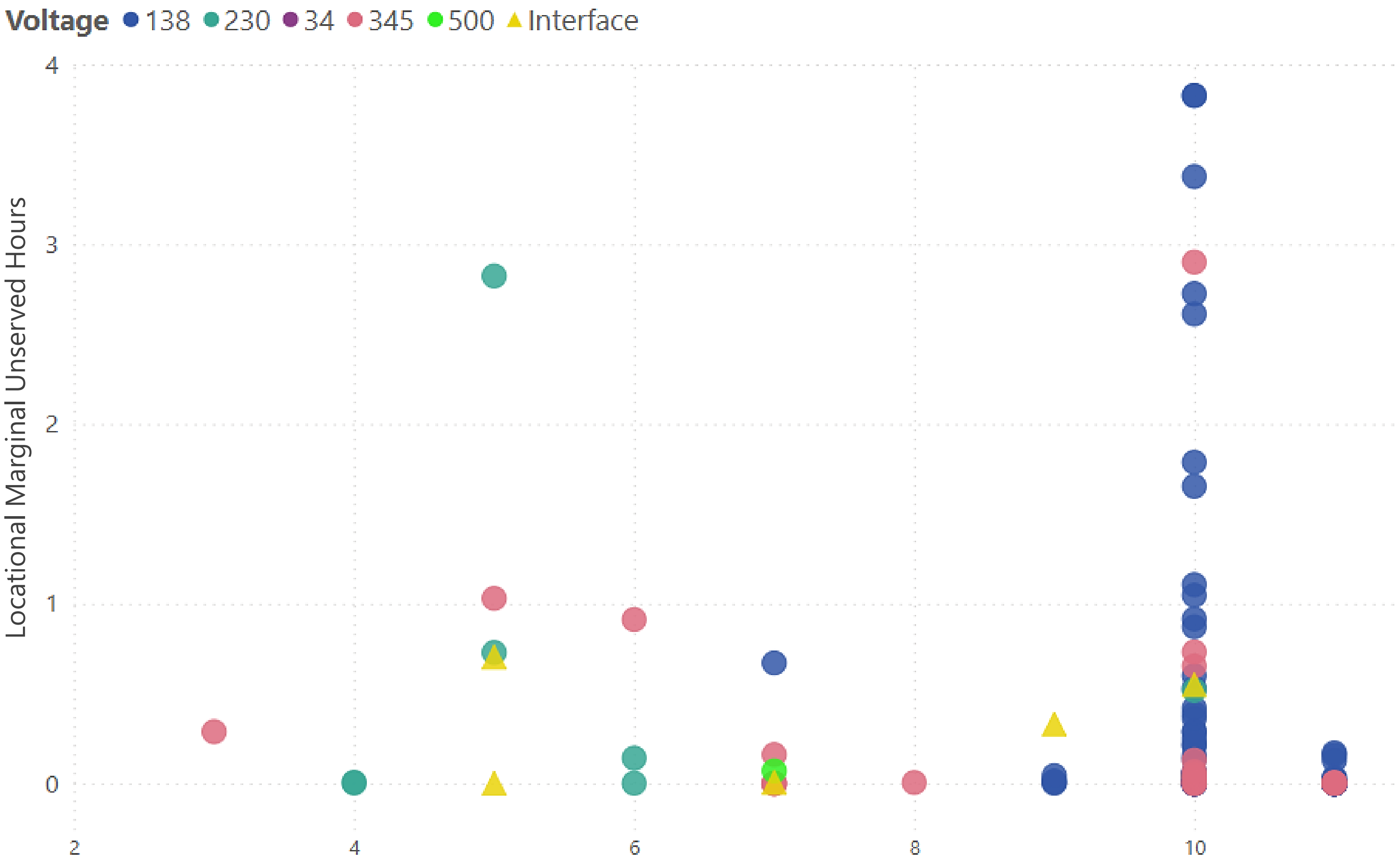
- 2+ times more efficient at avoiding loss of load than adding capacity at a "green dot" location and
- 4+ times more efficient than adding capacity at a "blue dot" location

- In the zonal model, each zone has an LMUH value whereas in the nodal models we can see the locational variation within the same zone
- Especially under the internal transmission constraints, contribution to reliability massively varies within New York City by location

Impact of Internal Transmission Constraints

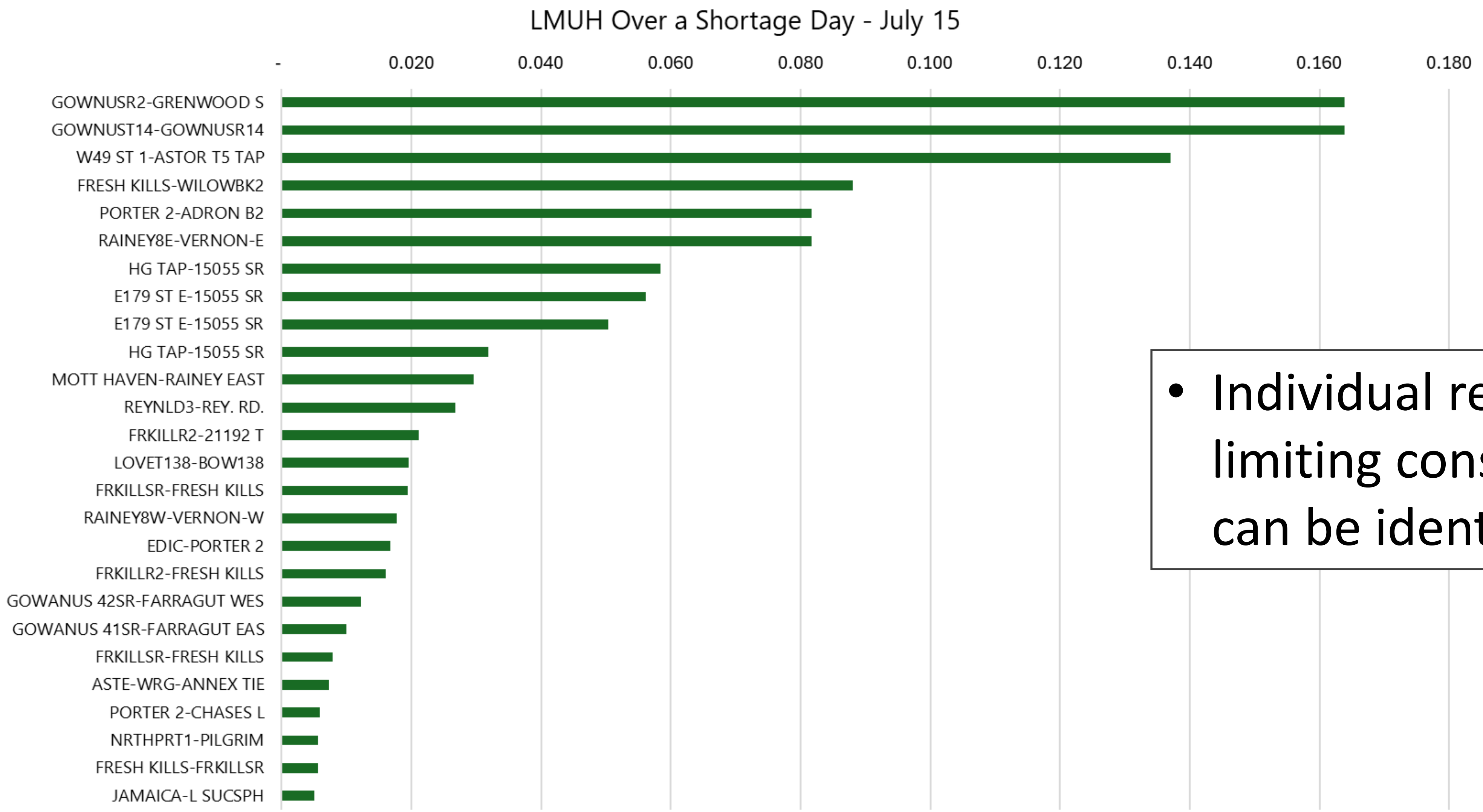
- We can identify top **reliability limiting constraints** that bind at the time of load shedding
- Should not be confused with transmission congestion which is an economic phenomenon, not a reliability concern
- We can rank constraints by the level of EUE reduction per incremental increase of the constraint limit
  - Locational Marginal Unserved Hours for a transmission constraint measures *"MWh reduction in unserved energy per MW increase in transmission constraint limit in the course of a year"*

Impact of Internal Transmission Constraints



✓Each bubble represents a transmission constraint
✓New York City (Zone J) has the largest number of reliability limiting constraints
✓LMUH of transmission assets versus generation locations allows comparison between efficiency of adding capacity at a location versus increasing the transmission capacity
✓Majority of the local reliability limiting constraints have a higher LMUH than interfaces

Impact of Internal Transmission Constraints



- Individual reliability limiting constraints can be identified

Impact of Operational Details

	Full Nodal With UC and Ancillary Services	Full Nodal ED Only and Ancillary Services
LOLH (hours/year)	19.36	16.42
EUE (MWh)	9,074	7,851
LOLH + EOPH[1]	182.70	77.84

[1]EOPH = Hours where any Emergency Operating Procedure is used (e.g., *demand response*)

DISCLAIMER

These results do not indicate that the NYISO system is not reliable. They provide, however, a highly granular representation which may reveal locational infeasibilities in the system overlooked by the traditional tools and normally avoided through operational actions. This analysis provides granular representation of efficiency of such operational actions such as relaxation of transmission limits.

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- Demonstrated on a single weather year
- Both cases explicitly model ancillary services
  - Regulation, spin, and non-spin
- Including Unit Commitment limitations **more than doubles the hours where emergency procedures are deployed**
- Including operational details significantly impact marginal accreditation

Summary

- **Location of generation and transmission capacity matters**
  - Nodal analysis differentiates locational impacts of adding resources by factor of 2 or even 5 and can lead to a much better decisions on which resource to build and where to build them, including
    - Generation additions
    - Transmission upgrades and GETs
    - Load management
- **Is nodal analysis practical?**
  - Yes, with the right computational approach and cloud computing
- **Zonal analysis issues**
  - Zonal analysis does not capture “deliverability” in typical marginal accreditation methods
- **Next steps**
  - Impact of operational constraints
  - Locational impact of load shedding
  - Economic connection and how to apply nodal RA results in planning studies
  - Impact of specific transmission investments on RA

THANK YOU

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