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ESIG
Spring Technical Workshop
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Zonal vs Nodal Reliability Analysis in NYISO

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Outline

- Traditional versus High-Fidelity Reliability Analysis
- Why should we care about Nodal Analysis and Operational Details?
- Re-studying NYCA 2023 IRM Study* using both the zonal and nodal configurations of the same model**
- What have we learned from the nodal assessment compared to the zonal representation?

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

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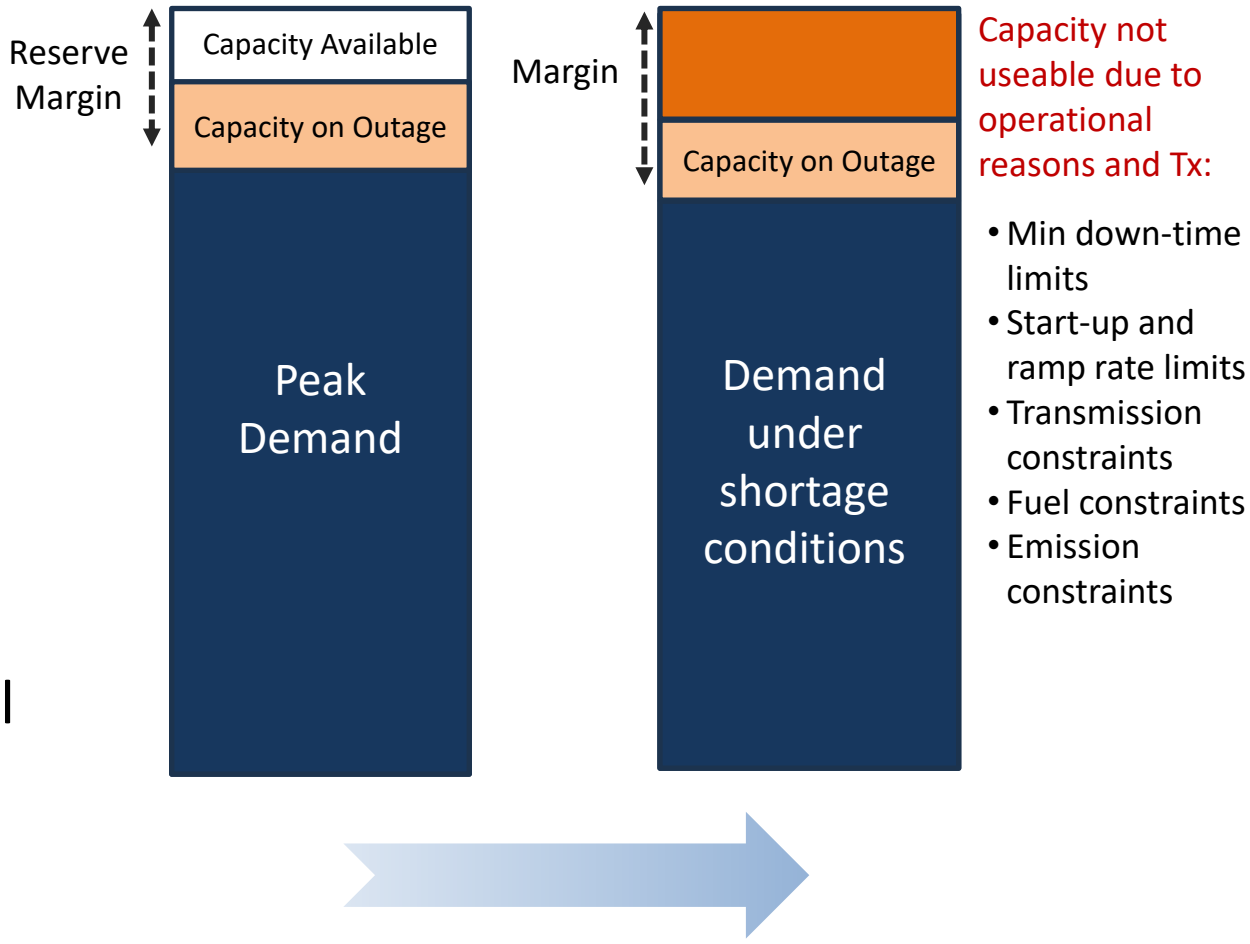
Why Should We Care About Tx and Operational Details?

- Zonal models require defining zones with no or low congestion within them and limits between zones
- Poorly coordinated generation and transmission expansion lead to suboptimal decisions
- Shortages can occur even when capacity is available system-wide or elsewhere because of other operational limitations (e.g. ramping and commitment constraints)



Planning reserve margin is no longer a safe margin

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Zonal versus Nodal Reliability Analysis

Zonal

- **Modeling effort:** Need to define homogenous zones and produce zonal transfer limits between zones
- **Accuracy:** Violates Kirchhoff Voltage Law. Highly dependent on the ability to define zones with little congestion inside and approximation of zonal transfer limits. Poor accuracy when the future topology and generation mix are unknown
- **Performance:** Fast especially if operational details are omitted
- **Outcomes:** No locational investment signals, inefficient investments in generation and transmission, excessive costs and high epistemic risk

Nodal

- **Modeling effort:** Physical system representation already exists
- **Accuracy:** Based on the physical realities of the system. Works under changing topology and generation mix.
- **Performance:** With appropriate integrated scenario reduction techniques, can be comparable to Zonal representation
- **Outcomes:** Locational investment signals for generation, transmission and demand-side resources for optimal investment costs. Reduced epistemic risk.

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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

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NYISO Probabilistic Reliability Study

14 Weather Years

200 Outage Samples / Partition

Parallel simulations

2010

2011

2012

⋮

2022

2023

×

Weeks 1-2

Weeks 3-4

Weeks 5-6

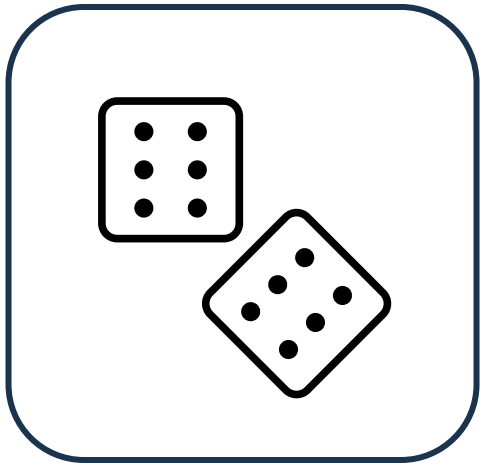
⋮

Weeks 49-50

Weeks 51-52

Parallel simulations

=



2800

annual samples for the study period

May 2024 – April 2025

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ENELYTIX Weather Used In the Study

Spatial historical weather data

Site technology specifications

Model Inputs

Generator dataset

Weather-to-Power

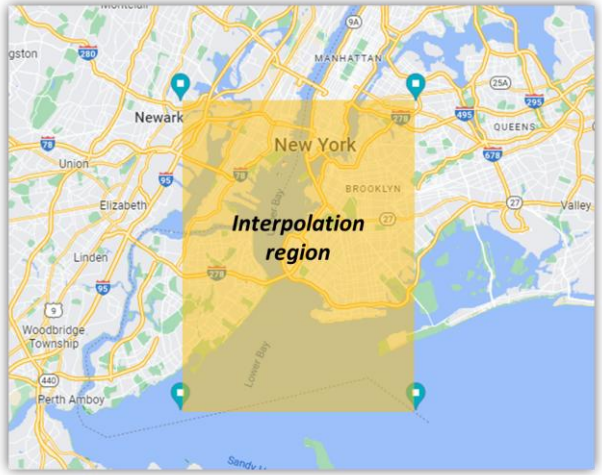
Wind

Solar

Historical net generation

Calibration

End-use power simulation studies



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

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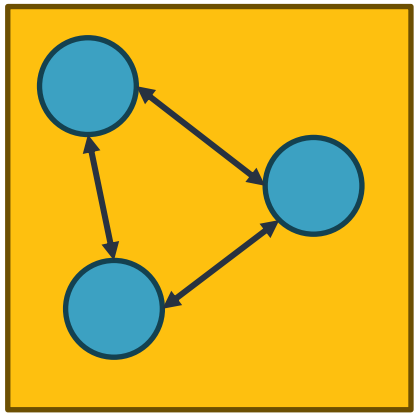
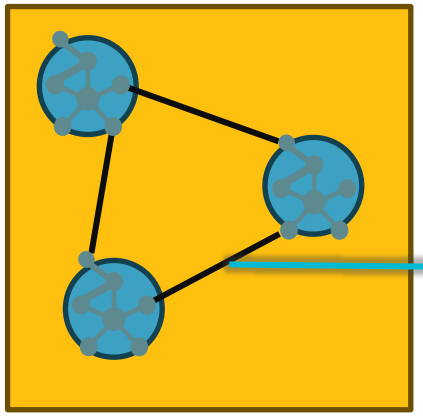
Types of Studies Performed

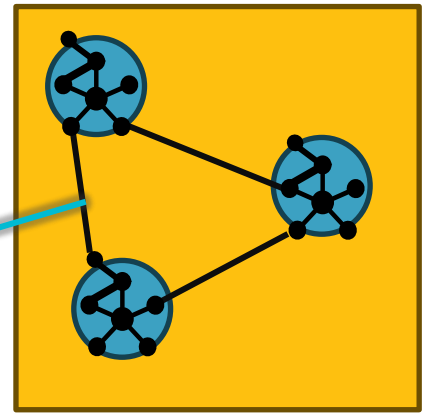


Zonal with transfer limits

- As used in the IRM study

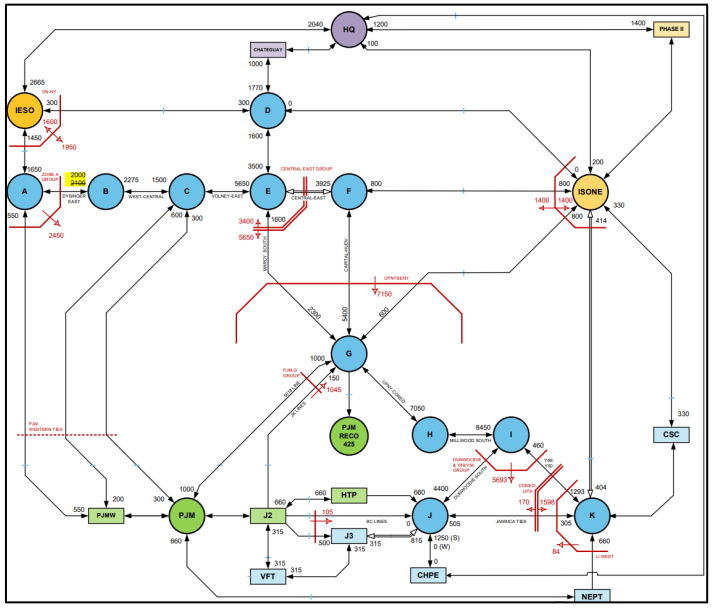


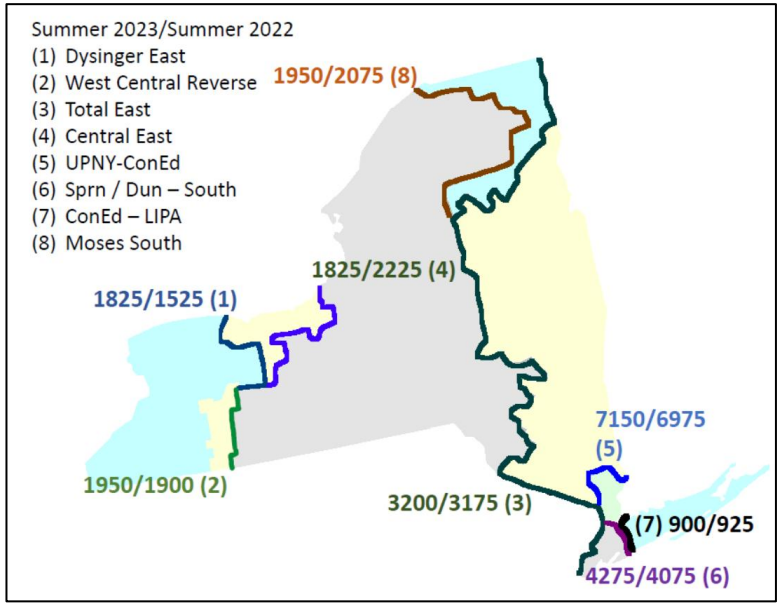
Interfaces
(physical ties)

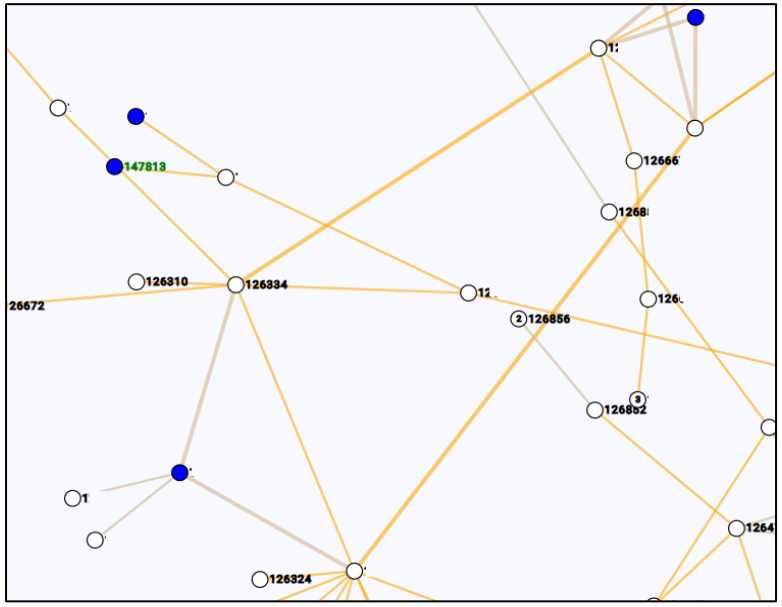


Nodal with major interfaces

Full nodal with internal transmission limits







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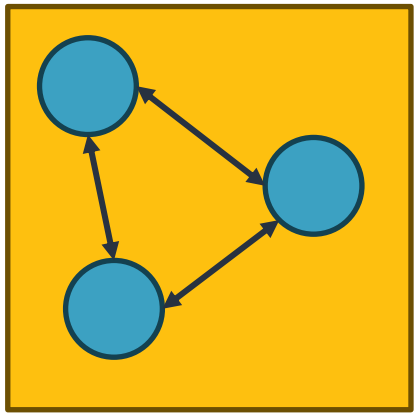

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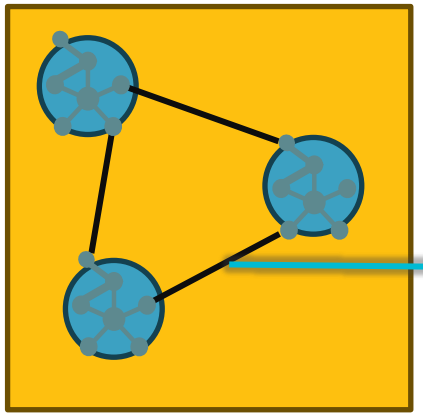

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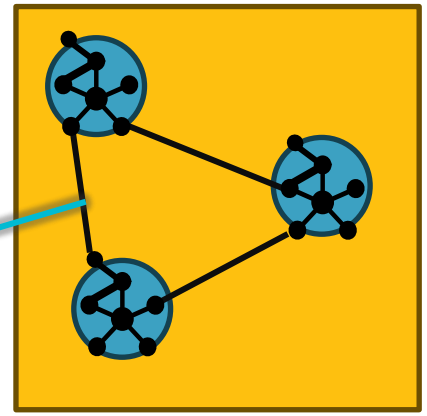
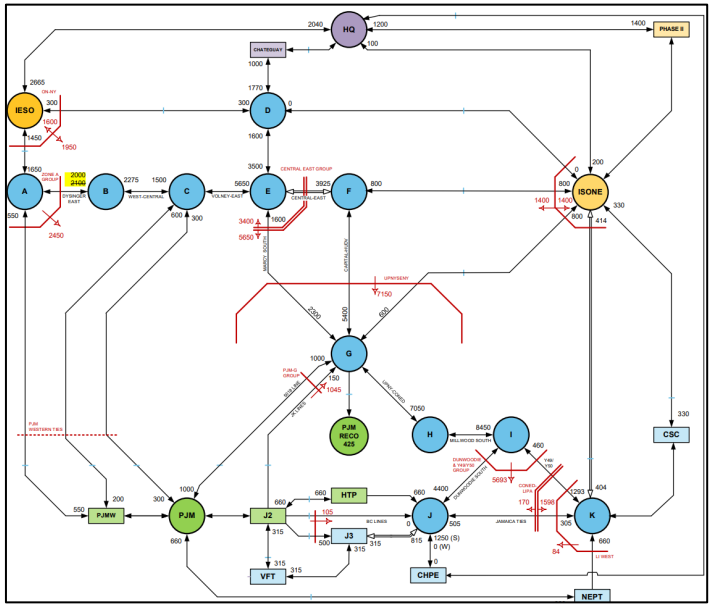
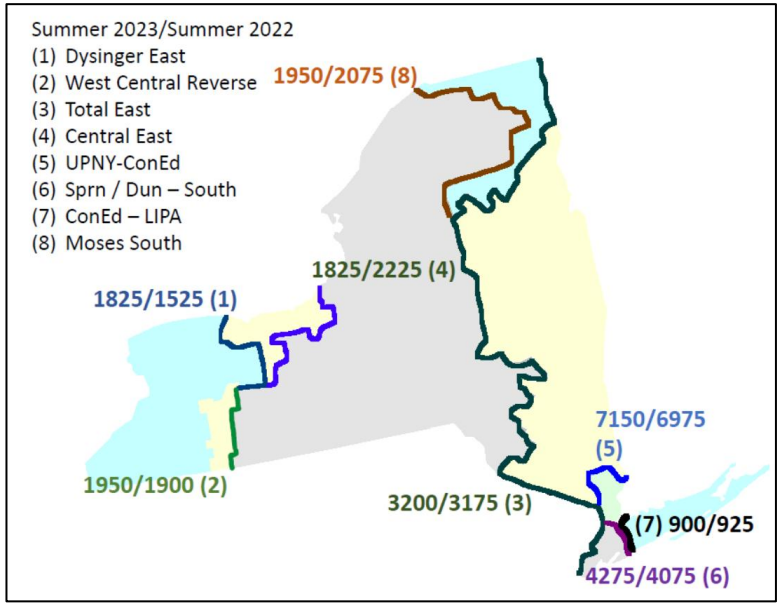


Nodal with major interfaces

Full nodal with internal transmission limits

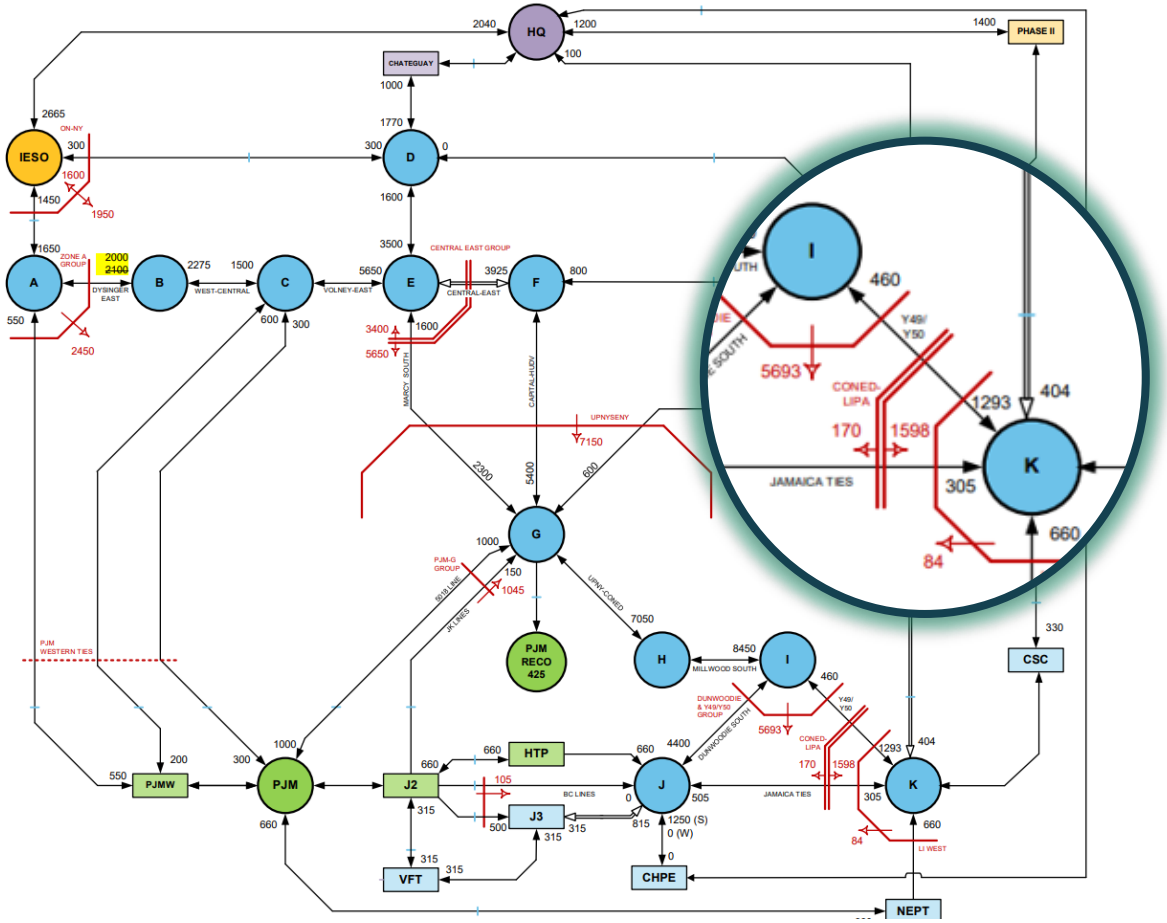




Study 1: Use transmission constraint violations to resolve local issues before load shed

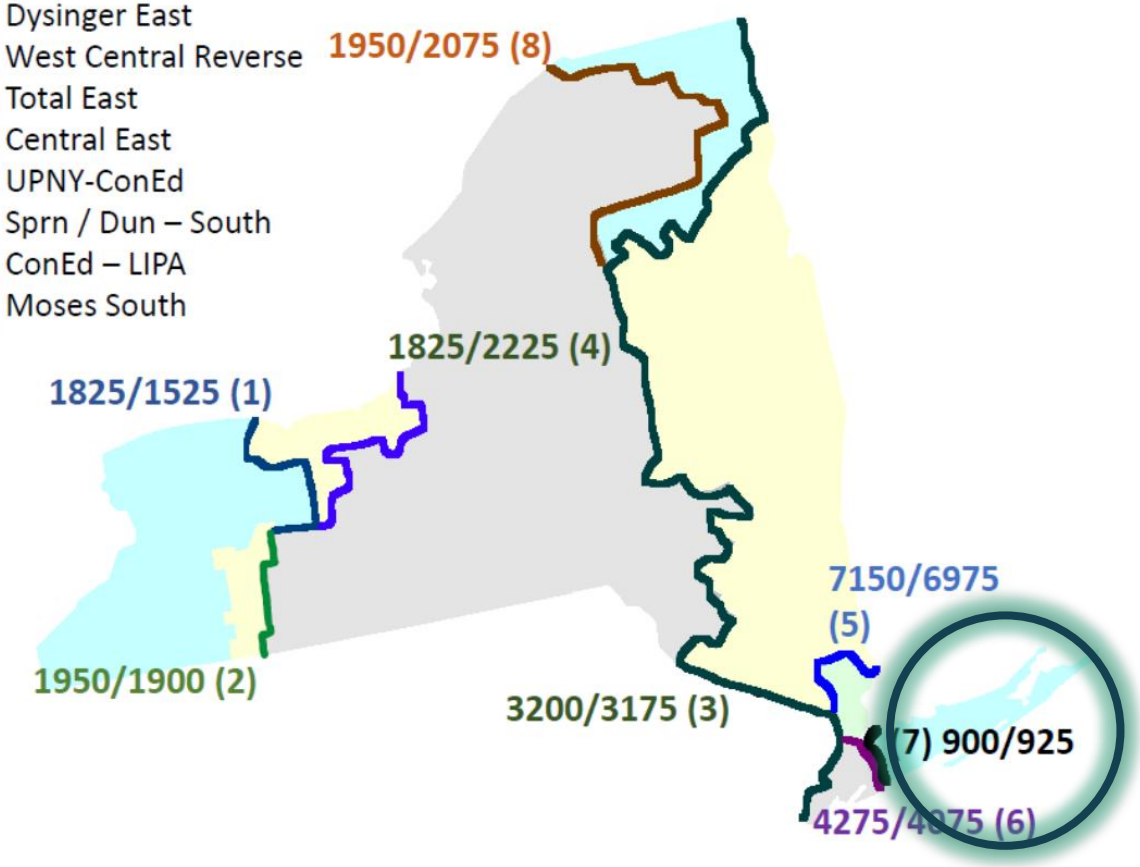
Study 2: Resolve shortages through load shed before violation of transmission constraints

Zonal Transfer Limits versus Physical Interfaces



Summer 2023/Summer 2022

(1) Dysinger East
(2) West Central Reverse
(3) Total East
(4) Central East
(5) UPNY-ConEd
(6) Sprn / Dun – South
(7) ConEd – LIPA
(8) Moses South



- Differences in zonal transfer limits and physical interface limits in the nodal model
  - ConEd – LIPA Zone K to J zonal transfer limit in IRM Study: 170 MW
  - ConEd – LIPA single thermal limit in Summer 2023 Operating Study: 900 MW
- Nodal model only with major interfaces lead to different economic / reliability outcomes than the zonal model

NYISO-Wide Metrics

	NYISO 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*	No data	8.62	9.53	12.11	34.95
EUE + EEOP (MWh)**	No data	6,150	6,678	8,313	24,188
Total computational time	No data	131 hours	189 hours	470 hours	480 hours
Turn-around time	No data	0.67 hours	0.87 hours	2.5 hours	2.6 hours

*EOPH = Hours where any Emergency Operating Procedure is used (e.g., *demand response*)
**EEOP = Expected dispatch of all Emergency Operating Procedures

- 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 and EUE than the zonal model due to physical limits and locational issues

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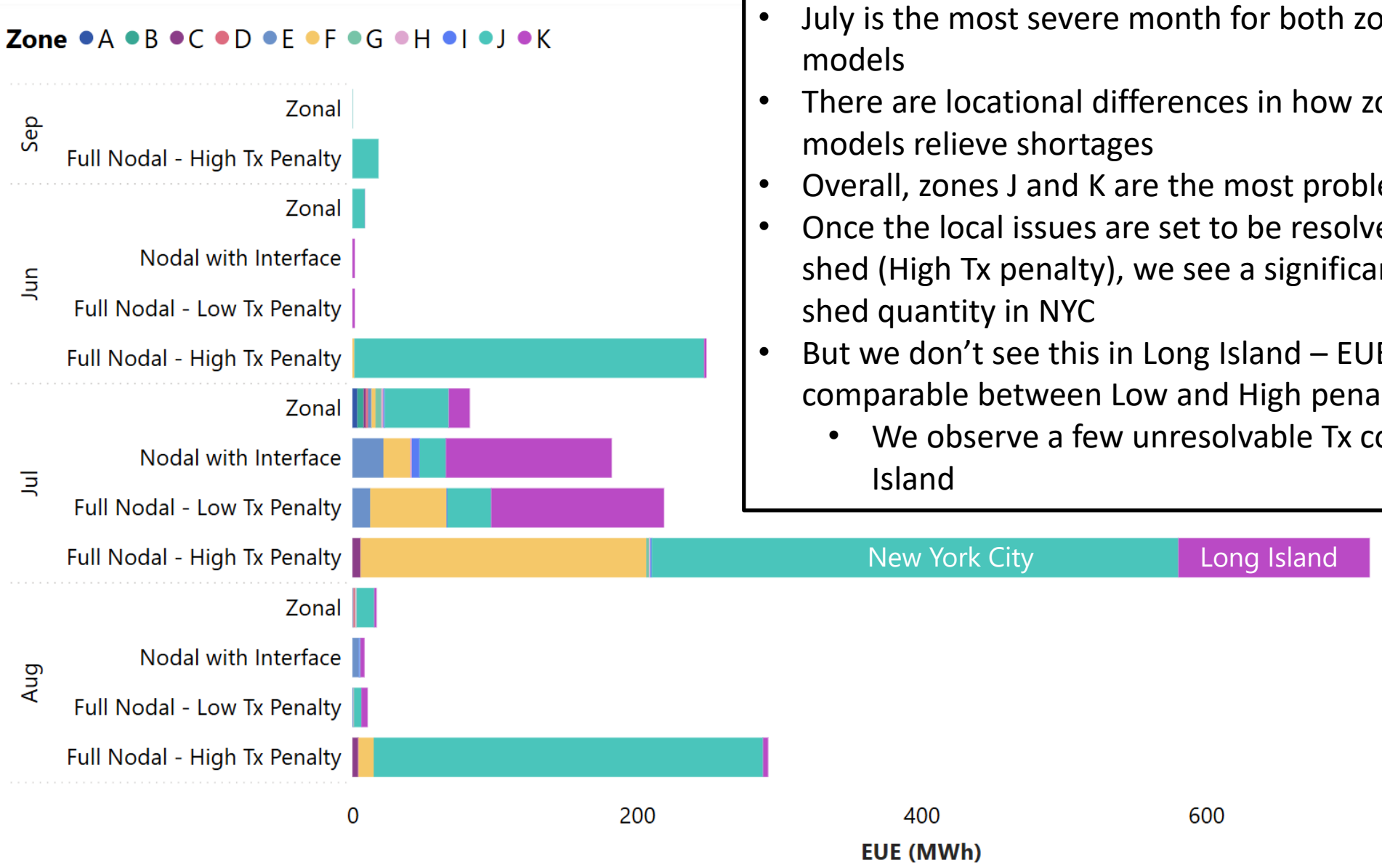
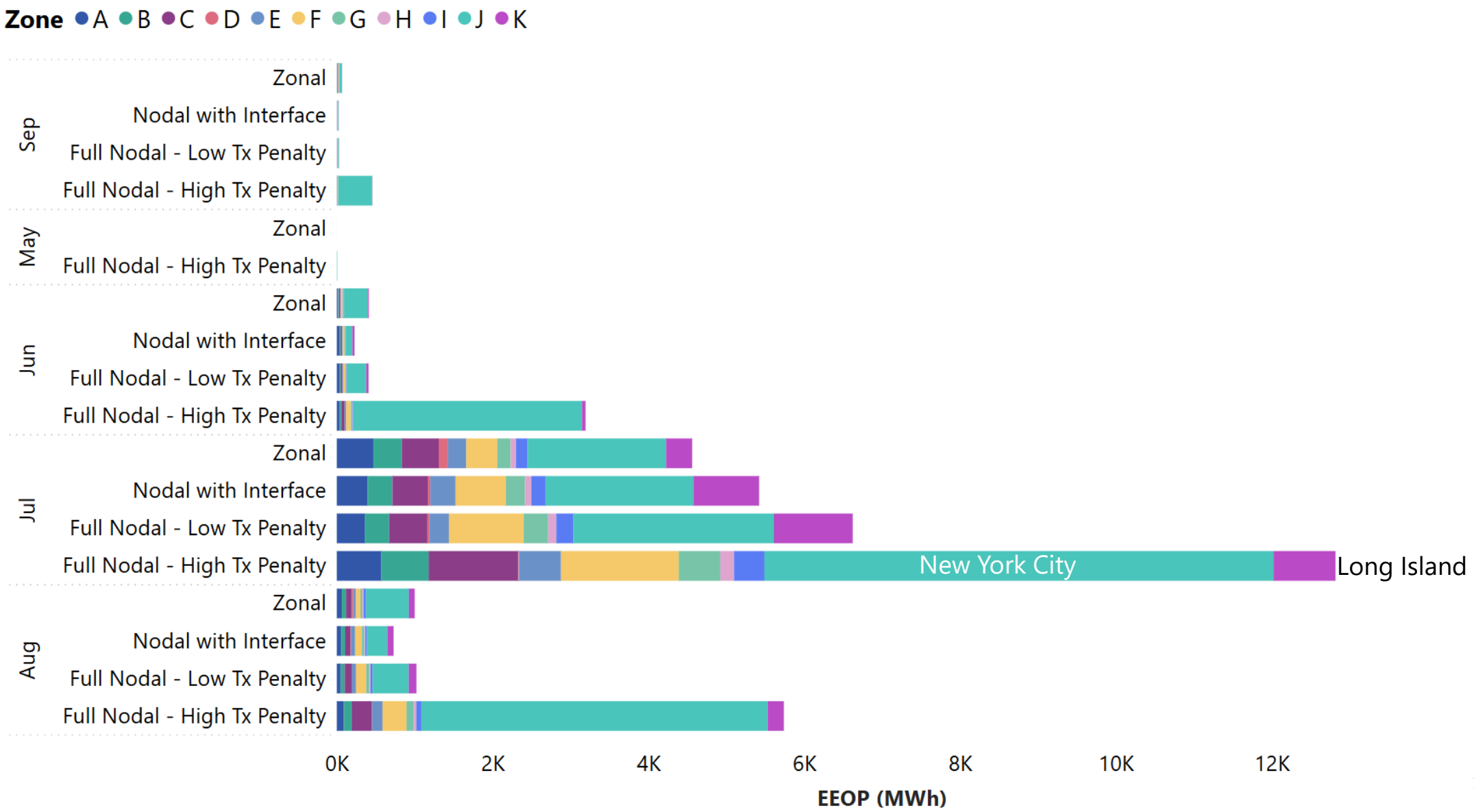
When and Where does Unserved Energy Occur?



- July is the most severe month for both zonal and nodal models
- There are locational differences in how zonal and nodal models relieve shortages
- Overall, zones J and K are the most problematic zones
- Once the local issues are set to be resolved through load shed (High Tx penalty), 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 penalty
  - We observe a few unresolvable Tx constraints in Long Island

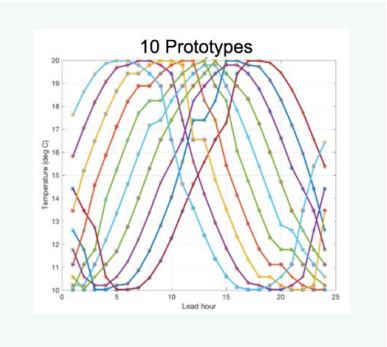
When and Where are Emergency Operating Procedures Applied?



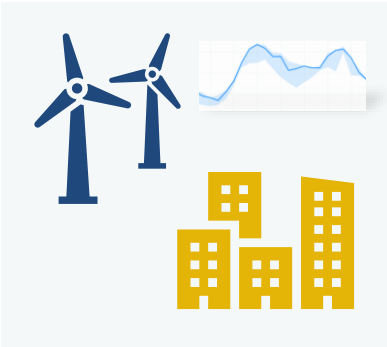
What are Marginal Reliability Metrics?

- *In addition to traditional metrics (LOLH, LOLE, EUE), optimization-based RA tools can provide dual variables that directly generate* ***Marginal Reliability Metrics***
- ***Marginal Reliability Metric:*** Expected contribution to adequacy of every resource at every location in the system for every hour of the day

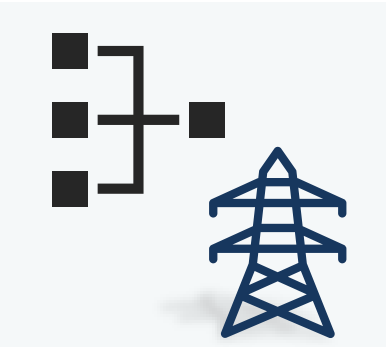
Parallelized processing ← →



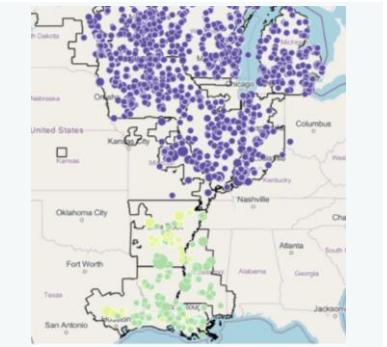
Short-Term Weather Scenarios or Historical Weather Years



Weather to Power Scenarios



Zonal/Nodal SCUC/SCED simulations



Zonal/Nodal and hourly inadequacy risk

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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

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Marginal Reliability Metrics are "Location Ready"

- LOLP and LOLH are marginal metrics:
  - *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**
  - *LOLH* = kWh of EUE reduction per 1 kW of added ideal capacity **in an unconstrained system in a course of one year**
  - $LOLH = \sum_{t=0}^{8760} LOLP(t)$
- In constrained system, the analog of LOLP is Locational Marginal Reliability Impact (LMRI) and analog to LOLH is Locational Marginal Unserved Hours (LMUH):
  - $LMRI_{node}$(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**
  - $LMUH_{node} = \sum_{t=0}^{8760} LMRI_{node}$(t)

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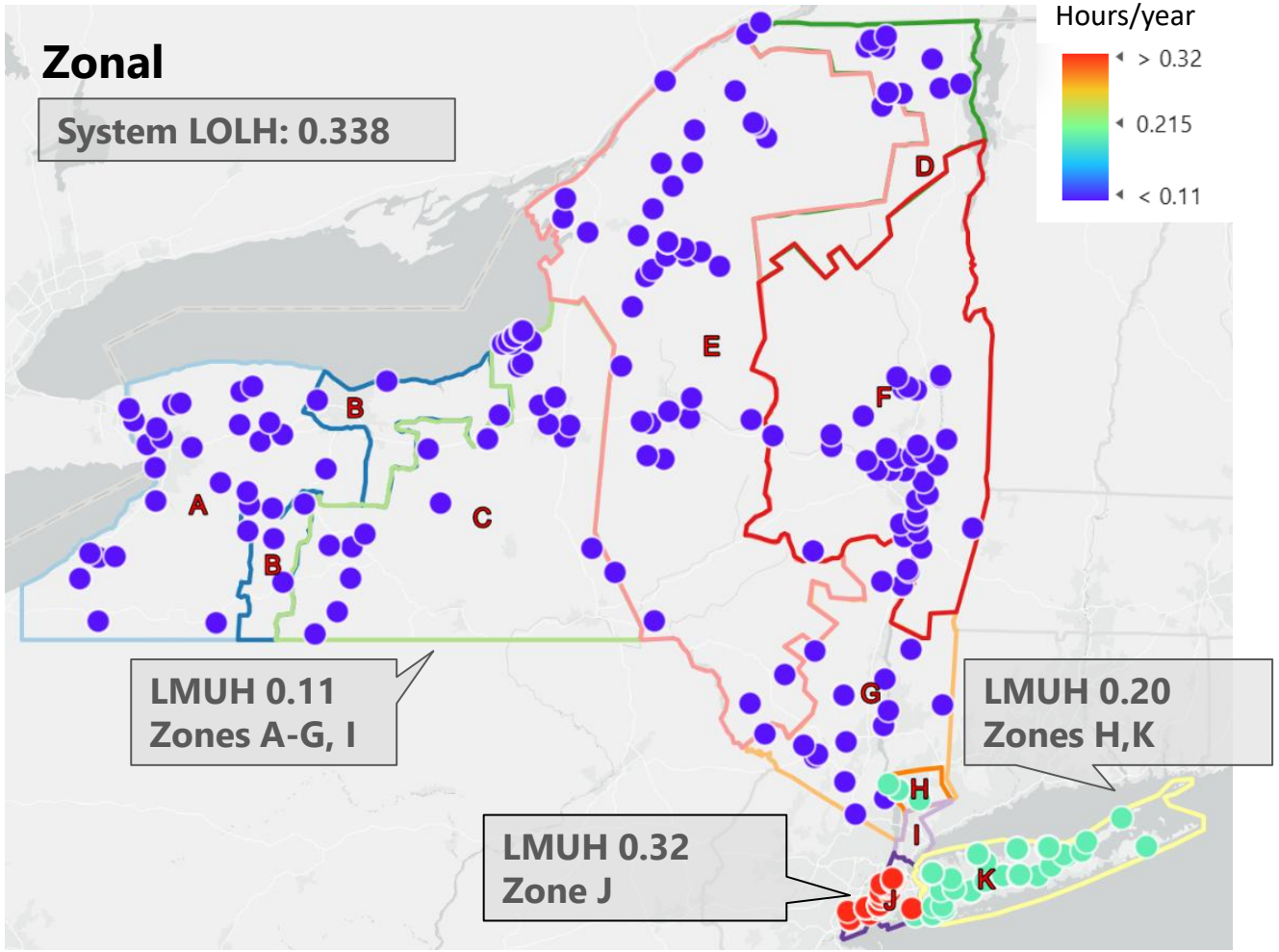
Locational (Zonal) Marginal Unserved Hours in Zonal Model



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

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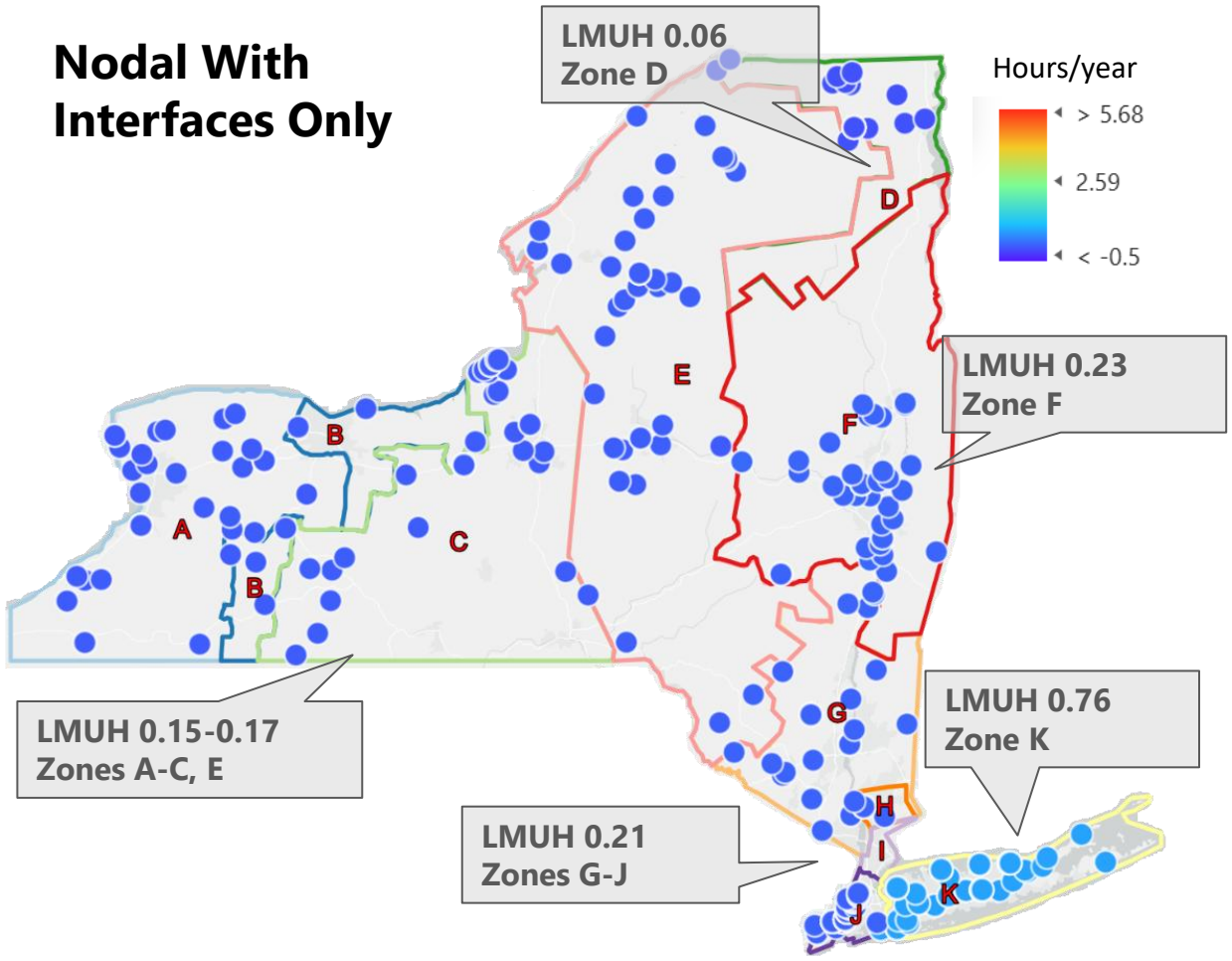
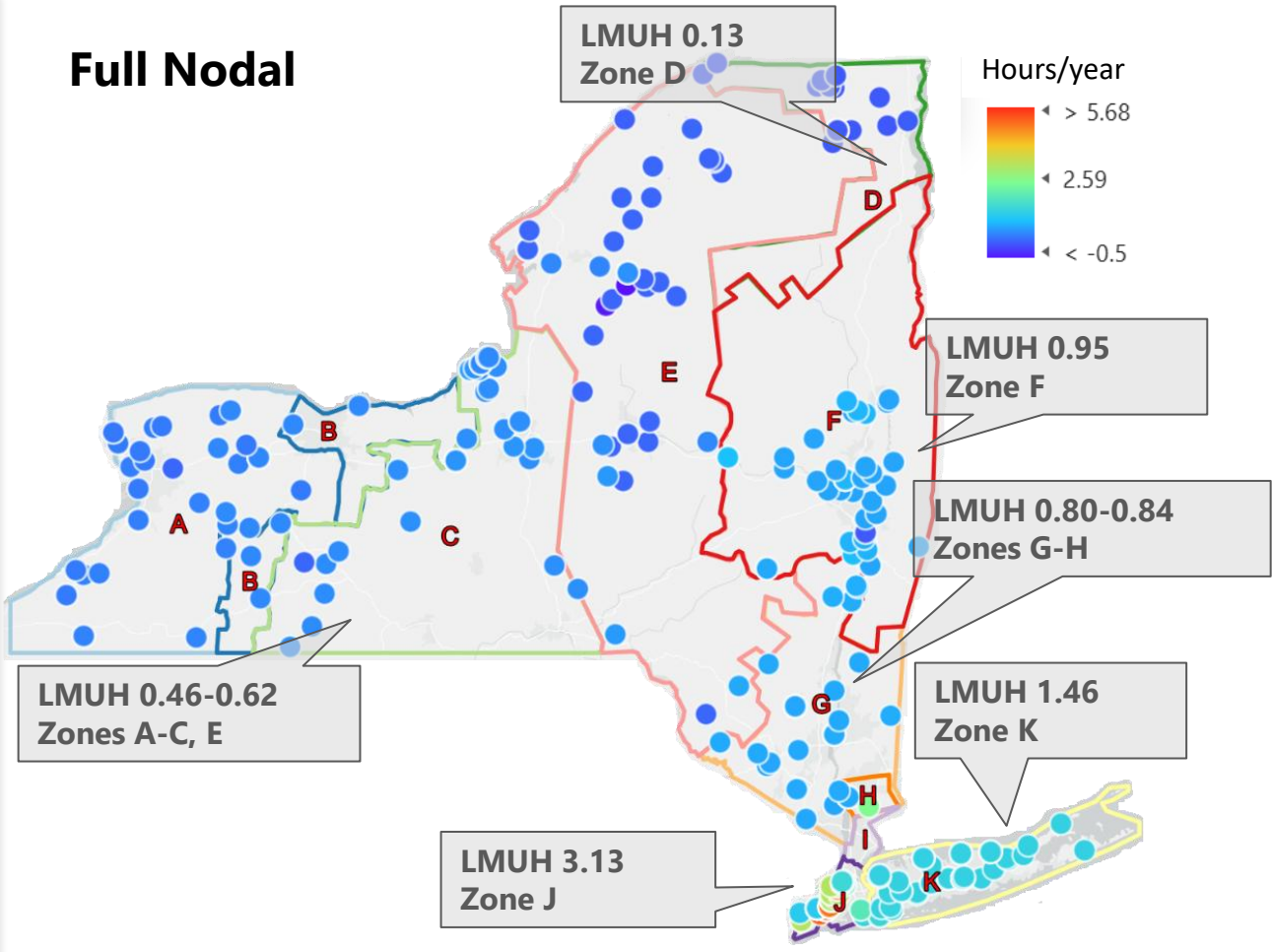
Locational Marginal Unserved Hours – Locational Variation

Nodal With Interfaces Only

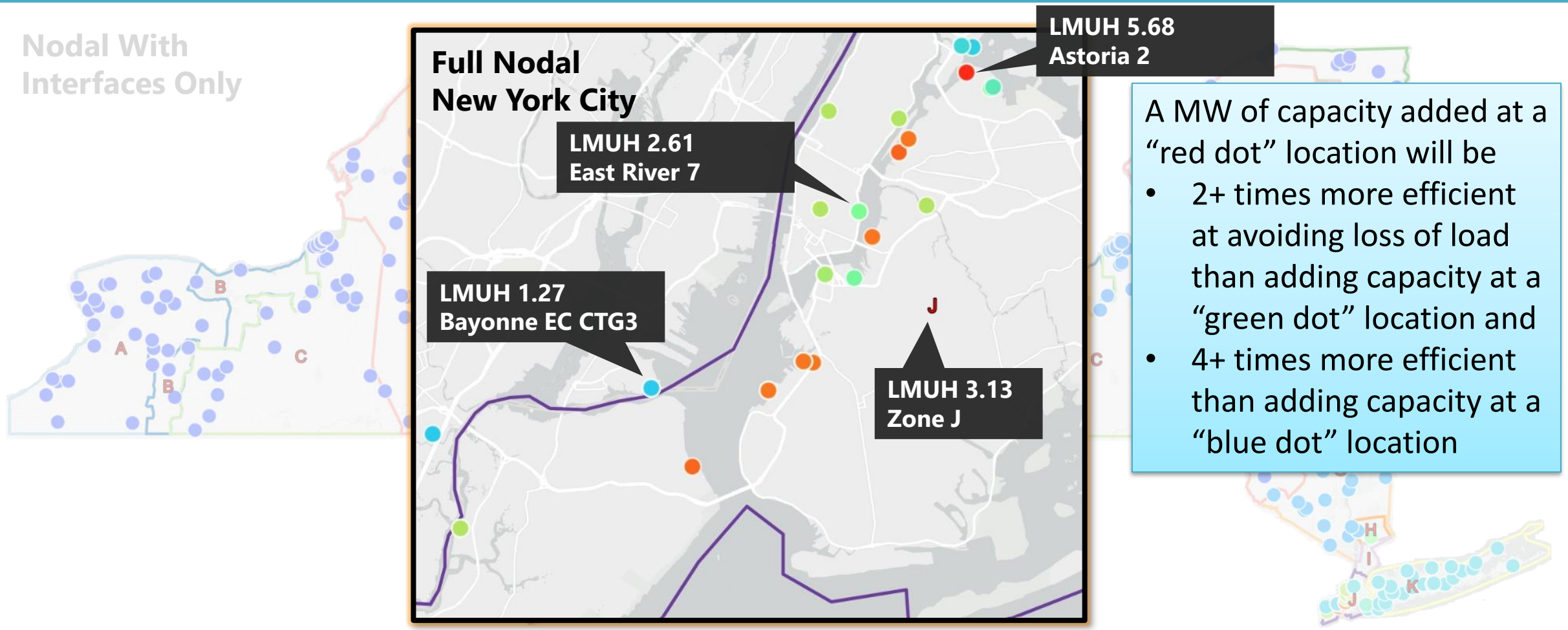


Full Nodal



- 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 have identified 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
- Results are still under review

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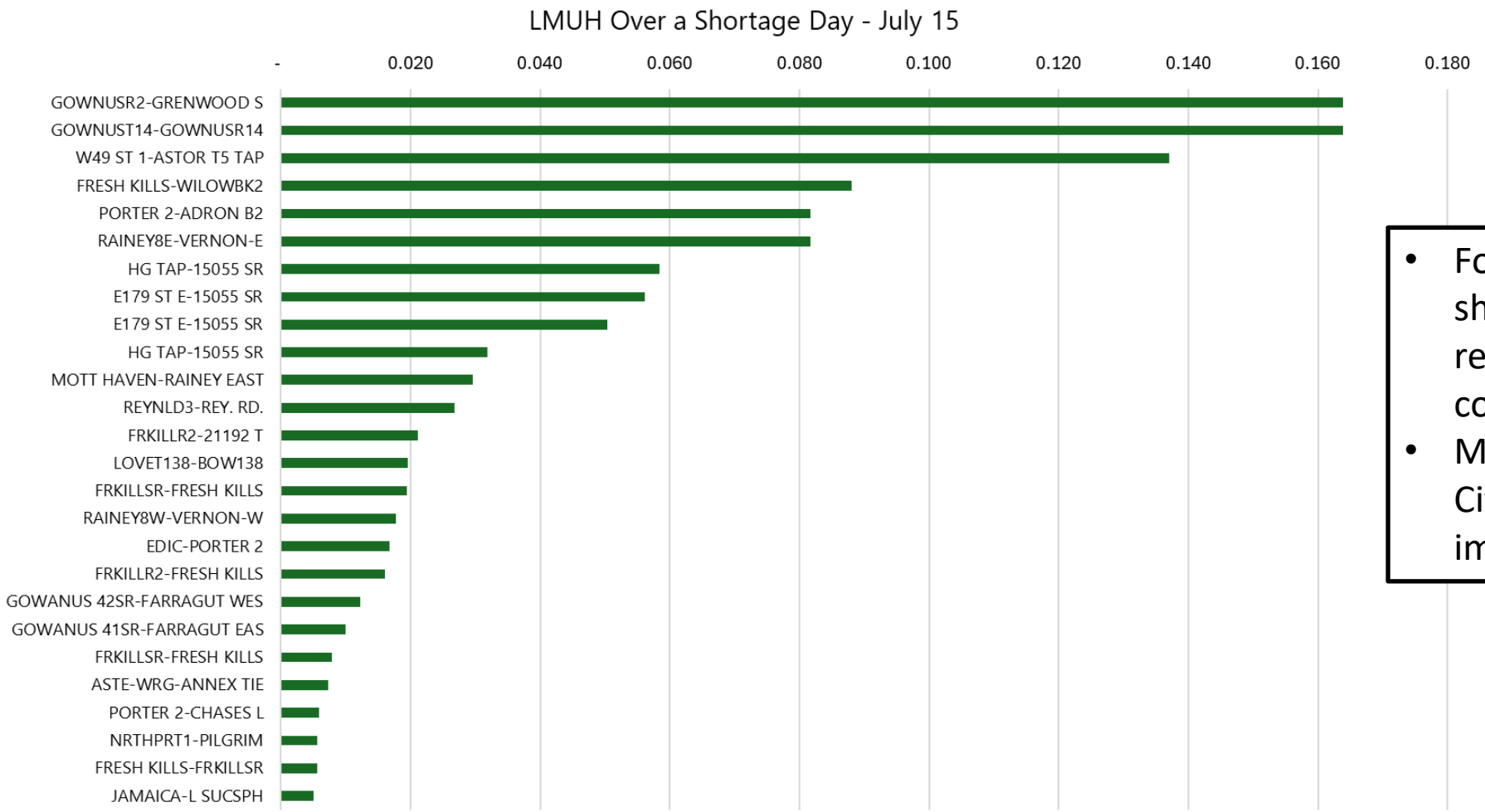
Impact of Internal Transmission Constraints



- Focusing on a single day with shortage in July, what are the most reliability limiting internal constraints?
- Many constraints within New York City (including top three with highest impact on EUE reduction)

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First Lessons Learned from the Nodal vs Zonal Reliability Assessment

- **Physics matters**
  - Accounting for Kirchoff Voltage Law may worsen the adopted adequacy metric (e.g., LOLH) 2.3 times
- **Location matters**
  - Accounting for local transmission constraints may worsen the adopted adequacy metric by factor of 10.5
  - More importantly, 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
    - GETs
    - Load management
- **Zonal analyses have serious problems**
  - Zones and transfer limits are unknown for future generation and topology mix
  - By limiting ourselves to zonal analysis of reliability, we give up any opportunity to find out where the real problems are
- **Next steps (should be ready for the 2025 summer PES meeting)**
  - Impact of operational constraints
  - Locational impact of load shedding
  - Economic connection and how to apply nodal RA results in planning studies

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Q&A

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