Analysis of the Potential Vulnerability of Lower-Carbon Power Grids

A New York State Case Study

PSERC Webinar

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November 22, 2023

Climate - Energy Policies

THE BIDEN PLAN TO BUILD A MODERN, SUSTAINABLE INFRASTRUCTURE AND AN EQUITABLE CLEAN ENERGY FUTURE

Sustainable Business

Canada sets new 2030 carbon reduction target, to issue first green bond

New York to Approve One of the World's Most Ambitious Climate Plans

The state would pledge to eliminate net greenhouse gas emissions by 2050, with all its electricity coming from carbon-free sources.

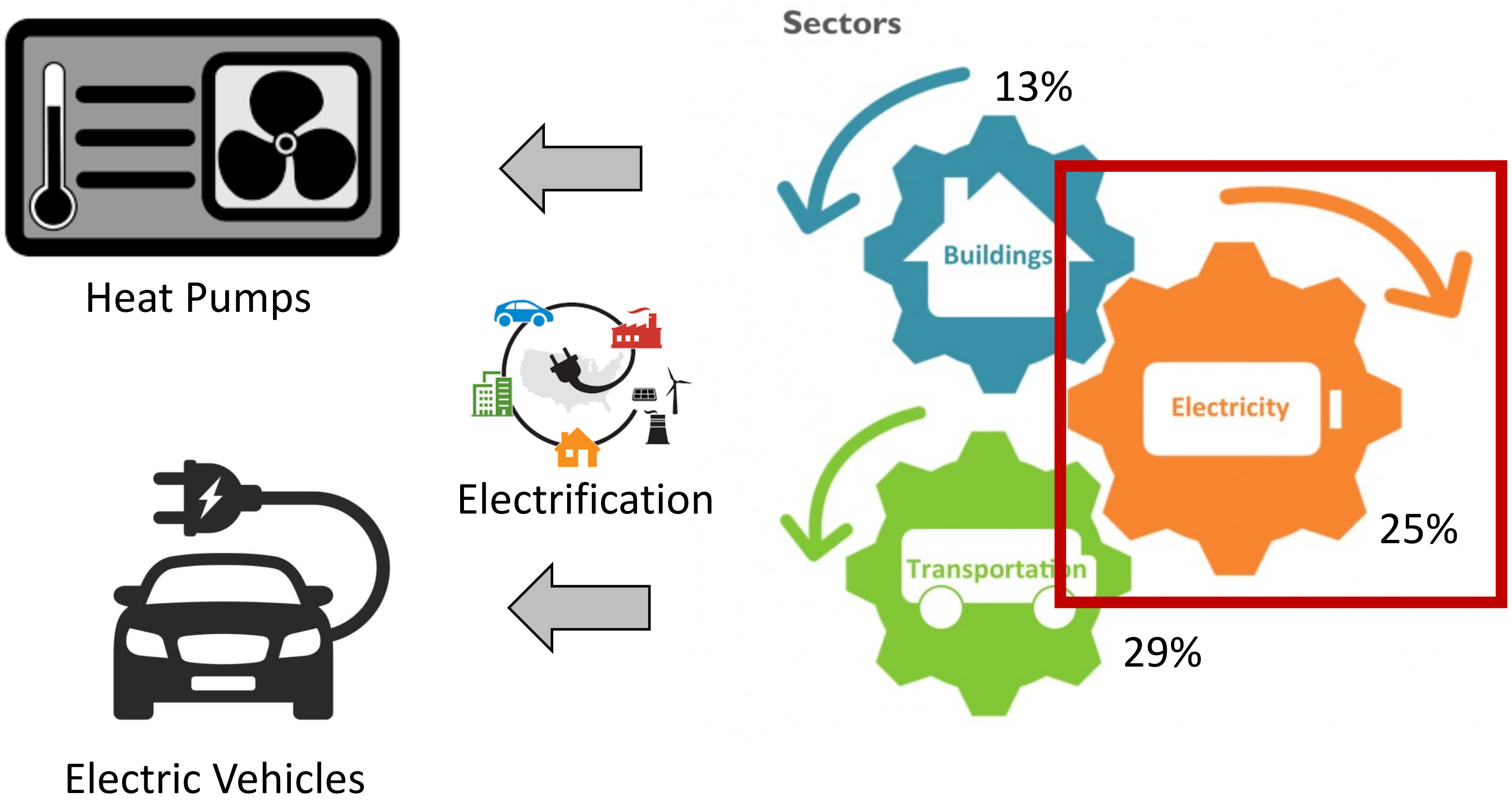
15 Apr 2021, 15:15 Julian Wettengel

New EU goal means Germany might have to cut emissions by 62-68% by 2030 – climate council

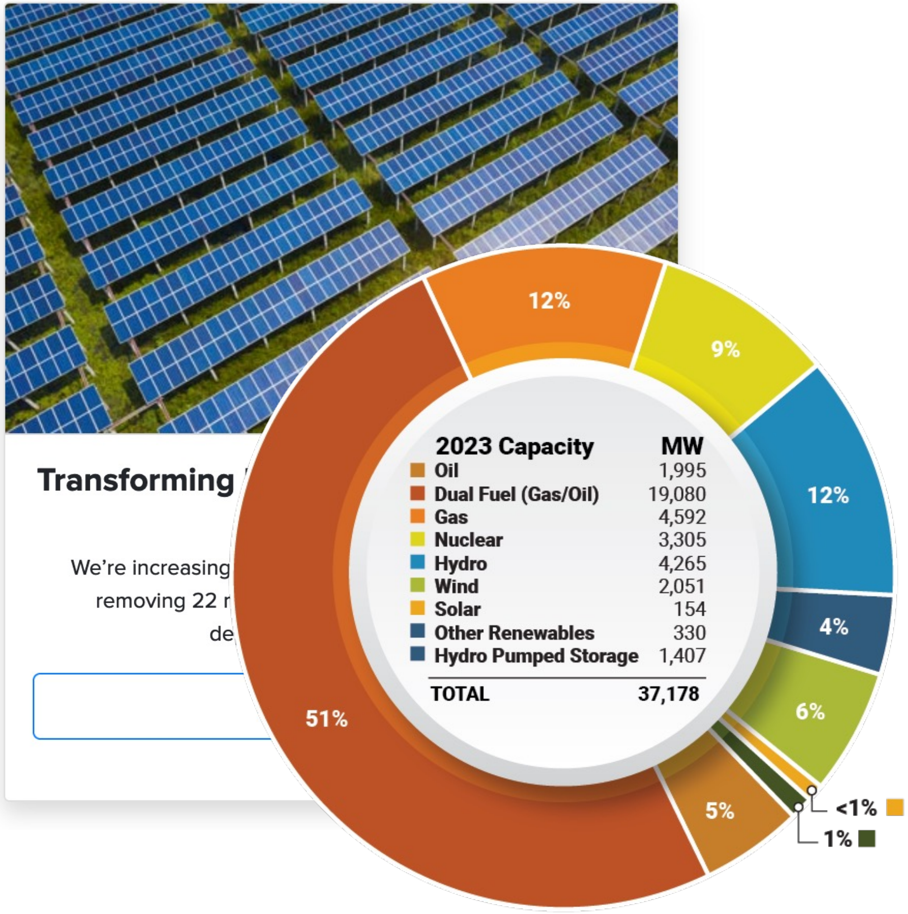
Clean Energy and Emissions Goals by State

Source: National Public Utilities Council Annual Report
https://www.motive-power.com/national-public-utilities-council/

Multi-sector decarbonization



NYS as a Case Study



Targets:

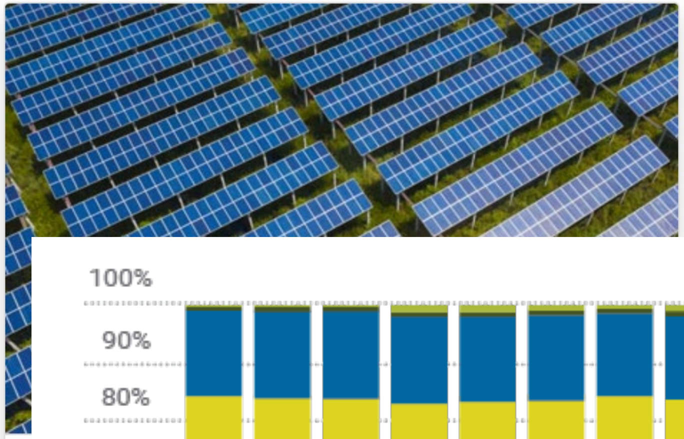
- 85% Reduction in GHG Emissions by 2050
- 100% Zero-emission Electricity by 2040
- 70% Renewable Energy by 2030

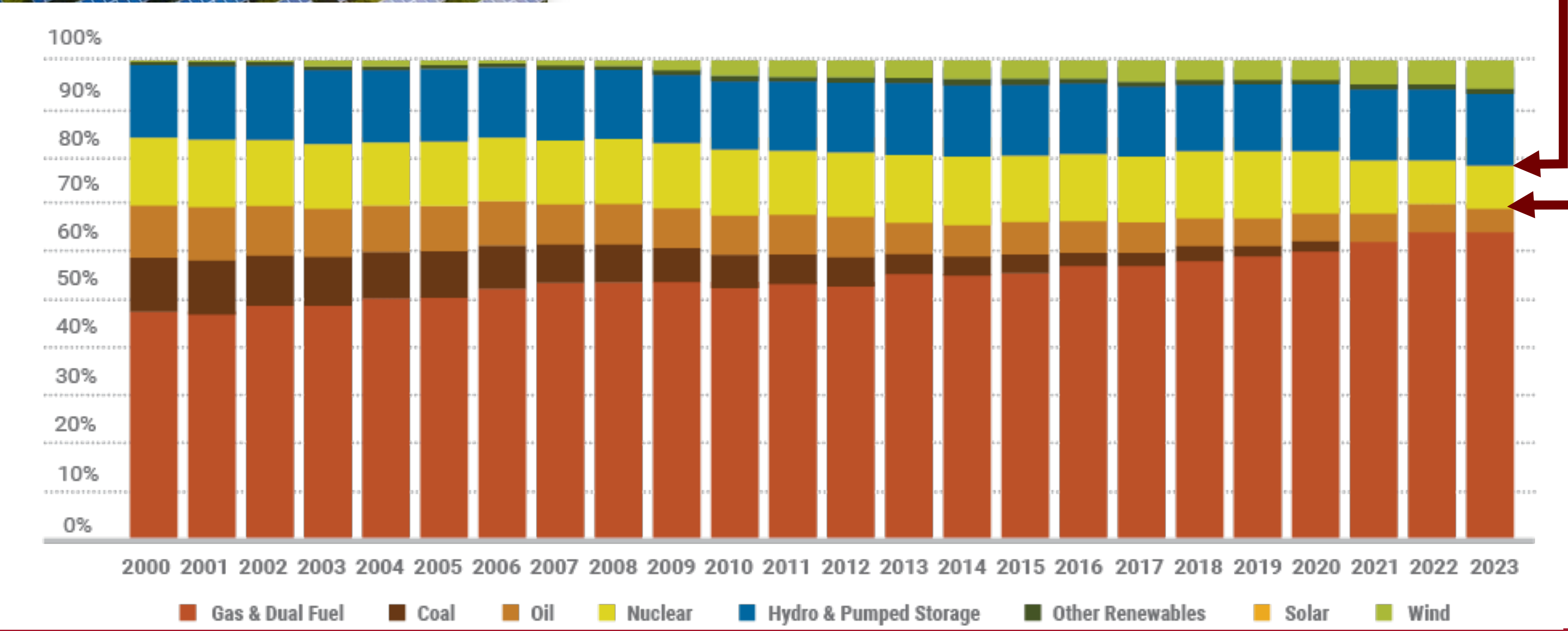
Additional Resources:

- 9,000 MW of Offshore Wind by 2035
- 3,000 MW of Energy Storage by 2030
- 6,000 MW of Solar by 2025

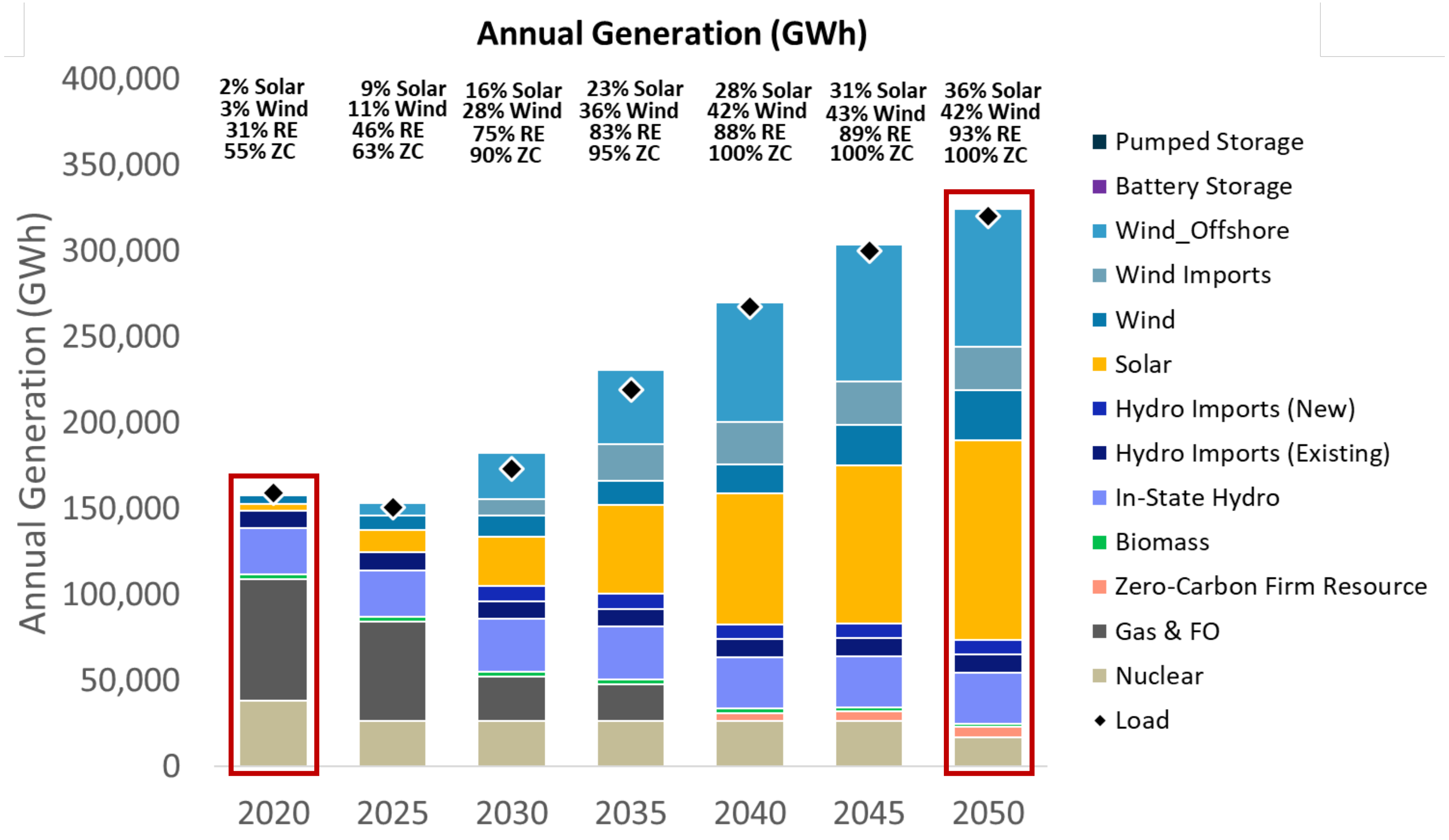
NYS as a Case Study

Emission Targets:
- 85% Reduction in GHG Emissions by 2050
- 100% Zero-emission Electricity by 2040
- 70% Renewable Energy by 2030





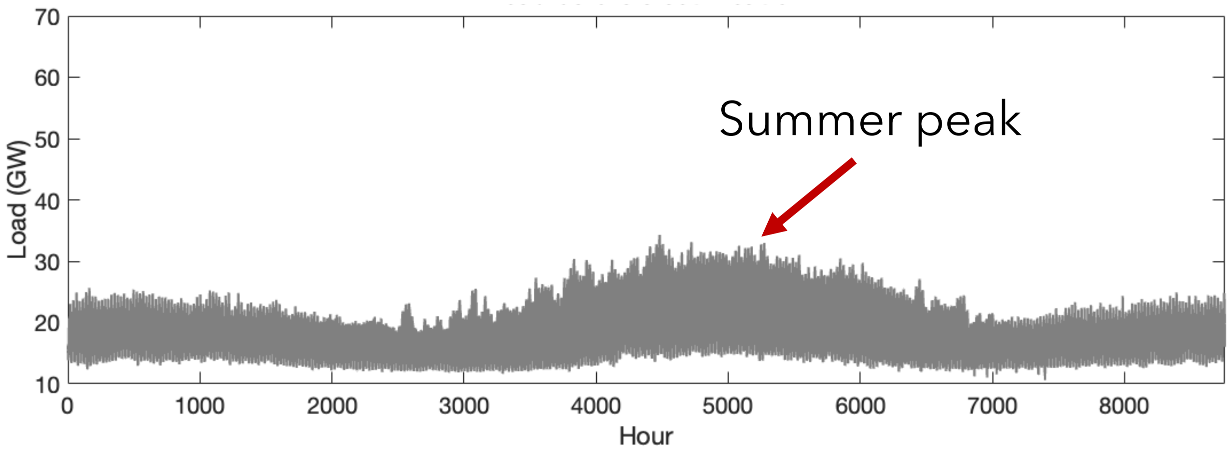
NYS Community Leadership and Climate Protection Act:



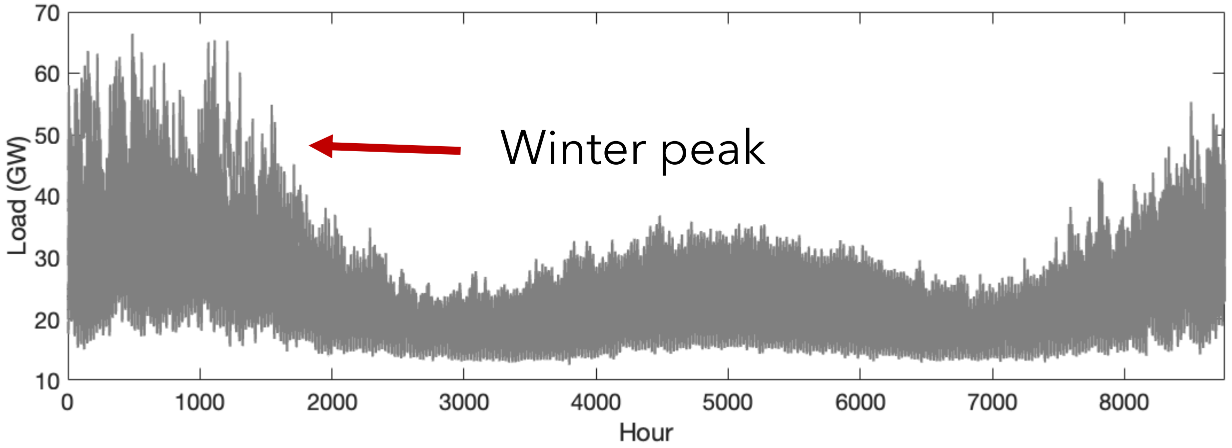
Source: Wilcox & Hammer, 2021

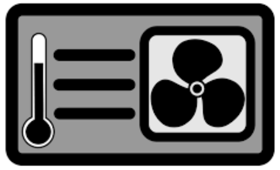
Changing Load Profiles

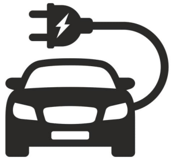
Before Electrification



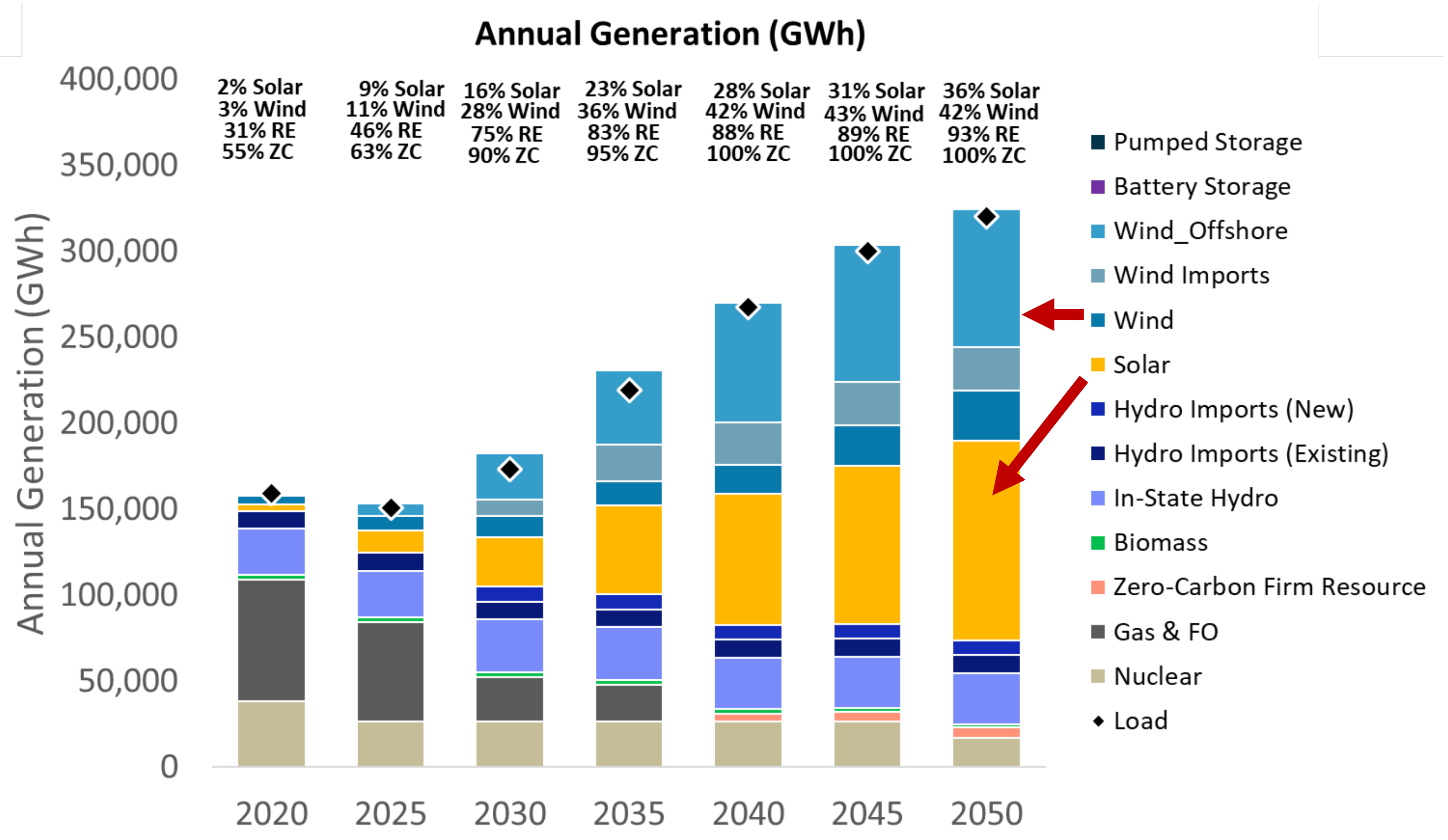
After Electrification





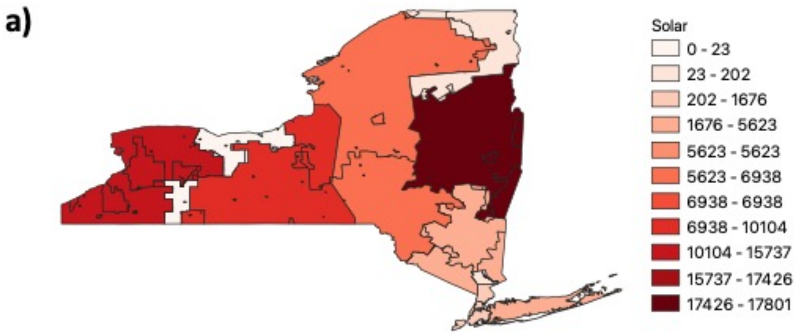


Increased wind and solar capacity

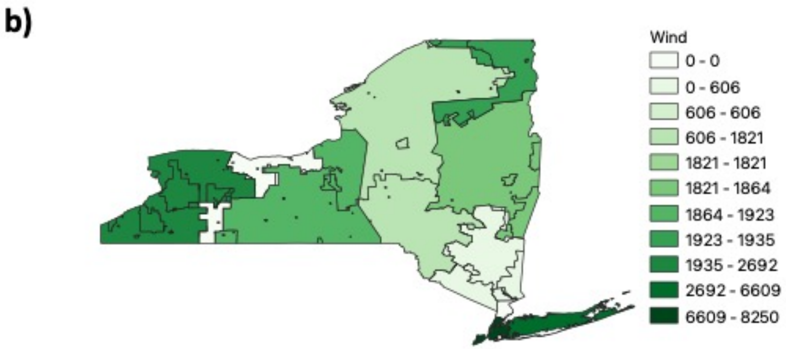


Zonal renewable allocation

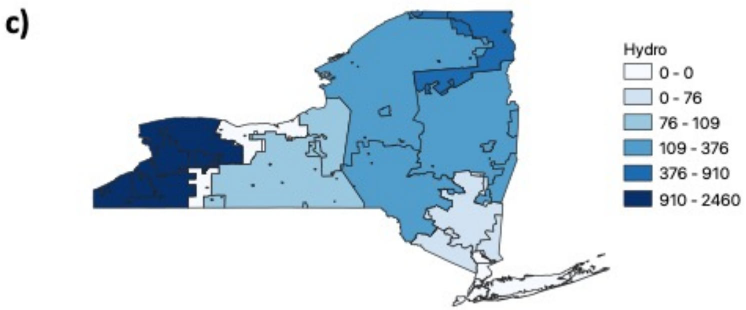
Solar



Wind

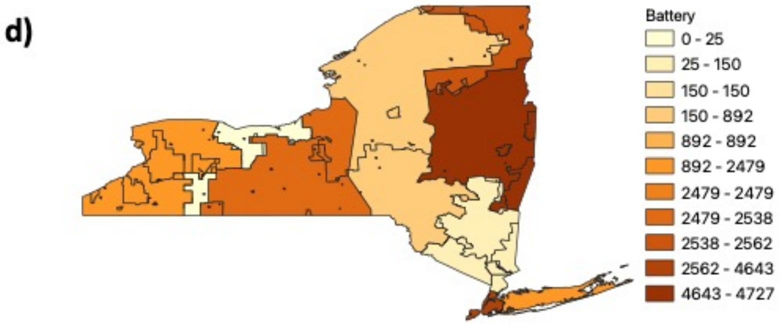


Hydro

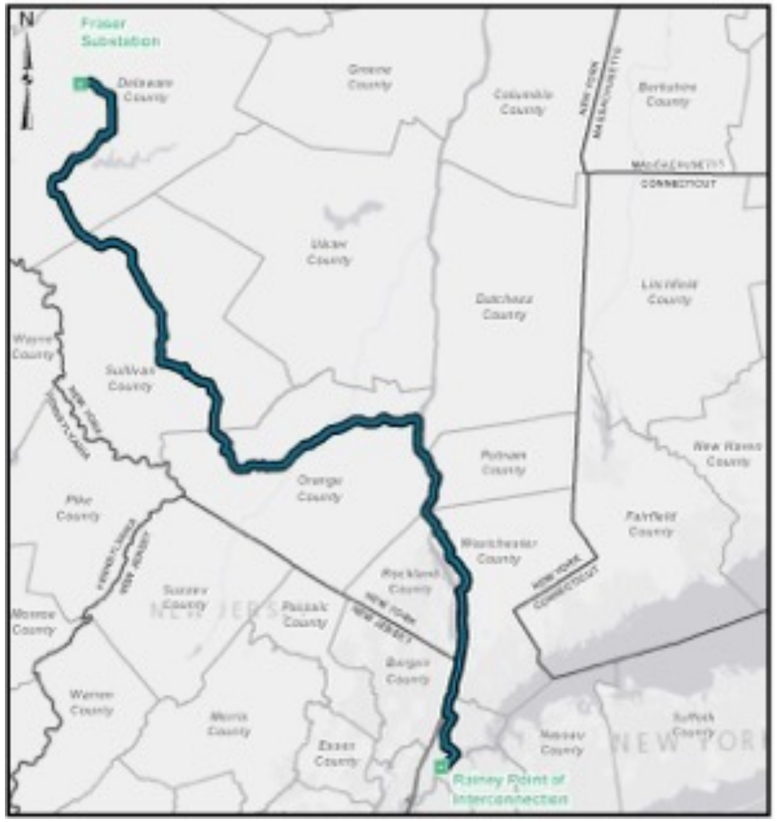


Battery

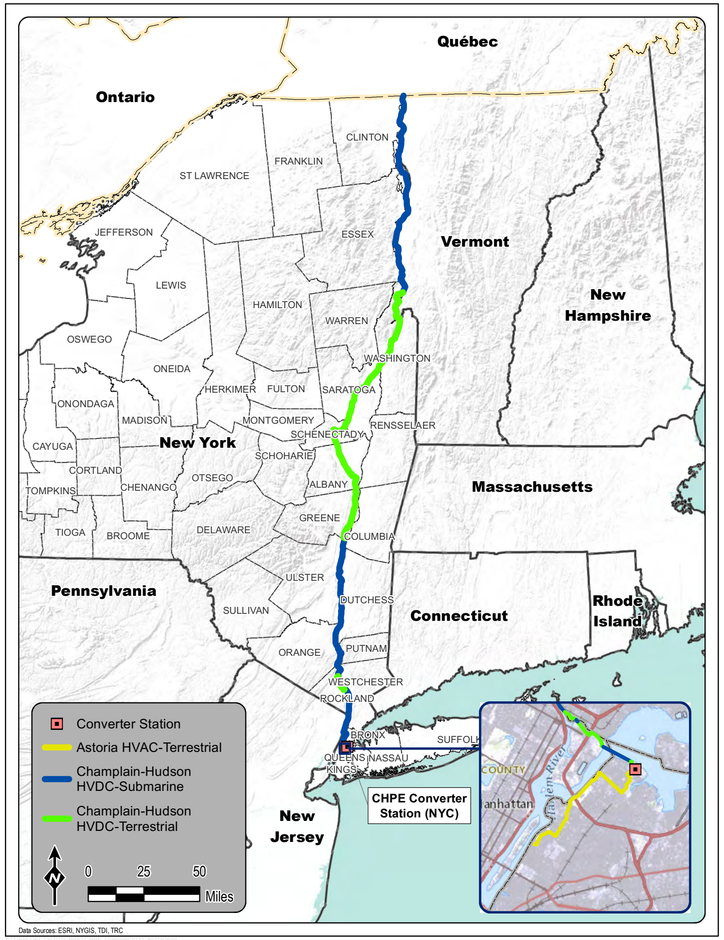
Offshore wind



New transmission lines



New York Clean Path



Champlain Hudson Power Express

Potential Vulnerabilities of the Post-transition Grid

For New York case, we envision

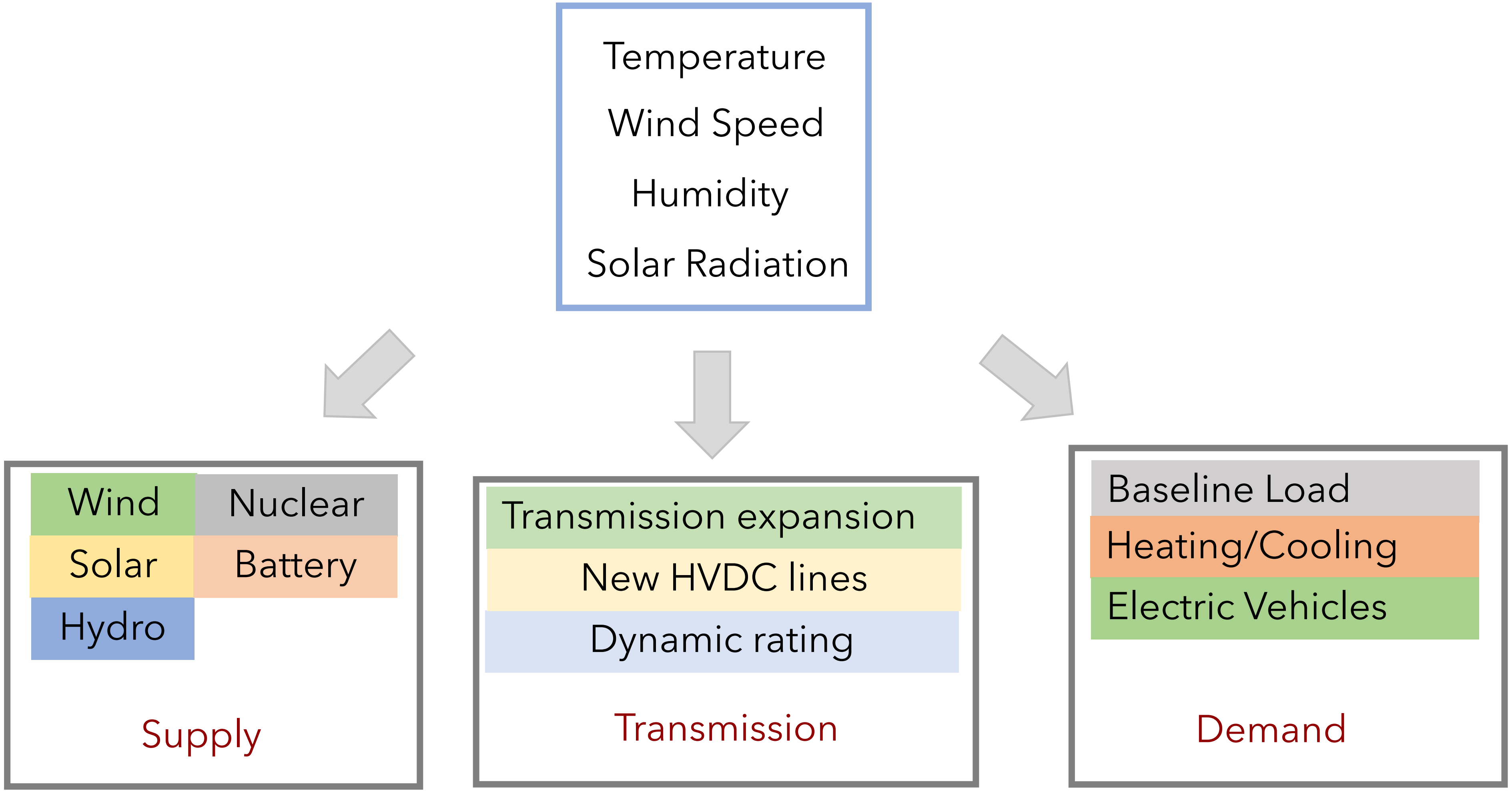
+ load increasing > 100%

- wind & solar resources increasing > 1000%
- significant increase in battery storage
- significant increase in transmission capacity

What are potential vulnerabilities that could arise due to

✓ Operational constraints over long time horizons
✓ Spatiotemporal correlations among resources and loads
✓ Uncertainty in transition parameters and climate conditions

Modeling the post-transition grid



Multi-criteria decision analysis

1998 ← 2019

MERRA-2

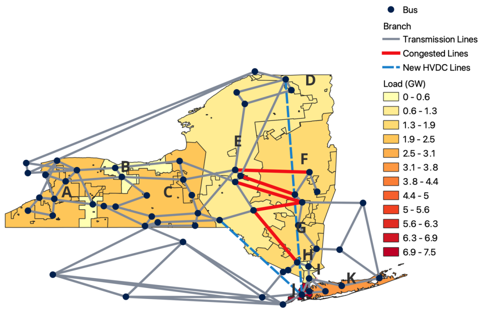
Simulated Wind

Simulated Solar

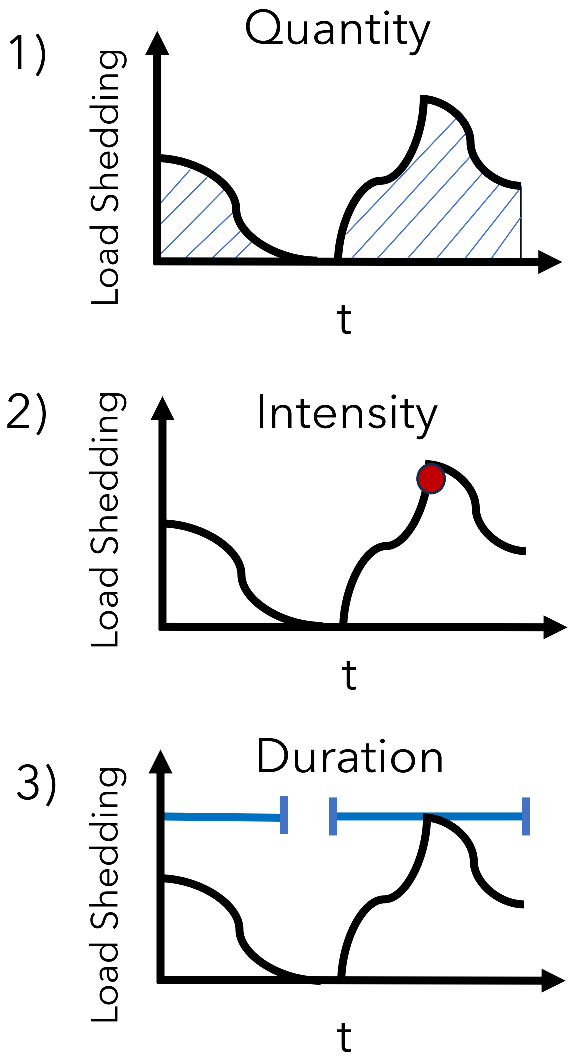
+

Simulated Load (baseload)

Simulated Electrified Load

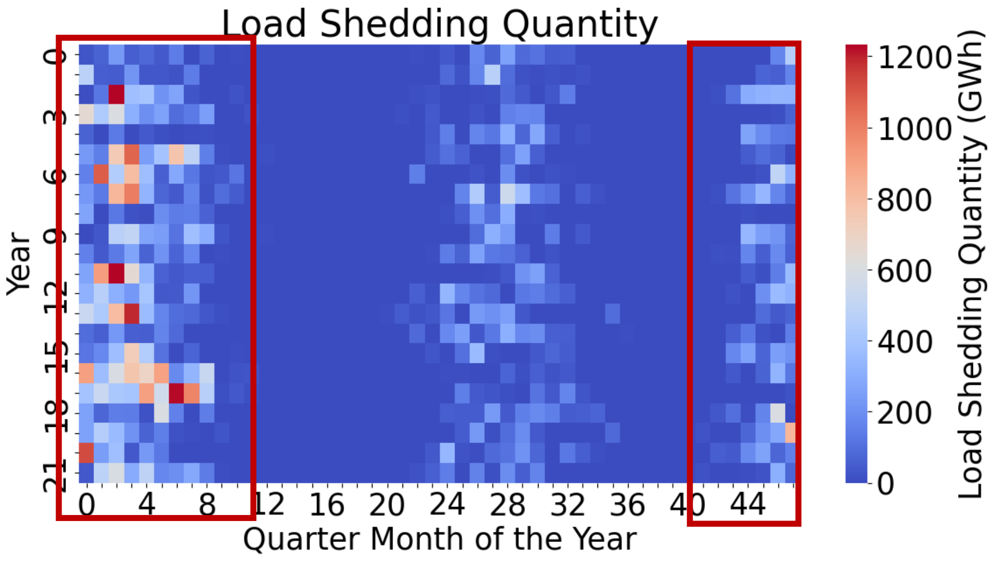


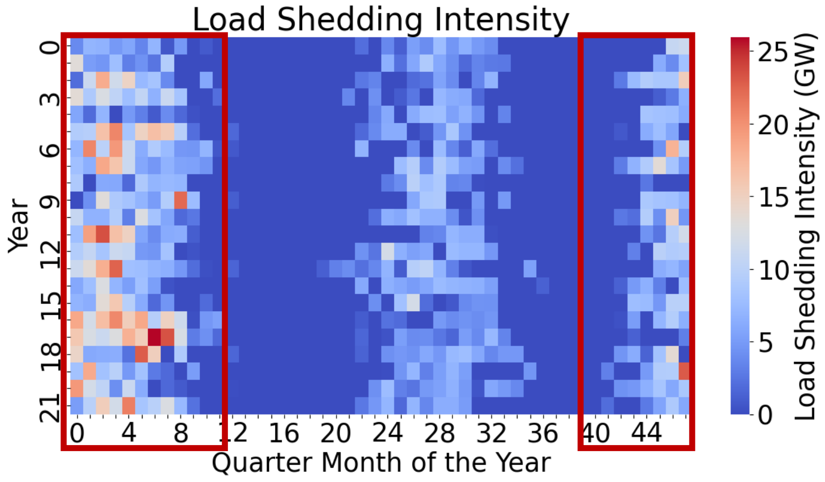
DC OPF:
Minimize
Load Shedding

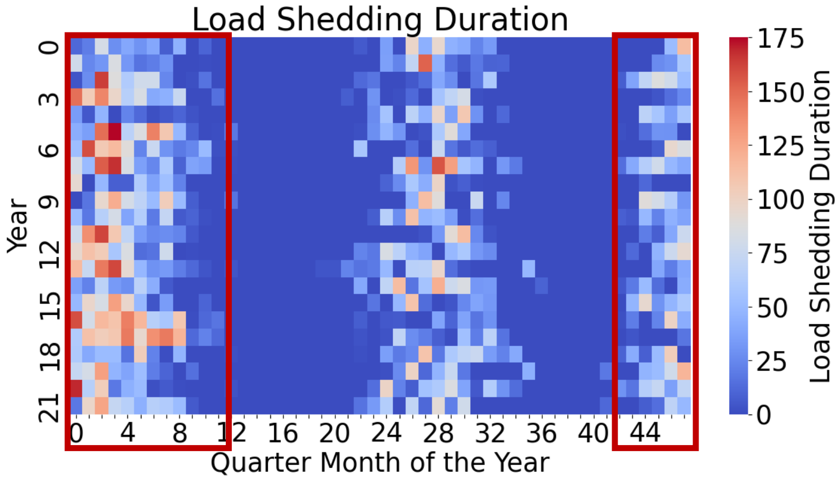


Liu, M. V., Yuan, B., Wang, Z., Sward, J. A., Zhang, K. M., & Anderson, C. L. (2022). An open-source representation for the nys electric grid to support power grid and market transition studies. IEEE Transactions on Power Systems.

Baseline: Seasonal differences across multiple years

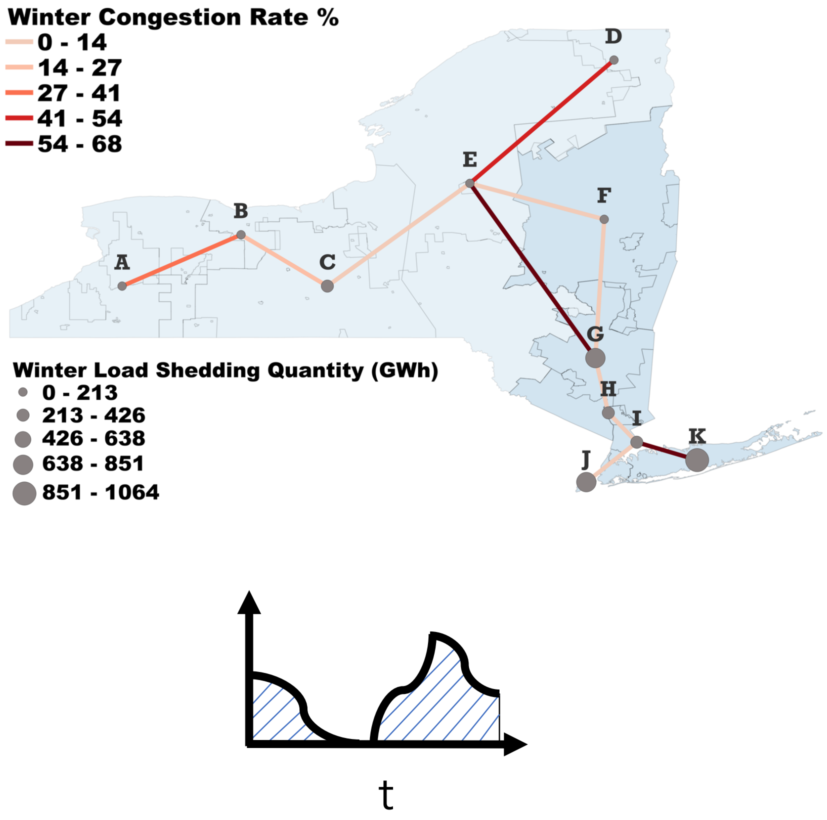




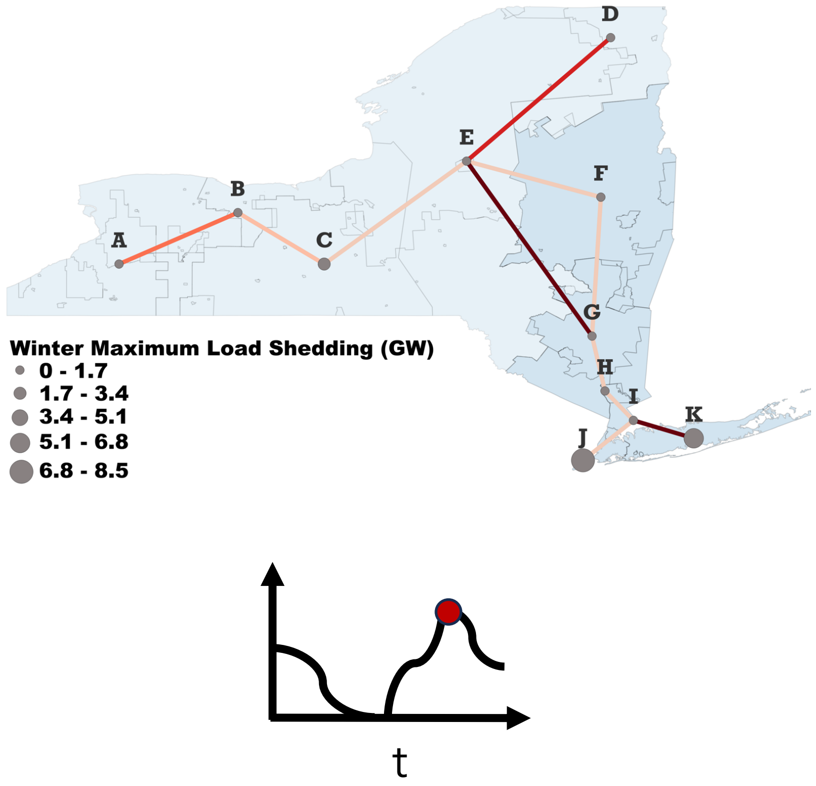


Spatially differentiated vulnerabilities

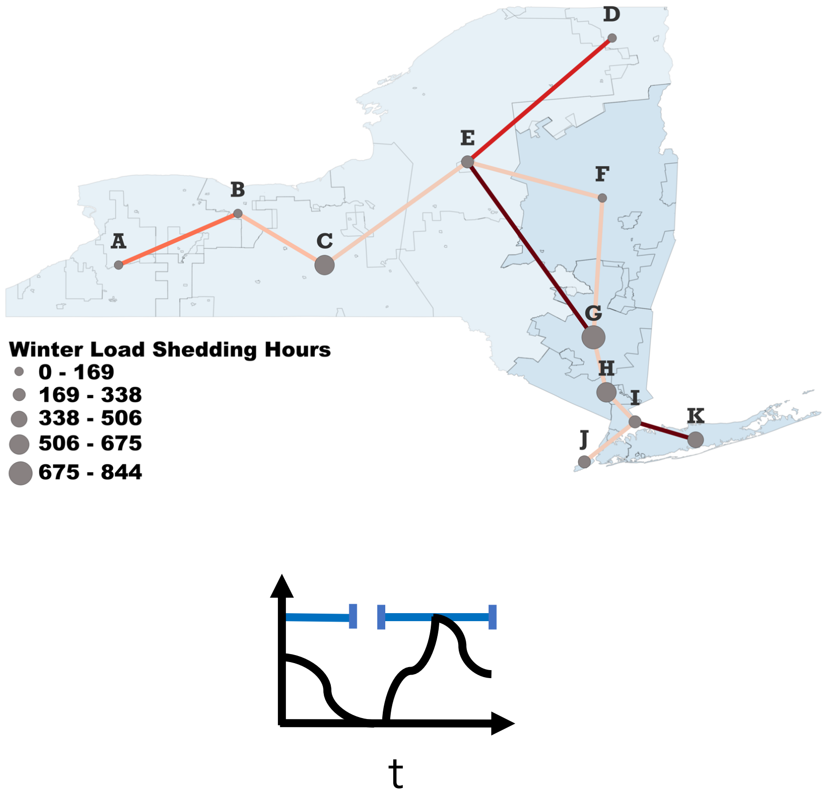
Quantity



Intensity

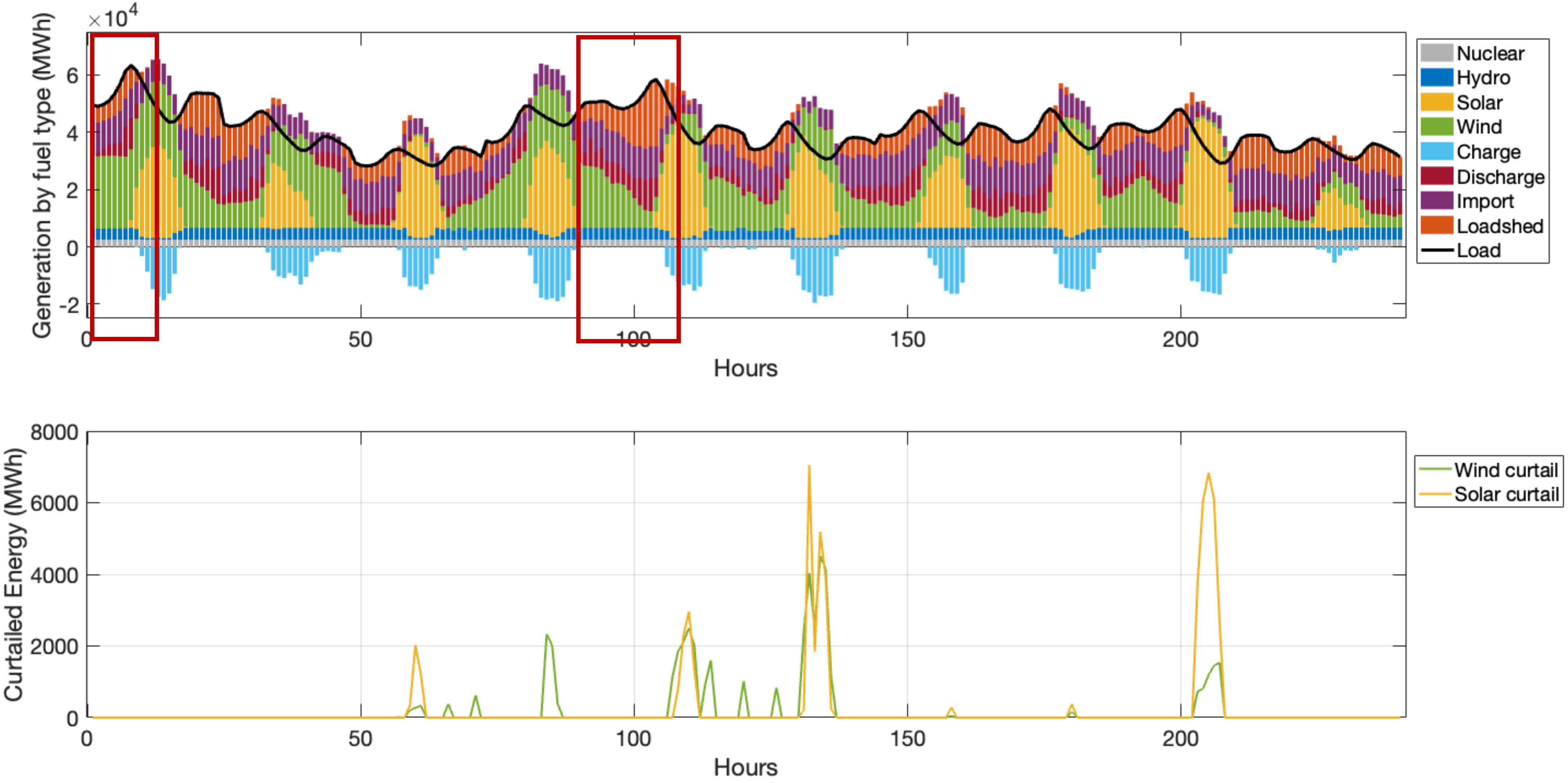


Duration

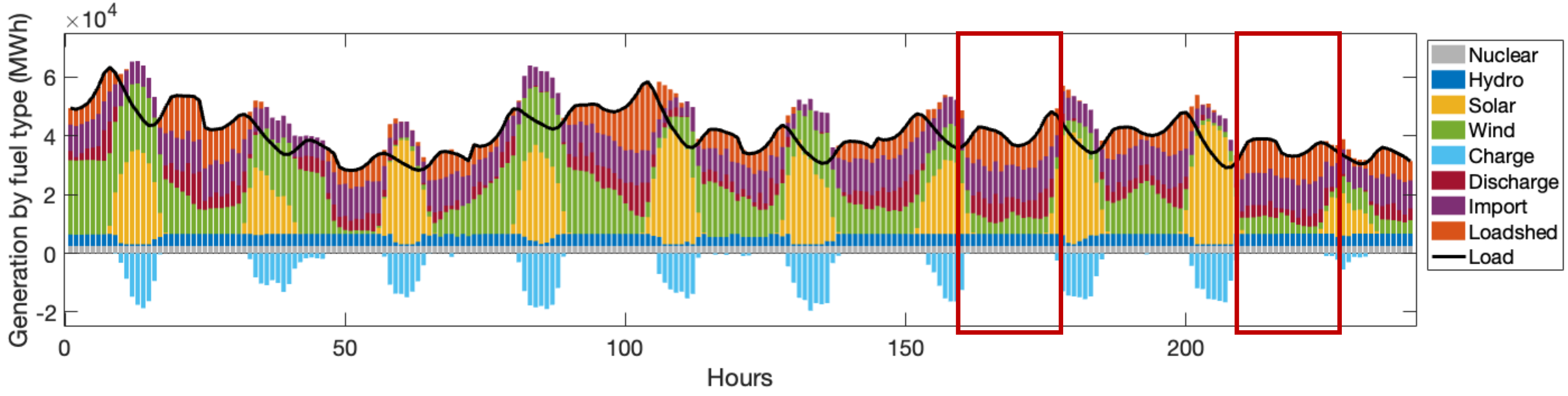


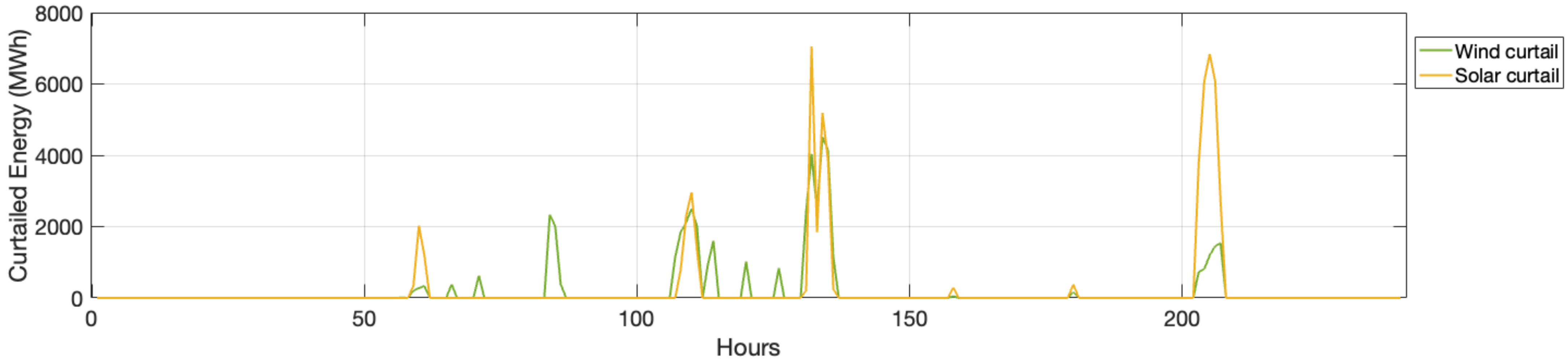
Winter: Low temperature and/or wind droughts

Load Shedding for a winter week

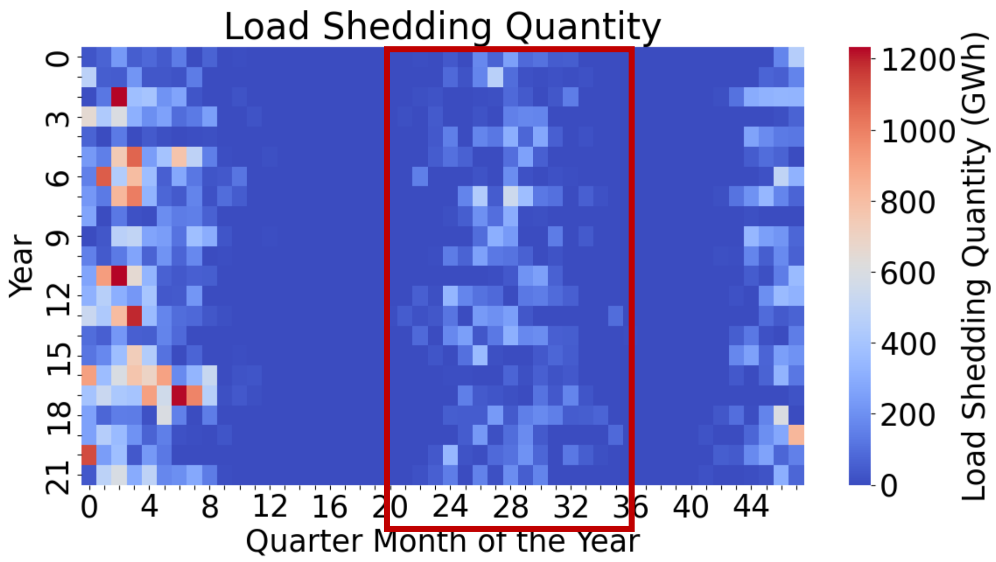


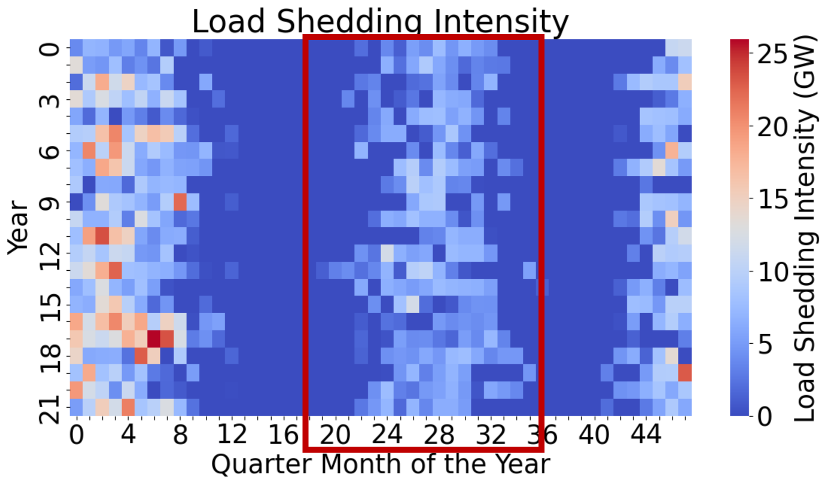
Load Shedding for a winter week

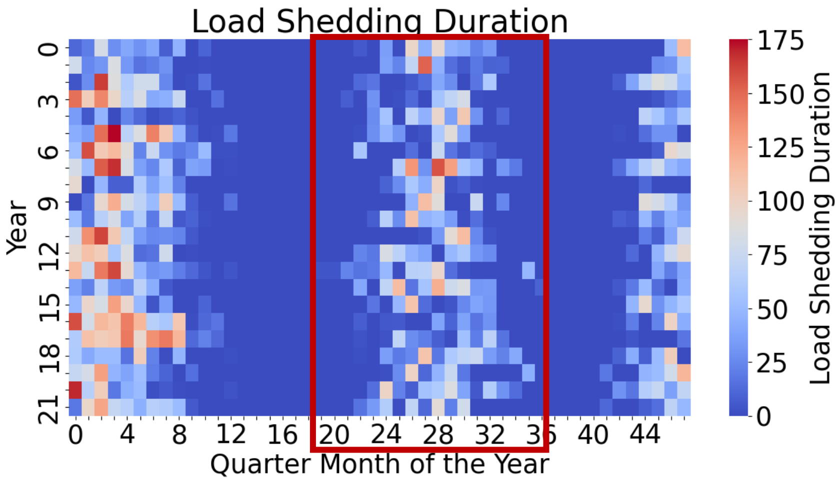




Summer vulnerabilities: duration

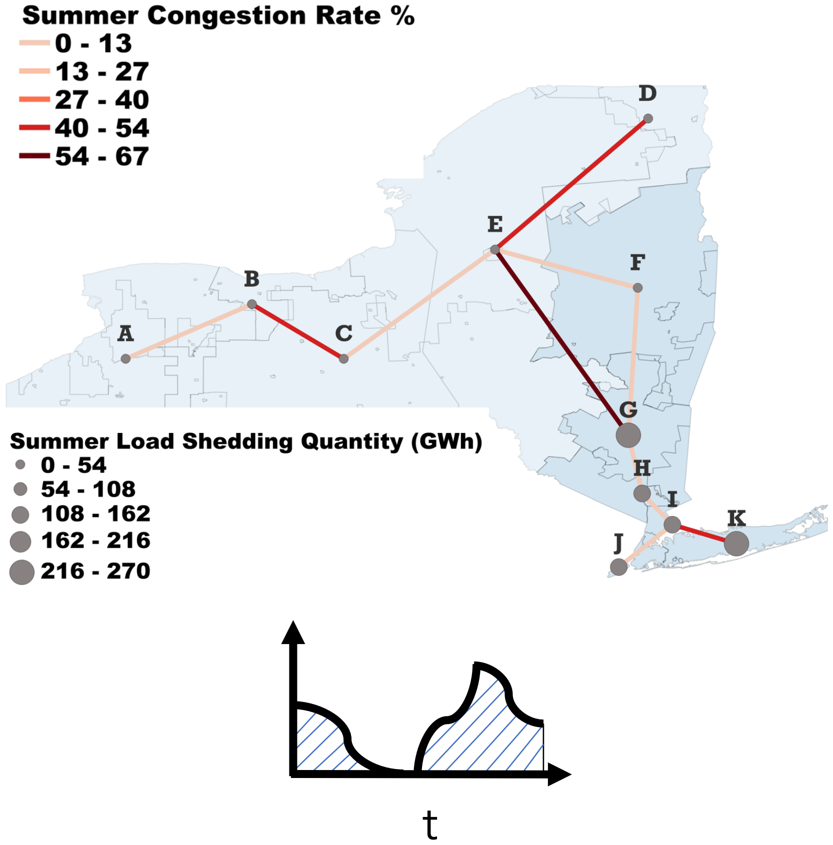




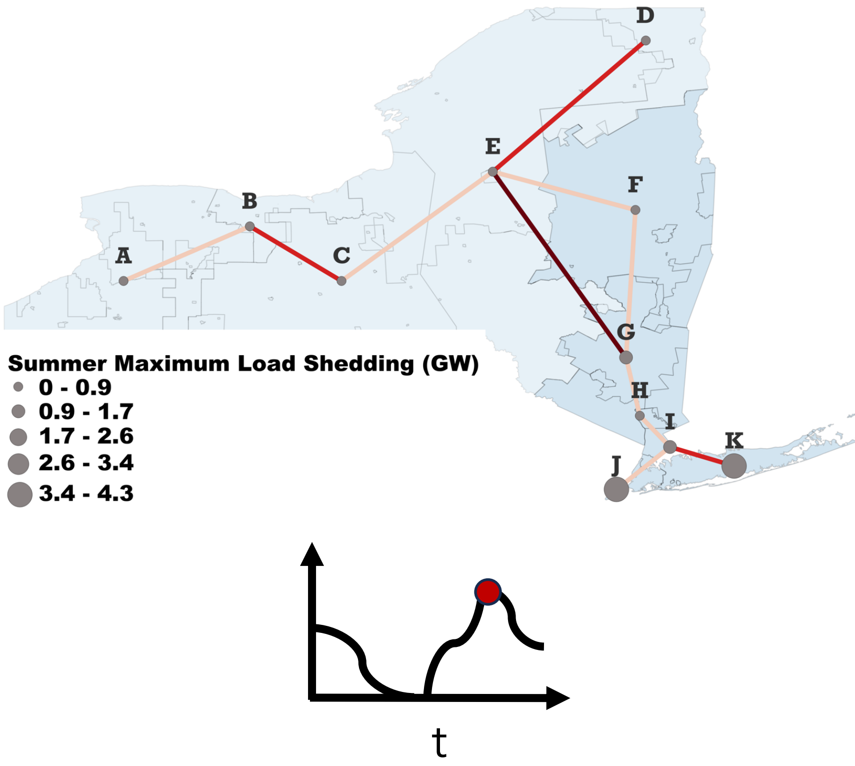


Vulnerability is generally lower in summer (with some exceptions in downstate zones)

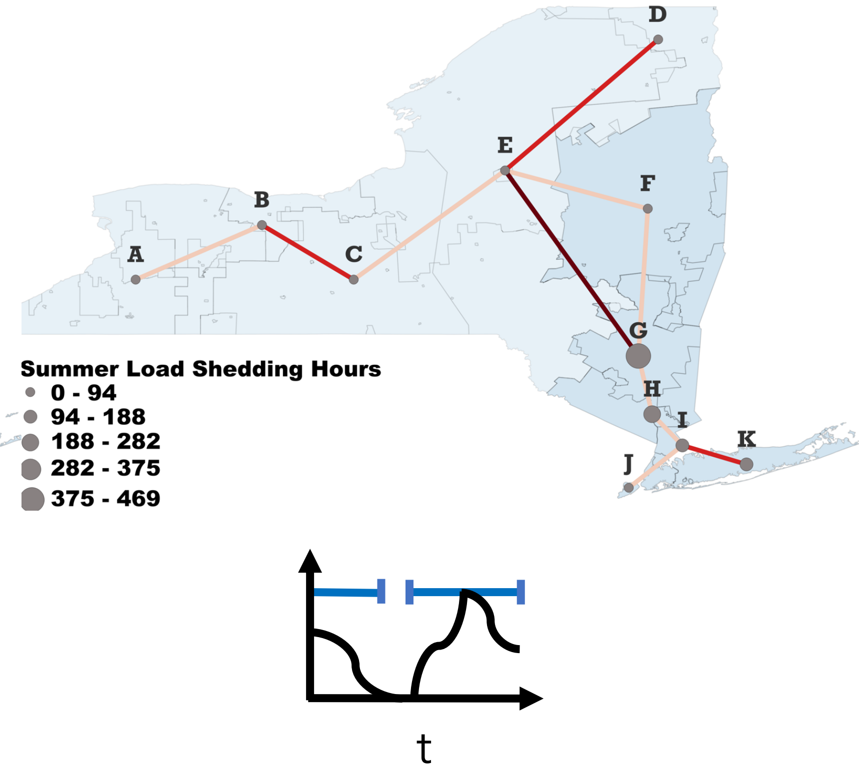
Quantity



Intensity

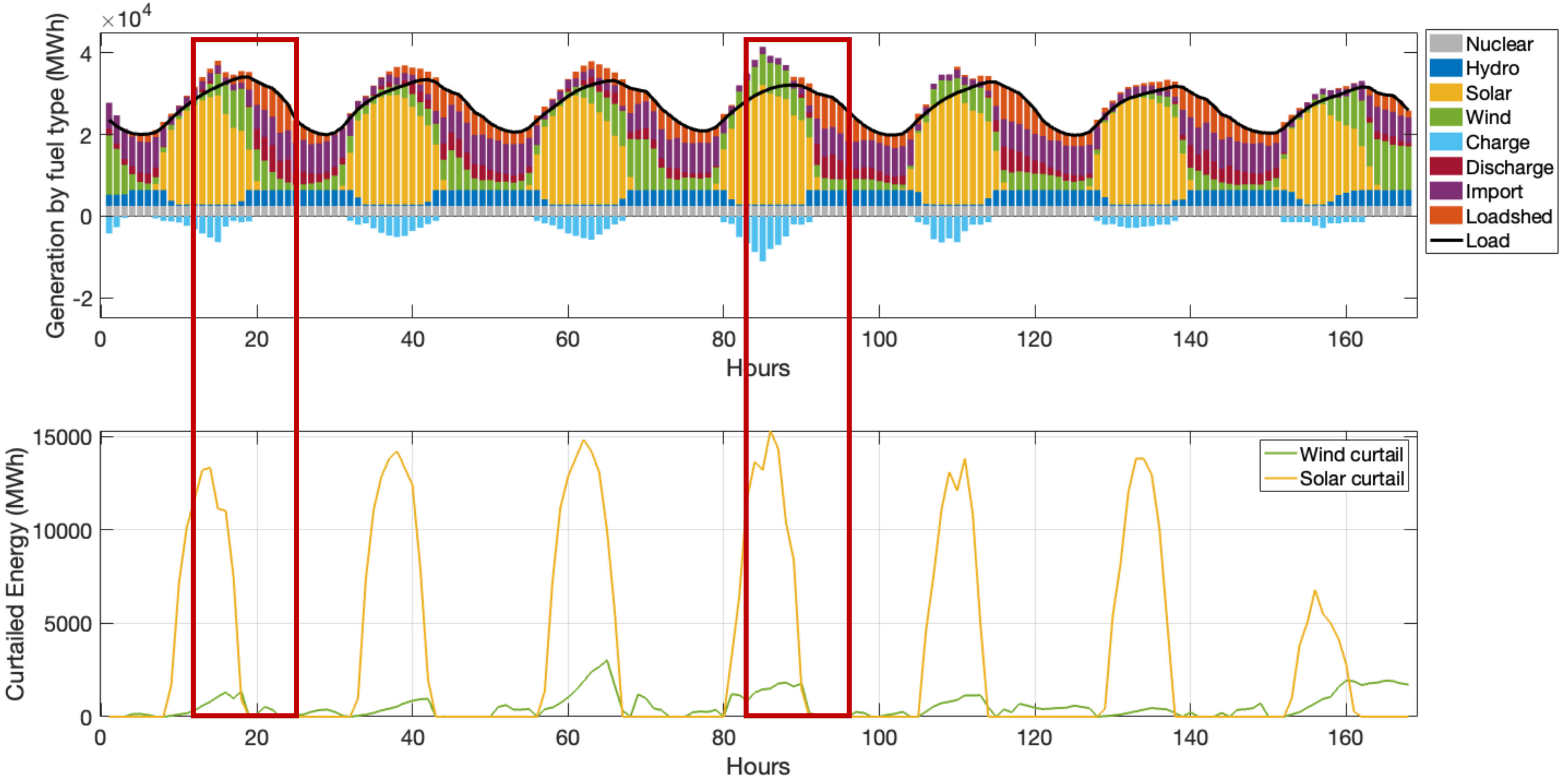


Duration

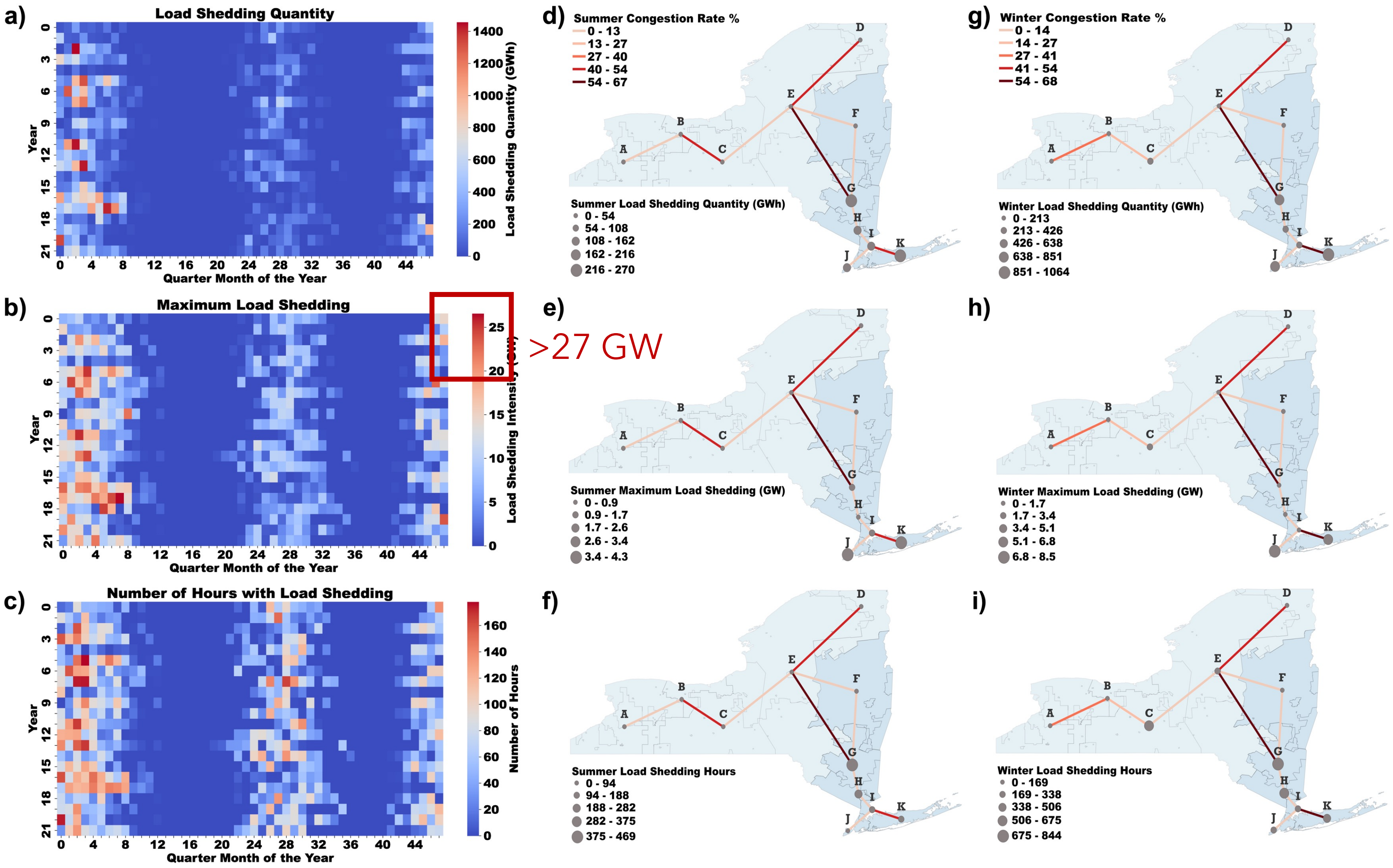


Summer: High Temperature with wind and/or hydro drought

Load Shedding for a typical summer week

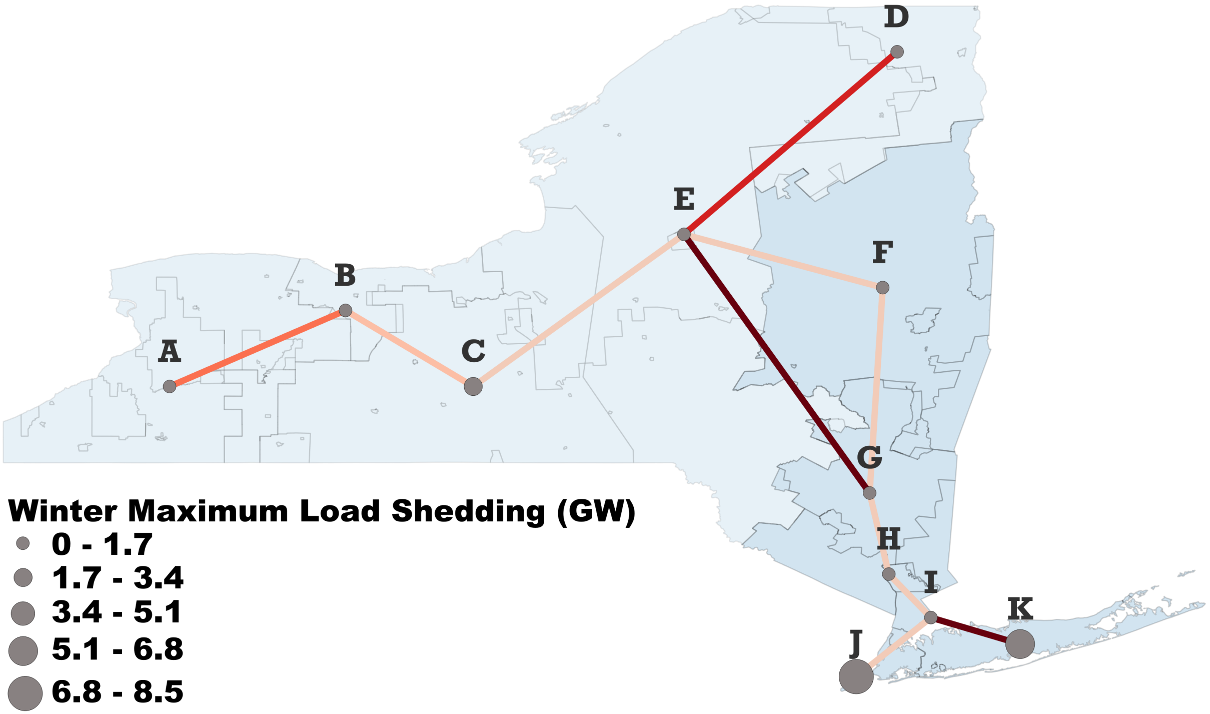


Spatiotemporal heterogeneity in system vulnerability



CLCPA: 18-23 GW Firm, Zero-Emission Capacity

Spatiotemporal heterogeneity in system vulnerability



CLCPA: 18-23 GW Firm, Zero-Emission Capacity

37 GW of Firm, Zero-Emission Capacity may be required

Takeaways

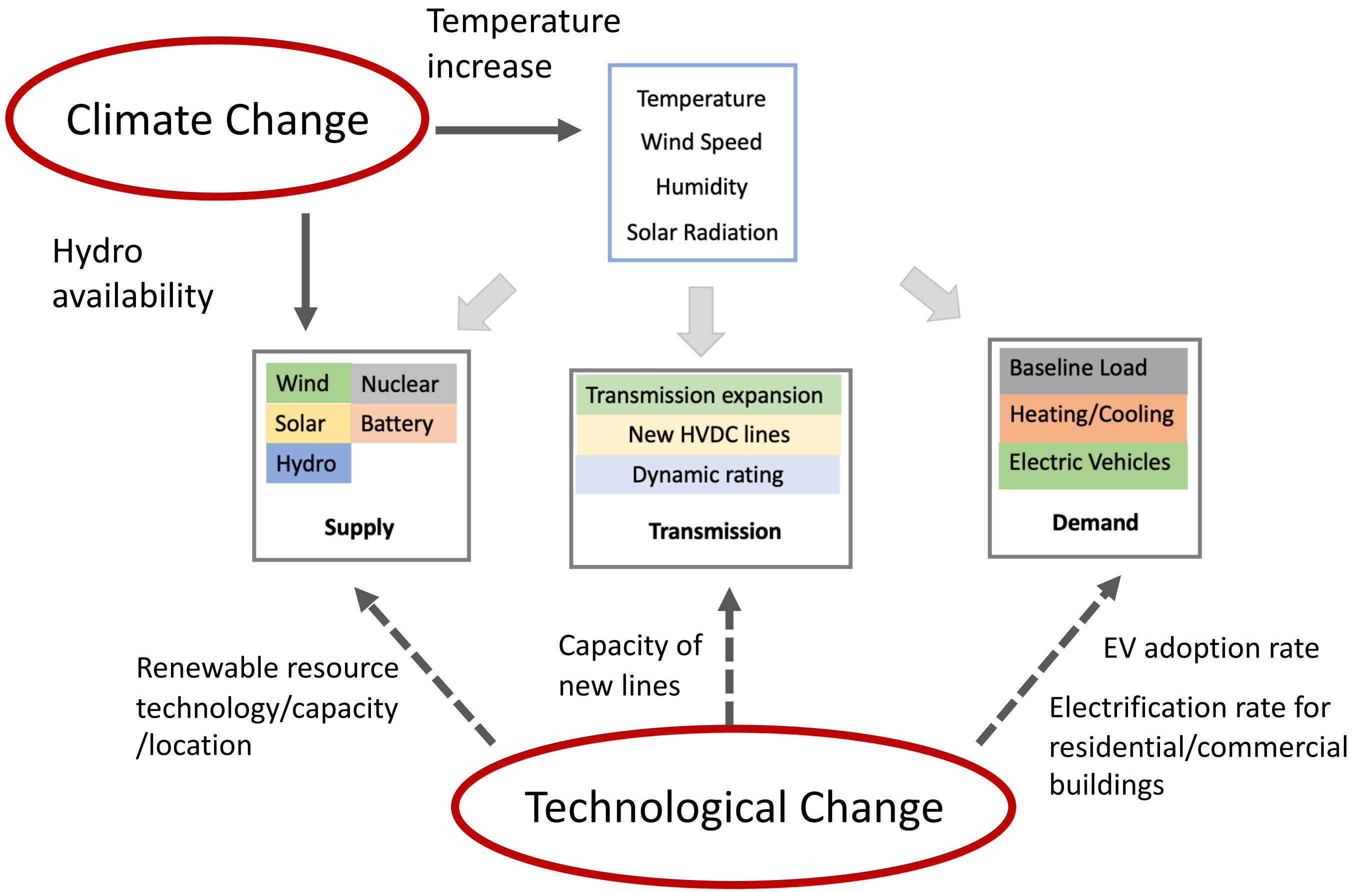
1

Spatiotemporal heterogeneity in the system vulnerabilities identifies a need for at least 60% more firm, zero-emission capacity than planned.

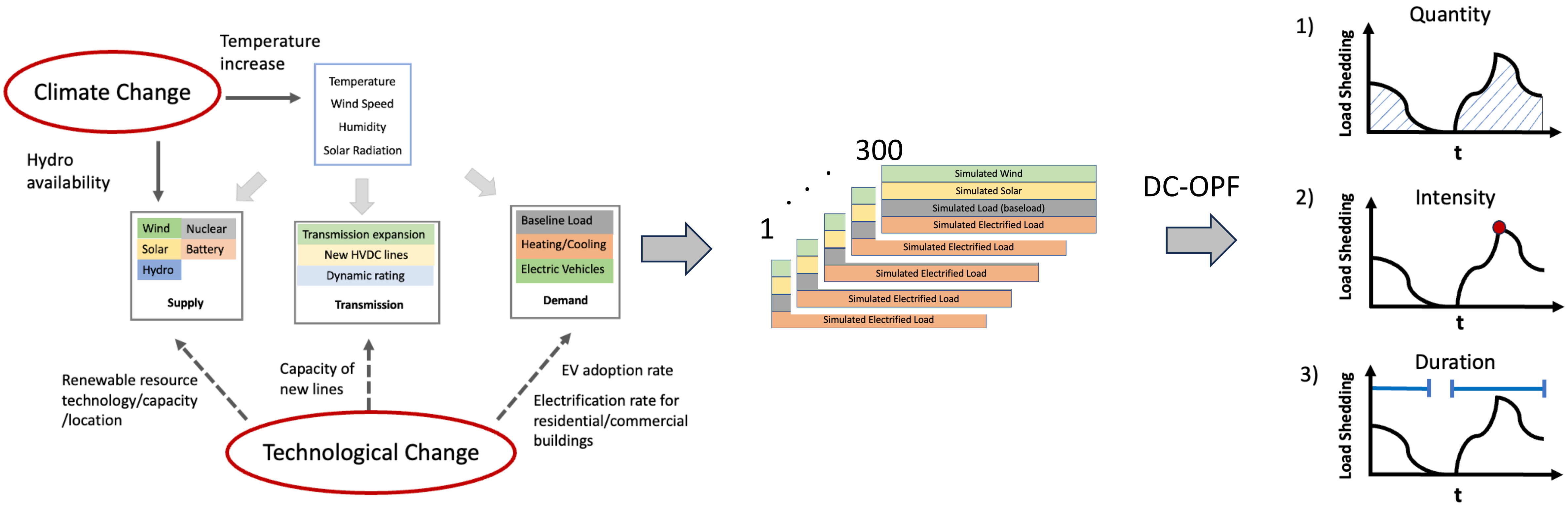
What about climate-technological changes?

Climatic and technological factors

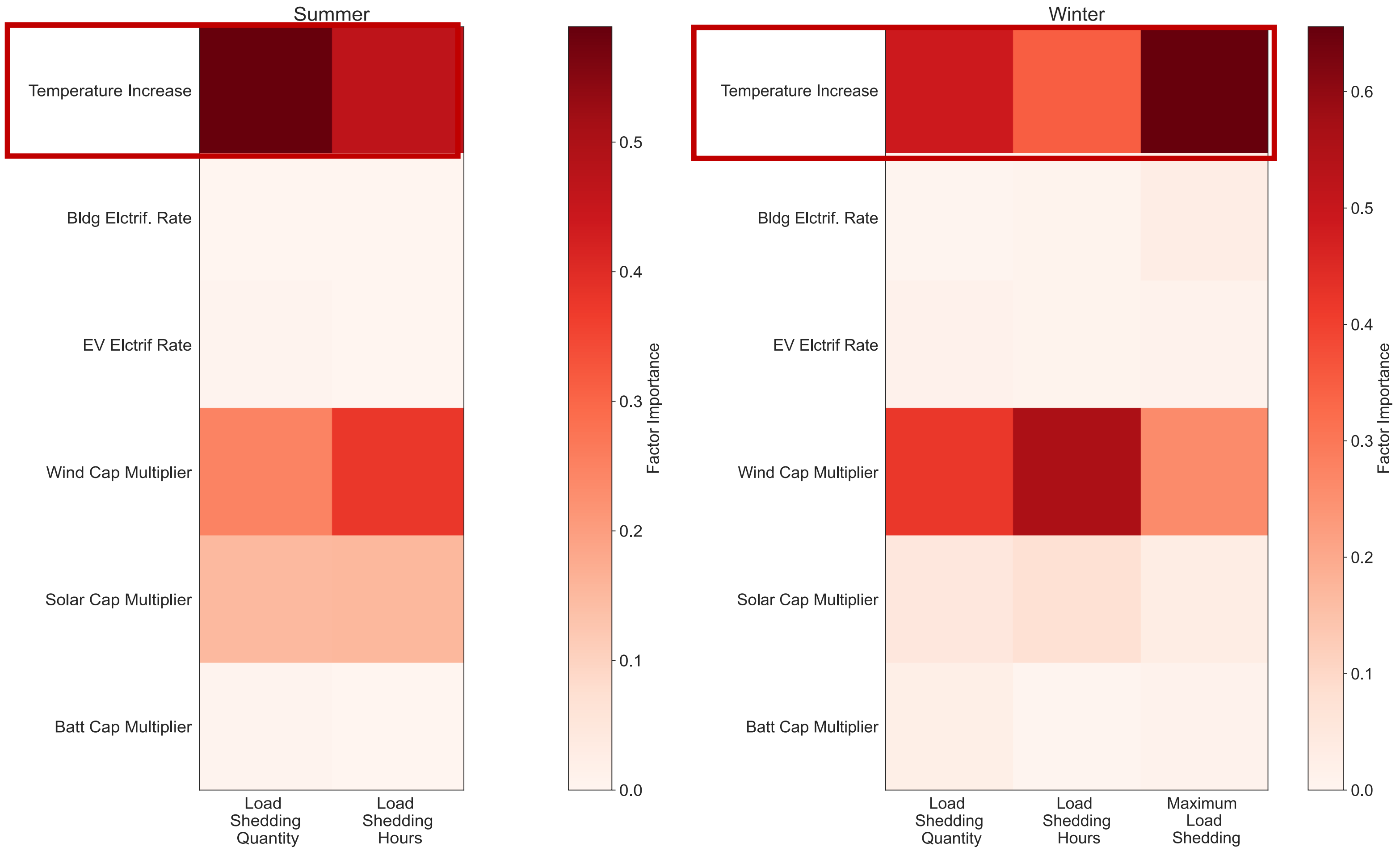
Parameter	Lower Bound	Upper Bound
Temperature increase	0.95	5.64
Building electrification rate	0.7	1.05
EV electrification rate	0.7	1.05
Wind capacity scaling factor	0.6	1.4
Solar capacity scaling factor	0.6	1.4
Battery capacity scaling factor	0.6	1.4



What about climate change?
Simulate over 300 climate-technological scenarios

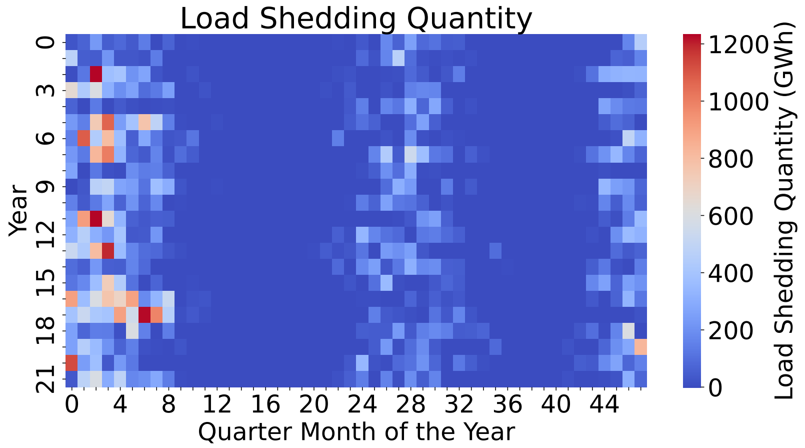


Temperature increase is the most significant factor

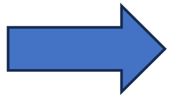


Define threshold based on CLCPA plan

Continuous

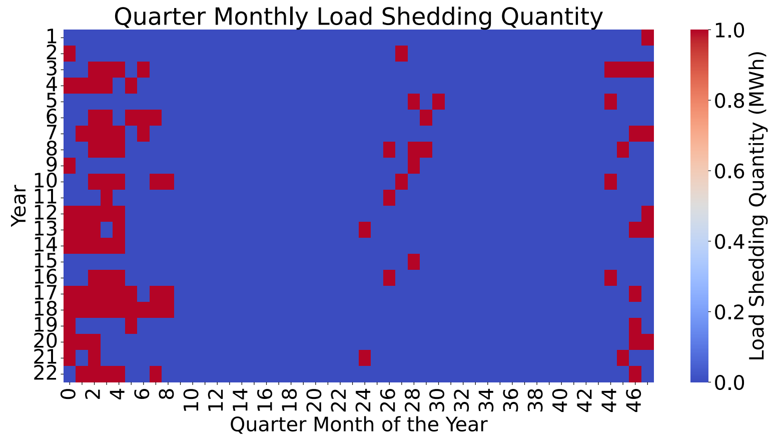


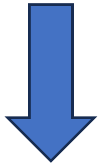
Threshold



- Quantity: 208 GWh
- Intensity: 18 GW
- Duration: 100 hour

Binary

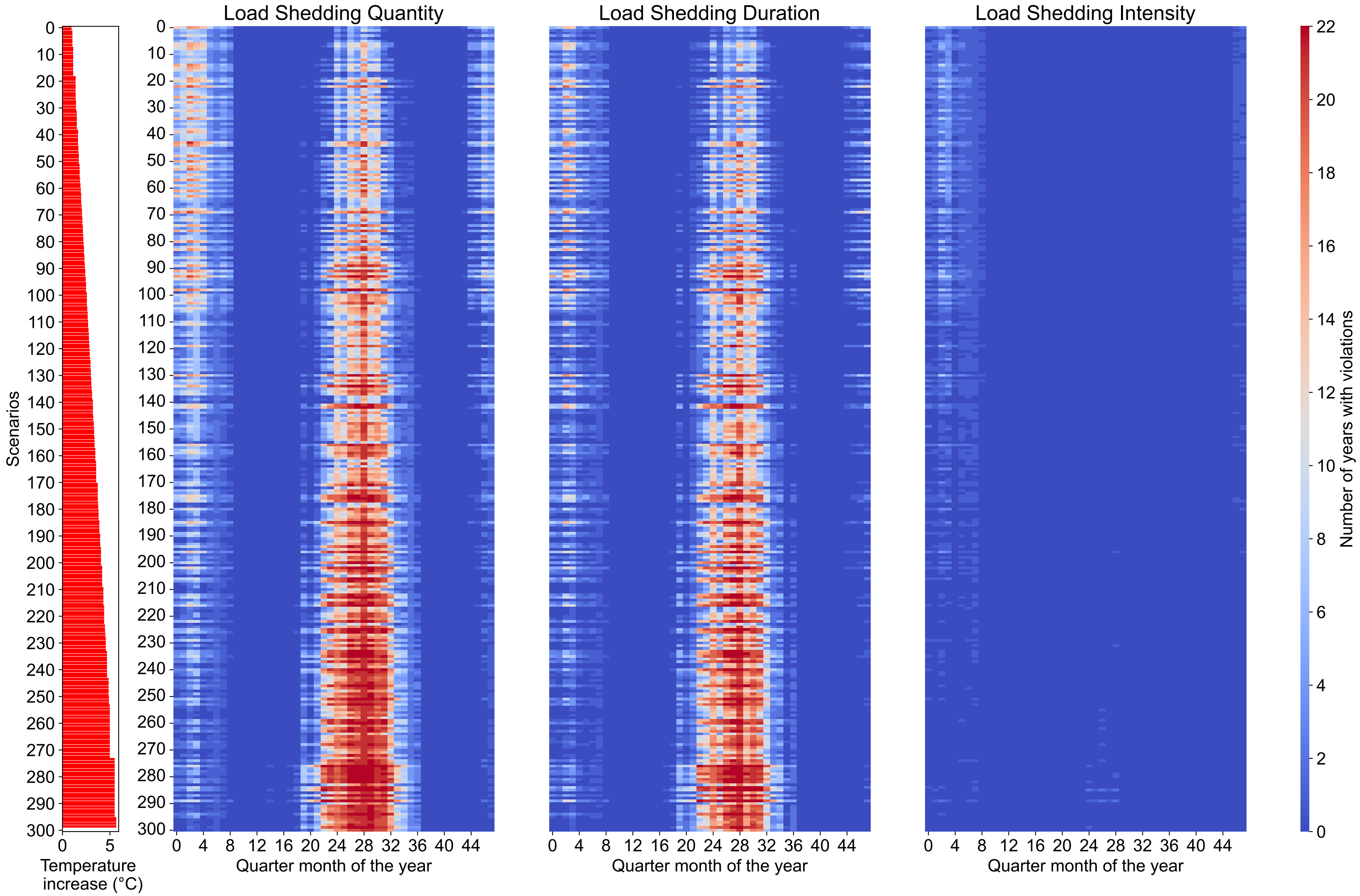




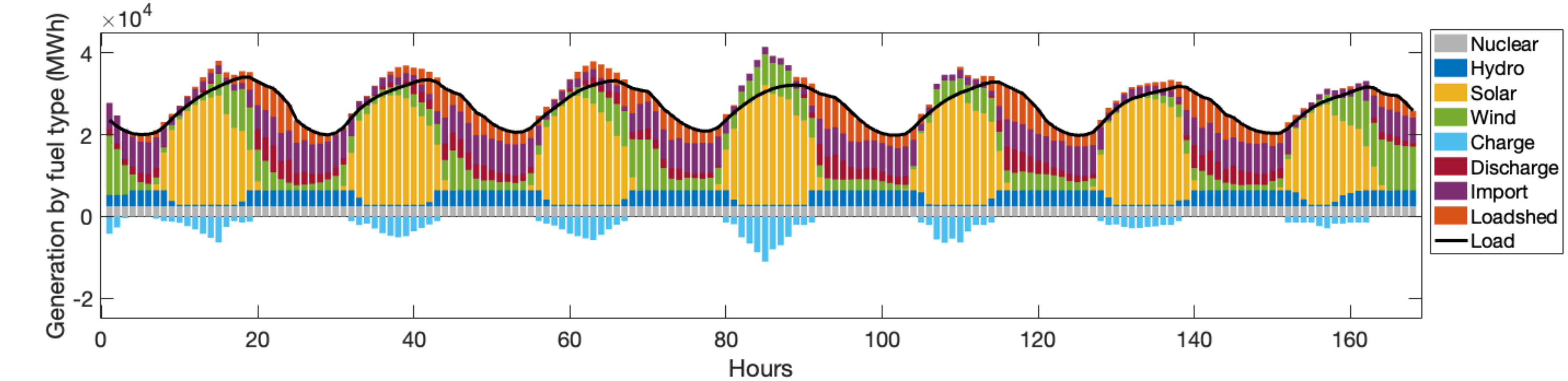
Sum over years

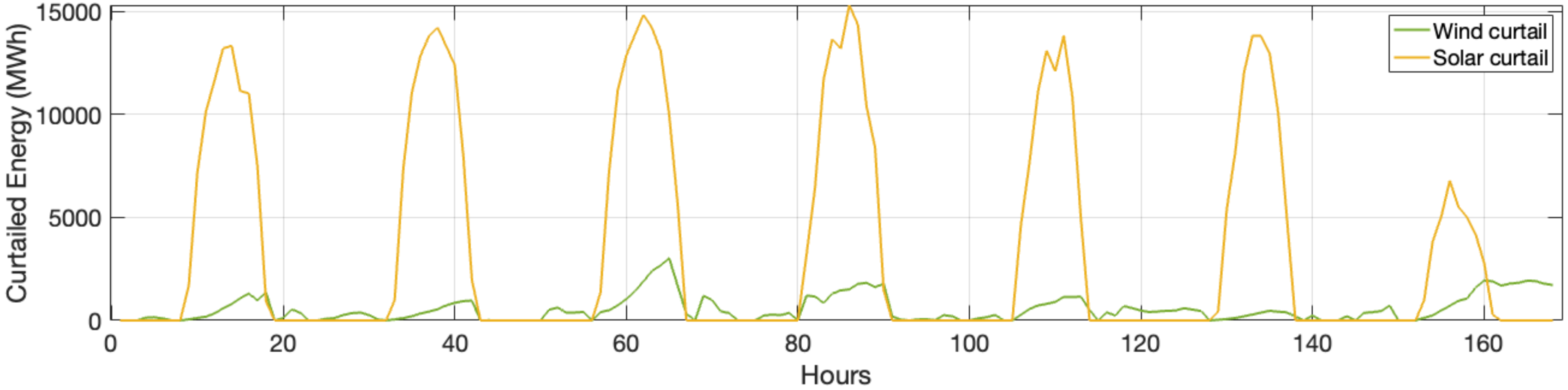
Scenario ranking based on temperature increase

Vulnerability shifts from winter to summer as temperature increase

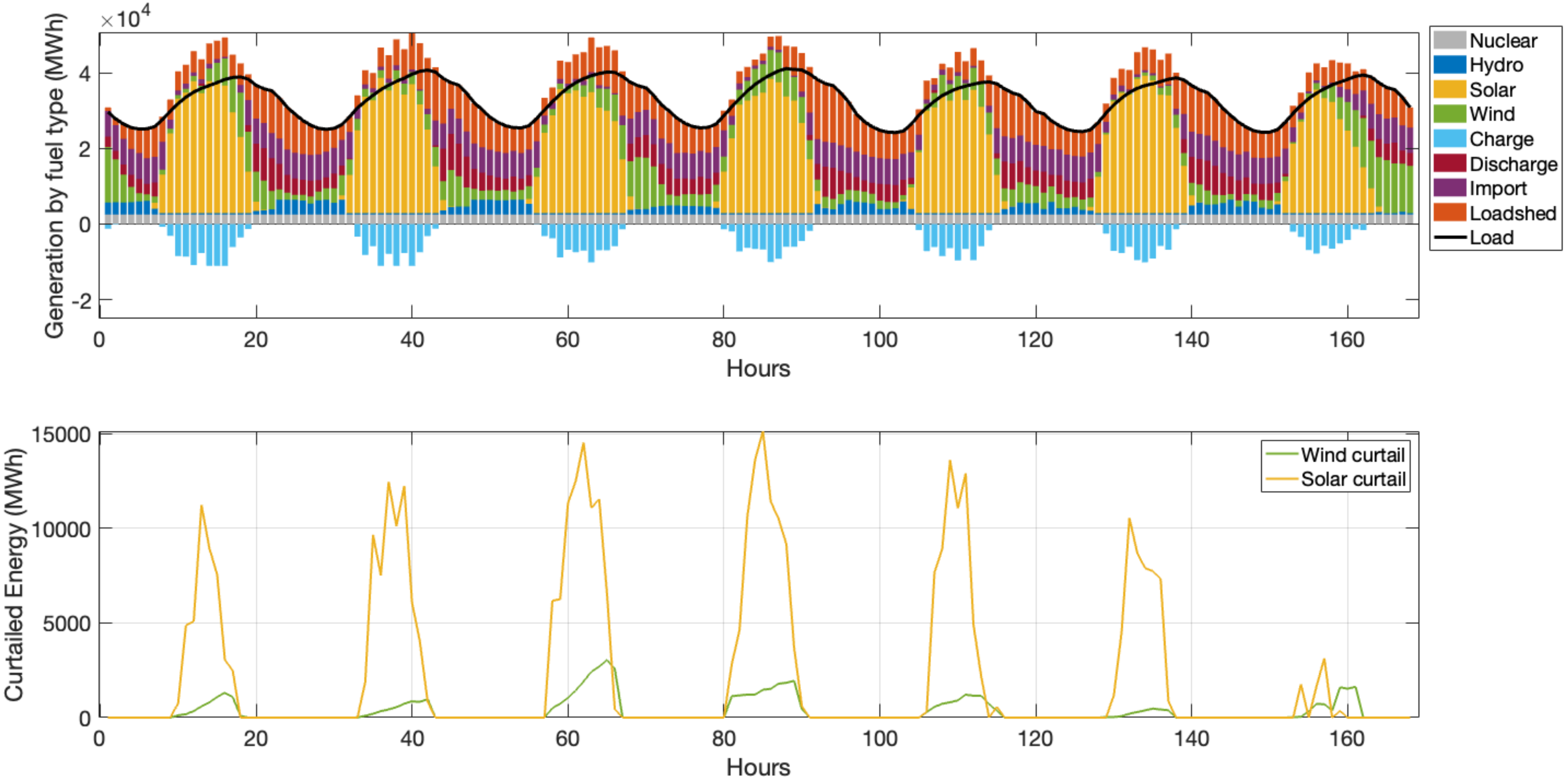


Load Shedding for a typical summer week: (baseline)

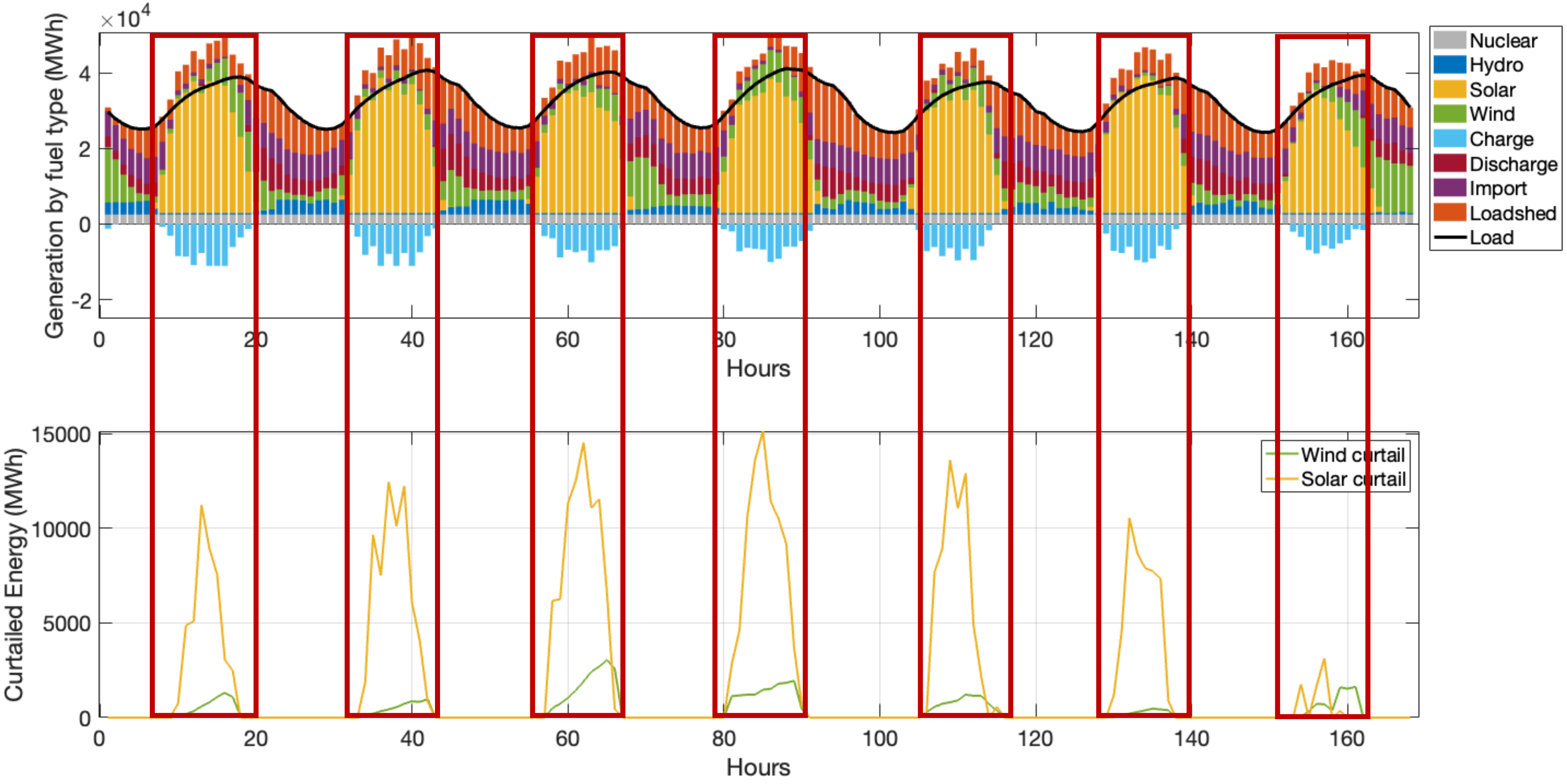




Exacerbated load shedding in summer (under temperature increase)

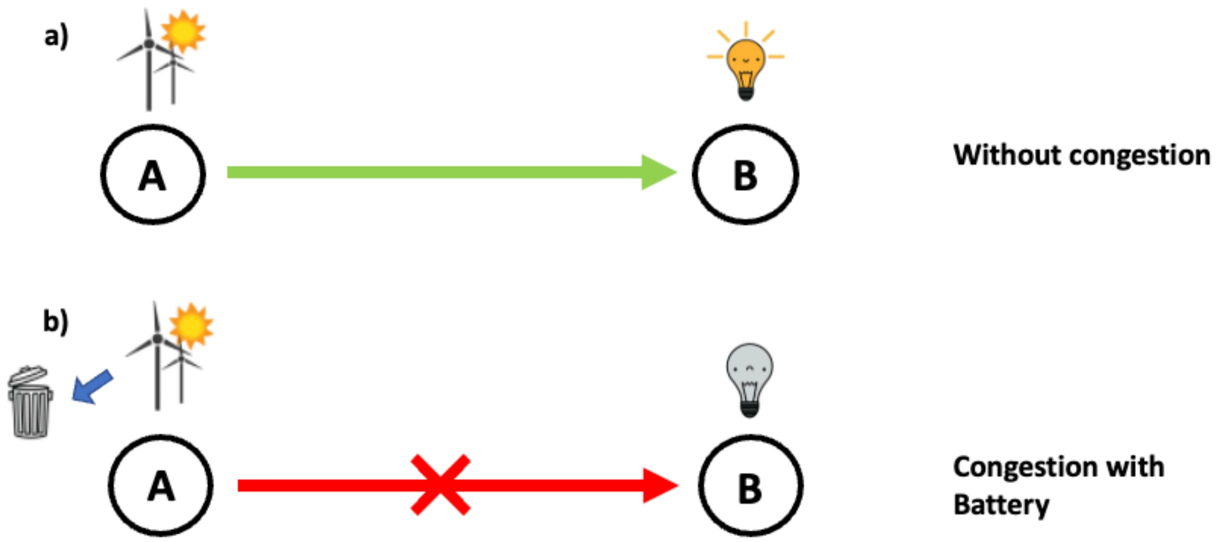


Load shedding and renewable curtailment coincide with transmission line congestion



Congestion limits the efficacy of renewable resources

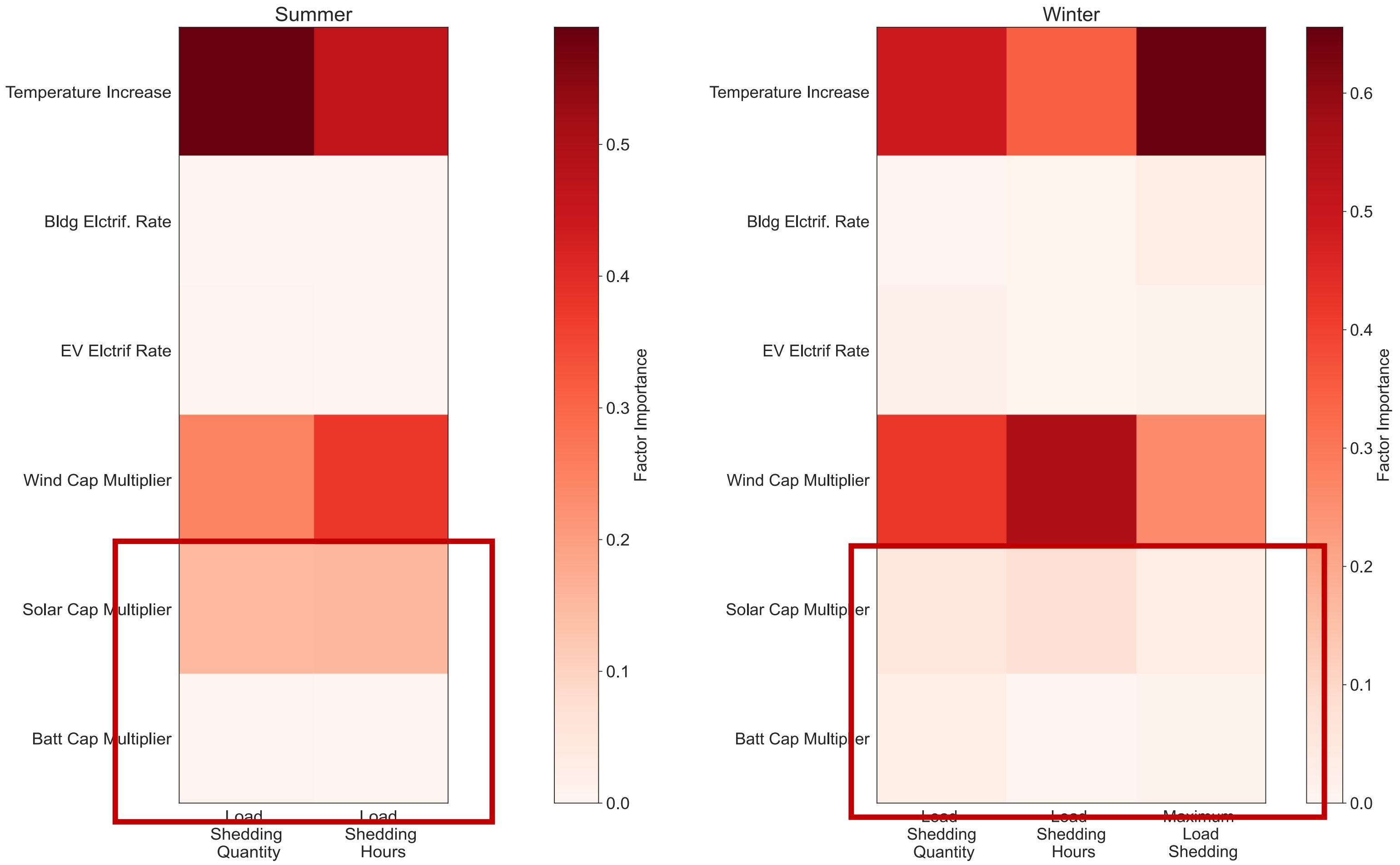
58%-90% of summer hours are congested



40%-84% of winter hours are congested

Consistent congestion means that increasing capacity has limited benefit

Congestion is limiting the efficacy of renewable resources



Takeaways

1. Spatiotemporal heterogeneity in the system vulnerabilities identifies a need for at least 60% additional firm, zero-emission capacity than planned.

2. Continuing to add wind, solar and battery capacity is ineffective in improving reliability due to spatiotemporal dynamics and operational constraints

3. Firm, zero-emission resource or a seasonal storage option is required that won't exacerbate transmission congestion.

Thank you

Additional resources:

Grid model:

Liu, M. V., Yuan, B., Wang, Z., Sward, J. A., Zhang, K. M., & Anderson, C. L. (2022). An open-source representation for the nys electric grid to support power grid and market transition studies. IEEE Transactions on Power Systems.

https://github.com/AndersonEnergyLab-Cornell/NYgrid

Manuscript and supplemental data and materials:
https://arxiv.org/abs/2307.15079

Questions or suggestions are appreciated: email cla28@cornell.edu