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

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.

New EU goal means Germany might have to cut emissions by 62-68% by 2030 – climate council
Clean Energy and Emissions Goals by State

11 states have not set clean energy or emission goals: Alabama, Arkansas, Florida, Georgia, Idaho, Iowa, Kentucky, Mississippi, Tennessee, West Virginia, and Wyoming.

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

- Heat Pumps
- Electric Vehicles

Sectors

13% Buildings
29% Transportation
25% Electricity
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

Summer peak

Winter peak
Increased wind and solar capacity
Zonal renewable allocation

a) Solar

b) Wind

c) Hydro

b) Wind

d) 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

Temperature
Wind Speed
Humidity
Solar Radiation

Supply
Wind
Solar
Hydro
Nuclear
Battery

Transmission expansion
New HVDC lines
Dynamic rating

Transmission
Baseline Load
Heating/Cooling
Electric Vehicles

Demand
Multi-criteria decision analysis

1998 MERRA-2 2019

Simulated Wind
Simulated Solar

Simulated Load (baseload)
Simulated Electrified Load

DC OPF: Minimize Load Shedding

1) Quantity
2) Intensity
3) Duration

Baseline: Seasonal differences across multiple years
Spatially differentiated vulnerabilities

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)

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

>27 GW
Spatiotemporal heterogeneity in system vulnerability

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

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

<table>
<thead>
<tr>
<th>Climatic and technological factors</th>
<th>Lower Bound</th>
<th>Upper Bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature increase</td>
<td>0.95</td>
<td>5.64</td>
</tr>
<tr>
<td>Building electrification rate</td>
<td>0.7</td>
<td>1.05</td>
</tr>
<tr>
<td>EV electrification rate</td>
<td>0.7</td>
<td>1.05</td>
</tr>
<tr>
<td>Wind capacity scaling factor</td>
<td>0.6</td>
<td>1.4</td>
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<tr>
<td>Solar capacity scaling factor</td>
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<td>Battery capacity scaling factor</td>
<td>0.6</td>
<td>1.4</td>
</tr>
</tbody>
</table>

Climate Change

Temperature increase

- Wind Speed
- Humidity
- Solar Radiation

Hydro availability

- Renewable resource technology/capacity/location

Technological Change

Transmission expansion
- New HVDC lines
- Dynamic rating

Supply
- Wind
- Nuclear
- Solar
- Battery
- Hydro

Transmission

Capacity of new lines

Demand
- Baseline Load
- Heating/Cooling
- Electric Vehicles

EV adoption rate
- Electrification rate for residential/commercial buildings
What about climate change?
Simulate over 300 climate-technological scenarios
Temperature increase is the most significant factor
Define threshold based on CLCPA plan

Threshold

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

Continuous

Load Shedding Quantity

Year

Quarter Month of the Year

Threshold

Binary

Quarter Monthly Load Shedding Quantity

Year

Quarter Month of the Year

Load Shedding Quantity (GWh)

0 200 400 600 800 1000 1200

Load Shedding Quantity (GWh)

0 0.2 0.4 0.6 0.8 1.0

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

Manuscript and supplemental data and materials:

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