ISO-NE ELCC STUDY: FINDINGS AND RECOMMENDATIONS

NRDC

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NEPOOL Markets Committee
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NRDC's Perspective on RCA Reforms

NRDC supports fair and robust accounting for the reliability contributions of both clean and conventional resources

The Resource Capacity Accreditation (RCA) decisions ISO-NE makes will impact whether FCM helps achieve:

- **Accurate Resource Adequacy:** a reliable grid that avoids retaining unneeded legacy resources
- **A Level Playing Field:** equitable and robust accreditation for all resources
- **Fair Allocation of Benefits:** fair compensation of state-level value creation from clean resource development
- **State Decarbonization Targets:** integration of ISO-NE's markets with state-level policy, planning, and procurements

As noted in our August 9 presentation, NRDC engaged GE Energy Consulting to provide quantitative analysis of key RCA methodology decisions in ISO-NE, which is the focus of our presentation today

Overview: Quantifying Design Choices for RCA Reform

The NRDC-GE study evaluated the impacts of different RCA methodology decisions on 2028 and 2040 ISO-NE resource portfolios, as the region decarbonizes, using an Effective Load Carrying Capability (ELCC) approach

As discussed in further slides, we found that:

1. **The growing portfolio of clean energy resources will provide substantial reliability value**

2. **Capturing thermal limitations is key to ensuring reliability and equity**

3. **Average and marginal RCA approaches produce markedly different incentives and equity outcomes**

4. **Reliability outcomes across summer and winter seasons are highly sensitive to input assumptions**

5. **Other policy choices, such as EUE/LOLE, have significant implications**

Overview: RCA Reform Recommendations

Based on these findings, we recommend:

1. **Clean Energy:** Ensure the RCA market design appropriately reflects the reliability contributions of clean energy resources, including solar, wind, and storage, and the interactive effects between resources

2. **Thermal Resources:** Ensure the RCA market design and modelling assumptions reflect the realities of thermal limitations, including correlated outage risk due to fuel supply constraints and ambient derates

3. **Average vs. Marginal:** Thoroughly examine the policy and efficiency benefits and trade-offs between marginal and average RCA approaches, as well as potential hybrid approaches, before moving forward with a final structure

Overview: RCA Reform Recommendations (continued)

Based on these findings, we recommend:

4. **Annual vs. Seasonal:** Consider the trade-offs between an annual and seasonal FCM and RCA in the context of ISO-NE's near-term transition to a dual-peaking and, later, winter-peaking system

5. **Other Parameters:** Consider the impacts and durability of other key RCA design features and assumptions, including choice of reliability metric (LOLE vs. EUE) and the impacts of climate change

ISO-NE ELCC STUDY APPROACH AND DESIGN

EDUARDO IBANEZ, TECHNICAL DIRECTOR, GE ENERGY CONSULTING

Study Methodology Overview

- GE Energy Consulting constructed a model of ISO-NE in GE MARS, using publicly available resources
- Two years were simulated:
  - 2028: one of the first capacity years that would be affected by new accreditation
  - 2040: to capture longer trends, especially increasing amounts of renewables and storage (model to match base case scenario in ISO-NE's Pathways study)
- Applied ELCC calculations to the model to study:
  - Marginal ELCC
  - Class average ELCC
  - Portfolio ELCC
- A list of sensitivities were considered, to study the impact of major assumption changes on the results
- Impacts on capacity value were studied for:
  - Thermal units
  - Utility-scale solar PV, onshore wind, offshore wind, and battery storage

GE Multi-Area Reliability Simulation (GE MARS)

- GE MARS is a full sequential Monte Carlo simulation, and the chronological representation of the system includes:
  - Equipment forced outages
  - Uncertainty in forecasted loads
  - Transmission interface forced outages and contracts
  - Uncertainty in renewable and storage output

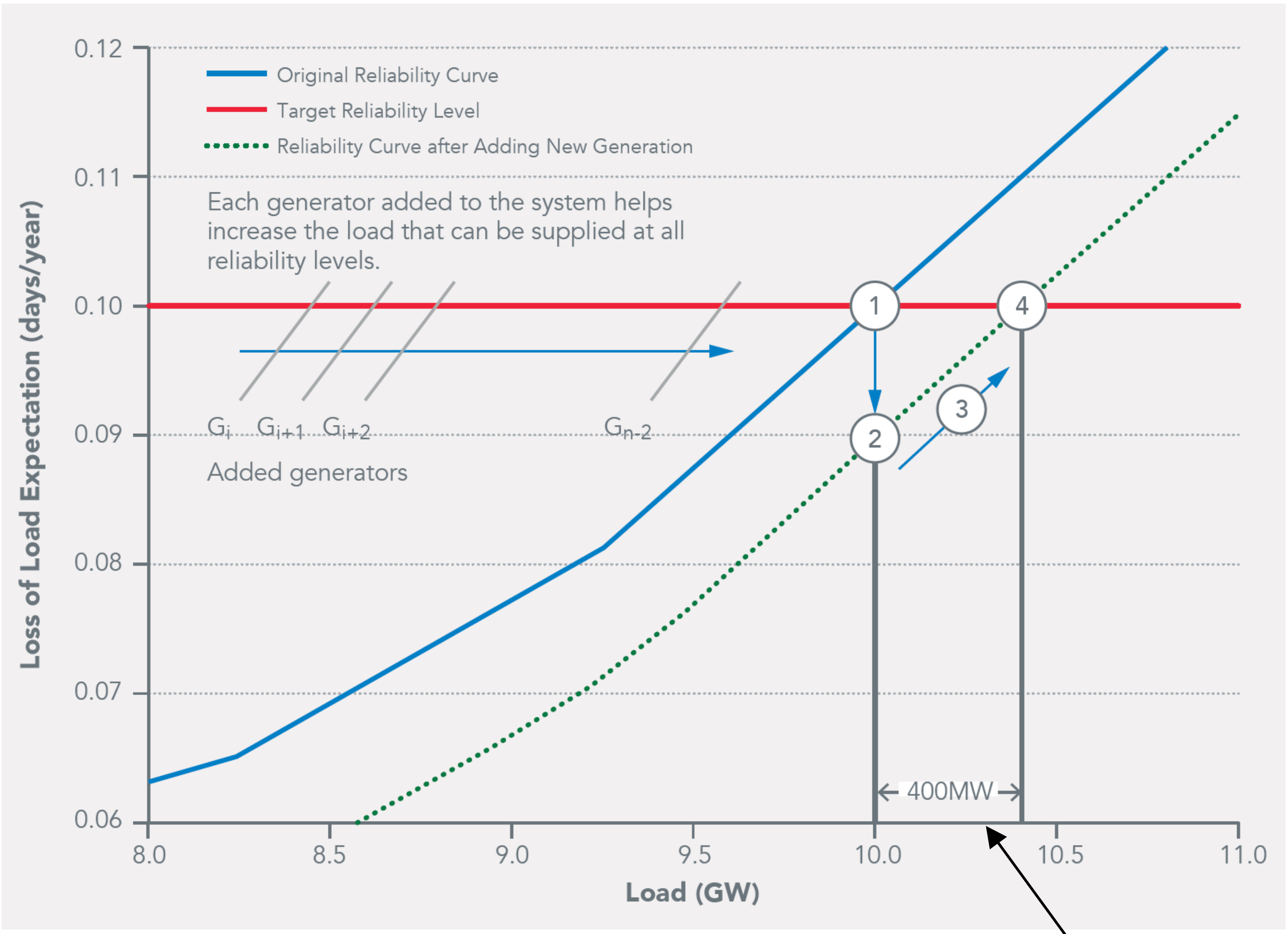
- GE MARS calculates several reliability indices, but in this study we focused on:
  - Daily loss of load expectation (LOLE) in days/year
  - Expected Unserved Energy (EUE) in MWh/year

- A wide range of unit types are supported by GE MARS:
  - Thermal units
  - Co-generation
  - Energy-limited units
  - Hourly-based generation units (such as wind or solar)
  - Energy storage units

- This study ignored internal transmission constraints in the ISO-NE and external assistance from neighboring regions

Effective Load-Carrying Capability (ELCC) Technique

Capacity values were calculated using the ELCC technique



1. Initial system
2. Add resource, reliability improves
3. Increase load
4. Match initial reliability target

J. Katz, P. Denholm "Using Wind and Solar to Reliably Meet Electricity Demand, Greening the Grid" http://www.nrel.gov/docs/fy15osti/63038.pdf

Background: Portfolio, Average and Marginal ELCC

Capacity value for resources can be estimated in several ways, amongst others:

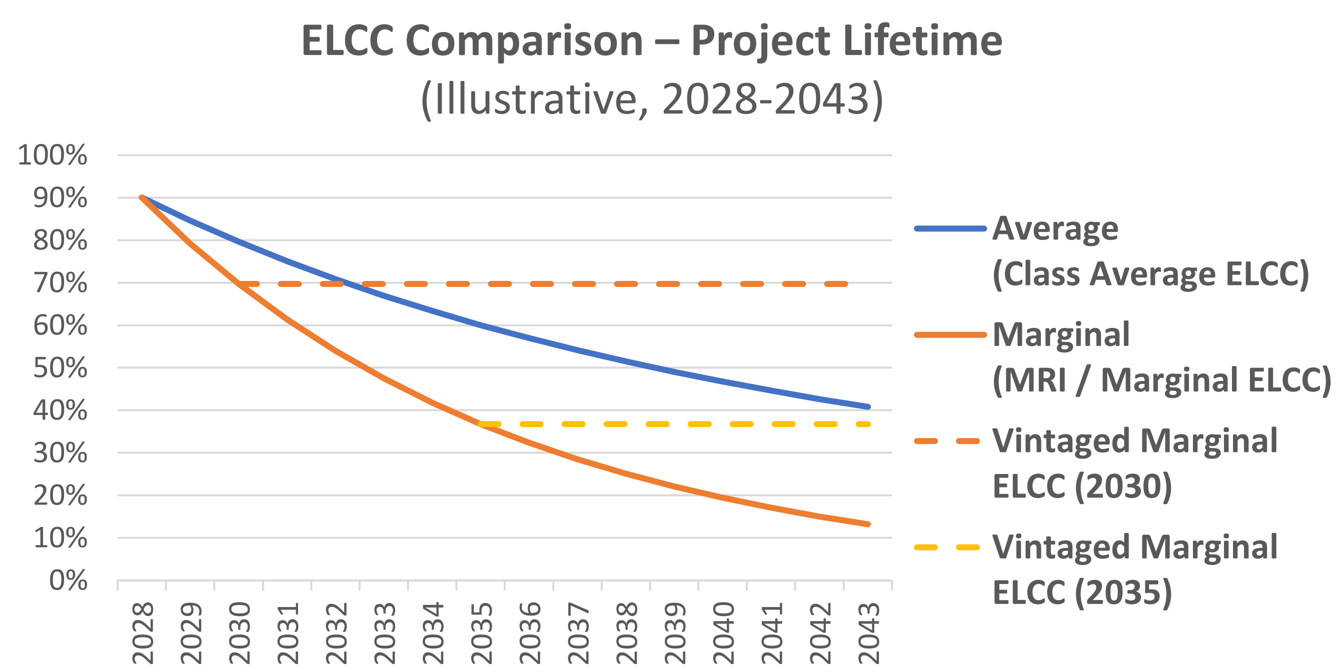
- **Marginal ELCC**: Marginal reliability benefit of the next incremental unit
- **Class average ELCC**: Average reliability contribution of all the resources of a single class
- **Portfolio ELCC**: Reliability contribution of resources across multiple classes (e.g., solar, wind, and battery storage)
- **Vintaged Marginal ELCC**: Marginal reliability benefit of the resource when installed (static over time)

Portfolio ELCC captures synergistic contributions between different classes (e.g., solar and battery storage) that would not be captured by the individual class average ELCC values

Certain resources can present saturation effects, and class average will decline with deployment; in those cases:

Marginal ELCC < Average ELCC

Vintaged Marginal ELCC is shown here for illustrative/comparative purposes but was not considered in this study



Model Description – 2028 and 2040 Resource Mix

Unit Type	2028	2040
Nuclear	3,356	3,356
Coal	95	0
CC Gas	12,388	12,388
ST Gas	1,337	1,337
GT Gas	1,855	1,855
Oil	4,430	4,430
Hydro	1,637	1,637
PSH	1,742	1,742
Other	1,241	1,241
Utility-scale solar	8,262	11,928
Distributed solar	4,943	7,500
Onshore wind	1,872	4,401
Offshore wind	4,700	16,014
Battery	2,000	12,953

- GE Energy Consulting's standard model for ISO-NE, which utilizes publicly available data from FERC, NERC, NPCC, and ABB's Velocity Suite, was used as the starting point
- Deployment of solar, wind, batteries was adjusted to match the main scenario in ISO-NE's Pathways study*
- Historical load data for 7 years (2007-2013) was used to represent weather variability
- Hourly renewable profiles were generated and matched the load weather years (2007-2013):
  - Onshore and onshore wind profiles were based on NREL's Wind Integration National Dataset Toolkit
  - Utility-scale and distributed solar PV profiles were based on the National Solar Radiation Database
- All storage units were assumed to be able to hold 4-hours of energy (e.g., a 100-MW unit can hold 400 MWh)

* The Analysis Group, "Pathways Study, Evaluation of Pathways to a Future Grid," available at: https://nepool.com/wp-content/uploads/2022/05/NPC_20220426_Pathways_FULL_REPORT_FINAL_v2.pdf

Model Description – Sensitivities

- Three sensitivities were used to capture impacts:
  - Sensitivity 1: Gas supply risk
  - Sensitivity 2: Impact of ambient temperature
  - Sensitivity 3: Higher levels of electrification

- Additionally, throughout the study we captured the impact of using different reliability metrics to calculate capacity value:
  - Daily loss of load expectation (LOLE) in days/year
  - Expected unserved energy (EUE) in MWh/year

Sensitivity 1: Gas Supply Risk

- The goal was to measure the impact that restrictions on non-firm gas supply could have on system reliability and capacity values across classes

- Three different levels of gas outages were considered as sensitivities:
  - Loss of 40% of gas unit capacity (3,700 MW*)
  - Loss of 50% of gas unit capacity (4,635 MW)
  - Loss of 60% of gas unit capacity (5,562 MW+)

- Along with the severity of the outage, we considered increasing durations of that outage around the winter peak day of:
  - 1 week
  - 2 weeks
  - 4 weeks

- All combinations were studied; the Base Case assumed a 1-week outage at 40% derate

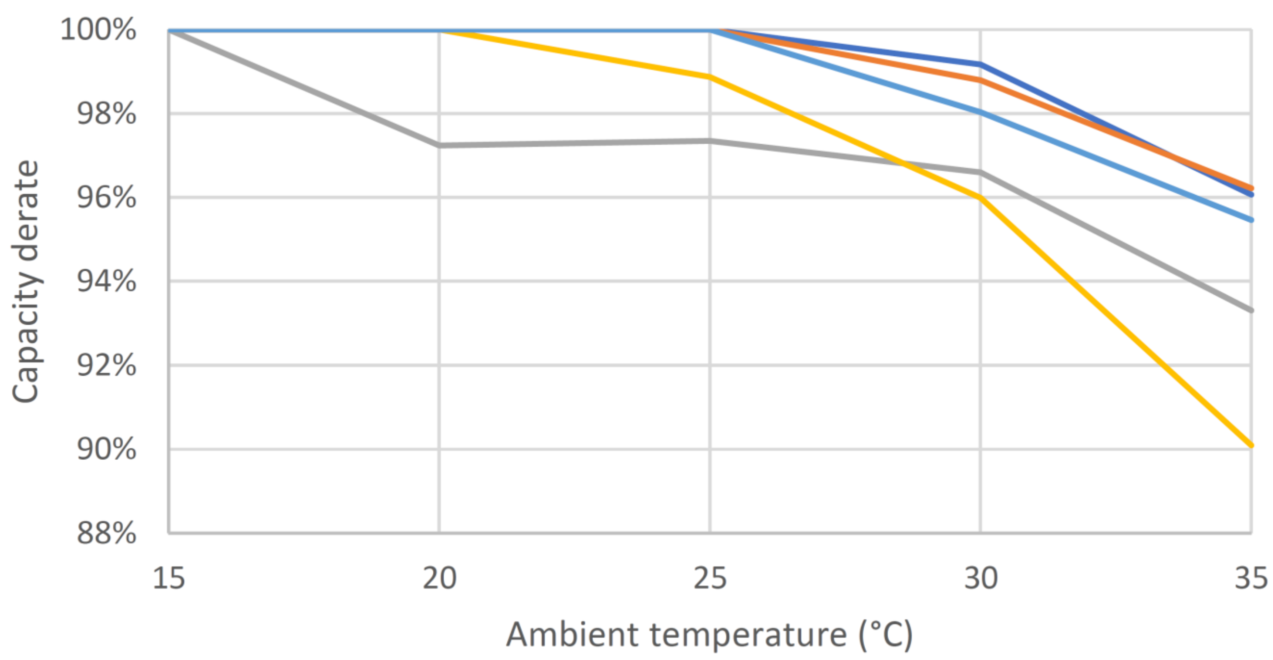
* 3,700 MW estimate from ISO-NE, "NEPOOL Participants Committee Report," November 3, 2021, slide 18, available at: https://www.iso-ne.com/static-assets/documents/2021/11/november-2021-coo-report.pdf

+ The 2021/22 NPCC Winter Assessment assumed "5,682 MW of gas-fired generation assumed unavailable due to the fuel supply constraint" for New England for the Severe assumptions in the probabilistic section of the study (Appendix VIII), available at: https://www.npcc.org/content/docs/public/library/reports/seasonal-assessment/2021/npcc-2021-2022-winter-assessment.pdf

Sensitivity 2: Impact of Ambient Temperature

- The study considered the impact of including derates in thermal unit capacity due to higher ambient derates
- Derate assumptions adapted from a recent EPRI study* and applied based on unit type
- In the worst-case scenario (above 35°C, or 95°F), this represented a loss of 1,300 MW

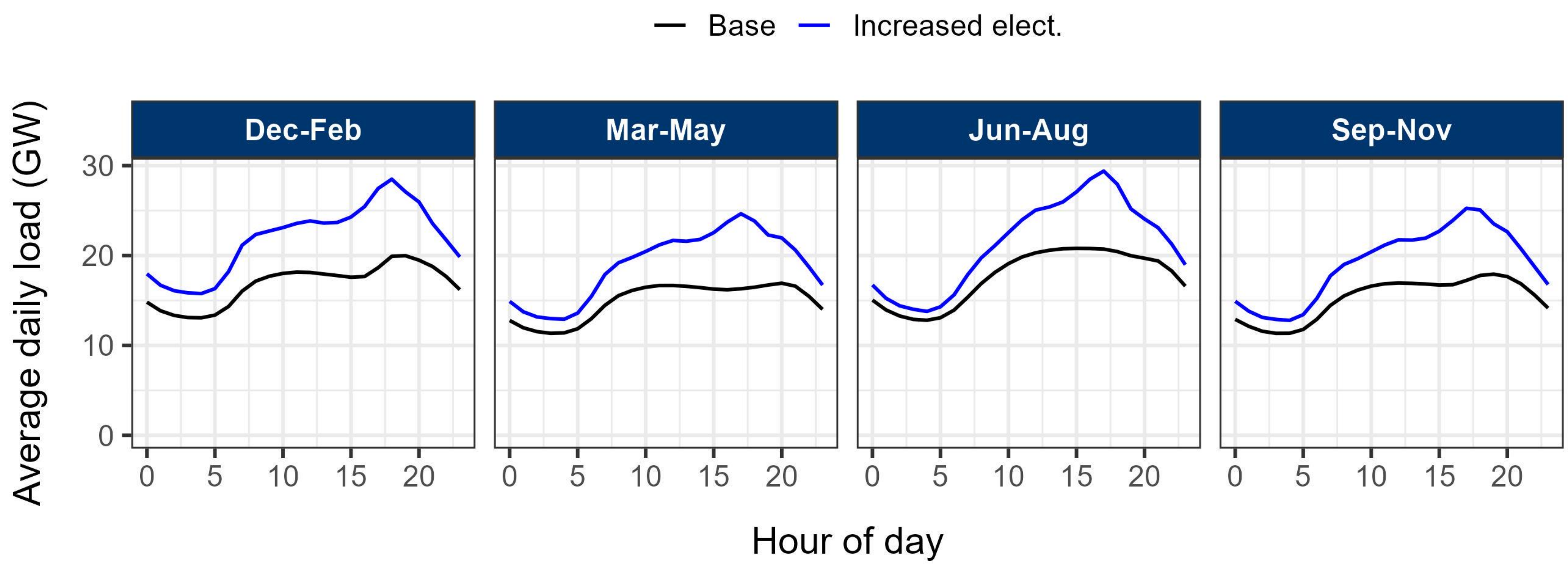
	Ambient temperature (°C)				
Generator type	15	20	25	30	35
Combined cycle	0	0	0	0.83	3.93
Combustion turbine	0	0	0	1.21	3.78
Diesel	0	2.76	2.65	3.40	6.69
Hydro/PS	0	0	0	0.42	5.83
Nuclear	0	0	1.14	4.01	9.91
Steam turbine	0	0	0	1.97	4.54



* S. Murphy, F. Sowell, J. Apt, "A time-dependent model of generator failures and recoveries captures correlated events and quantifies temperature dependence" (2019) Applied Energy, Vol. 253, Available: https://doi.org/10.1016/j.apenergy.2019.113513

Sensitivity 3: Higher Levels of Electrification

- The historical weather shapes (2007-2013) do not capture how load patterns are expected to evolved in the future, especially as electrification increases
- We used data from NREL's Electrification Future Study to develop load modifications
- Figure below shows the effect on average day per season in 2040:
  - Electrification increases peak load values
  - Changes are not uniform across seasons



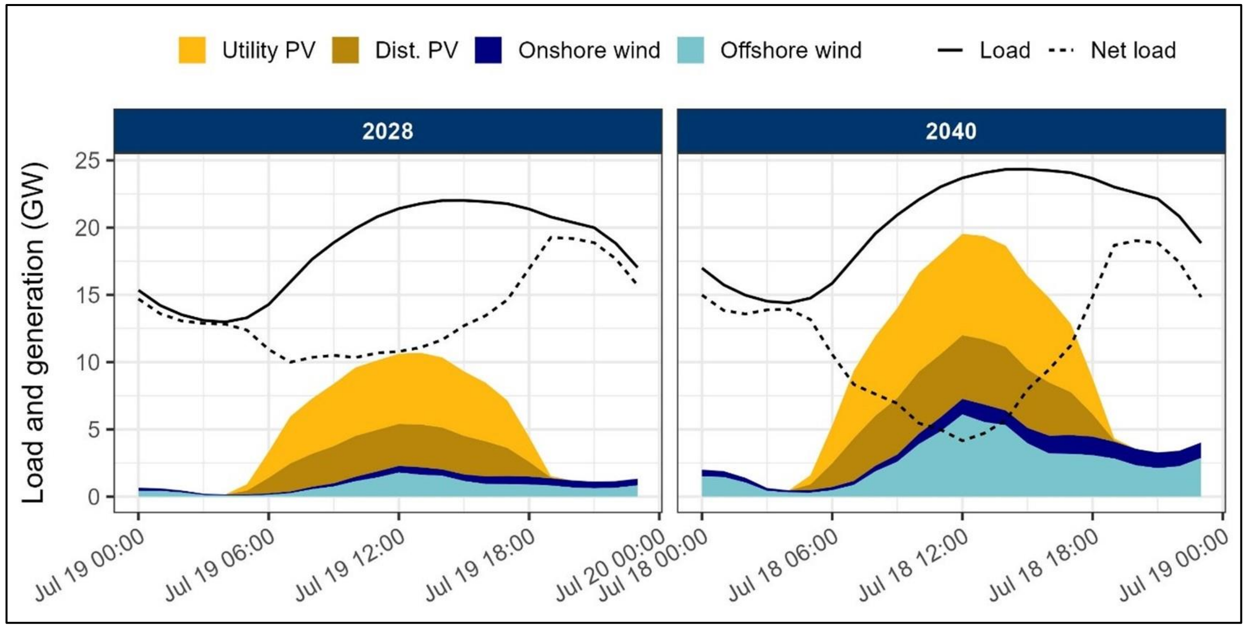
MODELING TAKEAWAYS:
KEY FINDINGS AND RECOMMENDATIONS

NICK PAPPAS, NP ENERGY (CONSULTANT TO NRDC)

Finding 1: Reliability Contributions of Clean Resources

Achieving the clean resource development identified in the Pathways report would result in significant reliability contributions from the clean resource fleet:

- Utility-scale solar, wind, and storage *capacity* can meet:
  - 21% of ISO-NE's gross peak in 2028 (5,388 MW PCAP)
  - 44% of ISO-NE's gross peak in 2040 (12,460 MW PCAP)
- Solar and wind *energy* can meet:
  - 34% of ISO-NE's energy needs in 2028
  - 65% of ISO-NE's energy needs in 2040
- Including hydro, nuclear, and distributed PV:
  - 61% of ISO-NE's energy needs in 2028
  - 90% of ISO-NE's energy needs in 2040



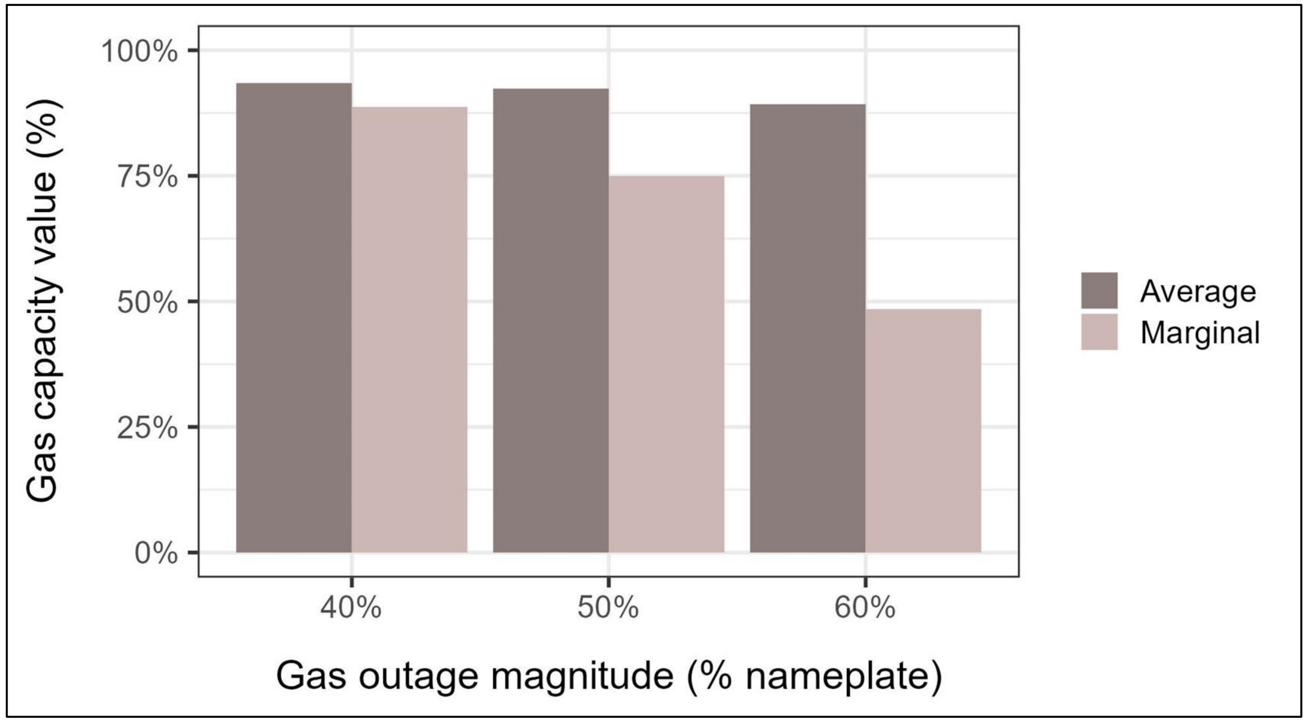
Portfolio Contributions of Clean Resource Fleet
Clean resources meet 44% of peak load by 2040

***Recommendation 1:** Ensure the RCA market design appropriately reflects the reliability contributions of clean energy resources, including solar, wind, and storage, and the interactive effects between resources*

Finding 2: No Resource is Perfect (Capacity), Including Thermal

Thermal resources face various use limitations, including correlated outages, ambient derates, and fuel supply risk, all of which should be included to accurately assess thermal reliability contributions

- **Ambient Derates at 95°F:**
  - Fossil resource output can decline by 4-7%
  - Nuclear output can decline by almost 10%
- **Fuel Supply Risk:**
  - Significant but uncertain; ELCC penalty is function of magnitude and duration (input assumptions)
  - Severe supply outage can have major impacts on marginal ELCC value of gas units



Gas Unit Average and Marginal ELCC
as a Function of Fuel Supply Risk in 2040
1 Week Outage Affecting 40-60% of Gas Fleet

Further analysis and input refinement is critical: Fossil risk drives reliability modeling results, seasonal LOLE variability, and market outcomes

Recommendation 2: *Ensure the RCA market design and modelling assumptions reflect the realities of thermal limitations, including correlated outage risk due to fuel supply constraints and ambient derates*

Finding 3: Major Gaps Between Average and Marginal Accreditation

At high penetrations, average and marginal accreditation have vastly different results for clean energy resources:

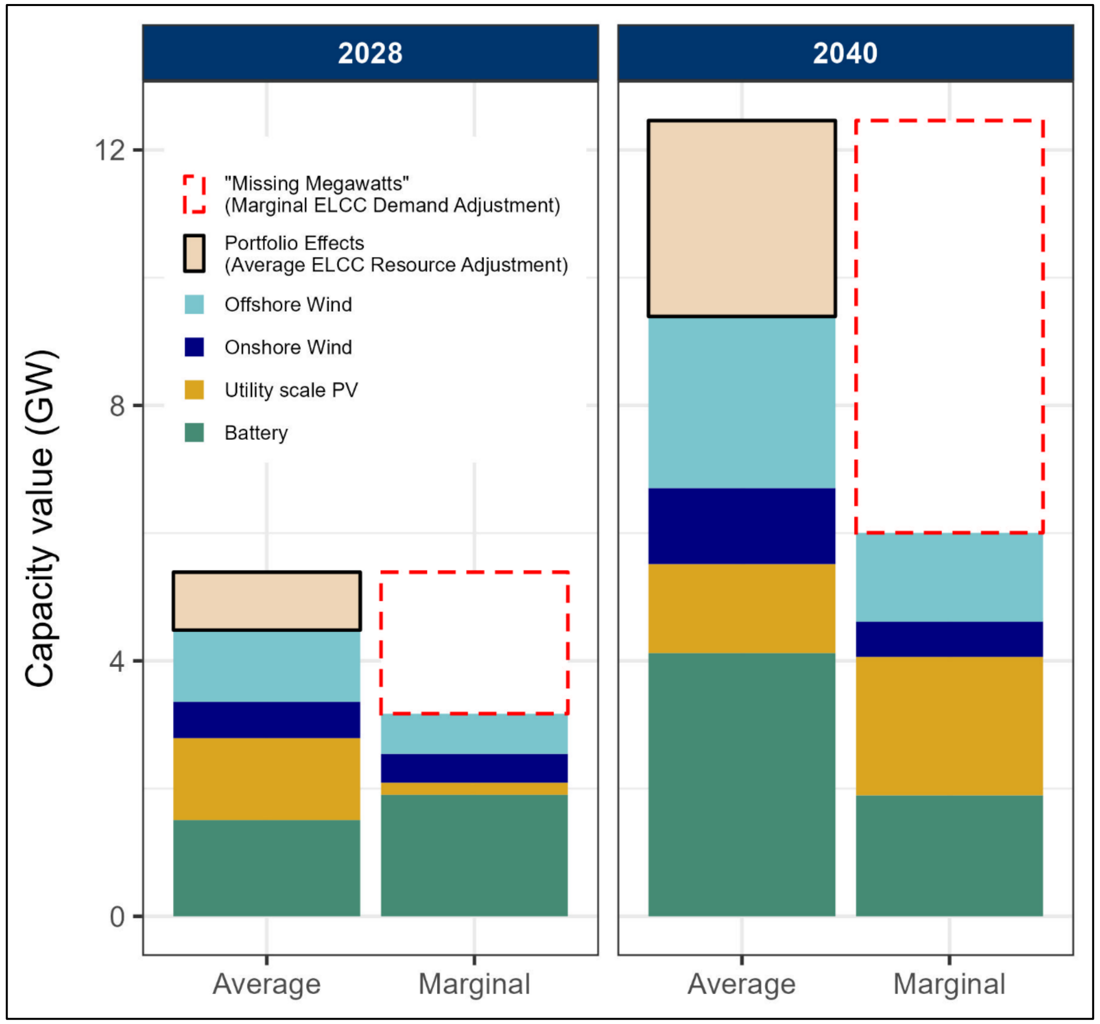
2028 Capacity Awards for RE + Batteries:

- **Average:** 5,388MW
- **Marginal:** 3,173MW
    - ***Missing Megawatts:*** *2,215MW (41%)*

2040 Capacity Awards for RE + Batteries:

- **Average:** 12,460MW
- **Marginal:** 6,005MW
    - ***Missing Megawatts:*** *6,455MW (52%)*

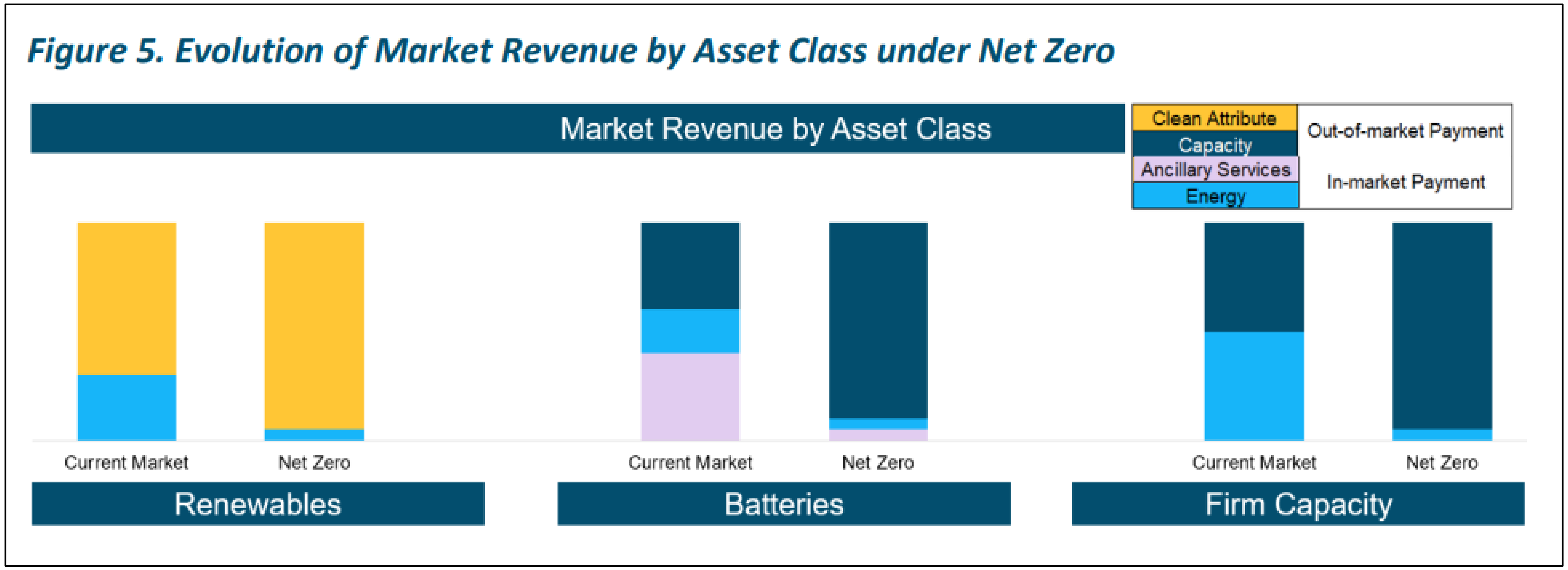
Socializing over half of the total reliability contributions of clean resources could result in a reduced market signal for reliability in clean resource selection and development



Total Accreditation of Clean Resources Under Average and Marginal ELCC

Recommendation 3: *Thoroughly examine the policy and efficiency benefits and trade-offs between marginal and average RCA approaches, as well as potential hybrid approaches, before moving forward with a final structure*

Finding 3 (continued): The "Missing Money" for Clean Resources



- Recent analysis from E3* identified major shifts in revenue sources for renewables and storage on a net zero system:
  - Renewable revenue would need to come largely from payments outside current markets (e.g., clean attribute payments under state policies, Forward Clean Energy Market, etc.)
  - Storage revenue would need to come largely from capacity awards
  - While not specific to ISO-NE, directional trends are likely to be consistent across decarbonizing regions
- If storage resources are accredited on a marginal basis, reducing their capacity awards by approximately half relative to the fleet's PCAP contribution, will other out-of-market payments be necessary to incentivize storage development?

* Electricity Resource Compensation Under a Net Zero Future, Energy and Environmental Economics, September 2022. https://www.ethree.com/wp-content/uploads/2022/09/E3-whitepaper_Electricity-Resource-Compensation-Under-a-Net-Zero-Future.pdf

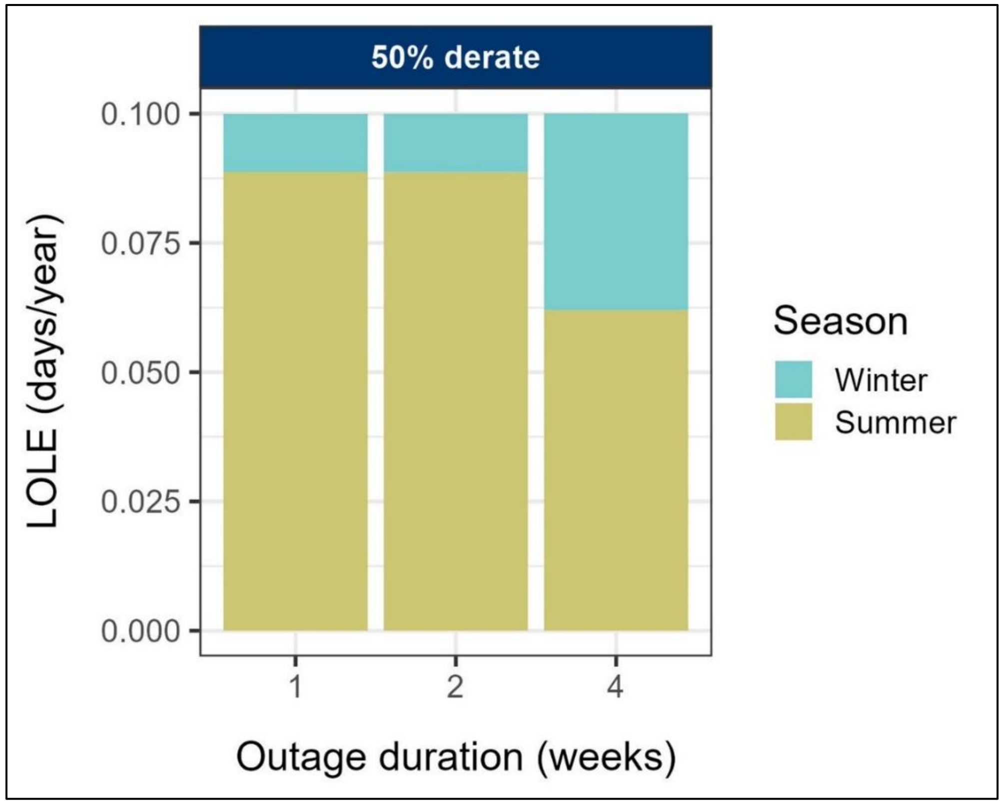
Finding 4: Balancing Seasonal Reliability Needs With Uncertainty

Understanding the timing and nature of reliability events is critical to ensuring accurate ELCC accreditation—assumptions about the distribution of outages between seasons will have significant impacts on ELCC results, particularly marginal ELCC:

Seasonal Distribution of Outages by Modeled Fuel Supply Risk Event:

- The share of outages occurring in winter is moderate, but present, in all fuel risk scenarios
- The share of outages occurring in winter is substantial at longer outage durations

Accurately identifying when and why outages occur will have outsized impact on marginal ELCC results



Seasonal Distribution of Outage Events at 50% Derate
Growing Share of Winter Outages at Longer Event Durations

***Recommendation 4**: Consider the trade-offs between an annual and seasonal FCM and RCA in the context of ISO-NE's near-term transition to a dual-peaking and, later, winter-peaking system*

Finding 5: Reliability Metrics, Load Forecasts, Other Metrics Matter

ELCC results are also highly sensitive to other input assumptions, including the choice of reliability metric, impacts of electrification, and impacts of climate change

Reliability Metric:

- Loss of Load Expectation (LOLE) and Expected Unserved Energy (EUE) are related but distinct reliability metrics which will calibrate differently and produce different ELCC results, particularly for marginal ELCC

Peak Load and Load Shapes:

- Future load is unpredictable, and will shift in magnitude and shape as electrification, climate change, and behind-the-meter resource development occur
- Differing assumptions for each of these inputs can result in significantly different ELCC Results

***Recommendation 5:** Consider the impacts and durability of other key RCA design features and assumptions, including choice of reliability metric (LOLE vs. EUE) and the impacts of climate change*

Summary of Recommendations

1. **Clean Energy:** Ensure the RCA market design appropriately reflects the reliability contributions of clean energy resources, including solar, wind, and storage, and the interactive effects between resources

2. **Thermal Resources:** Ensure the RCA market design and modelling assumptions reflect the realities of thermal limitations, including correlated outage risk due to fuel supply constraints and ambient derates

3. **Average vs. Marginal:** Thoroughly examine the policy and efficiency benefits and trade-offs between marginal and average RCA approaches, as well as potential hybrid approaches, before moving forward with a final structure

4. **Annual vs. Seasonal:** Consider the trade-offs between an annual and seasonal FCM and RCA in the context of ISO-NE's near-term transition to a dual-peaking and, later, winter-peaking system

5. **Other Parameters:** Consider the impacts and durability of other key RCA design features and assumptions, including choice of reliability metric (LOLE vs. EUE) and the impacts of climate change