AUGUST 25, 2023 | VIRTUAL

2050 Transmission Study

Massachusetts Clean Energy Transmission Working Group

Dan Schwarting

MANAGER | TRANSMISSION PLANNING

Outline of Today's Presentation

- 2050 Transmission Study Overview
- Key Takeaways
  - What are the high-level takeaways from the 2050 Transmission Study?
  - How can the key takeaways from the 2050 Transmission Study better inform how the region approaches transmission system expansion between now and 2050?
- Transmission Development Roadmaps
  - What are some high-level frameworks that might guide development of the New England transmission system?
- Current Status & Next Steps

2050 TRANSMISSION STUDY OVERVIEW

2050 Transmission Study Overview

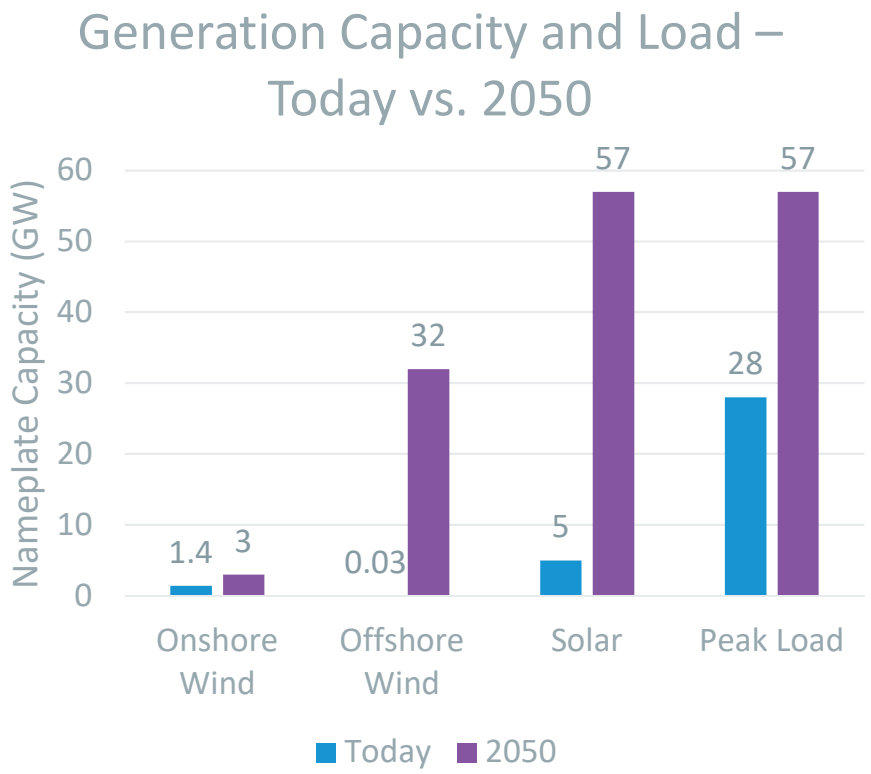
- In accordance with a recommendation from NESCOE's October 2020 "*New England States' Vision for a Clean, Affordable, and Reliable 21st Century Regional Electric Grid*," ISO-NE is conducting the 2050 Transmission Study in order to determine:
  - Transmission needs in order to serve load while satisfying NERC, NPCC, and ISO-NE reliability criteria in 2035, 2040, and 2050
  - Transmission upgrade "roadmaps" to satisfy those needs considering both constructability and cost
- ISO-NE has coordinated with NESCOE and PAC throughout this study
  - In November 2021, ISO-NE introduced the 2050 Transmission Planning Study Scope of Work, preliminary assumptions, and methodology
  - ISO-NE presented results showing transmission reliability concerns in peak load snapshots in March 2022, April 2022, and July 2022
  - ISO-NE presented updates on proposed solutions in December 2022 and April 2023
- Under the ISO-NE Tariff, there is no requirement to pursue solutions to the concerns identified
  - This study is meant to evaluate potential transmission scenarios and sample transmission upgrades, and is not a recommendation to develop specific transmission or generation projects
  - In late 2023 and 2024, NESCOE, ISO-NE, and NEPOOL will collaborate on a process to advance transmission upgrades to address concerns identified in longer-term transmission studies such as the 2050 Transmission Study

2050 Transmission Study Scope

- The 2050 Transmission Study examines only the thermal performance of the transmission system under summer and winter peak load snapshots
- Many other types of analysis are not covered by this study:
  - Voltage and transient stability performance
  - Electro-magnetic transient (EMT) analysis
  - Distribution system performance
  - Generator interconnection and deliverability during off-peak hours
- Costs identified by this study will not include any costs associated with these other types of analysis

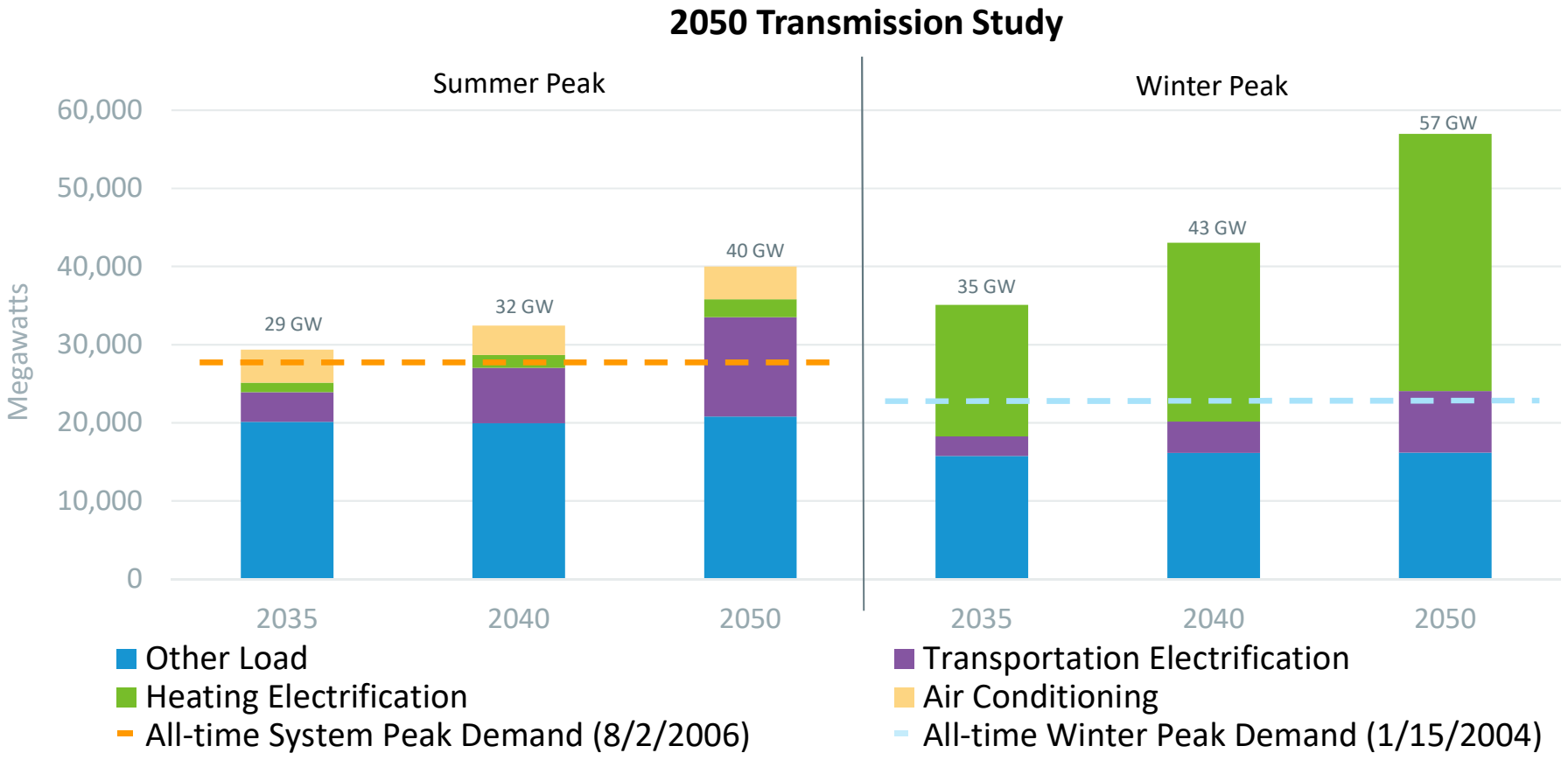
2050 Transmission Study Input Assumptions

- Inputs were based on the Massachusetts "Energy Pathways to Deep Decarbonization" study's "All Options" pathway
- Significant new renewable generation
- Retirement of all coal and oil generation
  - Some natural gas units retained
- Significant transportation and heating electrification
- Increased imports from Quebec and New York



Source: Energy Pathways to Deep Decarbonization; load recast to a 2019 weather year as described in a June 2021 Planning Advisory Committee presentation

New England System Peak Grows Substantially and Shifts to Winter-Peaking



KEY TAKEAWAYS

Key Takeaways: Introduction

- ISO-NE plans to organize the 2050 Transmission Study report around a few key themes, based on trends observed while performing analysis
- The following slides will outline some trends observed so far
  - Study work has not yet been completed, so these themes are subject to change as the study nears completion
  - A draft report, issued by November 1, 2023, will cover these themes in greater detail

Preliminary Lessons Learned

Reducing Peak Loads Significantly Reduces Transmission Cost

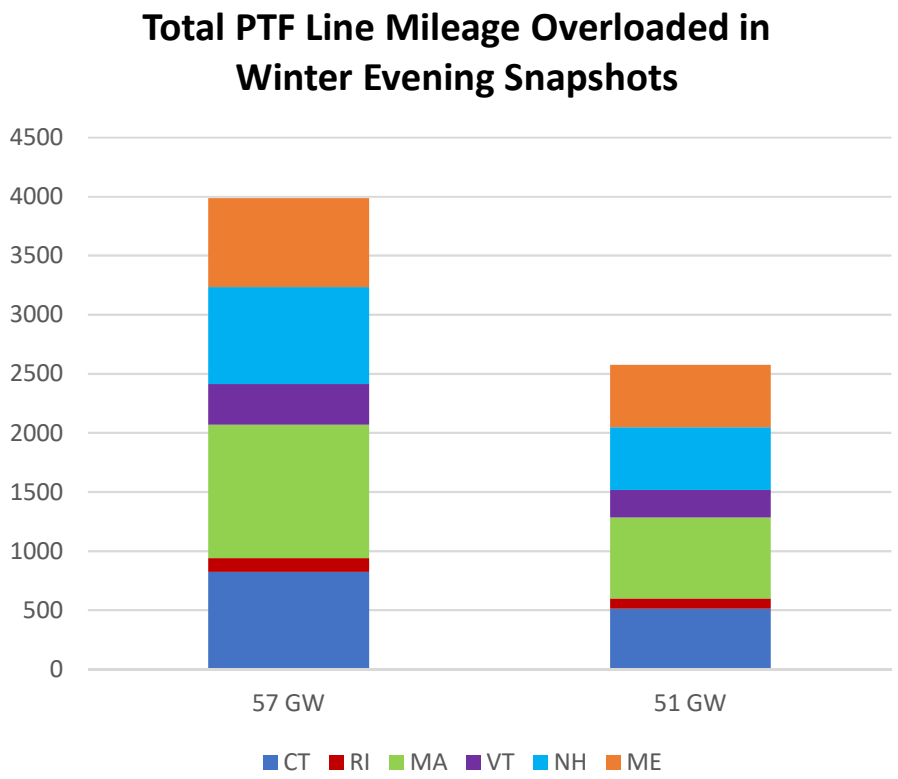
Generator Sizes and Locations Can Affect Overloads

High-Likelihood Concerns Can Be Prioritized

Incremental Upgrades Can Be Made As Opportunities Arise

Reducing Peak Loads Significantly Reduces Transmission Cost

- Original 2050 Winter Peak snapshot assumed a 57 GW peak load
- Results presented in April 2022 and July 2022 introduced the 2050 Winter Peak 51 GW sensitivity, and showed that the total mileage of transmission overloads decreased by about 35%
- Preliminary transmission costs show a similar effect: the cost of transmission upgrades required to serve a 51 GW winter peak is *significantly* lower than that required to serve a 57 GW winter peak



Reducing Peak Loads Significantly Reduces Transmission Cost

- For the purposes of reducing transmission cost, simply shifting load to another off-peak hour could help avoid upgrades
- Other studies, such as the EPCET study, show that additional capacity and production cost can only be avoided if energy demand is eliminated entirely or shifted seasonally
  - Shifting load to another hour in the same day cannot address multi-day or multi-week needs for stored energy

Generator Sizes and Locations Can Affect Overloads

- Strategically locating points of interconnection (POIs) for new generating resources can reduce transmission overloads
- Early 2050 Transmission Study analysis found that locating generation in southern New England is helpful to reduce North-South stresses
- Further analysis has shown that location on a finer scale is also critical to limiting overloads during peak load conditions
  - Choice of individual substations in urban areas
  - Choice of voltage level within a substation (115 vs. 345 kV)

High-Likelihood Concerns Can Be Prioritized

- As the region looks to transition to a low-emissions, electrified future, certain high-likelihood concerns* are likely to appear for many possible future scenarios
  - Investment in addressing these concerns may be prudent regardless of exact generator locations and load distribution
- The 2050 Transmission Study report will identify a few of these concerns, including North-South transfer capability

* High-likelihood concerns are those that would appear under a wide variety of conditions, including conditions that do not exactly match those examined in the 2050 Transmission Study. A detailed explanation may be found in the April 2023 PAC presentation on the 2050 Transmission Study.

Incremental Upgrades Can Be Made As Opportunities Arise

- Much of the investment needed to serve 2050 peak loads is in the form of rebuilding existing transmission lines
- These investments will be somewhat sensitive to generator locations, geographic distribution of load, and locations of new load-serving substations
- These upgrades can be pursued as better information on the system's evolution becomes available, or when it is efficient to pursue them as part of other construction work

TRANSMISSION DEVELOPMENT ROADMAPS

Transmission Development Roadmaps

- A main objective of the 2050 Transmission Study is to develop transmission upgrade “roadmaps” to satisfy anticipated concerns, considering both constructability and cost
- The final 2050 Transmission Study report will detail multiple roadmaps for the evolution of certain portions of the transmission system with high-likelihood concerns
  - A high-level summary of these roadmaps will be presented today
- Each roadmap will have a few major components, with additional existing line rebuilds and other components to form a complete solution
  - Timing of each component (2035, 2040, 2050 with 51 GW winter peak, or 2050 with 57 GW winter peak) will also be specified

Transmission Development Roadmaps

- ISO-NE does not plan to express a preference for any particular roadmap in the final 2050 Transmission Study Report, due to the following tradeoffs between competing priorities and concerns beyond the study's scope
  - Robustness and performance under off-peak conditions
  - Siting concerns
  - Environmental impact
  - HVDC technology availability and performance
- The intent of including multiple roadmaps is to provide a basis of comparison for decision-making by New England stakeholders

Roadmaps for North-South Transfers and Boston Import

Rebuild-Priority Roadmap

- Prioritize rebuilds of existing lines to the greatest degree possible

AC Roadmap

- New 345 kV overhead transmission

DC Roadmap

- New HVDC transmission – overhead, underground, or submarine

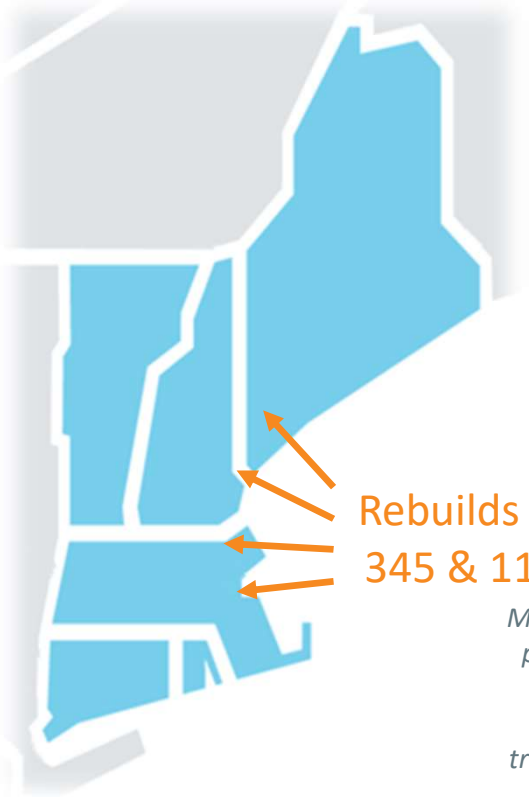
Offshore Grid Roadmap

- Connections between offshore wind farms to provide offshore paths for power transfer

Roadmaps for North-South Transfers and Boston Import

Rebuild-Priority Roadmap

- Large numbers of 345 kV and 115 kV transmission lines rebuilt to accommodate higher power flow
- Rebuilds alone cannot successfully serve a 57 GW winter peak load; this roadmap accommodates a 51 GW winter peak load only
- Large number of rebuilds may lead to a higher total cost than other roadmaps
- Most likely to require extra upgrades for voltage/stability concerns



Map is for illustrative purposes only, and does not define a route for any transmission project.

Roadmaps for North-South Transfers and Boston Import

AC Roadmap

- Major components are new 345 kV overhead transmission lines in Maine, New Hampshire, and the Boston area
- Increased transfer capability on Maine-New Hampshire, North-South, and Boston Import interfaces will bring energy from northern New England resources to southern New England load centers
- Fully underground/submarine AC transmission lines are likely infeasible due to the long distances involved and lower capacity than overhead transmission lines

Map is for illustrative purposes only, and does not define a route for any transmission project.

Roadmaps for North-South Transfers and Boston Import

DC Roadmap

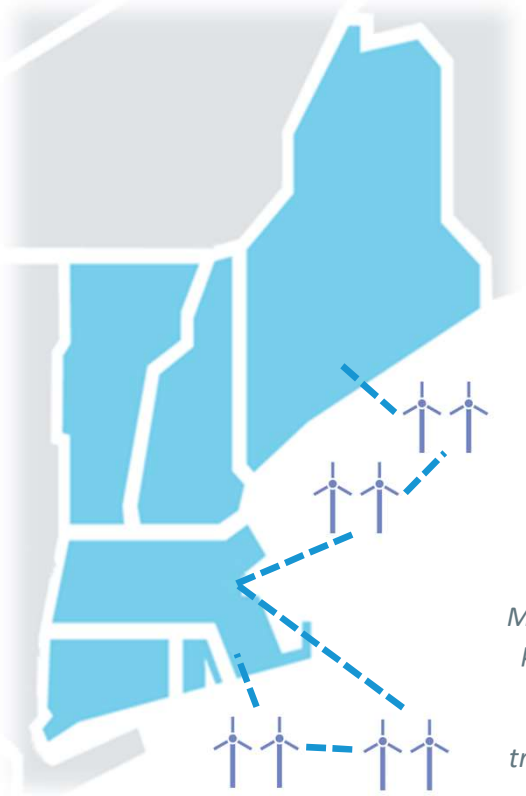
- Major components are new HVDC transmission lines between Maine and the Boston area
- Large portions of the HVDC lines could feasibly be placed overhead, underground, or submarine
- Onshore AC/DC converters at each terminal will add cost, but may bring voltage control and stability benefits to the grid

Map is for illustrative purposes only, and does not define a route for any transmission project.

Roadmaps for North-South Transfers and Boston Import

Offshore Grid Roadmap

- Primary components are new HVDC connections between offshore wind farms
- During periods of low wind availability, these connections would allow utilization of offshore wind transmission leads for power transfer between points onshore
- In addition to North-South transfers, offshore connections could also bring power from SEMA/RI into the Boston area
- Beyond what is modeled in the 2050 Transmission Study, these grids could be expanded to include wind farms connecting to New York, PJM, or other neighboring areas



Map is for illustrative purposes only, and does not define a route for any transmission project.

Offshore Grid Roadmap Scope

- The inclusion of the offshore grid roadmap is meant to answer the question: “If an offshore grid is built, how would it help to address transmission concerns related to serving peak loads?”
  - The inclusion of this analysis is not intended to be a full cost/benefit analysis of any hypothetical offshore system
  - Meshed offshore HVDC systems are not yet in use commercially, so design and cost relies on many assumptions and approximations
  - Many possible benefits could only be quantified with analysis beyond the scope of the 2050 Transmission Study

Additional Roadmaps

- Roadmaps may also be developed for other portions of New England where multiple transmission approaches are equally feasible and cost-competitive
- In many parts of New England, addressing concerns by rebuilding existing lines for higher capacity is clearly more cost-effective and feasible
  - Multiple roadmaps will not be developed for areas where a rebuild-based solution meets the identified concerns and is cost-effective

CURRENT STATUS & NEXT STEPS

2050 Transmission Study Status & Next Steps

- Solution development to address identified concerns is nearing completion
- Detailed cost estimates for complex projects are in progress
  - Electrical Consultants Inc. (ECI) is developing these cost estimates as ISO-NE's consultant
  - ISO-NE will use cost assumptions based on recent projects for rebuilds of existing transmission lines and other less-complex projects
- Report drafting will be underway shortly; a draft is expected to be released no later than November 1, 2023

Questions