2050 Transmission Study

Key Takeaways and Transmission Development Roadmaps

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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?
- Conclusion & 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

2050 Transmission Study Status

- 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

2050 Transmission Study Scope

- The 2050 Transmission Study examines only the thermal performance of the transmission system under 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

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 of the trends observed so far
  - Study work has not yet been completed, so these themes are subject to change as the study nears completion

Preliminary Lessons Learned

Reducing Peak Loads Significantly Reduces Transmission Cost

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 30-40%
- 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

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
- It may be prudent to wait for more precise information on future development before pursuing these upgrades

Incremental Upgrades Can Be Made As Opportunities Arise

- Many load-serving concerns do not appear until 2040 or 2050, allowing the region to spread the cost of upgrades over many years rather than addressing issues immediately
- As lines are replaced for asset condition concerns, increasing capacity may have a relatively small incremental cost
- Addressing these concerns as opportunities arise, rather than upgrading immediately, could lead to cost savings for the New England region

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

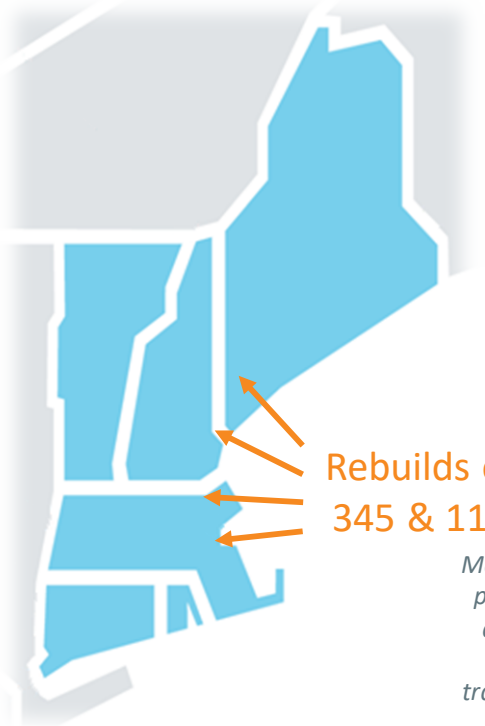
Offshore Grid Roadmap

- 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

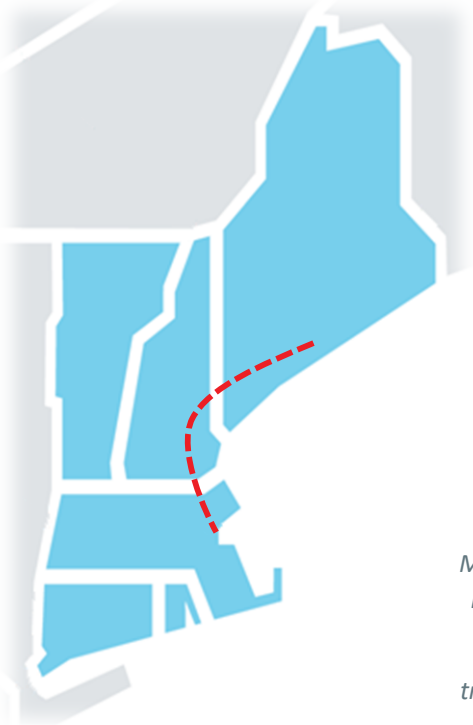


Map is for illustrative purposes only, and does not define a route for any transmission project.

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



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Roadmaps for North-South Transfers and Boston Import

DC Roadmap

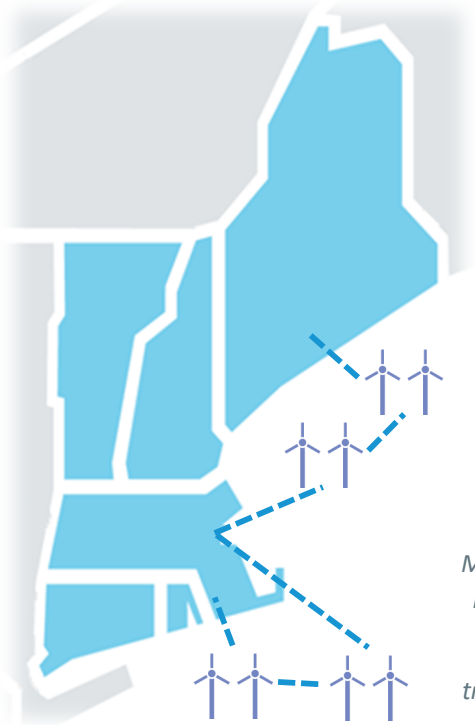
- Major components are new HVDC transmission lines between Maine and the Boston area
- Large portions of the HVDC lines could feasibly be placed overhead, underground, or submarine
- Onshore AC/DC converters at each terminal will add cost, but may bring voltage control and stability benefits to the grid

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



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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
  - Cost estimates will be approximate, and many possible benefits would need analysis beyond the scope of the 2050 Transmission Study

Offshore Grid Roadmap Caveats

- While significant research and development towards offshore transmission has been performed in Europe, meshed offshore HVDC systems are not yet in use commercially
  - Many assumptions will be made in design and modeling for the purposes of the 2050 Transmission Study
  - Costs should be considered to have an order-of-magnitude accuracy only, due to a lack of actual costs for comparison
  - Technology for HVDC breakers is not yet commercially available
  - ISO-NE is not aware of existing standards that would allow different manufacturers' HVDC systems to be interconnected together
  - Existing constraints, such as the 1200 MW loss-of-source limit, will continue to be observed to provide a fair comparison with AC and DC roadmaps

Offshore Grid Modeling

- Offshore connections are modeled between two or three offshore wind farms, as needed to address onshore overloads
  - Two- and three-terminal offshore networks are common in proposals for offshore networks in Europe
- Offshore networks are modeled to minimize the amount of equipment offshore (HVDC breakers, switching, etc.)
- Any offshore-to-onshore cable capacity not used to bring wind power to shore can be utilized for intra-area transfer capacity
  - For example: in summer daytime peak snapshots, wind is assumed to be at 5% output. The remaining 95% of cable capacity is available to transfer power from one point of interconnection to another

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

CONCLUSION & NEXT STEPS

Next Steps

- ISO-NE welcomes feedback on today's presentation
  - Feedback may be submitted to pacmatters@iso-ne.com by August 9
- ISO-NE anticipates releasing a draft 2050 Transmission Study Report to PAC for comment by November 1

Questions