MAY 1, 2024 | WEBEX

2050 Transmission Study

Informational Public Webinar

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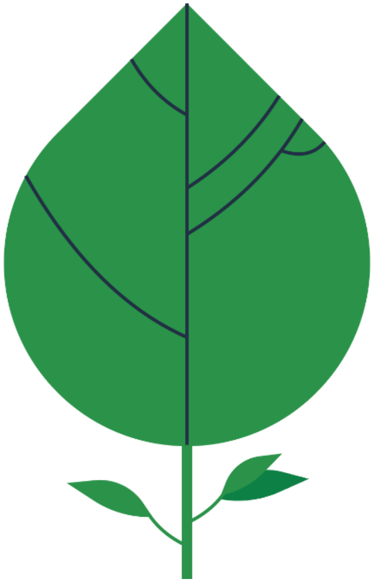
Overview

- ISO New England Overview
- 2050 Transmission Study (“Study”) Background
- Study Inputs & Methodology
- Study Results
- Key Takeaways
- Conclusion and Next Steps



ISO NEW ENGLAND OVERVIEW

ISO New England's *Mission and Vision*

Mission: *What we do*

Through collaboration and innovation,
ISO New England plans the transmission system, administers the region's wholesale markets, and operates the power system to ensure reliable and competitively priced wholesale electricity

Vision: *Where we're going*

To harness the power of competition and advanced technologies to reliably plan and operate the grid as the region transitions to clean energy

*The ISO's **Vision** for the future represents our long-term intent and guides the formulation of our Strategic Goals*

ISO New England (ISO) Has More Than Two Decades of Experience Overseeing the Region's Restructured Electric Power System

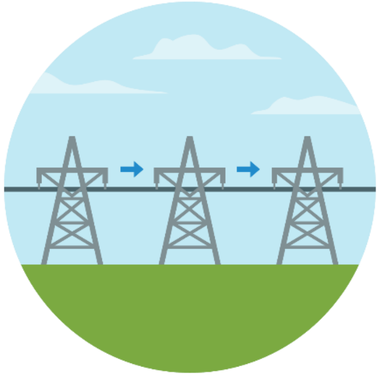
- **Regulated** by the Federal Energy Regulatory Commission (FERC)*
- **Reliability Coordinator** for New England under the North American Electric Reliability Corporation
- **Independent** of companies in the marketplace and **neutral** on technology

* ISO New England operates under a FERC-approved *ISO New England Inc. Transmission, Markets, and Services Tariff*, known as the **ISO Tariff**

ISO New England Performs Three Critical Roles to Ensure Reliable Electricity at Competitive Prices

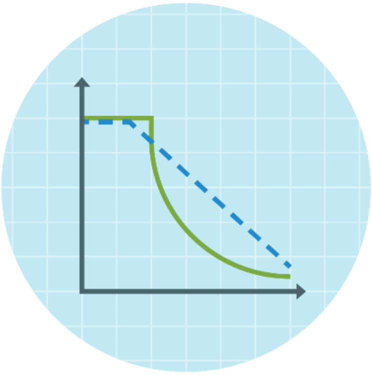
Grid Operation

Coordinate and direct the flow of electricity over the region's high-voltage transmission system



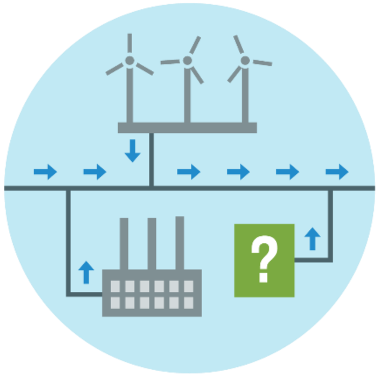
Market Administration

Design, run, and oversee the markets where wholesale electricity is bought and sold



Power System Planning

Study, analyze, and plan to make sure New England's electricity needs will be met over the next 10 years



Things We Don’t Do

Handle retail electricity

Own power grid infrastructure

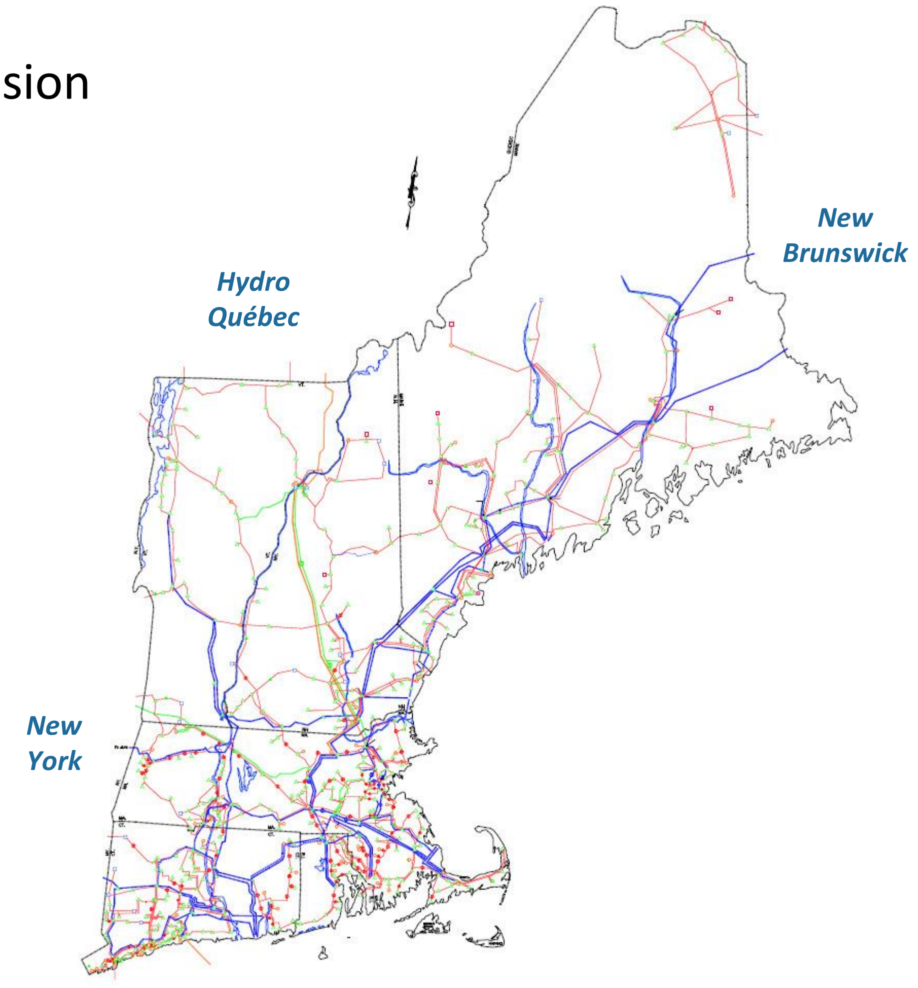
Have a stake in companies that own grid infrastructure

Have jurisdiction over fuel infrastructure

Have control over siting decisions

New England’s Transmission Grid Is the Interstate Highway System for Electricity

- **9,000 miles** of high-voltage transmission lines (primarily 115 kV and 345 kV)
- **13 transmission interconnections** to power systems in New York and Eastern Canada
- **13%** of region’s energy needs met by imports in 2023
- **$12.1 billion** invested to strengthen transmission system reliability since 2002; **$1.4 billion** planned
- Developers have proposed multiple transmission projects to access **non-carbon-emitting resources** inside and outside the region



ISO-NE Is Currently a Summer-Peaking System

New England shifted from a winter-peaking system to a **summer-peaking** system in the early 1990s, largely because of the growth of air conditioning and a decline in electric heating

- Peak demand on a normal summer day has typically ranged from 17,500 MW to 22,000 MW
- Summer demand usually peaks on the hottest and **most humid** days and averaged roughly 25,600 MW since 2000
- Region's all-time summer peak demand was **28,130 MW** on **August 2, 2006**

The region is expected to shift back to a **winter-peaking system** in the 2030s with the electrification of heating demand

- Region's all-time **winter** peak demand was **22,818 MW** on **January 15, 2004**

State Laws Target Deep Reductions in CO_2 Emissions and Increases in Renewable and Clean Energy

≥80% by 2050	Five states mandate greenhouse gas reductions economy wide: MA, CT, ME, RI, and VT (mostly below 1990 levels)
Net-Zero by 2050 80% by 2050	MA emissions requirement MA clean energy standard
90% by 2050	VT renewable energy requirement
100% by 2050 Carbon-Neutral by 2045	ME renewable energy goal ME emissions requirement
100% by 2040	CT zero-carbon electricity requirement
100% by 2033	RI renewable energy requirement

ROBERT ETHIER

Vice President, System Planning

There Are Four Pillars Necessary to Support a Successful Clean Energy Transition

PILLAR ONE
Clean Energy

Significant amounts of clean energy to power the economy with a greener grid

PILLAR TWO
Balancing Resources

Resources that can supply electricity, reduce demand, or provide other services to maintain power system equilibrium

PILLAR THREE
Energy Adequacy

A dependable energy supply chain and/or a robust energy reserve to manage through extended periods of severe weather or energy supply constraints

PILLAR FOUR
Robust Transmission

To integrate renewable resources and move clean energy to consumers across New England

STUDY BACKGROUND

2050 Transmission Study Background

- In October 2020, the **New England States Committee on Electricity (NESCOE)*** released the "*New England States' Vision for a Clean, Affordable, and Reliable 21st Century Regional Electric Grid*"
- Among other considerations, this vision statement recommended that the ISO work with stakeholders to conduct a **comprehensive long-term regional transmission study**
- In response, the ISO began the study and sought **FERC approval** to revise the ISO Tariff to establish a repeatable longer-term study process
  - Changes were approved by FERC in early 2022
- These changes allow the ISO to conduct planning studies **beyond** the traditional **10-year** planning horizon

* **NESCOE** is a not-for-profit entity that represents the collective perspective of the six New England Governors in regional electricity matters and advances the New England states' common interest in the provisions of electricity to consumers at the lowest possible prices over the long-term, consistent with maintaining reliable service and environmental quality (www.nescoe.com)

2050 Transmission Study Overview

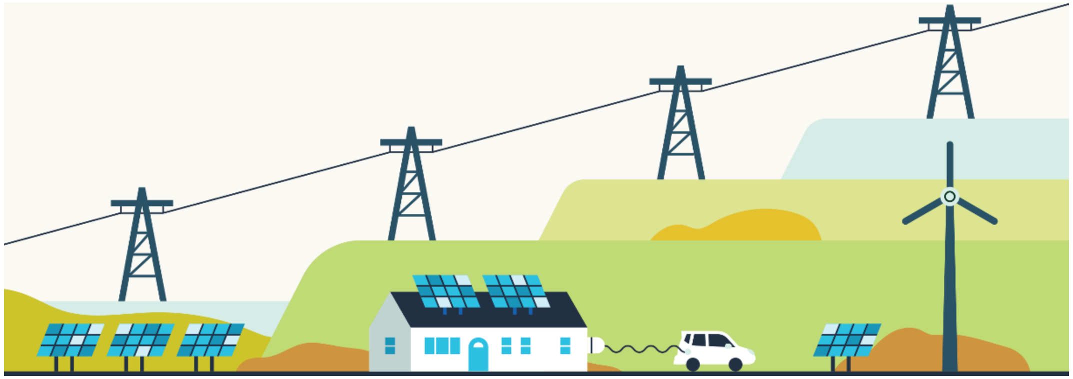
- The resulting 2050 Transmission Study is the **first example of its kind** within New England
- The study informs stakeholders of the **amount and type** of **transmission infrastructure** necessary to provide reliable, cost-effective energy to the region through the **clean energy transition**, driven by state policy
- Discussions took place at meetings of the **Planning Advisory Committee (PAC)**, an open stakeholder forum that provides input to ISO-NE regional system planning processes
- ISO-NE additionally **coordinated with NESCOE** throughout the study

Objectives

The 2050 Transmission Study has two main objectives:

1) Determine the **region's transmission needs** in order to serve load while satisfying NERC*, NPCC**, and ISO **reliability criteria**

2) Develop ***roadmaps*** for transmission upgrades designed to satisfy those needs while considering both the feasibility of construction and cost

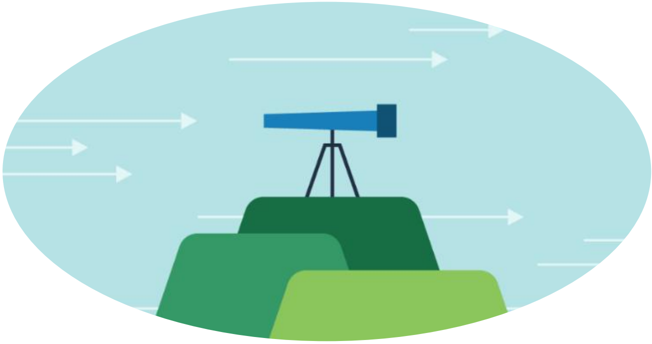


* North American Electric Reliability Corporation ** Northeast Power Coordinating Council, Inc.

Note: Both NERC and NPCC continually assess reliability of the electric grid and establish reliability standards

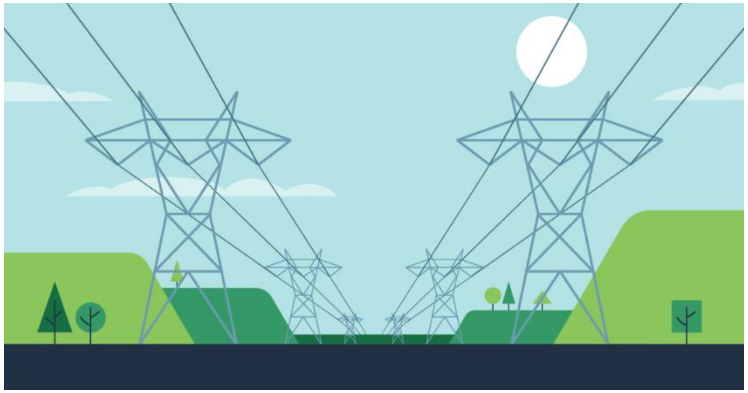
2050 Transmission Study Scope

- The 2050 Transmission Study examines the **thermal performance** of the transmission system under summer and winter **peak load** conditions
  - Thermal analysis identifies **overloads** – when transmission infrastructure carries more power than its rated amount, which can lead to overheating, equipment disconnection, or permanent damage
- Other types of analysis would be needed, but are **not covered** by this study:
  - Voltage
  - Short-Circuit
  - Transient stability
  - Electro-magnetic transient (EMT) analysis
  - Generator interconnection and deliverability during off-peak hours
- The Study does not evaluate the need to upgrade the distribution system
- The Study examined **one of many possible futures** for the New England power system
- Results can help inform which areas of the transmission system are likely to be most limiting as the **system evolves**



2050 Transmission Study Process Limitations

- The longer-term transmission study process is currently **informational**
- The process **does not** include a formal mechanism for triggering the construction of a new transmission project
- However, the ISO engaged in stakeholder discussions on a second phase of the longer-term transmission study Tariff changes that will establish a process to enable the states, through NESCOE, to **move policy-related transmission projects forward,** with an associated **cost allocation**
  - This effort began at stakeholder meetings in October 2023 and the ISO plans to file changes with FERC in Q2 of 2024

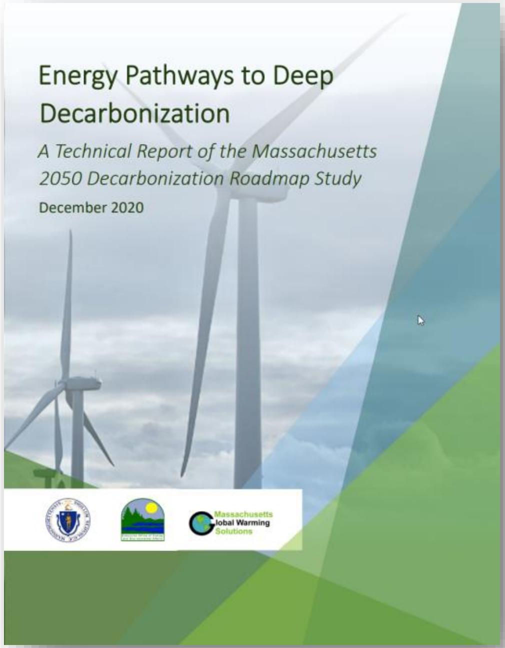


STUDY INPUTS & METHODOLOGY

Inputs to the 2050 Transmission Study

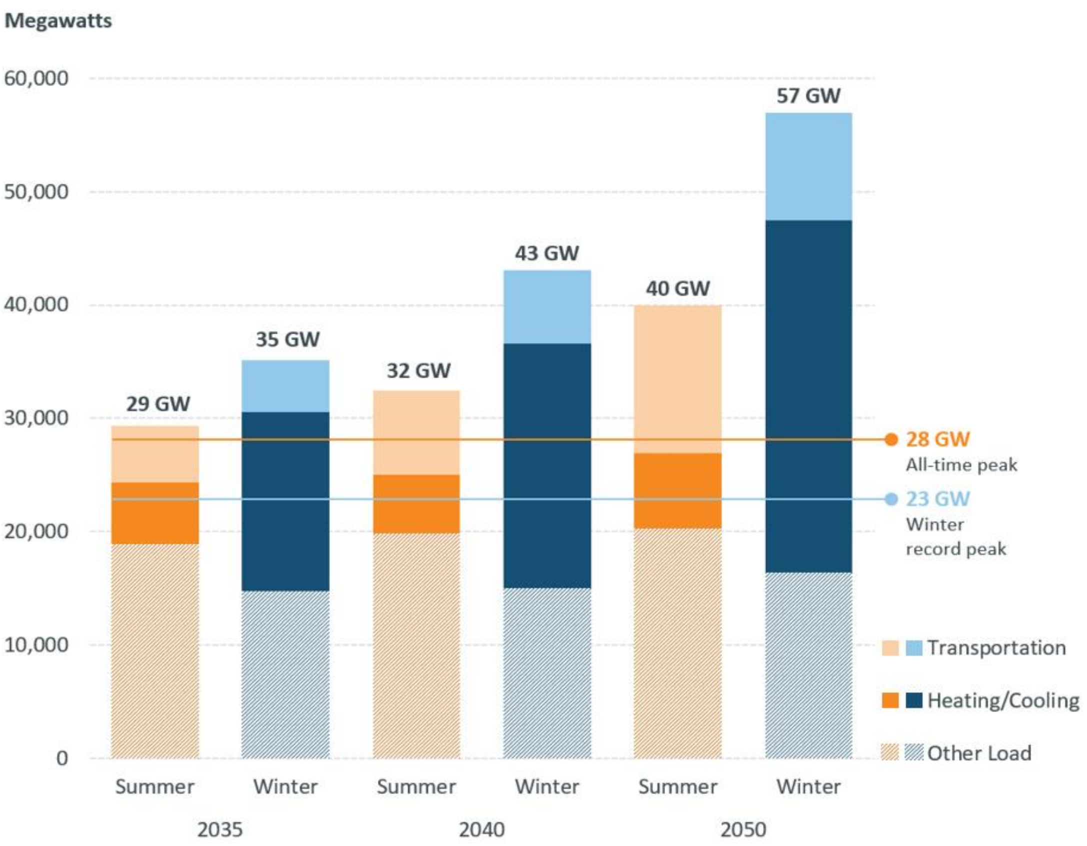
- The future scenarios envisioned by NESCOE included **load forecasts** and **potential resource mixes** for the years **2035, 2040 and 2050**
  - Input assumptions were provided to the ISO by NESCOE from the Massachusetts Executive Office of Energy and Environmental Affairs' report, *Energy Pathways to Deep Decarbonization*
- The ISO took the "**All Options Pathway**" input data from that report and created four types of **peak load snapshots**, creating a set for each of the study years 2035, 2040 and 2050

Snapshot	Months	Hours
Summer Daytime Peak	May – September	9 AM to 5 PM
Summer Evening Peak A (Coincidental NE Peak)	May – September	7 PM to 10 PM
Summer Evening Peak B (Northern NE Peak)	May – September	7 PM to 10 PM
Winter Evening Peak	January – April	4 PM to 10 PM



Study Inputs – Load Data

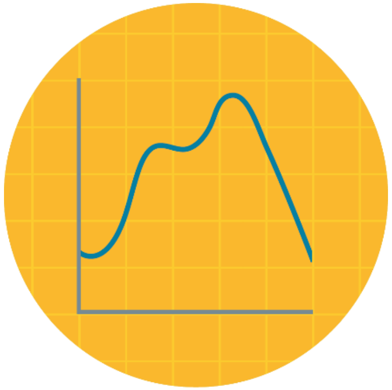
- Projected loads are **significantly higher** than any seen to date in New England
  - Primarily driven by **heating** and transportation **electrification**
- 2050 winter evening peak snapshot of **57 gigawatts (GW)*** is the **highest** load modeled
- For comparison, the highest load in New England to date is approximately:
  - Summer: **28 GW in 2006**
  - Winter: 23 GW in 2004



* One **gigawatt (GW)** is equal to 1,000 megawatts (MW); therefore 57 GW is equal to 57,000 MW

Two Winter Peak Snapshots

- The original 2050 Winter Peak snapshot assumed a **57 GW peak load**
- A majority of overloads identified in early analysis were related to the Winter Peak snapshot
  – Stakeholders expressed interest in information on the **sensitivity of overloads** to the exact peak load level
- In response, a sensitivity was included for a **51 GW winter peak load**
  – Analysis of load reduction strategies is beyond the scope of this analysis



Study Inputs – Generation Data

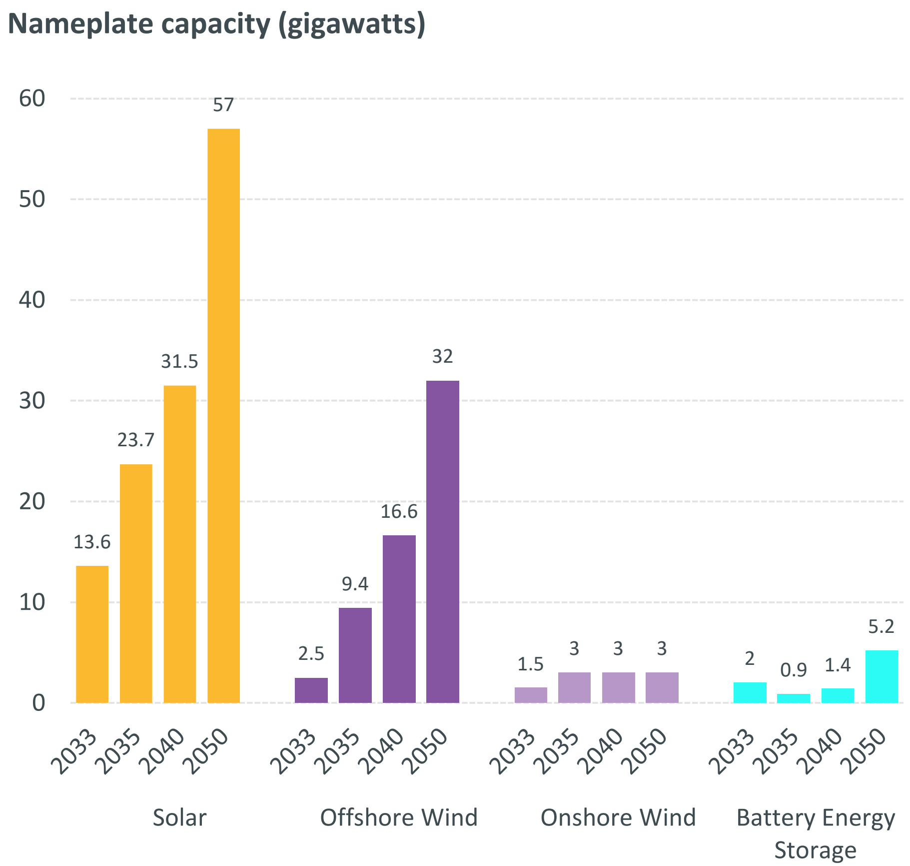
- The **All Options Pathway** resource data provided nameplate megawatt (MW) values for the study years 2035, 2040, and 2050
  - All oil, coal, diesel, municipal solid waste, and a portion of today's natural gas generation resources are **assumed retired by 2035**

- To account for the intermittency of renewable resources, the ISO assumes output of these resources based on their performance during peak load

Generation Type	Nameplate Capacity (MW)			Availability		
	2035	2040	2050	Summer Daytime Peak	Summer Evening Peak	Winter Peak
Nuclear	3,526	3,526	3,526	100%	100%	100%
Biomass	772	772	772	100%	100%	100%
Natural Gas (CCGT & CT)	15,848	16,548	16,645	100%	100%	100%
Hydro (RoR and Pondage)	1,814	1,814	1,814	Historical	Historical	Historical
Hydro Pumped Storage	1,841	1,841	1,841	Offline	Discharging	Discharging
Battery Energy Storage Systems (BESS)	888	1,395	5,182	Offline	Discharging	Discharging
PV (Rooftop and Ground Mount)	23,714	31,475	56,665	40%	10%/0%*	0%
Onshore Wind	3,006	3,006	3,006	5%	5%	65%
Offshore Wind	9,449	16,633	31,954	5%	5%	40%
Totals	60,858	77,010	121,405			

* Some Evening Peak snapshots occurred before sunset while some occurred after sunset
Note: Several changes were made from the All Options Pathway data. These changes were presented in the November 2021 Scope of Work

Generation Assumptions By Study Year



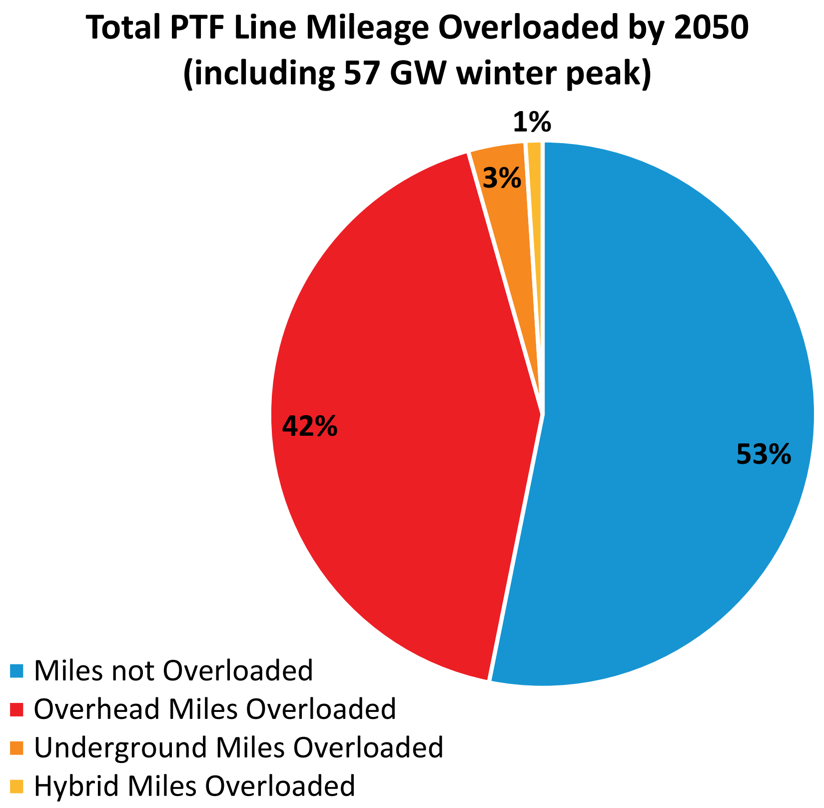
Note: The solar and battery energy storage numbers include both distribution-connected and transmission-connected generators

- The **2033 bar** represents existing resources and future resources that are **committed to operating**, either through ISO's Forward Capacity Market or other contractual obligations
- The 2050 Transmission Study assumes that **offshore wind and solar grow significantly** from 2033 to 2050

STUDY RESULTS

High-likelihood concerns, roadmaps, and cost estimates

Percentage of Line Mileage Overloaded



- Approximately half of the total Pool Transmission Facility (PTF*) line miles in New England (**~4,200 miles** out of ~9,000 miles) are **overloaded in 2050**
- Approximately **90 PTF transformers**** (of about 150 total) are also **overloaded in 2050**

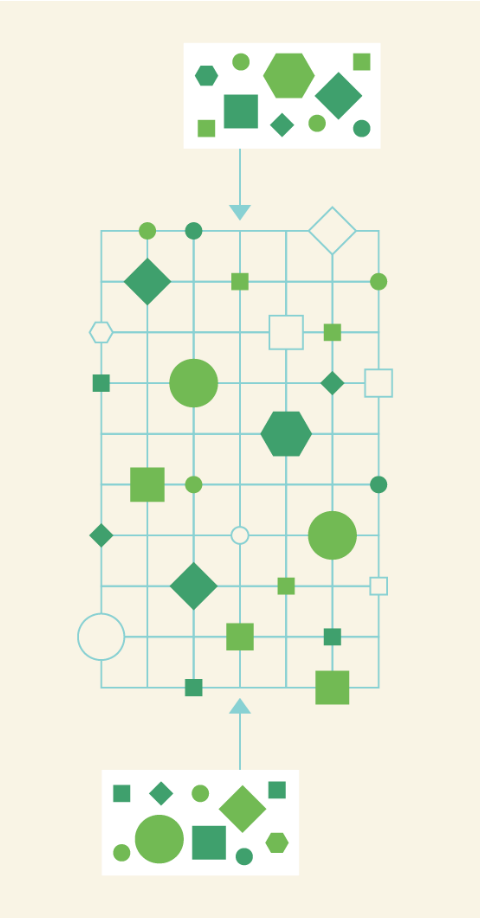
* The **Pool Transmission Facility (PTF)** is the portion of New England's transmission system over which the ISO has planning jurisdiction and consists primarily of transmission lines and transformers operated at or above 100 kV.
** **Transformers** convert electricity from a higher voltage to a lower voltage, or a lower voltage to a higher voltage, to allow power to flow between voltage levels that are most efficient for long-distance power transport and those that are appropriate for delivery to individual substations.

High-Likelihood Concerns Overview

- In response to stakeholder feedback, the Study identified what the ISO termed **high-likelihood concerns (HLC)**
  - These are transmission concerns that have a high-likelihood of occurring, even if the future does not unfold exactly as predicted by the Study's assumptions
- This categorization allows the New England region to **prioritize concerns** based on their likelihood
- The **ISO created criteria** to determine which transmission concerns should be categorized as "high-likelihood"
  - Additional information about the criteria is available in the final report

Transmission Development Roadmaps

- The Study developed transmission upgrade roadmaps to satisfy anticipated concerns, considering both **constructability and cost**
- **Roadmaps** were developed for regions in New England that saw **groupings** of high-likelihood concerns
  - Roadmaps are high-level plans to show generally how transmission-related objectives can be accomplished; they are not comprehensive plans for construction
- ISO **does not** express a preference for any particular roadmap
  - There are **tradeoffs** between competing priorities and concerns **beyond the study scope**
- The intent of providing multiple roadmaps for some high-likelihood concerns is to provide a **basis of comparison** for decision-making



Roadmap Development Cost Estimates

- The conceptual roadmaps in the study **do not constitute a transmission plan**
  - The region's transmission system will likely develop differently from the system envisioned in the Study
- However, the identified upgrades are useful for providing an **order-of-magnitude estimate** of the future transmission system costs
- **Estimated costs** were developed in consultation with Electrical Consultants, Inc. and from cost data assumptions based on recently-observed project costs in New England
- These estimated costs are intended to inform consumers, industry stakeholders, and policymakers of the costs inherent in maintaining reliable transmission service through the **clean energy transition**

Cost Estimate Limitations

- The cost estimates include **only a subset of possible total costs**
  - Costs related to voltage performance, transient stability performance, short-circuit performance, and other aspects of transmission planning are beyond the scope of the study
  - Other transmission upgrades (i.e. new load-serving substations and required generator interconnection upgrades) are not included
- Identifying cost estimates associated with significant upgrades to **distribution systems** that will be needed in this clean energy future are also **beyond the scope** of this study, and the ISO's jurisdiction
- All costs quoted are expressed as **present-day** (2023)
  - No adjustments were included to account for inflation, increases in equipment prices, or other long-term trends

HLC #1: North-South/Boston Import

There are a significant number of very high overloads seen along major 345 kV lines* leading from Maine and New Hampshire south into the Boston area

AC Roadmap

- New 345 kV overhead transmission

Minimization of New Lines Roadmap

- Prioritize rebuilds of existing lines to the greatest degree possible

DC Roadmap

- New HVDC transmission – overhead, underground, or submarine

Offshore Grid Roadmap

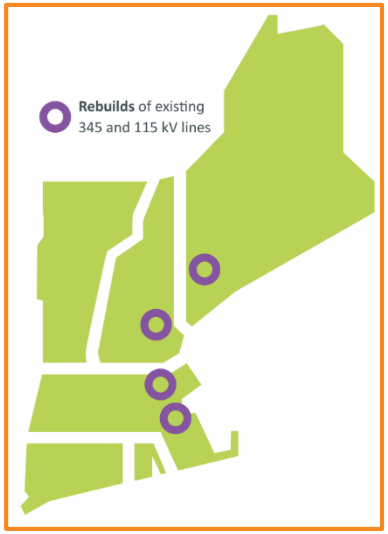
- Connections between offshore wind farms to provide offshore paths for power transfer

* **345 kilovolts (kV)**, or 345,000 volts, is the highest alternating current (AC) operating voltage used for transmission lines in New England. These lines form the highest-capacity backbone of the transmission system, and carry most state-to-state and inter-regional power transfers.

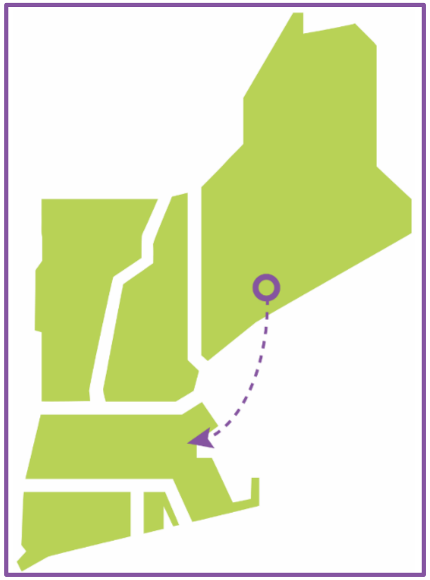
Note: ISO-NE is not recommending one roadmap over another; the intent of including multiple roadmaps is to provide a basis of comparison for decision-making by New England stakeholders

Roadmaps for HLC #1: North-South/Boston Import

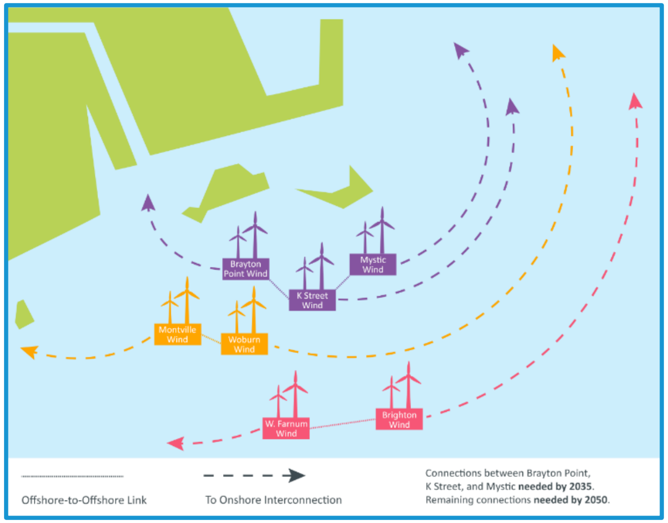
AC Roadmap



Minimization of New Lines Roadmap



DC Roadmap

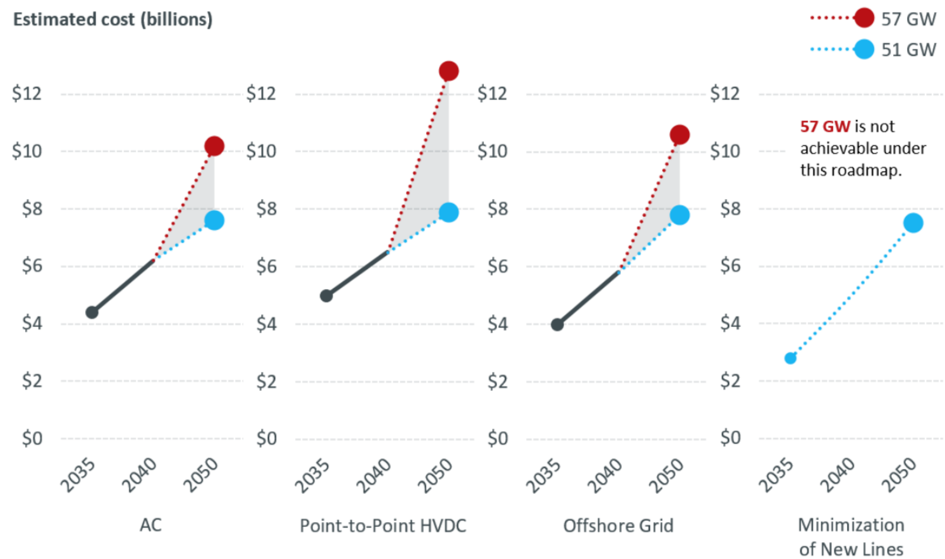


Offshore Grid Roadmap

Note: Maps are for illustrative purposes only and do not define a route for any transmission project

Cost Estimates for HLC #1: North-South/ Boston Import

Estimated Cumulative Costs for North-South/Boston Import Roadmap



Year/Load Level	AC Roadmap	Minimization of New Lines Roadmap	Point-to-Point HVDC Roadmap	Offshore Grid Roadmap
2035	$4.4 Billion	$2.8 Billion	$5.0 Billion	$4.0 Billion
2040	$6.2 Billion	$5.0 Billion	$6.5 Billion	$5.8 Billion
2050 (51 GW winter peak)	$7.6 Billion	$7.5 Billion	$7.9 Billion	$7.9 Billion
2050 (57 GW winter peak)	$10.2 Billion	Not Achievable*	$12.8 Billion	$10.7 Billion

*As described previously, the Minimization of New Lines roadmap is not capable of reliably serving a 57 GW peak load.

Note: The costs reflected on this slide only reflect those identified through steady-state thermal analysis; the total transmission and distribution costs are anticipated to be much higher

HLC #2: Northwestern Vermont Import

There are a significant number of overloads seen on the 115 kV lines that lead to northwestern Vermont, around the city of Burlington

PV-20 Upgrade and Doubling of K-43 Roadmap

- Upgrade the PV-20 tie between Sandbar substation (Milton) and Plattsburgh substation in NY from 115 kV to 230 kV
- Build a new overhead 115 kV line adjacent to the existing K-43 line between New Haven and Williston substations

Coolidge – Essex Roadmap

- Build a new 345 kV overhead line from Coolidge (Ludlow) to Essex substations

New Haven – Essex and Granite – Essex Roadmap

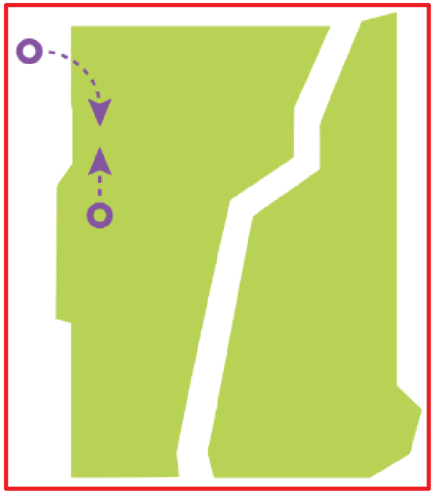
- Build a new 345 kV overhead line from New Haven to Essex substations
- Build a new 230 kV overhead line from Granite (Williamstown) to Essex substations

Minimization of New Lines Roadmap

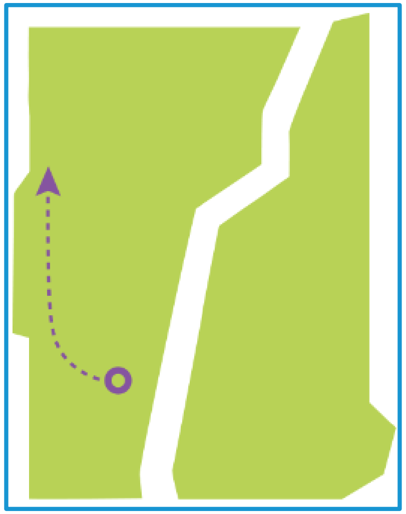
- Prioritize rebuilds of existing lines to the greatest degree possible

Note: ISO-NE is not recommending one roadmap over another; the intent of including multiple roadmaps is to provide a basis of comparison for decision-making by New England stakeholders

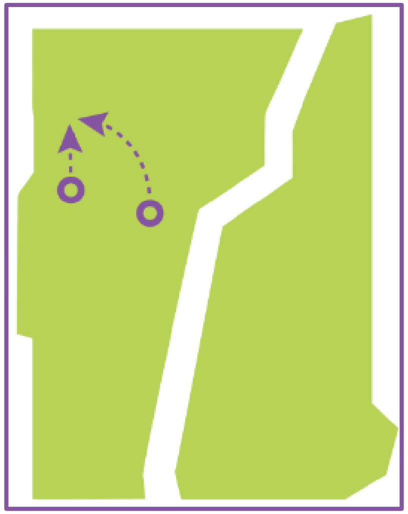
Roadmaps for HLC #2: Northwestern Vermont Import



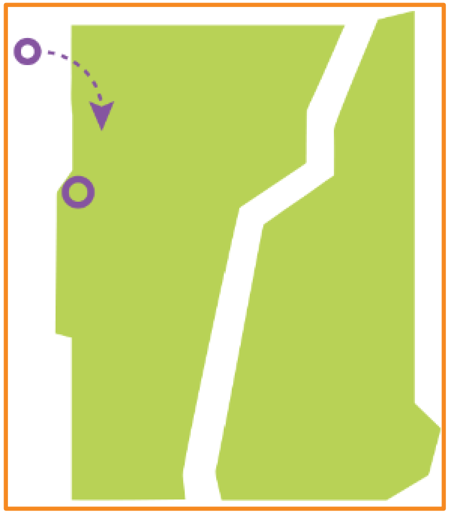
PV-20 Upgrade and Doubling of K-43 Roadmap



Coolidge-Essex Roadmap



New Haven-Essex and Granite-Essex Roadmap



Minimization of New Lines Roadmap

Note: Maps are for illustrative purposes only and do not define a route for any transmission project

Cost Estimates for HLC #2: Northwestern Vermont Import

Estimated Cumulative Costs for Northwestern Vermont Import Roadmaps

Year/Load Level	PV-20 Upgrade and Doubling of K-43 Roadmap	Coolidge – Essex Roadmap	New Haven – Essex and Granite – Essex Roadmap	Minimization of New Lines Roadmap
2035	$0.7 Billion	$1.1 Billion	$1.1 Billion	$0.6 Billion
2040	$0.8 Billion	$1.3 Billion	$1.1 Billion	$0.8 Billion
2050 (51 GW winter peak)	$0.9 Billion	$1.5 Billion	$1.2 Billion	$0.9 Billion
2050 (57 GW winter peak)	$1.2 Billion	$2.0 Billion	$1.4 Billion	$1.2 Billion

Note: The costs reflected on this slide only reflect those identified through steady-state thermal analysis; the total transmission and distribution costs are anticipated to be much higher

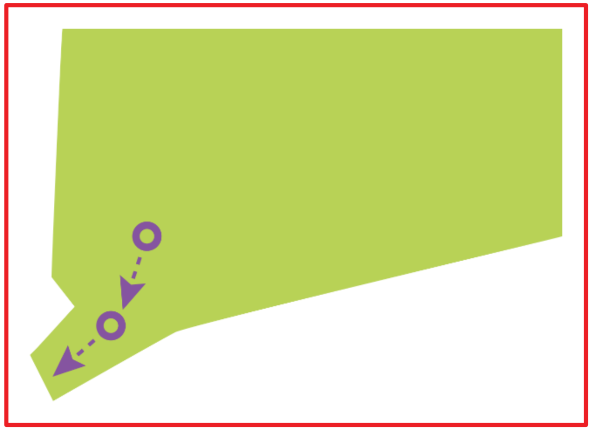
HLC #3: Southwest Connecticut Import

There were several thermal overloads seen in Southwest Connecticut

Southwest Connecticut Solutions

- Build three new underground 115 kV cables in Norwalk, Stamford, and surrounding towns
- Re-energize an existing de-energized 345 kV underground cable between Plumtree (Bethel) and Norwalk substations

- The study found that one set of solutions could address reliability concerns in Southwest Connecticut at a relatively lower cost and impact than other solution alternatives; therefore only one roadmap was identified



Southwest Connecticut Solution

Cost Estimates for HLC #3: Southwest Connecticut Import

Estimated Cumulative Costs for Southwest Connecticut Import Roadmap

Year/Load Level	Southwest Connecticut Import
2035	$0.5 Billion
2040	$0.7 Billion
2050 (51 GW winter peak)	$0.8 Billion
2050 (57 GW winter peak)	$1.6 Billion

Note: The costs reflected on this slide only reflect those identified through steady-state thermal analysis; the total transmission and distribution costs are anticipated to be much higher

Transformer Additions

- In addition to new and rebuilt transmission lines, a **significant number of new bulk power transformers** (mostly 345/115 kV) are required
  - Transformers step down from voltages appropriate for inter-state/inter-regional power transfers to those appropriate for delivery to individual substations
- Depending on the winter peak load level and the roadmaps chosen, **approximately 30-50 new transformers** are required to mitigate overloads on existing transformers
- Transformers are **fairly large** and present supply chain and delivery **challenges**, and often must be ordered years in advance of installation

Photo illustrates the relative size of transformers on the New England bulk power system

Miscellaneous High-Likelihood Concerns

- There were a variety of other high-likelihood concerns that were more **isolated thermal overloads** than the other HLCs identified
- **These were still considered HLCs** due to the fact that they were not heavily dependent on specific input assumptions
- The table on the right summarizes the upgrades required to address these miscellaneous high-likelihood concerns

Upgrades Required to Serve 51 GW Load
Upgrade 298 miles of 69 kV lines to 115 kV
Rebuild 225 miles of overhead 115 kV lines
Rebuild 37 miles of overhead 345 kV lines
Build approximately 13 miles of new 115 kV overhead lines
Build two new overhead 345 kV lines from Brayton Point – Grand Army, 3 miles total
Increase the series capacitor rating on the 3023 line
Install 14 new 345/115 kV Transformers

Cost Estimates for Miscellaneous High-Likelihood Concerns

Estimated Cumulative Costs for Miscellaneous High-Likelihood Concerns

Year/Load Level	Miscellaneous High-Likelihood Concerns
2035	$1.7 Billion
2040	$2.8 Billion
2050 (51 GW winter peak)	$3.1 Billion
2050 (57 GW winter peak)	$3.1 Billion

Note: The costs reflected on this slide only reflect those identified through steady-state thermal analysis; the total transmission and distribution costs are anticipated to be much higher

Non-High-Likelihood Concerns

- There were a significant number of thermal overloads observed that **did not meet the criteria** for being a high-likelihood concern
  - These are overloads may be less likely to occur if the input assumptions to this study do not closely match the future evolution of the power grid
- **However**, in order to fully resolve all of the overloads in the study, **solutions were developed** for the non-high-likelihood concerns

Upgrades to Address Non-High-Likelihood Concerns
Rebuild approximately 393 miles of overhead 115 kV lines
Rebuild approximately 287 miles of overhead 345 kV lines
Build approximately 103 miles of new 115 kV overhead lines to resolve load loss concerns
Build approximately 48 miles of new 115 kV underground cables to resolve load loss concerns
Build approximately 2 miles of new 115 kV overhead lines to resolve non-load loss concerns
Build approximately 9 miles of new 115 kV underground cables to resolve non-load loss concerns
Replace approximately 10 miles of underground 115 kV cables to XLPE
Install 4 new series reactors throughout New England
Install 10 new 345/115 kV Transformers
Install approximately 300 new circuit breakers throughout New England
Separate 10 sections of double-circuit tower lines

Cost Estimates for Non-High-Likelihood Concerns

Estimated Cumulative Costs for Non-High-Likelihood Concerns

Year/Load Level	Non-High-Likelihood Concerns
2035	$0.4 Billion
2040	$1.4 Billion
2050 (51 GW winter peak)	$3.2 Billion
2050 (57 GW winter peak)	$6.6 Billion

Note: The costs reflected on this slide only reflect those identified through steady-state thermal analysis; the total transmission and distribution costs are anticipated to be much higher

Range of Final Costs

- Between **2002 to 2023** the region spent approximately **$15.3 billion** on **reliability-based** projects and asset condition projects
  - Roughly **$0.73 billion** per year
- The 2050 Transmission Study upgrades, averaged per year in 2023 dollars equal approximately:
  - **$0.58-0.65 billion** per year to reach **51 GW**
  - **$0.85-1.00 billion** per year to reach **57 GW**

Year/Load Level	Maximum Load Served (MW)	Total Cost Range ($)	Cost Breakdown ($ Billion)	
2035	35,000	**$6-9 Billion**	$2.8-5.0	N-S/Boston
			$0.6-1.1	NWVT
			$0.5	SWCT
			$1.7	Misc. HLC
			$0.4	Non-HLC
2040	43,000	**$10-13 Billion**	$5.0-6.5	N-S/Boston
			$0.8-1.3	NWVT
			$0.7	SWCT
			$2.8	Misc. HLC
			$1.4	Non-HLC
2050 51 GW	51,000	**$15-17 Billion**	$7.5-7.9	N-S/Boston
			$0.9-1.5	NWVT
			$0.8	SWCT
			$3.1	Misc. HLC
			$3.3	Non-HLC
2050 57 GW	57,000	**$22-26 Billion**	$10.2-12.8	N-S/Boston
			$1.2-2.0	NWVT
			$1.6	SWCT
			$3.1	Misc. HLC
			$6.6	Non-HLC

Note: The costs reflected on this slide only reflect those identified through steady-state thermal analysis; the total transmission and distribution costs are anticipated to be much higher

KEY TAKEAWAYS

Key Takeaways

- The assumptions used for the 2050 Transmission Study represent numerous **paradigm shifts** for New England
  – Shift from a summer peaking to a **winter peaking system**
  – Shift to increasing utilization of **renewable resources**
  – Electrification of heating and transportation **more than doubles** the amount of peak power **consumption** by 2050

- **Significant new transmission** will be needed to reliably serve load under the assumptions analyzed in this study

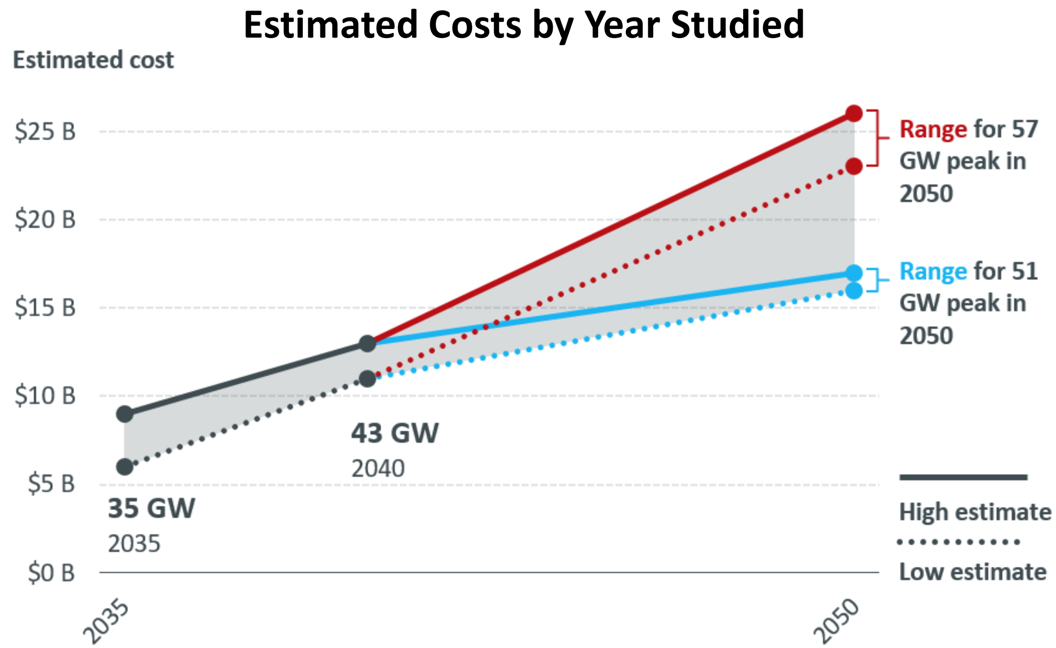
Key Takeaways, continued

- The **Winter Peak in 2050** is the **most challenging** snapshot
  - The overloads are driven primarily by high heating load
  - Shortfalls in resources due to low resource availability require additional resources in all three snapshot years
  - The majority of the overloads come from the 2050 Winter Evening Peak snapshot, which occurs infrequently

Lessons Learned

- Reducing peak loads significantly **reduces transmission cost**
- Targeting and prioritizing high-likelihood concerns is **highly effective**
- **Incremental upgrades** can be made as opportunities arise
- Generation **location matters**
- **Transformer capacity** is crucial

Reducing Peak Load Significantly Reduces Transmission Cost



- **6 GW (about 10%) reduction** in winter peak **could save** approximately **$8 billion (about 35-45%)** in costs of addressing overloads as compared to the 57 GW peak load values
  - Identifying strategies for reducing peak load was beyond the scope of the study
  - Some level of load flexibility is already included in the inputs to this study*

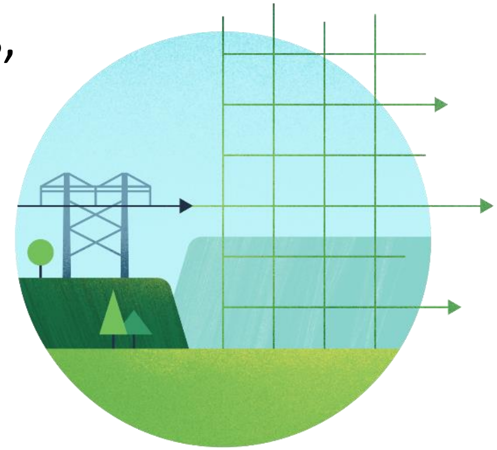
* The "All Options" pathway inputs to this study considered that 50% of electric vehicle charging load, 15% of space heating/cooling load, and 25% of water heating load could be shifted

Reducing Peak Load 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 ISO's Economic Planning for the Clean Energy Transition (EPCET) Pilot 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

* The Economic Planning for the Clean Energy Transition (EPCET) is a pilot study intended to prepare ISO models, tools, and processes such that informative and actionable results can be more readily produced in future Economic Study cycles; more information is available on the ISO Economic Studies webpage.

Targeting and Prioritizing High-Likelihood Concerns is Highly Effective



- The study examined just **one of many possible futures**, and further examined only certain hours of the year when load is expected to be the highest
- While there is a fair amount of uncertainty in the assumptions used for this study, the high-likelihood concerns **are likely to appear** even under somewhat different future scenarios
- Results of the study can be used to infer **which areas** of the transmission system **are likely to need to be upgraded to serve load** as the system evolves
- The identification of high-likelihood concerns allows the New England region to **prioritize concerns based on their likelihood**

Incremental Upgrades Can Be Made as Opportunities Arise

- Many of the transmission system concerns could be addressed by **rebuilding existing transmission lines** with larger conductors, potentially minimizing costs
- While incremental upgrades should be considered crucial to the improvement of New England's transmission system, it is **not necessarily prudent** for the region to pursue large numbers of line rebuilds immediately
  - Many of these line rebuilds are **highly dependent** on the locations of generator interconnections, the geographic distribution of end-user load, and the locations of new load-serving substations
- This strategy would allow the region to delay further transmission system investment until new information is available, and provide opportunities for cost-effective **"right-sizing"* of transmission projects**

* **"Right-sizing"** is a term used to describe combining line rebuilds necessitated by increased loads with replacements designed to meet asset condition needs; in New England, asset condition projects are identified by transmission owners when equipment exceeds its useful life

Generator Location Matters

- The **location of generators** can have a **significant impact** on the transmission upgrades required for reliability
- The study attempted to **optimize**, within reason, **new generator locations** for wind, solar, and batteries
  - Locating generators in suboptimal areas would likely significantly worsen the overloads, particularly in import-constrained* regions like Boston
- Exact generator location is **less important** for some of the **larger-scale upgrades** like new major lines leading from northern New England to southern New England
  - As long as generators in northern New England are located in the general vicinity of the terminal of a large-scale upgrade, the exact substation where they interconnect is not as critical

* **Import-constrained** refers to an area that does not have enough local generating resources and transmission-import capability to serve local demand reliably or economically

Transformer Capacity is Crucial

- The significant load increases projected across the region coupled with increased generation located away from load centers increases the **importance of higher voltage lines**, such as the 345 kV system
  - 345 kV transmission increases the capacity to transfer more power across long distances while minimizing losses of power along the way
  - The power transferred on the 345 kV lines must eventually “step down” to 115 kV via transformers, on its way to distribution substations fed by 115 kV lines
- **Additional transformers will be necessary** for the reliable delivery of bulk power as loads increase
  - While distribution system modeling is beyond the scope of this study, presumably a large number of additional distribution transformers will be required in order to step down power from the 115 kV line to individual customers
- Due to the long lead times and large number of transformers needed, it may be prudent for New England transmission owners to **start ordering transformers** ahead of time and determining their exact locations later

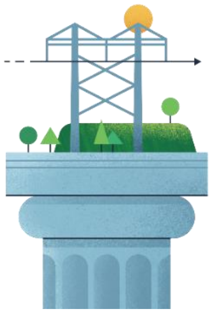
CONCLUSION AND NEXT STEPS

Future Work

- The 2050 Transmission Study is the **first longer-term transmission study** conducted for New England
- One potential area of focus for **future** longer-term transmission studies is the addition of analysis **beyond steady-state thermal analysis**
- At the time of this webinar, the longer-term transmission study process is **purely informational**; however, the ISO began stakeholder discussions on Phase II* of the longer-term transmission study process in October 2023
  - The ISO anticipates filing a proposal to FERC in Q2 of 2024
- While plans for the **distribution system** are outside the ISO's jurisdiction and area of expertise, they could be a key input for future transmission studies

* The second phase is designed to create a process in the ISO New England Open Access Transmission Tariff by which NESCOE can request ISO-NE to conduct Request for Proposals (RFP) to solicit transmission project proposals that address NESCOE-identified longer-term system concerns in connection with Longer-Term Transmission Studies, such as the 2050 Transmission Study, and move forward policy-based transmission to address those concerns.

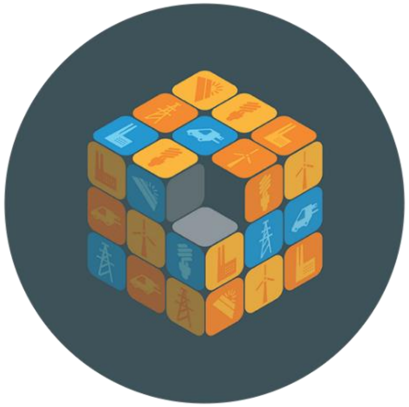
Conclusions



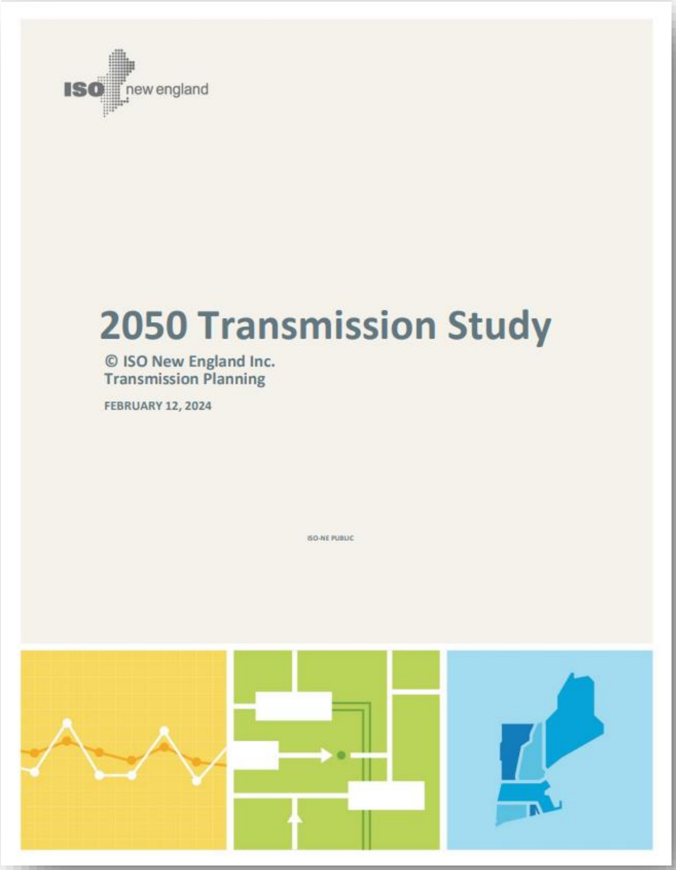
- The 2050 Transmission Study is an **unprecedented look** at the future of New England's transmission system
- The **region's aging transmission system** has the potential to become **a significant bottleneck** to progress if it does not keep pace with changes to other elements of the power system
  - Assuming increased build-outs of renewables continue, and electrification of heating and transportation proceeds as expected
- Although the roadmaps provided are not comprehensive plans and transmission concerns may not occur in exactly the way the Study outlines, these big-picture **observations can help inform future decision making**

Conclusions, continued

- Targeted problem solving and **innovative solutions** will be required to ensure the future reliability of the grid, as well as continued **collaboration and communication** between stakeholders, the states, transmission owners, and the ISO
- The ISO will continue to provide the forward-looking analysis presented in this study in future studies, and will continue to focus on longer-term transmission planning studies in collaboration with stakeholders to **help identify the best paths forward**



Final Report & Fact Sheet


ISO new england

2050 Transmission Study

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Transmission Planning

FEBRUARY 12, 2024

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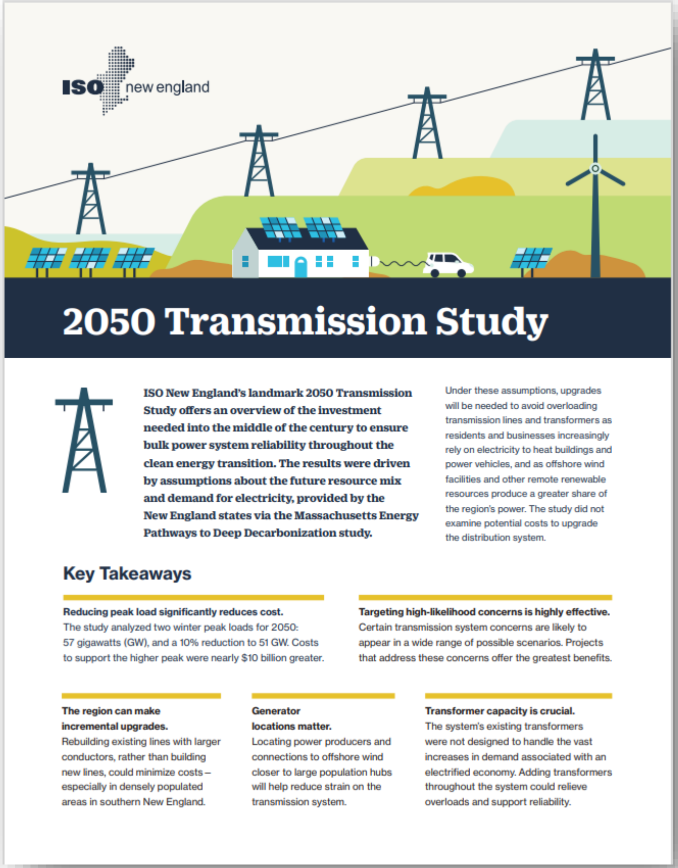
[2050 Transmission Study Final Report](#)


ISO new england

2050 Transmission Study

ISO New England's landmark 2050 Transmission Study offers an overview of the investment needed into the middle of the century to ensure bulk power system reliability throughout the clean energy transition. The results were driven by assumptions about the future resource mix and demand for electricity, provided by the New England states via the Massachusetts Energy Pathways to Deep Decarbonization study.

Under these assumptions, upgrades will be needed to avoid overloading transmission lines and transformers as residents and businesses increasingly rely on electricity to heat buildings and power vehicles, and as offshore wind facilities and other remote renewable resources produce a greater share of the region's power. The study did not examine potential costs to upgrade the distribution system.

Key Takeaways

Reducing peak load significantly reduces cost.
The study analyzed two winter peak loads for 2050: 57 gigawatts (GW), and a 10% reduction to 51 GW. Costs to support the higher peak were nearly $10 billion greater.

Targeting high-likelihood concerns is highly effective.
Certain transmission system concerns are likely to appear in a wide range of possible scenarios. Projects that address these concerns offer the greatest benefits.

The region can make incremental upgrades.
Rebuilding existing lines with larger conductors, rather than building new lines, could minimize costs – especially in densely populated areas in southern New England.

Generator locations matter.
Locating power producers and connections to offshore wind closer to large population hubs will help reduce strain on the transmission system.

Transformer capacity is crucial.
The system's existing transformers were not designed to handle the vast increases in demand associated with an electrified economy. Adding transformers throughout the system could relieve overloads and support reliability.

[2050 Transmission Study Fact Sheet](#)

Additional study materials are available on the ISO [Planning Advisory Committee (PAC) webpage](#)

Questions