2050 Transmission Study

Vermont Upgrades & Estimated Costs

Dan Schwarting

MANAGER | TRANSMISSION PLANNING

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 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
  - ISO-NE presented initial key takeaways and roadmap outlines in July 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
  - Discussions on "Phase 2 of Extended/Longer-Term Planning," which will create a Tariff process for advancing transmission projects from longer-term transmission studies like the 2050 Transmission Study, began at the NEPOOL Transmission Committee on October 17

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
  - Short-Circuit
  - Transient stability
  - 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

INPUT ASSUMPTIONS

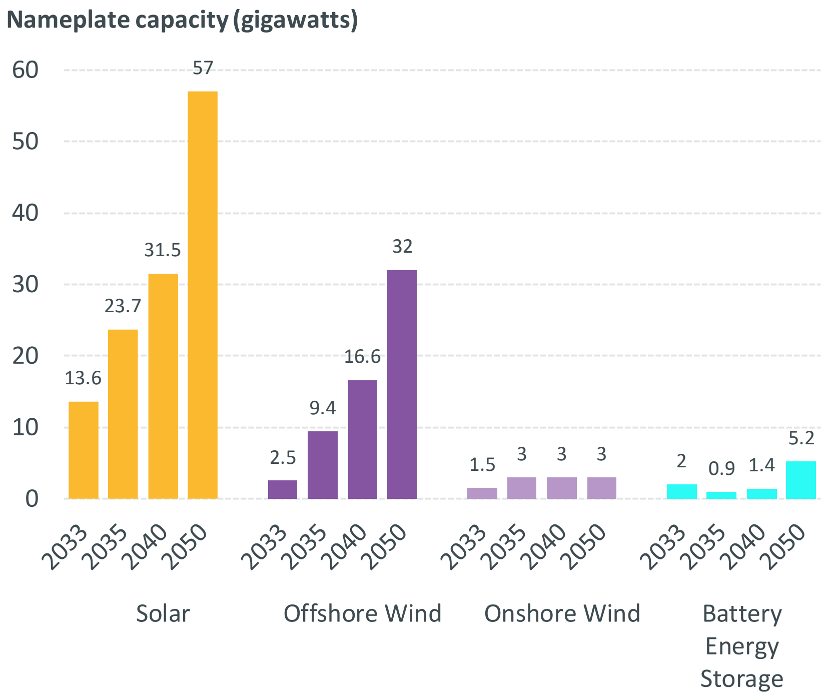
Review from Planning Advisory Committee Presentations

Background on Input Assumptions

- Input assumptions for load and generation totals were provided to ISO-NE from the "All Options" pathway in the "Energy Pathways to Deep Decarbonization" report by Massachusetts (December 2020)
- ISO-NE took the "All Options" input data 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

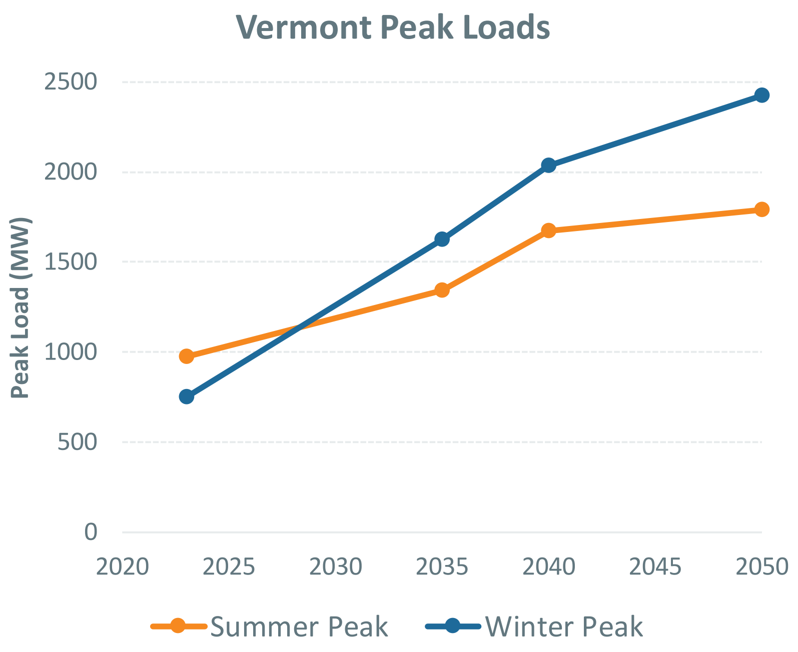
Generation Assumptions



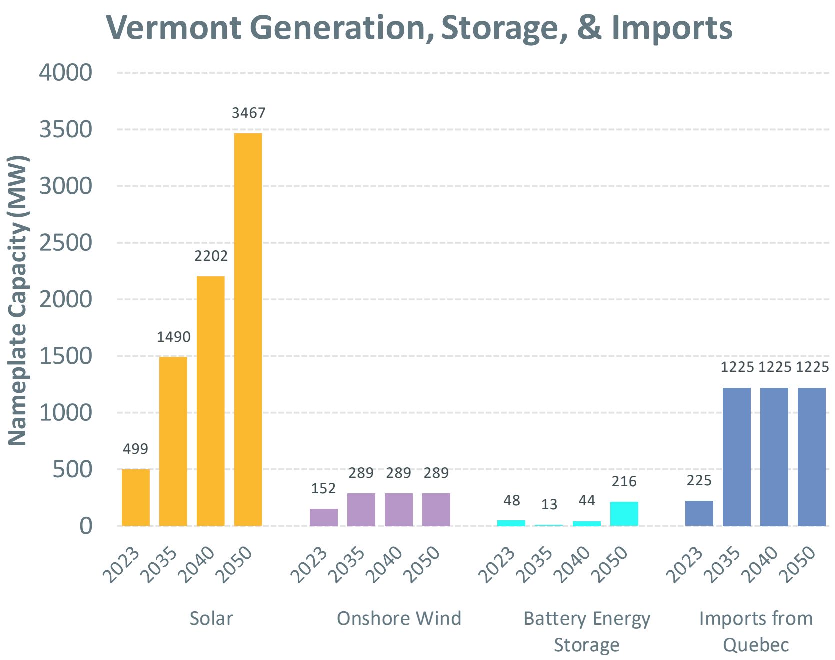
Note: The PV and battery numbers include both distribution-connected and transmission-connected generators.

- The 2033 bar represents the latest resource mix in the 10-year cases modeled for Needs Assessments
- The 2050 Transmission Study assumes that offshore wind and solar grow significantly from 2033 to 2050

Input Assumptions for Vermont



Load values in this chart reflect reductions due to energy efficiency, but not due to behind-the-meter PV or storage.



The PV and battery totals include both distribution-connected and transmission-connected generators.
All 2023 values are from the ISO-NE 2023 CELT Report.

51 GW Winter Peak Snapshot

- After obtaining initial results for the 2050 Transmission Study, it was observed that the 2050 57 GW Winter Peak snapshot caused the vast majority of the overloads seen in the study
- An additional snapshot, studying a 51 GW winter peak load, was added to the study to investigate how a reduced peak load would affect transmission overloads
- A 57 GW winter load essentially represents New England with 100% transportation and heating electrification
- A 51 GW winter load can be thought of in a couple of different ways:
  - The same 2050 future but with somewhat lower electrification
    - This could mean that fewer people adopt heat pumps and electric vehicles
    - If the full 6 GW reduction in load from 57 GW to 51 GW came from decreased heating electrification, this could represent roughly 80% heating electrification while still maintaining roughly 100% transportation electrification
    - It could also mean that more people use furnace backups during the extremely cold days that this winter peak represents, and use heat pumps the rest of the time
  - 100% electrification but with a significant increase in demand response and energy efficiency programs
    - Better insulation in buildings
    - Smart thermostat programs to keep buildings somewhat cooler during the peak hours
    - Utilizing more efficient ground-source heat pumps rather than air-source heat pumps

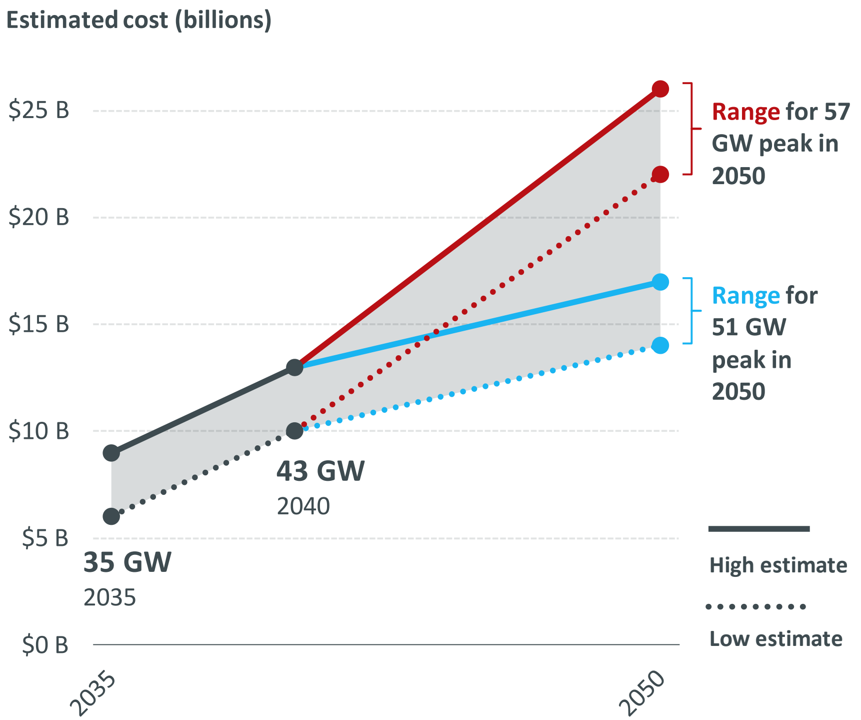
KEY TAKEAWAYS

Key Takeaways from the 2050 Transmission Study

- Reducing Peak Loads Significantly Reduces Transmission Cost
- High-Likelihood Concerns Can Be Prioritized
- Incremental Upgrades Can Be Made As Opportunities Arise
- Generator Location Matters
- A Significant Number of Transformers Need to Be Added

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%
- Serving a 57 GW winter peak load costs approximately $8 billion more than serving a 51 GW winter peak load



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

- NESCOE and other stakeholders have expressed their interest in identifying system concerns that would be most likely to appear, and most helpful to resolve
  - These 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
- The 2050 Transmission Study has identified a few of these high-likelihood concerns:
  - North-South transfers
  - Boston Import
  - Northwestern Vermont Import
  - Southwest Connecticut Import

High-Likelihood Concerns Can Be Prioritized

- For each concern identified in the 2050 Transmission study, the following criteria were used to determine whether the concern was "high-likelihood:"
  - The concern must be observed for **at least two of the studied snapshots**, with these two snapshots needing to be either different seasons from each other or different years (and hence different load levels) from each other
    - Consideration was also given to concerns that exist on today's system, or those that match other ISO-NE study outcomes, such as the Future Grid Reliability Study or Cluster Regional Planning Studies
  - The concern must **not be heavily dependent on load growth at a specific substation(s)**
    - Additional load-serving substations are likely to be built between 2023 and 2050, and these future substations are not included in the 2050 Transmission Study due to a lack of information on their location
    - This means that a concern related to transporting power between sub-regions within New England would be more likely to be considered a "high-likelihood" concern than one that is only related to feeding radial load
  - The concern must **not be solely caused by the injection of power from a specific generator at a specific substation**
    - The generation locations chosen in the 2050 Transmission Study are not necessarily where actual future generation will be built
    - A concern related to the delivery of a generator's power from a specific interconnection point would not be a "high-likelihood" concern, as this generator may in reality be interconnected to a different station, eliminating this concern

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
  - Many of these concerns do not appear until 2040 or 2050, meaning that they do not have to be addressed immediately
  - Opportunities for cost savings may also arise by “right-sizing” equipment when replacements occur for other reasons, such as asset condition issues

Generator Location Matters

- Throughout the study, generator points of interconnection (POIs) for offshore wind and batteries that were added in the 2050 Transmission Study were gradually optimized, within reason
- As a result, any overloads seen in the 2050 Transmission Study were in spite of these generator POI relocations
- Relocating large offshore wind interconnections from 345 kV to 115 kV was particularly effective at decreasing the number of transformer overloads observed in the study
- Generator POI relocation was less effective at avoiding some of the higher-level upgrades such as the large North-South upgrades because the exact generator location was less critical for these interface-related overloads

A Significant Number of Transformers Need to Be Added

- A large number of transformer overloads were seen throughout the New England system
  - These overloads are seen as the load grows higher, meaning that they are worst in the winter, and in later years, but many also show up in earlier years and sometimes in the summer
- These transformer overloads are often very dependent on the location of generation and load at specific stations
  - This makes it hard to pinpoint exactly where new transformers need to be built
  - Relocating new generators from 345 kV to 115 kV helped to eliminate some of the transformer overloads, but many still persisted
- Ideally the region would wait to order new transformers until closer to when they are definitely needed; however, transformers often have 18-24 month lead times, meaning that physically building/installing the number of transformers needed will be challenging
  - It may be necessary to order a large number of transformers ahead of time, figuring out their exact location later on

ROADMAPS FOR TRANSMISSION IN VERMONT

Transmission Development Roadmaps

- A main objective of the 2050 Transmission Study was to develop 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
  - Each roadmap consists of several major components, paired with rebuilds of existing lines and other components to form a complete solution for that region
- ISO-NE does not express a preference for any particular roadmap developed in the 2050 Transmission Study 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 for some high-likelihood concerns is to provide a basis of comparison for decision-making by New England stakeholders

High-Likelihood Concerns and Roadmaps

- North-South/Boston Import
  - Two categories of high-likelihood concerns combined for solutions development, since many solutions addressed both
  - Four roadmaps developed
- Northwestern Vermont Import
  - Four roadmaps developed (details on the following slides)
- Southwest Connecticut Import
  - One roadmap developed; other alternatives investigated but found to be far more costly without significant advantages
- Miscellaneous High-Likelihood Concerns
  - Various line rebuilds and transformer additions in other sub-areas of New England, as well as limited (<20 miles) new line construction

Roadmaps for Northwestern Vermont Import

Minimization of New Lines Roadmap

- Prioritize rebuilds of existing lines to the greatest degree possible
- Requires the upgrade of PV-20 to 230 kV and installation of two parallel underground cables in Charlotte and Shelburne

PV-20 Upgrade and Doubling of K-43 Roadmap

- Upgrade the PV-20 (Plattsburgh-Sandbar) tie with NY from 115 kV to 230 kV
- Double the K-43 (New Haven-Williston) overhead 115 kV line

Coolidge – Essex Roadmap

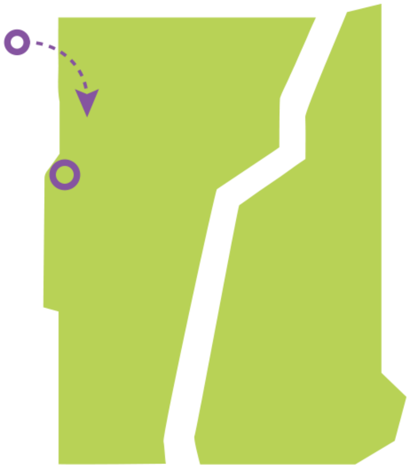
- Build new 345 kV overhead line from Coolidge to Essex

New Haven – Essex and Granite – Essex Roadmap

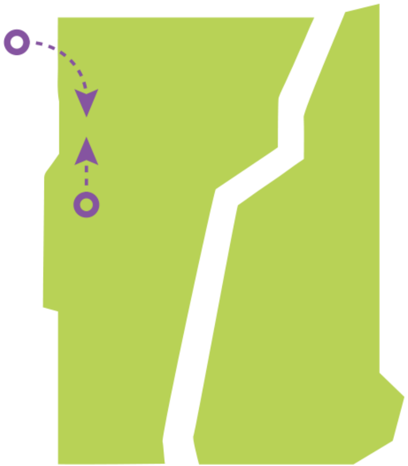
- Build new 345 kV overhead line from New Haven to Essex
- Build a 230 kV overhead line from Granite - Essex

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.

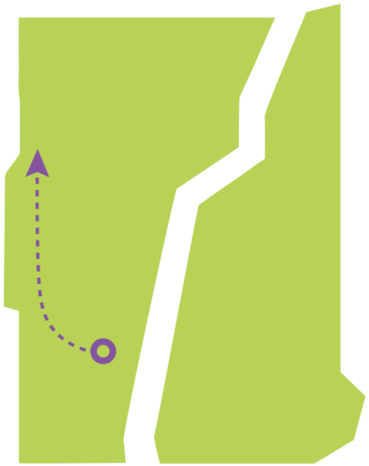
Roadmaps for Northwestern Vermont Import



Minimization of
New Lines Roadmap



Upgrade PV-20 Roadmap



Coolidge-Essex
345 kV Roadmap

New Haven-Essex
345 kV Roadmap

Northwestern Vermont Import: Other Components

- Each roadmap also includes rebuilds of overhead 115 kV lines
  - 79-142 miles, depending on roadmap, to reach a 51 GW winter peak
  - 121-192 miles, depending on roadmap, to reach a 57 GW winter peak
- Each roadmap requires 3-6 new 345/115 kV or 230/115 kV transformers
  - Transformers are installed at existing substations, but may require expansion of the substation fence

COST ESTIMATES

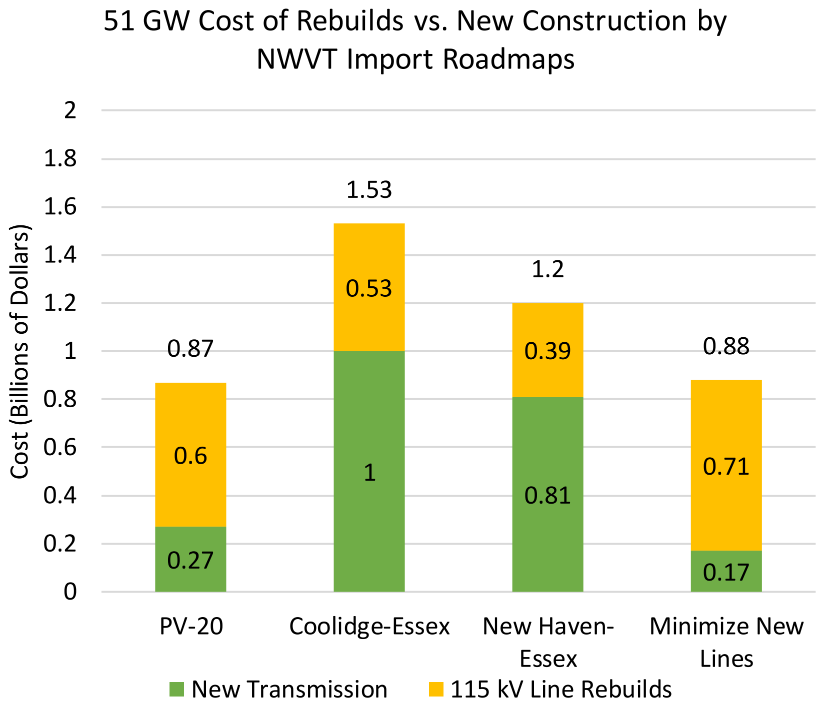
Approach and Final Cost Range

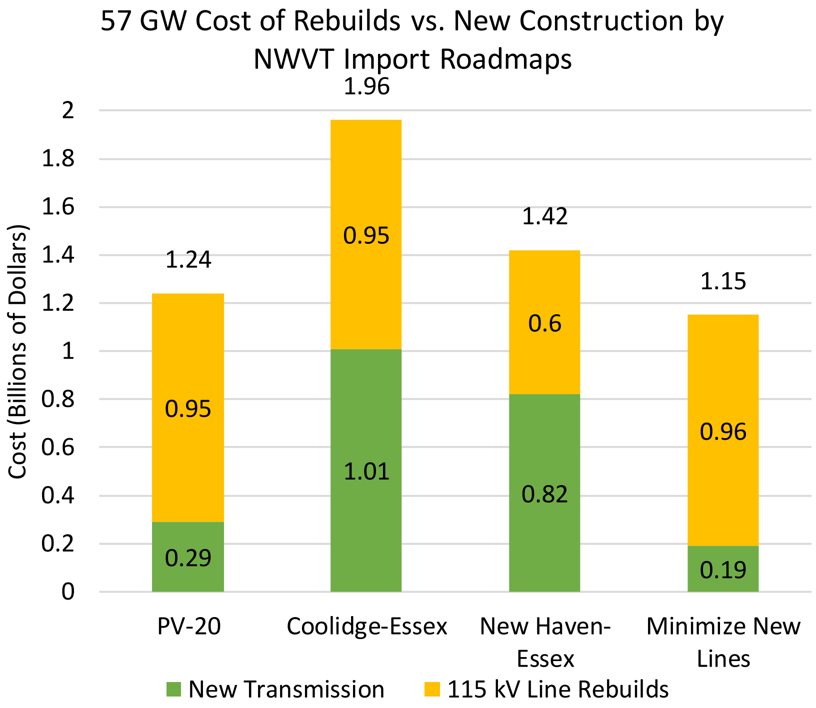
Approach to Estimating Costs

- ISO-NE hired Electrical Consultants Inc. (ECI) to develop detailed cost estimates for some of the more complex solutions that were developed in the 2050 Transmission Study
  - Examples of projects for which ECI provided detailed costs include a Surowiec – Mystic HVDC link and a Stoughton – K St 345 kV underground cable
- For less complex solutions, such as line rebuilds or new overhead lines through less congested locations, ISO-NE used cost assumptions that were developed by looking at a variety of recent projects
  - Recent projects were used as a comparison because there has been a noticeable increase in project costs since the COVID-19 pandemic in 2020
  - The numbers at right were used for cost assumptions

Component	Cost
69/115 kV OH line - rebuild	$5M/mile
69/115 kV OH line - new build	$7M/mile
230/345 kV OH line - rebuild	$6M/mile
230/345 kV OH line - new build	$8M/mile
Autotransformer	$10M
New breaker - 69/115 kV	$2M
New breaker - 230/345 kV	$2M
115 or 345 kV XLPE	$35M/mile

Northwestern Vermont Import Roadmap Costs





Range of Final Costs

- Totaling up all of the upgrades identified in all six New England states gives the range of cost totals seen at right*
- The numbers at right represent the cumulative estimated cost to reach the load level shown in the middle column, starting from 2023
- 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**

* Costs shown on this slide address all thermal transmission concerns for serving peak loads, including non-high-likelihood concerns. Other transmission concerns (voltage, stability, EMT, short-circuit, off-peak loads) and distribution costs are not included.

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

CONCLUSION & NEXT STEPS

Conclusion

- Reducing the peak load seen in winter from 57 GW to 51 GW could save New England roughly $8 billion in PTF transmission costs
- Several high-likelihood concerns can be prioritized since these are more likely to occur under a variety of possible futures
- Many of the solutions needed involve rebuilding existing lines
  - This can be done incrementally as the system gradually shifts and as line rebuilds become necessary due to asset condition concerns
- Generation location affects required transmission upgrades
  - This study has attempted to optimize the new generator locations within reason, but where these generators actually interconnect will play a large part in determining how the system needs to evolve
- A large number of new transformers will need to be added to the New England system
  - These devices have long lead times, meaning that the region will need to plan ahead in order to ensure that they can get the number of transformers that are needed

Next Steps

- ISO-NE will post the draft 2050 Transmission Study Report on November 1
- ISO-NE will post the draft 2050 Transmission Study Technical Appendix later in November
- Discussions on “Extended-Term/Longer-Term Transmission Planning Phase 2,” which will create a Tariff process for advancing transmission projects from longer-term transmission studies like the 2050 Transmission Study, began at the NEPOOL Transmission Committee on October 17 and will continue

Questions