EVERSOURCE

Eastern Massachusetts Underground Cable Modernization Program

Chris Soderman, Eversource Energy

ISO New England Planning Advisory Committee (PAC) Meeting

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Overview

- Eversource's underground transmission lines in Eastern Massachusetts consist of a mix of high-pressure fluid-filled (HPFF) pipe-type cables (PTCs) and solid dielectric cables using cross-linked polyethylene (XLPE) technology
- Many HPFF circuits have **exceeded the manufacturer's operating life expectancy,** have **increasing risk of prolonged outages**, and can leak dielectric fluid into the environment resulting in **costly and lengthy cleanup requirements**
- Over the past three decades, the industry has transitioned to XLPE cables as the preferred technology for new underground transmission line construction and limited options remain for procuring new HPFF cable
- **Going forward, Eversource plans to address HPFF line asset condition issues primarily by replacing HPFF lines with XLPE cable systems**
  - Transition will be gradual to **minimize customer impacts and support coordination with other projects**
- In response to stakeholder feedback Eversource is providing a **broad overview of the program** and a **forecast of the first phase of anticipated PTF projects in Eastern Massachusetts through 2033**
  - First phase will address approx. 67 circuit-miles of HPFF and require the construction of approx. 35 miles of new ductbank
  - Conceptual cost estimates are under development for a follow-up PAC presentation this summer
  - Recent cost estimates for 115 kV double-circuit underground ductbank in urban areas range from $46 M to $51 M per mile
- Longer-term forecast of upcoming projects will also support consideration of planned HPFF replacement projects in ongoing studies, including the Boston 2033 Needs Assessment

Agenda

- Background on underground transmission line technologies
- Concerns with ongoing reliance on HPFF cable technology and reliability risks
- HPFF asset management alternatives
- Overview of Eastern Massachusetts underground cable modernization program
- Initial phase of projects
- Summary and schedule

Background on Underground Transmission Line Technologies

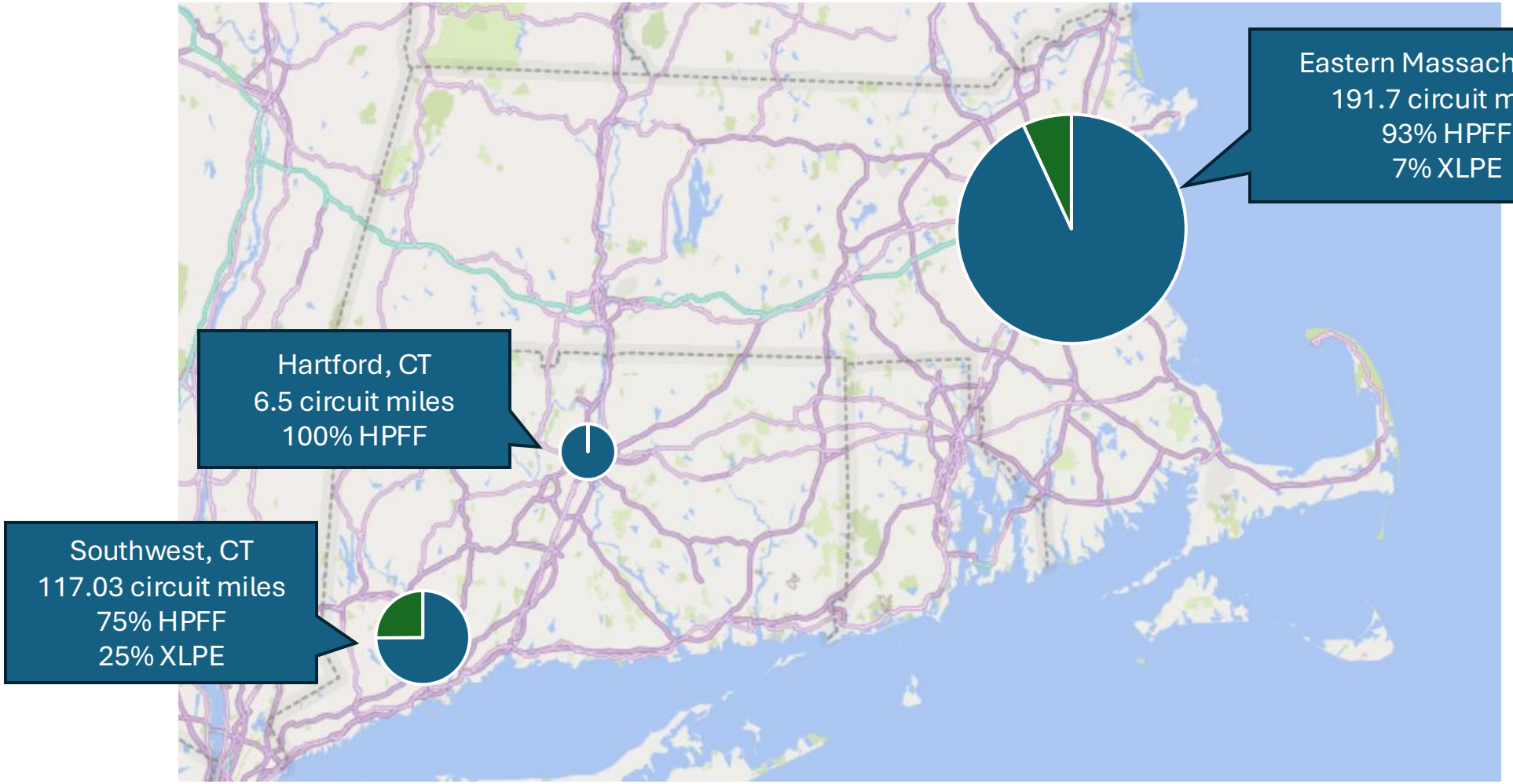
Eversource owns and operates the majority of underground 115 kV and 345 kV transmission lines in New England

- Includes both Pool Transmission Facilities (PTF) and non-PTF circuits
- Primarily consists of XLPE and HPFF technologies
- Earliest existing HPFF lines in Eastern Massachusetts were commissioned in 1951
- Average age of Eversource HPFF lines in Eastern Massachusetts is 47 years old
  - Manufacturer-specified design life of HPFF cable is 40 years

Eastern Massachusetts Underground Transmission Lines

Voltage	PTF			Non-PTF		
	Total	HPFF	XLPE	**Total**	HPFF	XLPE
115 kV	**97.6**	89.4	8.2	**86.2**	65.7	13.4
345 kV	**94.1**	89.1	5.0	**0.0**	0.0	0.0
Total	**191.7**	178.5	13.2	**86.2**	65.7	13.4

Eastern Massachusetts underground transmission facilities are primarily HPFF circuits



Notes:

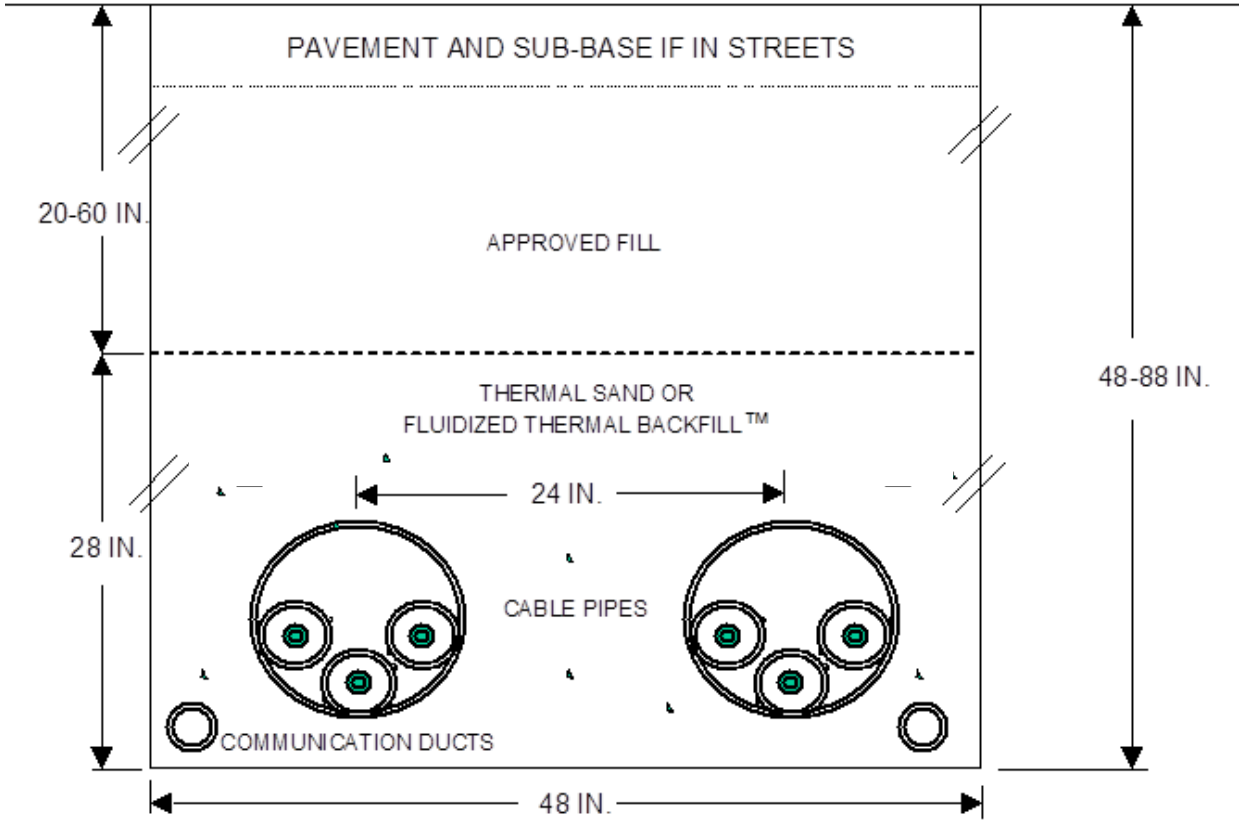
- Statistics include only PTF lines
- To preserve readability, relative size of pie charts is not to scale

HPFF transmission lines consist of three cables within a steel pipe, surrounded by dielectric fluid under pressure

- HPFF cable is typically installed in buried steel pipe
  - Cables for all three phases installed in a single pipe
  - Cables are surrounded by a dielectric insulating fluid (currently DF100 synthetic lubricant)
  - Dielectric fluid must be pressurized to approximately 200 psi to be fully insulating
  - Pressurization is maintained by plants (pumps) located at substations
  - Steel pipe is surrounded by thermal sand or thermal concrete
- HPFF transmission cables were first installed in the early 1930s
- HPFF became Eversource's standard technology for underground transmission cables in the mid-1950s

Typical HPFF circuit design

Typical HPFF Cross-Section
(Two Circuits)



HPFF Pipe Cutaway View
(Single Circuit)

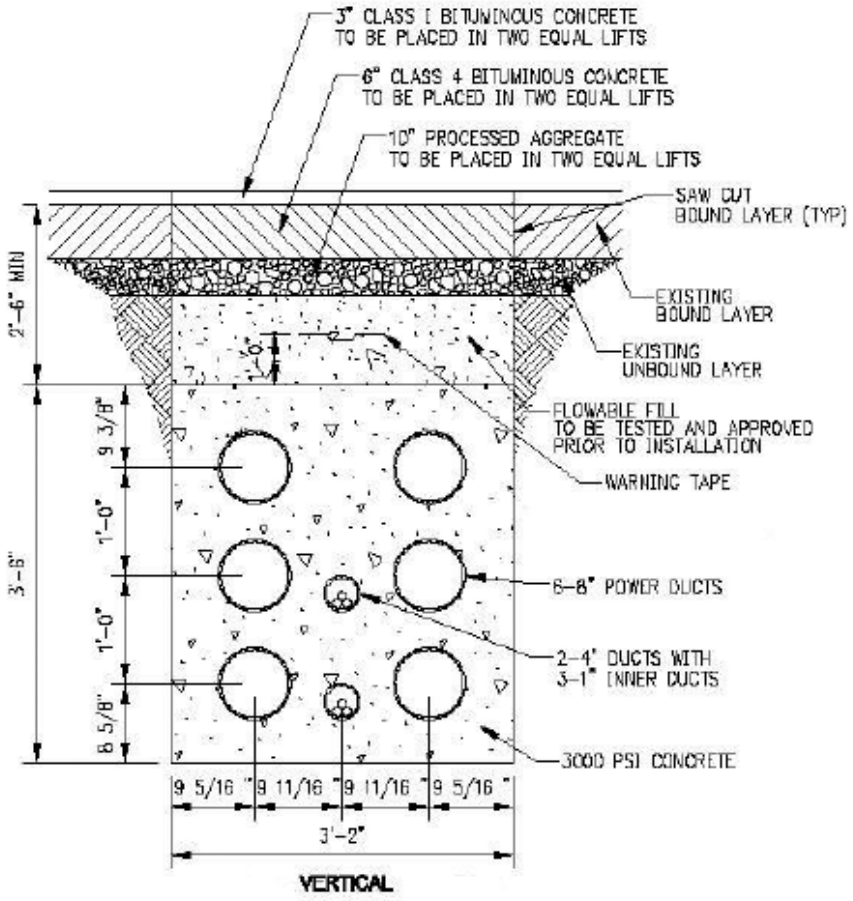
HPFF cable and splice installation

XLPE transmission lines consist of cables with solid dielectric insulation installed in conduits within a duct bank

- XLPE cable is typically installed in PVC conduit within a concrete-encased duct bank
  - One phase per conduit
  - Multiple circuits per duct bank when necessary
  - Duct bank typically includes additional ancillary conduits for communications, ground continuity conductor, and future distributed temperature sensing fiber
- Widespread deployment of XLPE transmission in the US began in the 1990s
- Eversource first installed 115 kV XLPE cable in 1990 and 345 kV XLPE cable in 2006

Typical XLPE circuit design

Typical XLPE Duct Bank Cross-Section (Two Circuits, Vertical Configuration)



Typical XLPE Cable (Single Phase)

XLPE construction

Concerns with Ongoing Reliance on HPFF Cable Technology and Reliability Risks

Aging HPFF lines present several asset condition concerns & threaten reliability for customers

Corrosion and degradation of pipes

- Over time, environmental factors lead to corrosion of steel pipes and increased risk of leaks and failures
- Exposure to runoff containing road salt during winter is largest driver of corrosion
- Cathodic protection installed in the 1990s reduced rate of corrosion, but does not completely prevent ongoing degradation

Cable defects

- Cable defects introduced during manufacturing or installation can also lead to failures
- With limited exceptions, cable-related issues have been less frequent than problems with steel pipes

Failures can result in months-long outages due to difficulty of repairs

Repairs to HPFF lines can take weeks or months, with lengthy outages and traffic disruptions

Typical scope of work for repairing an HPFF line

- Line removed from service in response to fault or suspected leak
- Perform initial environmental cleanup
- Freeze pipe using liquid nitrogen at an existing vault or excavate in-street freeze pits, depending on location of problem
- Remove faulted cable section if needed
- Excavate streets and repair pipe as needed
- Install new HPFF cable in faulted section (using spare from inventory)
- Replace dielectric fluid
- Restore streets and perform any additional environmental cleanup (often taking months, if not years)

Recent repair to 148-522Y line

Initial leak - December 23, 2023

- Leak suspected based on dielectric fluid reservoir monitoring
- Leak due to pipe corrosion located at Chestnut Street Bridge over Charles River (Dover and Needham, MA) due to pooling from dielectric fluid on road surface
- Line removed from service and environmental cleanup initiated. Total estimated fluid loss of 6,000 gallons, including majority of fluid loss into Charles River. Environmental cleanup work continues as of today.

Repair (Approx. 2 months)

- Designing repair and obtaining approvals took approx. 1 month
- Construction of repair took approx. 1 month
- One-lane traffic with 24-hour police detail for entire period

Notable aspects to repair

- Leak was located more quickly than normal due to visible dielectric fluid on road surface
- Repair was constructed more quickly than normal because HPFF cable was not damaged and did not require replacement

Recent pipe inspections show widespread corrosion of older steel pipes

- Eversource recently reconductored the 110-510 and 110-511 lines in Brookline and Boston
  - Lines were originally commissioned in 1965 and were approximately 58 years old
- Magnetic flux testing was performed while the lines were out of service
  - Magnetic flux testing requires pulling a “smart pig” device through the pipe and can only be performed when the cable and fluid are removed
- Test results showed 12 locations on the 110-510 line and 14 locations on the 110-511 line with pipe wall loss greater than 50%, indicating an increased risk of leaks and failures at these locations
- Excavations and pipe repairs were performed at these locations
- Eversource anticipates that other lines constructed from the 1950s through 1970s may have similar levels of degradation and will continue to perform pipe inspections as part of ongoing reconductoring projects

Potential discontinuation of HPFF cable production

- Okonite operates the world's only remaining HPFF cable manufacturing plant
- In April 2018, Okonite sent a letter to utilities signaling intent to leave HPFF market segment
  - No other cable manufacturers have signaled intent to enter (or re-enter) HPFF market
  - HPFF manufacturing at Okonite plant continues today and Okonite has stated that there are currently no near-term plans to close the plant
  - However, letter indicates long-term fragility of HPFF supply chain
- Cable accessory manufacturers and qualified workers are also becoming increasingly hard to find due to the "sunset" of HPFF technology
  - For example, a major Eversource contractor currently has only a single worker qualified to perform HPFF cable splicing
- Lack of manufacturers and skilled labor will make repairs to HPFF cables increasingly difficult
- Due to the uncertainty for the HPFF market in the future, the most responsible solution to ensure long-term reliability for customers and protection of the environment is to transition away from HPFF cables as the assets reach end of usable life

If HPFF manufacturing ceases, repairs will deplete existing inventory of spare cables

- Eversource's HPFF facilities currently consist of a mix of HPFF cable sizes, ranging from 250 kcmil to 3500 kcmil, and installed in pipes ranging from 5 to 10 inches in diameter
- Current HPFF spare cable reel inventory provides coverage for existing range of in-service HPFF cable sizes
  - This includes transition splices to mate between different cable sizes
- If HPFF cable manufacturing were discontinued today, Eversource estimates that spare inventory would be sufficient to maintain existing HPFF lines during the conversion to XLPE – but not over the long-term

Dielectric fluid discharges (leaks) result in disruptive and lengthy clean-up and repair operations

- Releases result in significant cleanup time and cleanup costs often reach millions of dollars
- Fluid discharges into waterways are particularly challenging due to complexity of fluid recovery
  - Dielectric fluid is viscous (similar to mineral oil) but quickly spreads to thin sheens when released to surface water
- Fluid releases into subsurface soils and groundwater can take years to fully remediate
  - Remediation of a release in Watertown, MA is still ongoing 5 years later
- Recent leaks have affected the Charles River and Boston Harbor
- Fluid from other leaks continues to linger in subsurface soil and groundwater

Leaking HPFF pipes

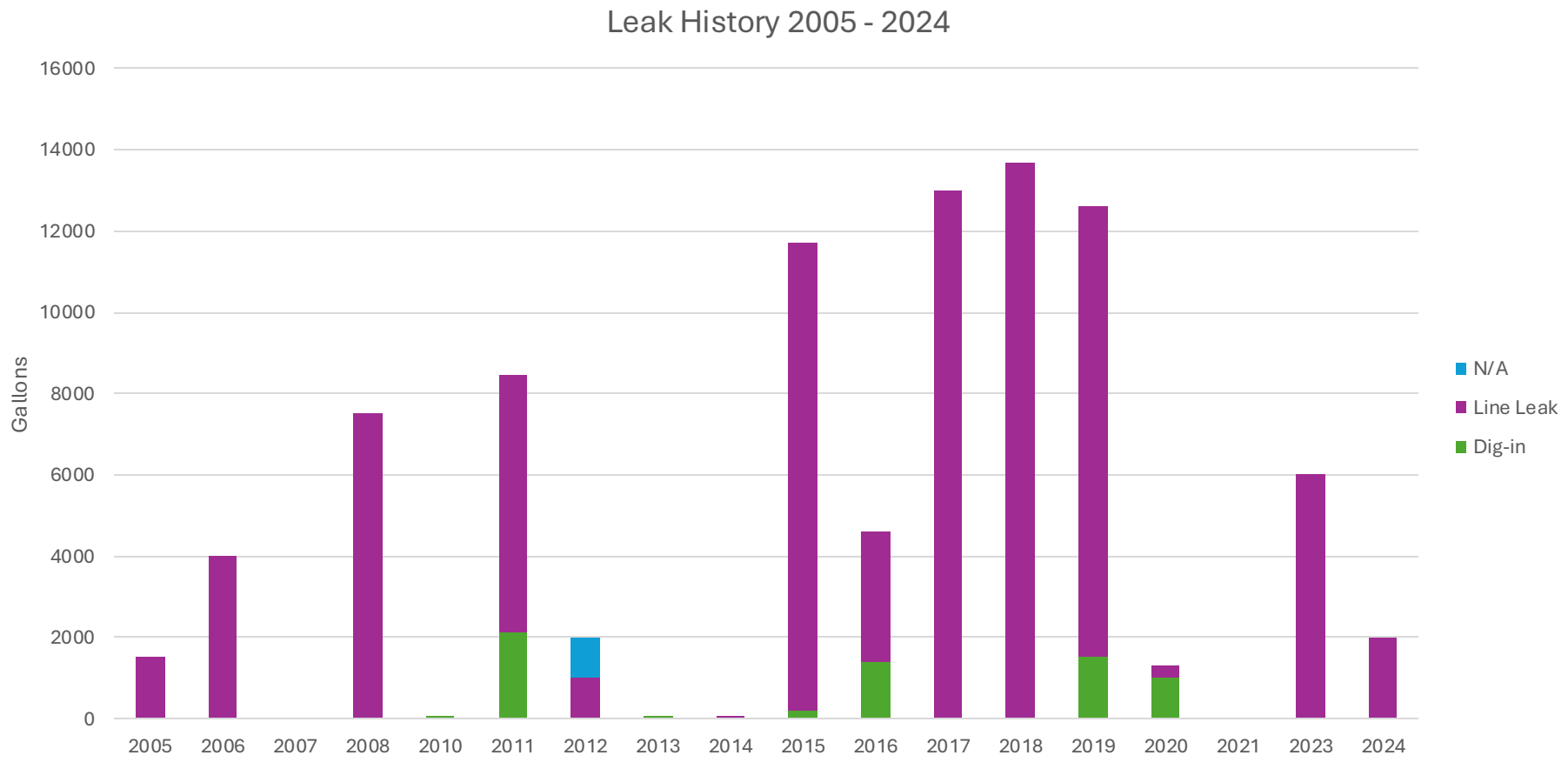
Leak cleanup in Boston Harbor

Government agency oversight has increased due to ongoing risks of leaks

- Fluid releases are highly regulated and must be reported immediately to state and federal agencies
- Agency oversight and inquiries have increased significantly due to ongoing risks
  - Massachusetts Department of Environmental Protection (DEP) has issued notices of violations and assessed penalties due to surface water impacts
  - United States Environmental Protection Agency (EPA) has multiple requests for information (RFIs) to Eversource
  - United States Coast Guard has raised concerns to Eversource about previous responses to surface water spills

Recovery wells to remove spilled fluid from soil and groundwater

HPFF fluid leaks have become larger and more frequent as lines age



Dielectric fluid spills require lengthy and expensive cleanup activities

Summary of asset condition needs associated with HPFF lines

Primary need

- Deterioration of underground steel pipes with increasing risk of failures or prolonged outages

Secondary needs

- Need to transition away from HPFF technology due to limited manufacturing capability and skilled labor
- Ongoing risk of leaks from HPFF lines with substantial cleanup-related costs and potential impacts to waterways, soil, and groundwater

HPFF Asset Management Alternatives

Eversource is prioritizing future HPFF asset condition projects based on a multifaceted framework

- For overhead transmission facilities, Eversource typically uses direct inspections and test results as the primary tools for determining when asset condition replacements are required
- However, there are limited options for inspecting and testing underground cables
  - Visual inspections can only be performed at vaults
  - Pipe inspections can only be performed during a reconductoring when cable and fluid are removed
- For HPFF lines, Eversource has relied on other information to develop the prioritization of HPFF line replacements
  - Prioritization factors are described on following slides
- Eversource will continue to gather inspection and test information from ongoing HPFF line asset condition projects and update prioritization if needed

Asset condition considerations in prioritization framework

- Age
  - Older lines given higher priority
- Leak Risk
  - Higher priority given to lines with high number of historical leaks, higher number of manholes, and proximity to water bodies (including water body crossings)
- Cathodic Protection
  - Higher priority given to lines in-service for longer periods of time without cathodic protection, and lines with fewer zones of cathodic protection
- Loading History and Projected Future loading
  - Higher priority given to cables with a history of heavy loading, which are expected to deteriorate more quickly
  - Higher priority given to cables forecasted to be heavily loaded in the future based on recent planning studies

Prioritization also considers timing relative to other projects

- Prioritization attempts to minimize construction impacts to towns and communities
- Prioritization considers timing of new substations identified by Eversource Electric Sector Modernization Plan (ESMP)
  - Potential new substations are listed on Eversource's Local System Plan (LSP)
  - Reconstruction of existing underground cables which will supply these substations will be sequenced to occur before substations are completed, or in coordination with construction of the substations
  - Routing and location of splice vaults will be selected to support substation connections
- Prioritization considers forecasted future loading
  - Lines forecasted to be overloaded in ISO-NE Boston 2033 Needs Assessment will be prioritized to avoid potential duplicative transmission investments

Eversource evaluated four alternatives for addressing asset condition issues on higher-priority HPFF lines

1. Repair failures as they occur
   - No proactive repairs or replacements; address problems as failures occur
2. Refurbish existing HPFF cables and pipes
   - Periodically refurbish HPFF lines by replacing existing HPFF cables with new HPFF cables and repairing pipes as needed
3. Replace existing HPFF circuits with XLPE circuits in new ductbanks
4. Replace existing HPFF cables with XLPE cables within existing pipes

Alternative 1: Repair failures as they occur

Typical scope of work

- Remove cable(s) from service as faults and leaks occur
- Perform initial environmental cleanup
- Freeze pipe using liquid nitrogen at existing vault or excavate in-street freeze pits, depending on location of problem
- Remove faulted cable section
- Excavate streets and repair pipe as needed
- Install new HPFF cable in faulted section (using spare from inventory)
- Replace dielectric fluid
- Restore streets and perform additional environmental cleanup (months to years)

Advantages

- Only feasible response to cable failures

Disadvantages

- Unpredictable, multi-week outages place reliability at risk
- Emergency lane or road closures impact local communities
- Limited inventory of spares and qualified line workers
- Environmental cleanup may be extensive depending on location of leak

Alternative 2: Refurbish existing HPFF cables and pipes

Typical scope of work

- Remove existing HPFF cable (cannot be reused)
- Recover dielectric fluid and inspect pipe
- Excavate and repair pipe as needed
- Pull new HPFF cable into existing pipe
- Replace and repressurize dielectric fluid

Advantages

- Lower cost due to reuse of existing components (pipes, vaults, etc.)
- Excavation only required in targeted locations

Disadvantages

- Continued risk to the environment due to continued use of dielectric fluid and potential for leaks
- Extends reliance on obsolete HPFF technology
- Future repairs/maintenance may become more complicated and costly due to lack of available parts and skilled maintenance workers

Alternative 3: Replace existing HPFF cables with new XLPE cables in new ductbanks

Typical scope of work

- Excavate streets and construct new ductbank and splice vaults
- Pull new XLPE cable
- Remove HPFF cable from existing pipe
- Decommission HPFF system and dispose of dielectric fluid
- Retire existing pipe in-place

Advantages

- Eliminates dependence on a sole-source supplier for HPFF cables
- Increased cable size allows for higher capacity*
- Solid dielectric cable eliminates need for dielectric fluid and eliminates environmental concerns caused by leaks

Disadvantages

- Higher upfront cost than Alternative 2
- More complex siting, permitting, and construction

** See appendix for more information*

Alternative 4: Convert existing HPFF cables to XLPE within existing pipes

Typical scope of work

- Remove existing HPFF cable (cannot be reused)
- Recover dielectric fluid and inspect pipe
- Excavate and repair pipe as needed
- Expand existing splice vaults and install new splice vaults where necessary
- Pull new XLPE cable into existing pipe

Advantages

- Lower cost due to reuse of existing components (pipes, vaults, etc.)
- Less excavation required
- Solid dielectric eliminates environmental concerns caused by leaks

Disadvantages

- Would require installation of a smaller XLPE cable with higher AC resistance and lower thermal capacity leading to substantial derates of existing circuits*
- Would require use of a speciallized, non-standard, sole-sourced XLPE cable design with limited operational history industry-wide

** See appendix for more information*

Assessment of underground cable asset management strategy

- Alternative 1 (emergency repairs) alone is not prudent
  - Repairs will always be performed when cable failures occur, but relying solely on emergency repairs is not a prudent asset management strategy and does not proactively protect reliability for customers
- Until recently, Alternative 2 (periodic refurbishment) was Eversource's preferred asset management approach for existing HPFF cables
  - Lower cost than other alternatives
  - Spare parts and qualified line workers were readily available
  - Refurbishment can add several decades to service life for existing lines
- Increasing concerns about availability of HPFF cables and qualified line workers prompted Eversource to reassess our underground cable asset management strategy
- Alternative 4 (convert to XLPE using existing pipe) is not currently viable because it results in lower ratings, has limited operational history, and requires purchase of specialized XLPE cable

Going forward, Eversource will seek to replace existing HPFF cables with XLPE cables in new ductbanks

Continuing to rely on refurbishment (Alternative 2) is not a viable, long-term strategy

- Continuing widespread installations of new HPFF cable would perpetuate dependence on a single supplier with known intention to exit the market
- Loss of ability to obtain replacement cables would put reliability at risk and lead to rushed, costly projects to convert rapidly to XLPE
- Exceptions may be needed for certain situations where reconductoring with HPFF is preferable to reconstruction with XLPE (see slide 38)

For most existing underground lines replacement with XLPE (Alternative 3) is the preferred approach

- Over time, replacement of HPFF circuits with XLPE will mitigate reliance on obsolete technology
- Upfront project costs will be higher, but will reduce reliability risk and environmental impact from continued reliance on HPFF
- Anticipate that projects will be spread over several decades, mitigating rate impact
- Lines will be prioritized primarily based upon vintage, maintenance history, environmental considerations, and historic and future loading

Overview of Eastern Massachusetts Underground Cable Modernization Program

Eversource is developing a multi-decade plan to modernize our Eastern MA underground cables

- Based on Alternative 3, Eversource is developing a multi-decade plan to modernize our Eastern MA underground cable facilities by replacing HPFF cable systems with XLPE cable systems
- Conversions will be constructed gradually over time, beginning in 2025 and extending into the 2040s
- Preliminary evaluation indicates that approximately 35 miles of double-circuit underground ductbank will need to be constructed in first phase of program (through 2032)
  - Accurate estimates require detailed engineering on an individual project basis. As a result, Eversource is not able to develop a cost estimate for the entire program
  - Instead, cost estimates will be developed for individual UCMP projects and presented to PAC when available (see tentative schedule on slide 37)
  - Estimates developed for recent projects have yielded costs between $46 M and $51 M per mile for new, underground, double-circuit 115 kV ductbank

Factors affecting estimated in-service dates

- In response to stakeholder requests for greater transparency into upcoming asset condition projects, Eversource has forecasted which projects may be completed during the next 10 years
- Many factors can affect in-service dates for underground transmission line projects, including:
  - Changes to laws and regulations (including changes to siting processes)
  - Refined design and engineering
  - Time necessary to obtain certificates and permits
  - Material procurement
  - Scheduling of construction crews and outages
  - Difficulty of constructing around other underground infrastructure
  - Coordination with other projects, including new substation projects
- **In-service dates provided in this presentation should be regarded as *conceptual* and subject to change**

Proposed Phase 1 HPFF Conversion Projects

Cable or Cable Pair	Terminal Substations	Overload in Boston 2033 Needs Assessment	Voltage	Length (mi)	Vintage
148-522X/Y	Dover – Needham	No	115 kV	1.3	1967
329-520/521	Electric Ave – Brighton	No	115 kV	1.3	1967
329-512/513	Brighton – Carver St	Yes	115 kV	4.4	1962
346/365	Woburn – N. Cambridge	Yes	345 kV	6	1976/1986
496-528/529	Baker St. – Hyde Park	No	115 kV	3.6	1974
385-510/511	Kingston St – High St – K St	No	115 kV	1.9	1967
351/358	N. Cambridge – Mystic	Yes	345 kV	5	1975/2001
514-510/511	Kingston St – Colburn St	No	115 kV	3.6	1976
514-512/513	Carver St – Kingston St	No	115 kV	1.1	1965
329-530/531	Brighton - Belmont	Yes	115 kV	3.7	1974
385-512/513	Kingston St – K St	No	115 kV	2.4	1965

- Additional details, including cost estimates, are under development and expected to be presented to PAC in Summer 2025
- In-service dates for these projects are expected to range from 2028 to 2033

Unique considerations for cable sets with different ages

- Several Boston-area 115 kV underground circuits consist of two sets of parallel cables operated together as a single circuit
  - Second set of cables increases thermal capacity of the circuit
  - Cable sets are designated “X” and “Y”
- On three of these circuits, only one cable set was installed originally
  - Second cable set was installed later to increase capacity
- Eversource is analyzing these three circuits separately to determine if conversion to XLPE is appropriate
  - For example, refurbishing 211-514X with new HPFF cable is likely more appropriate than converting to XLPE
- Results will be presented to PAC when available

115 kV underground circuits with cable sets of differing ages

Cable	Terminal Substations	Voltage	Length	Vintage
211-514X/Y	Mystic – Woburn	115 kV	7.7	1965/2024
423-515X/Y	Mystic – Everett* Underground Section	115 kV	0.5	1964/2012
488-518X/Y	Mystic – Hendersonville* Underground Section	115 kV	0.7	1970/2001

**National Grid station. Overhead section and approx. 0.50 miles of underground cable owned by National Grid*

Summary

- Eversource is beginning to convert HPFF circuits to XLPE because of concerns associated with long-term supply of HPFF cables and parts, as well as environmental concerns and reliability risks as existing HPFF circuits approach/exceed their age of operational life
  - There are approximately 179 miles of PTF HPFF circuits under evaluation for replacement with XLPE as part of this program
  - Addressing all impacted transmission lines is forecasted to take many years
- Eversource will provide periodic updates to PAC on the overall program and any changes to anticipated projects
  - Because of scope and duration of program, Eversource is able to offer much longer-term view than is typically provided for asset condition projects

PAC Presentations and Project Tracking

- Projects included in this presentation will be added to the Asset Condition List as "Proposed" projects once cost estimates are available
- Eversource expects to provide a follow-up PAC presentation in the summer of 2025

Schedule

Submission of Questions and Comments	
Please submit questions and comments by:	March 12, 2025
ISO-NE Contact Email Address	pacmatters@iso-ne.com
Transmission Owner Contact Name	Dave Burnham
Transmission Owner Contact Email Address	PAC.Responses@eversource.com

- Follow-up PAC presentation planned for Summer 2025

Questions

Appendix

XLPE typically provides additional capacity compared to HPFF cable

Typical Capacity	Typical capacity and cable size @ 115 kV	Typical capacity and cable size @ 345 kV
HPFF*	192 MVA (2500 kcmil CU)	518 MVA (2500 kcmil CU)
XLPE installed in duct bank	270 MVA (5000 kcmil AL)	770 MVA (5000 kcmil AL)
XLPE installed with existing HPFF steel pipe**	160 MVA (2500 kcmil CU)	N/A

**HPFF ratings based off trench installation in 8" pipe*

***Experimental technology available if existing steel pipes are suitable for reuse*

Conversion of HPFF lines outside of Eastern Massachusetts is also needed, but projects will be smaller and less complex

- There are three locations in Connecticut with PTF HPFF cables
  - Projects to reconstruct Hartford-area HPFF cables (Lines 1704 and 1722) were presented to PAC on June 15, 2023 and August 16, 2023
  - Underground portions of Plumtree – Norwalk 345 kV line (Line 3024) are HPFF, but are relatively new and in good condition
  - Underground cables connecting to Norwalk Harbor (Lines 1608, 1867, 1880) are HPFF but were recently reconductored and were presented to PAC on September 27, 2018
- Non-PTF PTC replacements in Connecticut and Western Massachusetts are listed on the LSP
- There are no PTF HPFF cables in Western Massachusetts or New Hampshire
- This presentation, combined with the Hartford cables presentation and the LSP provide a **complete** overview of Eversource's plans to replace our PTC circuits

Other underground cable technologies

- High-pressure gas-filled (HPGF)
  - Similar to HPFF, but uses pressurized nitrogen gas as insulating medium, not dielectric fluid
  - Three installations in Eastern Massachusetts, all non-PTF
  - Refer to Eversource Local System Plan for additional information

- Ethylene Propylene Rubber (EPR)
  - Used primarily for short underground transmission segments within substations
  - Modern, reliable technology with no concerns about obsolescence at this time