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VIA ELECTRONIC MAIL

January 6, 2023

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From: Melanie Bachman, Executive Director MAB

RE: **LIFE-CYCLE 2022 -** Connecticut Siting Council 2022 Analysis of Life-Cycle Costs of Electric Transmission Lines.

Enclosed please find a copy of the Council's Final 2022 Analysis of Life-Cycle Costs of Electric Transmission Lines Report, pursuant to Connecticut General Statutes § 16-50r (b).

MAB/MP/laf

c: Deborah Denfeld, Eversource Energy (deborah.denfeld@eversource.com)
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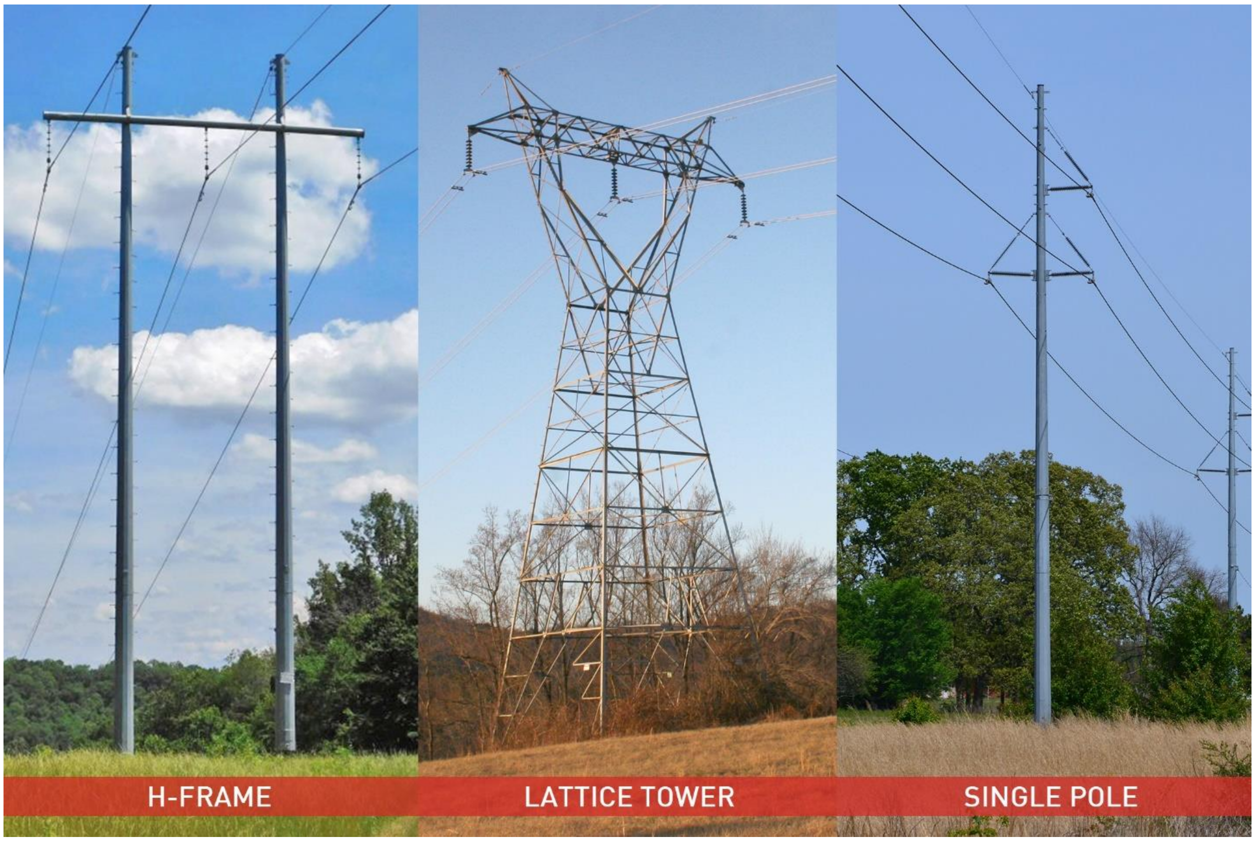
CONNECTICUT SITING COUNCIL

LIFE-CYCLE 2022

Connecticut Siting Council
Life-cycle Cost Analysis of Overhead and Underground Electric Transmission Lines



Report
January 5, 2023

I. INTRODUCTION

Electric power transmission is the backbone of the electricity delivery system. It efficiently transmits high-voltage electric current over long distances to the electric distribution grid in populated areas.

Current is the rate of flow of electrons in a circuit. Direct current (DC) flows in one direction[1] and alternating current (AC) flows in two directions (forward and backward)[2] to transmit electric power from a generating facility to substations.

Voltage is the pressure from a power source that pushes electric current between two points. Typically, higher voltage lines are higher capacity lines. They reduce electrical losses (power lost as heat) because less current is required to serve a given electrical load, and losses are a function of current.

High voltage direct current (HVDC) lines are used for long distance power transfers or for interconnecting two systems that require isolation to preserve system reliability. HVDC transmission lines require the installation of a converter station at each end of the circuit. Converter stations are costly to install, require ongoing maintenance, incur power losses and have a useful life of approximately 20-25 years.[3]

Under Connecticut General Statutes (CGS) §16-50i, an electric transmission line facility has a design capacity (or line voltage) of at least 69,000 Volts or 69 kilovolts (kV) and is subject to the jurisdiction of the Connecticut Siting Council (Council). Electric lines with voltages under 69-kV are electric distribution level and subject to the jurisdiction of the Public Utilities Regulatory Authority. Connecticut's existing electric transmission lines are comprised of three AC line voltages: 69-kV[4], 115-kV and 345-kV.

Transmission lines can be overhead, underground, or a combination of the two (ex. a hybrid line).[5] The total cost of ownership of a transmission line over the course of its useful life, including but not limited to, design, engineering, construction, operation, maintenance and repair is referred to as the "life-cycle cost." Life-cycle cost analysis is an objective method to compare alternative configurations over the life of a transmission line, rather than comparing the initial costs to design, permit and build a transmission line.

CGS §16-50r(b) requires the Council to establish a proceeding not less than once every five years to investigate and determine life-cycle costs for both overhead and underground transmission line alternatives (Life-Cycle Cost Analysis). Life-cycle costs of electric transmission lines are generally comprised of first costs, operations and maintenance (O&M) costs, and electrical loss costs. The scope of the Life-Cycle Cost Analysis shall include, but not be limited to:

A. Life-cycle costs;
B. Relative reliability;
C. Constraints concerning access and construction;
D. Potential damage to the environment; and
E. Compatibility with the existing electric supply system.

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[1] Eversource and UI Response 30.
[2] AC transmission lines are comprised of **three electrical phases** in which three line conductors are typically used. Some transmission lines can have more than one conductor per phase. This is known as bundled conductors.
[3] Eversource and UI Response 30; The scope of the LCA does not include HVDC transmission lines.
[4] Eversource and UI Response 25 (69-kV transmission lines have limited capacity. Neither Eversource nor UI plan to construct new 69-kV transmission lines within the next five years.)
[5] Transmission lines can also be underwater. The scope of the LCA does not include submarine transmission cables.

Connecticut is mainly served by two transmission owners – United Illuminating Company (UI) and Connecticut Light and Power Company d/b/a Eversource Energy (Eversource). UI serves the municipalities of Ansonia, Bridgeport, Derby, East Haven, Easton, Fairfield, Hamden, Milford, New Haven, North Branford, North Haven, Orange, Shelton, Trumbull, West Haven, and Woodbridge. Eversource serves the remaining municipalities in the state, except for certain municipally-served areas. Wallingford has its own municipal utility. Bozrah, Groton, Norwich, Jewett City, South Norwalk, the Third Taxing District of Norwalk, and the Mohegan Tribal Utility Authority are under the Connecticut Municipal Electric Energy Cooperative.

The Council issued its 2017 Life-Cycle Cost Analysis (2017 LCA) on October 11, 2018. Pursuant to CGS §16-50r, the Council issued interrogatories to the transmission owners for the 2022 Life-Cycle Cost Analysis (2022 LCA) on March 16, 2022. UI and Eversource responded to the Council's interrogatories on June 30, 2022 and July 29, 2022, respectively. The Council approved the 2022 LCA schedule on September 15, 2022, including a 6:30 p.m. public comment session that was held on October 19, 2022.[6]

A. Life-Cycle Costs

1. 115-kV and 345-kV Overhead Transmission Lines

First Costs

The estimated useful life of an overhead electric transmission line is 40 years.[7] The costs to design, permit and build a line are referred to as "first costs," composed of the following cost categories: poles and foundations; conductor and hardware; site work; construction; engineering; sales tax; and project management. First cost data is project-specific; it cannot be readily generalized for transmission lines across the state. The costs in each first cost category vary depending on the overhead transmission line configuration and conductor arrangement.

Overhead transmission line configurations are generally defined by voltage, structure design and conductor arrangement. Structures may be designed for single-circuit or double-circuit transmission lines. See Figure 1. The H-frame structure design uses vertical poles with horizontal cross-arms to make an H-pattern. The monopole structure design uses one vertical pole. The lattice structure design uses steel angle sections. See cover page for examples of transmission line structure designs.

Wood structures are not typically used for new transmission lines as they are susceptible to degradation from environmental factors.[8] Steel lattice structures are also not typically used for new transmission lines as they require a larger footprint, have higher labor costs and are susceptible to climbing, trespassing and vandalism.[9] Laminate wood structures are comparable in cost to steel structures.[10] Steel transmission structures are preferred over wood structures for their strength, durability and availability.[11] Weathering

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[6] Council Public Comment Session Notice, dated September 16, 2022.
[7] Eversource Responses 1 and 6; UI Responses 1 and 6.
[8] Eversource Response 2 (Eversource uses wood structures for limited purposes, such as emergency replacements and temporary support during construction.); UI Responses 2 and 10 (UI uses wood structures for limited purposes, such as at bypasses and for temporary support during construction.).
[9] Eversource Response 2, UI Response 2 (Lattice structures may still be used for rural areas and special design considerations, such as at Ultra High Voltage (UHV) levels (765-kV)).
[10] Eversource Response 2; UI Responses 2 and 10; Sub-Petition 1293-BR-03 (Eversource is replacing laminated wood structures as part of an ongoing maintenance program due to wood rot and pole top rot.)
[11] Eversource Response 1; UI Response 1.

steel is designed to oxidize to more of a "rustic" or "wood" look than a galvanized gray steel.[12] Weathering steel can also be used as a replacement for wood structures for aesthetic purposes.[13]

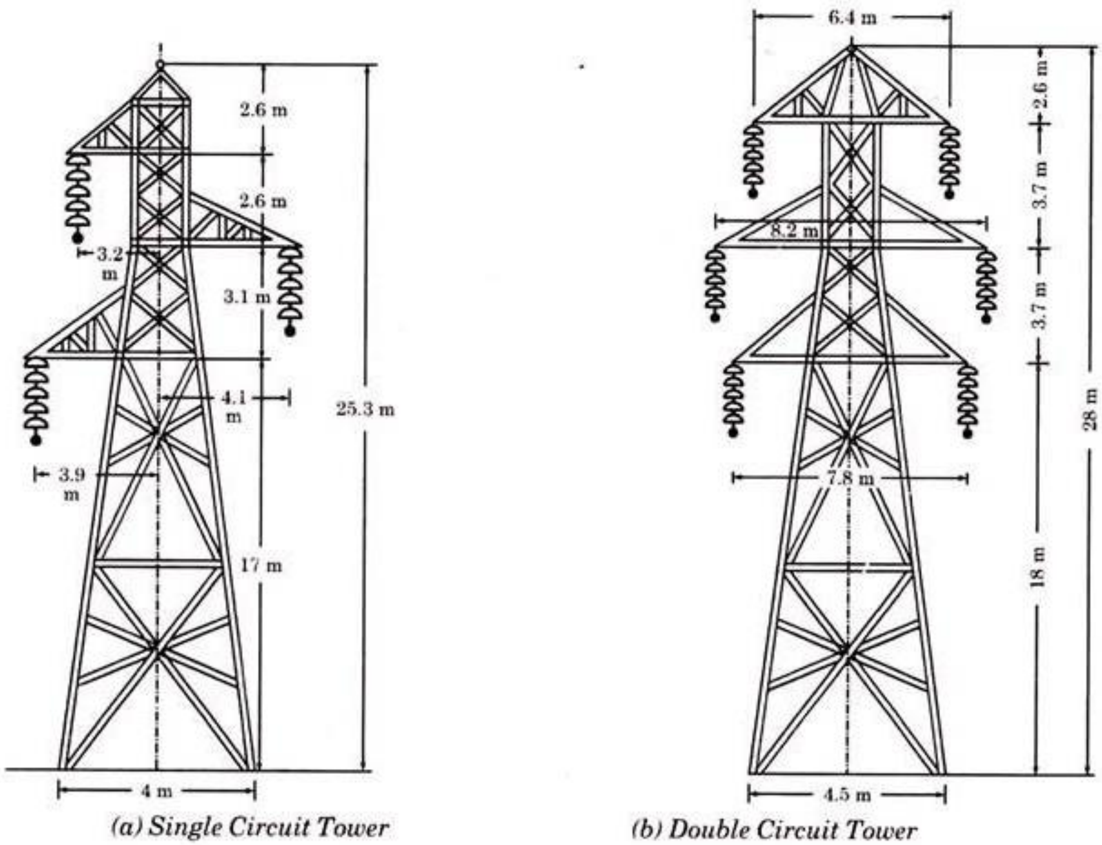

Figure 1 – Single-circuit and Double-circuit transmission line on lattice structures.

Conductor arrangements may be horizontal, delta or vertical on single-circuit or double-circuit transmission lines.[14] See Figures 1 and 2. Single-circuit transmission lines carry three conductors pertaining to the three phases of AC transmission and double-circuit transmission lines carry six conductors, or two separate circuits each consisting of three conductors, pertaining to the three phases of AC transmission. Double-circuit transmission line costs are more variable due to design and location-specific considerations.[15]

In horizontal conductor arrangements, all conductors are mounted over one cross-arm. This arrangement employs structures of shorter height, but also requires a wider right of way (ROW). In delta, or triangular, conductor arrangements, conductors are typically mounted two over one cross-arm and one on top of the structure. This arrangement and the horizontal arrangement is the most economical for single-circuit transmission lines. In vertical conductor arrangements, conductors are mounted one below the other along the length of the structure. This arrangement employs structures of taller height, but it is the most economical for double-circuit transmission lines.

[12] Galvanized steel structures provide greater corrosion resistance than weathering steel in salt air environments.
[13] For compromised asset conditions, Eversource typically replaces wood structures with weathering steel structures.
[14] Eversource Response 2 and 3 (Double-circuit transmission line costs are more variable); UI Response 2.
[15] Eversource Response 3.

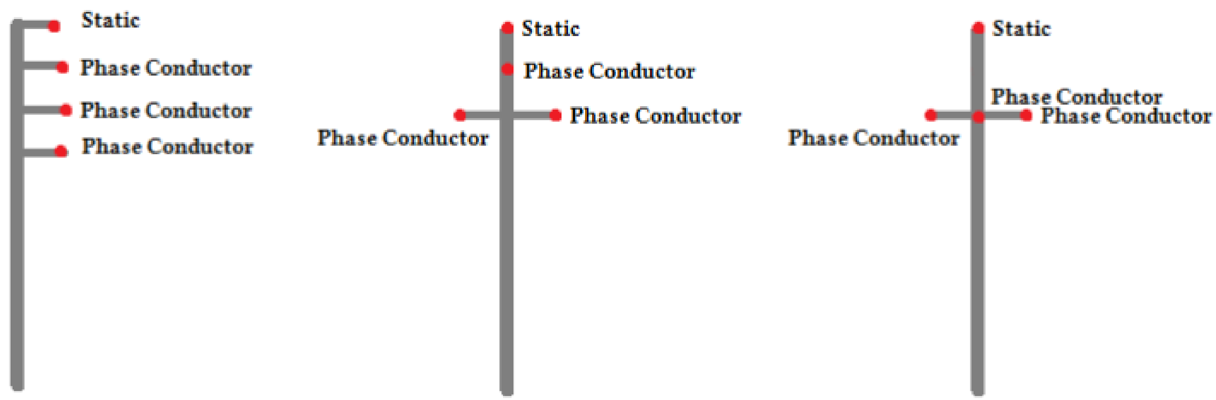

Figure 2 – Vertical, Delta and Horizontal conductor arrangements.

Conductor selection is based upon circuit ampacity requirements. Ampacity is the maximum current that a conductor can carry continuously under the conditions of use without exceeding its temperature. UI and Eversource typically install Aluminum Conductor Steel Supported (ACSS) conductor due to its current carrying capability, low sag and high temperature characteristics.[16] ACSS conductor generally has better performance than Aluminum Conductor Steel Reinforced (ACSR) conductor, which is used in limited applications to match existing conductor on a transmission line.[17]

In general, there are four common overhead transmission line configurations in Connecticut for which data is readily available:

a. 115-kV horizontal H-frame;
b. 115-kV delta monopole;
c. 345-kV horizontal H-frame; and
d. 345-kV delta monopole.

First costs provided by Eversource for a new single-circuit overhead line on a $/mile basis are as follows:[18]

Eversource Energy - Typical OH Transmission Types

Life-Cycle Cost Components - Estimated Overhead Construction Costs/ Typical Mile

Cost Category	115-kV H Frame - Wood or WPE Steel	115-kV Delta - Steel Monopole	345-kV H Frame - Wood or WPE Steel	345-kV Delta - Steel Monopole
Poles & Foundations	$1,098,718	$1,025,312	$1,314,095	$1,789,171
Conductor & Hardware	$374,464	$343,670	$663,053	$627,077
Site Work	$855,333	$796,971	$974,944	$904,084
Construction	$1,954,208	$1,563,719	$2,365,318	$2,405,711
Engineering	353,586	$330,756	$499,710	$505,960
Sales Tax	$0	$0	$0	$0
Project Management	$304,191	$274,071	$364,681	$384,697
Totals	**$4,940,500**	**$4,334,499**	**$6,181,801**	**$6,616,700**

[16] Eversource Response 5; UI Response 5.
[17] Eversource Response 5.
[18] Eversource Response 3.

First costs provided by UI for a new single-circuit overhead line on a $/mile basis are as follows:[19]

	First Costs per Circuit Mile
Poles & Foundations	$1,461,542
Conductor & Hardware	$183,304
Site Work	$2,351,990
Construction	$3,627,148
Engineering	$1,430,839
Sales Tax	$48,451
Project Management	$569,124
UI's Costs	$1,147,095
Total Cost	**$10,819,493**

Operations and Maintenance Costs

Operations and maintenance (O&M) costs for overhead transmission lines are provided by the utilities in the Federal Energy Regulatory Commission (FERC) Form 1 and are listed below for Eversource and UI:[20]

Eversource Energy Operation & Maintenance Costs
CT Only - FERC Form 1, years 2017-2021

	O&M Cost Per Circuit Mile - Overhead Transmission					
560 / 568	Supervision Costs (line 1+4)	5,915,669	7,116,466	7,527,130	10,004,566	6,487,249
	% of Overhead to Total (line 9)	91.42%	91.46%	91.46%	91.06%	91.07%
	Supervision % allocated to Overhead	5,407,829	6,508,787	6,884,595	9,110,153	5,907,751
563 / 571	Direct Overhead Costs (line 2+5)	18,300,560	17,847,505	33,439,698	42,826,275	35,009,909
	Total Overhead Costs	23,708,389	24,356,292	40,324,293	51,936,428	40,917,660
	Overhead Circuit Miles (line 7)	1247.92	1255.21	1255.66	1258.23	1259.34
	O&M Costs - Overhead Trans. Per Circuit Mile	$18,998	$19,404	$32,114	$41,277	$32,491
		34.95%	2.14%	65.50%	28.53%	-21.29%
					5 year O&M Cost Average - OH	$28,857

[19] UI Response 3 (Based on actual construction costs of a single circuit vertical steel pole configuration using 1590 ACSS conductor along the MetroNorth ROW).
[20] Eversource Response 8 (FERC Form No. 1 is a financial and operating report submitted annually for electric rate regulation, market oversight analysis, and financial audits by electric utilities).

UI Operation & Maintenance Costs:

	2017	2018	2019	2020	2021
Costs per circuit mile for O&M of UI's existing overhead transmission lines of 109.6 miles	$43,876	$45,298	$42,770	$40,129	$20,691

O&M costs are provided based on the utility's experience with all of its overhead transmission, irrespective of pole types or conductor configuration. Based on data from years 2017 through 2021, Eversource estimates that the 5-year O&M cost average for overhead transmission in its service area is approximately $28,857 per circuit-mile. Based on data from years 2017 through 2021, UI estimates that the 5-year O&M cost average for overhead transmission in its service area is approximately $38,553 per circuit mile. Given that Eversource has significantly greater circuit-mileage than UI, the Council uses a weighted average rather than a simple average to determine an overall O&M cost average per circuit-mile. UI's overhead circuit mileage (as of July 2022) was approximately 109.6 circuit-miles.[21] Over the five year time period, Eversource's overhead circuit mileage ranged from 1247.9 circuit-miles to 1259.3 circuit-miles for an average of about 1255.3 circuit-miles. Thus, the approximate weighted average O&M cost for an overhead transmission line is computed as follows:

Annual O&M Cost per Circuit-mile = [($28,857/circuit-mile)(1255.3 circuit-miles) + ($38,553/circuit-mile)(109.6 circuit-miles)] / (1255.3 circuit-miles + 109.6 circuit-miles)

Annual Overhead Transmission O&M Cost per circuit-mile ≈ $29,636 per circuit-mile

Costs of Electrical Losses

Electric transmission line losses represent power lost as heat due to the resistance of the conductors. Power loss is proportional to the resistance of the conductors and proportional to the square of the current. Since line currents vary over time in response to changing load conditions, power losses also vary over time. To convert average power loss to energy consumption (per year) and compute the cost of energy (due to losses) per year, additional data has been provided by Eversource and UI.

Eversource estimates that loads (and therefore currents) would decline by about 0.07 percent per year during the life-cycle study period.[22] A standard peak line current of 1,000 amps was assumed.[23] A loss factor of approximately 0.31 was applied to estimate the ratio of the average losses to peak losses, so that the average power losses can be estimated.[24] Energy costs were estimated to be about $100 per megawatt-hour, or 10 cents per kilowatt-hour, at the beginning of the study period.[25] Energy costs were estimated to remain unchanged per year over the study period.[26] Eversource electrical loss cost data is below.

[21] UI Response 8.
[22] *Id.*
[23] Eversource Responses 3 and 4.
[24] *Id.*; Eversource Response 7 (Based on data from ISO-NE.)
[25] *Id.*
[26] *Id.*

Typical Overhead - Electrical, Loss and Cost Assumptions				
Value	**115-kV H Frame - Wood or WPE Steel**	**115-kV Delta - Steel Monopole**	**345-kV H Frame - Wood or WPE Steel**	**345-kV Delta - Steel Monopole**
Conductor Size & Type - 1 conductor per phase for 115kV / 2 conductors per phase for 345kV	1272 kcmil ACSS 54/19 Pheasant	1272 kcmil ACSS 54/19 Pheasant	2 conductor x 1590 kcmil ACSS 54-19 Falcon	2 conductor x 1590 kcmil ACSS 54-19 Falcon
Resistance (ohms / mile)	0.0741	0.0741	0.0602	0.0602
Peak Line Current (first year)	1000	1000	1000	1000
Load Growth	-0.07%	-0.07%	-0.07%	-0.07%
Loss Factor	0.310	0.310	0.310	0.310
Energy Cost ($/MWH)	$100	$100	$100	$100
Energy Cost Escalation	-0%	-0%	-0%	-0%

UI estimates that loads would increase by about 0.61 percent per year during the life cycle study period.[27] A standard peak line current of 2,148 amps was assumed.[28] A loss factor of approximately 0.35 was applied to estimate the ratio of the average losses to peak losses, so that the average power losses can be estimated.[29] Energy costs were estimated to be about $45 per megawatt-hour, or 4.5 cents per kilowatt-hour at the beginning of the study period.[30] Energy costs were estimated to decline by 0.29 percent per year over the study period.[31] UI electrical loss cost data is below.

	Losses
Conductor Size & Type	1590 ACSS
Resistance	.0622 ohm/mile
Peak Line Current	2148 A (428 MVA)
Load Growth	.61%
Loss Factor	.35
Energy Cost	44.66 $/MWh
Energy Cost Escalation	-0.29%

[27] UI Responses 3, 4 and 7 (Based on actual construction costs of single circuit vertical steel pole configuration using 1590 ACSS conductor along MetroNorth Railroad ROW.)
[28] Eversource Responses 3 and 4.
[29] *Id.*
[30] *Id.*
[31] *Id.*

See Appendix A for a breakdown on electrical loss costs for different overhead transmission configurations.

2. 115-kV and 345-kV Underground Transmission Lines

First Costs

The estimated useful life of an underground electric transmission line is 40 years.[32] Like overhead transmission lines, the costs in each first cost category for underground transmission lines vary depending on the underground transmission line configuration.

Underground transmission line configurations are generally defined by voltage and cable type (pipe or solid cable). Installed within duct banks, underground transmission lines require splice vaults at regular intervals along the route and transition stations wherever the underground cable connects to overhead transmission.

High pressure fluid-filled (HPFF) underground transmission lines consist of three insulated conductors that are installed within a steel pipe. Cross-linked polyethylene (XLPE) underground transmission lines consist of three solid cables that are buried side-by-side in concrete ducts. See Figures 3 and 4.

XLPE lines are the current standard technology for underground transmission lines, replacing HPFF lines due in part to environmental, constructability and maintenance factors.[33]

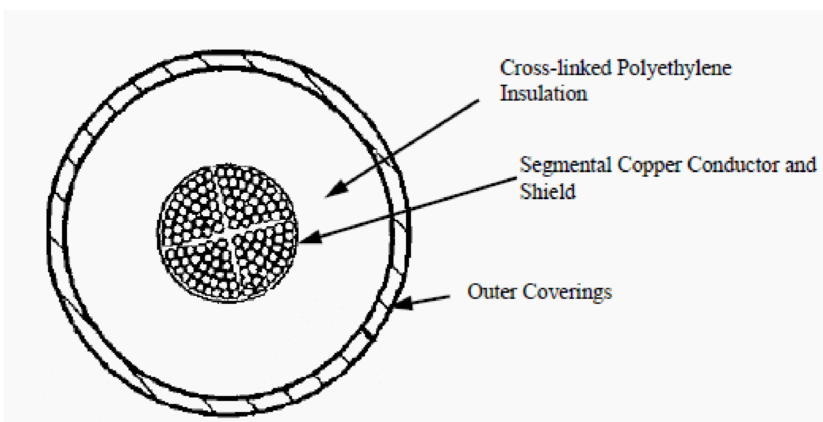

Figure 3 - XLPE Cable cross-section.

[32] Eversource Response 17; UI Response 17.
[33] Eversource Responses 11 and 12; UI Responses 11, 12 and 19.

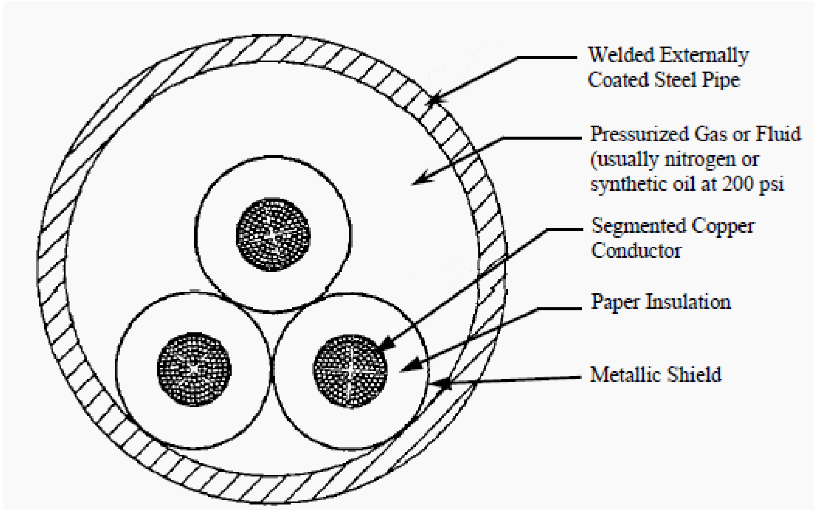

Figure 4 - HPFF (or High Pressure Gas-Filled) Pipe cross-section.

In general, there are four common underground transmission line configurations in Connecticut for which data is readily available:

a. 115-kV cross-linked polyethylene (XLPE);
b. 115-kV high-pressure fluid-filled (HPFF);
c. 345-kV XLPE; and
d. 345-kV HPFF.[34]

First costs provided by Eversource for new single-circuit underground lines on a $/mile basis are as follows:[35]

Eversource Energy - Typical UG Transmission Types Life-Cycle Cost Components - Estimated Underground Construction Costs/ Typical Mile				
First Costs	**XLPE 115-kV**	**HPFF 115-kV**	**XLPE 345-kV**	**HPFF 345-kV**
	Single Circuit	Single Circuit	Single Circuit	Single Circuit
Ducts & Vaults	$6,325,268	$5,831,008	$6,564,081	$5,813,944
Cable & Hardware	$4,907,153	$5,231,053	$6,298,925	$6,573,099
Site Work	$2,322,881	$2,327,613	$2,296,640	$2,320,,802
Construction	$4,414,236	$3,677,883	$4,691,790	$3,735,001
Engineering	$1,750,256	$1,666,245	$1,939,625	$1,800,084
Sales Tax (X %)	$0	$0	$0	$0
Project Management	$1,120,706	$1,006,499	$1,232,438	$1,075,170
Totals	**$20,840,500**	**$19,740,301**	**$23,023,499**	**$21,318,100**

[34] Eversource Response 11, UI Response 11.
[35] Eversource Responses 13 and 14.

Since LCA 2017, UI has not constructed any 115-kV XLPE, 115-kV HPFF, 345-kV XLPE or 345-kV HPFF transmission lines.[36]

Operations and Maintenance Costs

O&M costs for underground transmission lines are also provided by utilities in the FERC Form 1 and are listed below for Eversource and UI:[37]

Eversource Energy Operation & Maintenance Costs

CT Only - FERC Form 1, years 2017-2021

	O&M Cost Per Circuit Mile - Underground Transmission					
560 / 568	Supervision Costs (line 1+4)	5,915,669	7,116,466	7,527,130	10,004,566	6,487,249
	% of Underground to Total (line 10)	8.58%	8.54%	8.54%	8.94%	8.93%
	Supervision % allocated to Underground	507,840	607,679	642,535	894,413	579,498
564 / 572	Direct Underground Costs (line 3+6)	1,506,782	1,434,554	1,690,373	2,259,850	1,979,546
	Total Underground Costs	2,014,622	2,042,233	2,332,908	3,154,263	2,559,044
	Underground Circuit Miles (line 8)	117.19	117.19	117.19	123.53	123.53
	O&M Costs - Underground Trans.Per Circuit Mile	$17,191	$17,427	$19,907	$25,534	$20,716
		34.88%	1.37%	14.23%	28.27%	-18.87%
					5 year O&M Cost Average - UG	$20,155

UI Operation & Maintenance Costs:

	2017	2018	2019	2020	2021
Costs per circuit mile for O&M of UI's existing underground transmission lines of 28.8 miles	$41,641	$42,945	$40,854	$36,679	$10,387

Based on data from 2017 through 2021, Eversource estimates that the 5-year O&M cost average for underground transmission in its service area is approximately $20,155 per circuit-mile. Based on data from 2017 through 2021, UI estimates that the 5-year O&M cost average for underground transmission in its service area is approximately $34,501. Given that Eversource has significantly greater circuit-mileage than UI, the Council uses a weighted average rather than a simple average to determine an overall O&M cost average per circuit-mile. UI's underground circuit mileage (as of July 2022) was approximately 28.8 circuit-miles.[38] Over the five year time period, Eversource's underground circuit mileage ranged from 117.19 circuit-miles to 123.53 circuit-miles for an average of about 119.73 circuit-miles.[39] Thus, the approximate weighted average O&M cost for an underground transmission line is computed as follows:

[36] UI Responses 13 and 14.
[37] Eversource Responses 8, 13, 14 and 18; UI Responses 13, 14 and 18.
[38] UI Response 18.
[39] Eversource Responses 8 and 18.

Annual O&M Cost per Circuit-mile = [($20,155/circuit-mile)(119.73 circuit-miles) + ($34,501/circuit-mile)(28.8 circuit-miles)] / (119.73 circuit-miles + 28.8 circuit-miles)

Annual Underground Transmission O&M Cost per Circuit-mile ≈ $22,937 per circuit-mile

Costs of Electrical Losses

The assumptions and method of calculation regarding losses are similar for both underground and overhead transmission lines. The only material difference is the resistance in ohms per mile for the various underground cables versus the overhead conductors. All else being equal, electrical loss costs increase as the resistance increases.

Eversource estimates that loads (and therefore currents) would decline by about 0.70 percent per year during the life-cycle study period.[40] A standard peak line current of 1,000 amps was assumed.[41] A loss factor of approximately 0.31 was applied to estimate the ratio of the average losses to peak losses, so that the average power losses can be estimated.[42] Energy costs were estimated to be about $100 per megawatt-hour, or 10 cents per kilowatt-hour at the beginning of the study period.[43] Energy costs were estimated to remain unchanged per year over the study period.[44] Eversource electrical loss cost data is below.

Typical Underground - Electrical, Loss and Cost Assumptions				
Value	**XLPE 115-kV**	**HPFF 115-kV**	**XLPE 345-kV**	**HPFF 345-kV**
Cable Size & Type - 1 conductor per phase	3000 kcmil XLPE	2500 kcmil HPFF	3000 kcmil XLPE	2500 kcmil HPFF
Resistance	0.0268	0.0317	0.0268	0.0317
Peak Line Current	1000	1000	1000	1000
Load Growth	-0.70%	-0.70%	-0.70%	-0.70%
Loss Factor	0.3100	0.3100	0.3100	0.3100
Energy Cost	$100	$100	$100	$100
Energy Cost Escalation	-0%	-0%	-0%	-0%

See Appendix A for a breakdown on loss costs for different underground transmission configurations.

B. Costs of Relative Reliability

The Federal Energy Policy Act of 2005 required FERC to designate an Electric Reliability Organization (ERO) to develop and enforce a system of mandatory reliability standards for planning and operations of the bulk power electric system. "Bulk power system" means the facilities and control systems necessary for operating an interconnected electric energy transmission network, or any portion thereof, and electric energy from generation facilities needed to maintain transmission reliability. FERC designated the North American Electric Reliability Corporation, Inc. (NERC) as ERO. Under federal law, compliance with the

[40] Eversource Responses 13 and 14.
[41] *Id.*
[42] *Id.*; Eversource Response 16.
[43] *Id.*
[44] *Id.*

mandatory reliability standards is mandatory and violations are punished by fines. NERC is charged with improving the reliability of the bulk power electric system in four regional networks.

ISO-NE, Inc. is the not-for-profit corporation responsible for the reliable and economical operation of the New England regional electric power system. Connecticut is part of the New England region.

1. Reliability Standards

Eversource and UI have identified the following national and regional reliability standards for overhead and underground transmission lines:[45]

a) North American Electric Reliability Corporation (NERC) TPL-001-4 Transmission Planning Performance Requirements;
b) Northeast Power Coordinating Council (NPCC) Regional Reliability Reference Directory #1 Design and Operation of the Bulk Power System;
c) Independent System Operator New England (ISO-NE) PP 03 Reliability Standards for the New England Area Pool Transmission Facilities.

For UI's service territory, Avangrid (UI's parent company) Planning Criteria is used in addition to the national and regional reliability standards for electric transmission lines.

The Council issued declaratory rulings to Eversource and UI in 2011 and 2013, respectively, for completion of all transmission remediation activities associated with NERC reliability standards.[46]

2. Security Standards

NERC issues standards governing the protection of critical electric transmission infrastructure of the bulk power system. These standards are referred to as the "Critical Infrastructure Protection Program (CIP)." CIP coordinates all of NERC's efforts to improve the North American power system's security. These efforts include standards development, compliance enforcement, assessments of risk and preparedness, dissemination of critical information and raised awareness regarding key security issues as follows:

a) CIP-002-5.1a Cyber Security – Bulk Electric Power System Cyber System Categorization;
b) CIP-003-6 Cyber Security – Security Management Controls;
c) CIP-004-6 Cyber Security – Personnel & Training;
d) CIP-005-5 Cyber Security – Electronic Security Perimeter(s);
e) CIP-006-6 Cyber Security – Physical Security of BES Cyber Systems;
f) CIP-007-6 Cyber Security – System Security Management;
g) CIP-008-5 Cyber Security – Incident Reporting and Response Planning;
h) CIP-009-6 Cyber Security – Recovery Plans for BES Cyber Systems;
i) CIP-010-2 Cyber Security – Configuration Change Management and Vulnerability Assessments;
j) CIP-011-2 Cyber Security – Information Protection; and
k) CIP-014-2 Physical Security.

In addition to NERC standards, the National Electrical Safety Code (NESC) requires signage on all transmission structures as a security standard. Eversource and UI also consider four areas of physical

[45] Eversource Response 22; UI Response 22.
[46] Petition Nos. 1000 and 1073.

security – planning, preparedness, response and recovery – identified in the Council's White Paper on the Security of Siting Energy Facilities.[47]

The Council issued a joint declaratory ruling to Eversource and UI in 2015 for completion of all transmission substation remediation activities associated with NERC's CIP.[48]

3. Transmission Vegetation Management (TVM) Standards

Eversource and UI have identified the following national vegetation management standards for overhead transmission lines:[49]

a) NERC Transmission Vegetation Management Standard FAC-003-4;
b) American National Standards Institute (ANSI) Z-133 Standards for Arboriculture Operations; and
c) ANSI A-300 – Tree Care Practices.

The NERC standard mandates management of vegetation from encroachments into a Minimum Vegetation Clearance Distance to prevent vegetation-related outages that could lead to cascading.

4. Storm Hardening

There are no known national standards for storm hardening for transmission line construction. Eversource and UI standards for storm hardening are designed in accordance with the NESC, which dictates design criteria for wind and ice loading that may occur on an overhead transmission line. UI designs overhead transmission facilities to the level of a Category III hurricane and 1.5 inches of radial ice.[50] Eversource designs overhead transmission facilities in accordance with the following:[51]

a. Rule 250B Grade B Heavy Loading (combined ice and wind);
b. Rule 250C Extreme Wind Loading (100-120 mph based on wind region); and
c. Rule 250D Extreme Ice with Concurrent Wind Loading.

Underground transmission generally does not have "structures" to "storm harden" except, for example, transition structures that convert overhead transmission to underground transmission or vice versa.

5. NESC and Building Codes

NESC is a national standard for the practical safeguarding of persons, utility facilities, and affected property during the installation, operation, and maintenance of electric supply facilities, under specified conditions. The 2017 NESC is the most current edition. In the context of overhead electric transmission lines, among other considerations, NESC standards govern the spacing of conductors and clearances under conductors, which can affect structure heights.[52] In the context of underground electric transmission lines, among other considerations, NESC standards govern the spacing of cables and burial depths.

[47] https://portal.ct.gov/-/media/CSC/1_Dockets-medialibrary/Docket_346/whiteypprFINAL20091009114810pdf.pdf
[48] Petition No. 1157.
[49] Eversource Response 22; UI Response 22 (UI also uses its own Transmission Vegetative Management Program)
[50] UI Response 22.
[51] Eversource Response 22.
[52] The Council issued a declaratory ruling to Eversource in 2017 to complete all transmission facility asset condition maintenance improvements associated with the updated NESC clearance requirements. (Petition No. 1293).

Structural design considerations for overhead transmission structures, include, but are not limited to, utility-specific wind and ice load design criteria, and American Society of Civil Engineers (ASCE) standards. For electric transmission line structures with a collocated wireless telecommunications facility, TIA-222 "Structural Standards for Antenna Supporting Structures and Antennas" Version H would also apply. Neither Eversource nor UI have a telecommunications antenna attachment policy for overhead transmission line structures; however, Eversource has an evaluation process for telecommunications collocations on its structures to verify compliance with applicable standards and ensure collocation does not pose a risk to transmission system operation or maintenance.[53]

The Connecticut State Building Code (CSBC) is not applicable to electric transmission line construction. Based on all applicable code considerations, the lines must be designed to the controlling standard.

C. Costs of Access and Construction Constraints

The costs of acquiring temporary or permanent access easements is negotiated between the utility and the adjacent property owners. While it may be preferable to utilize existing utility property or ROW to the extent feasible, acquiring a new easement or additional easement is both an engineering and business decision. Costs to obtain permits are included in the engineering costs of construction.[54]

1. Connecticut Department of Transportation (DOT) permits

Construction within state highway ROW generally requires a DOT Encroachment Permit. To the extent that the underground duct banks are to be located within state highway ROW, the burial depth of such underground transmission duct banks must be reviewed for compliance with the Connecticut Department of Transportation Utility Accommodation Manual.

2. United States Army Corps of Engineers (USACE) permits

The following USACE permits may be required for various types of transmission projects:[55]

a) USACE 404 permit for dredge and fill activities (wetlands and watercourses);
b) USACE 10 permit for work in navigable waterways;
c) USACE 408 permit for altering federal land public works projects, such as dams/levees;
d) USACE Self-Verification Form (SVF) for impacts to resource areas outlined under impact-specific General Permit(s) within Connecticut Programmatic General Permit;
e) USACE Pre-Construction Notification (PCN) for impacts to resource areas outlined under impact-specific General Permit(s) within Connecticut Programmatic General Permit; and
f) USACE Individual Permit for large-scale impacts not covered under SVF or PCN General Permits in Connecticut Programmatic General Permit.

3. Connecticut Department of Energy and Environmental Protection (DEEP) permits

The following DEEP permits may be required for various types of transmission projects:[56]

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[53] Eversource Response 34; UI Response 34.
[54] Eversource Response 24; UI Response 24.
[55] *Id.*
[56] *Id.*

a) Natural Diversity Database (NDDB) Project review for potential impacts to state-designated Threatened Species, Endangered Species or Species of Special Concern;
b) Section 401 Water Quality Certification (related to inland impacts and filters up to USACE SVF or PCN);
c) Registration under DEEP General Permit and submission of Stormwater Pollution Control Plan for projects with a construction disturbance area of greater than one acre;
d) Coastal Zone Consistency Review; and
e) Certification of Structures and Dredging Permit for coastal zone or tidally influenced areas from Office of Long Island Sound Programs.

4. United States Fish & Wildlife Service (USFWS) permit

Applicants may utilize the USFWS Information for Planning and Consultation (IPaC) tool to determine if any federally-listed species, critical habitat, migratory birds or cultural resources may be impacted by a proposed project. Connecticut is within the range of the northern long-eared bat (NLEB), a federally-listed Threatened Species and State-listed Endangered Species. The submission of a NLEB Review Form to the USFWS is required for projects that would potentially impact NLEB hibernacula and roosting trees.[57]

5. **Legal Costs**

Under CGS §16-50z, a person engaged in transmission of electric power in the state may acquire real property, and exercise any right of eminent domain, for:

a. Relocation of a transmission facility or ROW required by a public highway project or other governmental action;
b. Acquisition of additional rights or title to property already subject to an easement or other rights for electric transmission lines; or
c. Widening a portion, not exceeding one mile in length, of a transmission ROW for reasons of safety or convenience of the public.

Under CGS § 4-183, a person who has exhausted all administrative remedies available within an administrative agency by participating as a party or intervenor in the proceedings held on a matter and who is aggrieved by a final decision of the Council may appeal to Superior Court. A Council decision to grant or deny a Certificate of Environmental Compatibility and Public Need for a new transmission line or a Declaratory Ruling for a modified/rebuilt transmission line is appealable. An appeal must be filed with the court within 45 days after the mailing of the Council's final decision.

D. Costs of Potential Impacts to the Environment

Eversource and UI employ Best Management Practices in environmental resource areas.[58] UI has experienced higher costs with soil management, such as installing monopoles within areas where there is a protective environmental cap, and ecological sensitivities, such as blocking out windows of time when construction activities are limited or prohibited to avoid impacts to species.[59] Eversource has experienced higher costs that are summarized as follows:[60]

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[57] Eversource Response 24; UI Response 24.
[58] Eversource 27; UI Response 27.
[59] UI Response 27.
[60] Eversource Response 27.

- $90/linear foot for installation of construction matting for access roads
- $54k per work pad for installation and removal of construction matting for work pads
- $8/linear foot for installation of stormwater management features
- $8,400 per pipe installed for culverts
- $30,000/mile for site restoration

1. **Wildlife Habitat**

Tree clearing, the use of construction vehicles, and project development may be disruptive to certain wildlife habit and/or result in the incidental take of certain state or federally-listed species. As previously discussed above, consultation with DEEP and USFWS may be required. To the extent that known state or federally-listed species are located within a project area, a species-specific protection plan would be developed and may include, but not be limited to, third party environmental inspector(s), contractor education regarding the species, seasonal restrictions on tree clearing and/or other construction activities, and measures to isolate the construction area to prevent such species from entering.

2. Wetlands and Watercourses

In the design of a new transmission line, wetland and watercourse locations are an important consideration when selecting the locations of transmission structures and associated access roads. While utilities generally seek to avoid placing new structures in wetland locations when feasible, sometimes wetland and watercourse areas cannot be avoided due to limitations in the span (i.e. distance between structures), structural/design considerations that require turning structures or dead-end structures in certain locations and ROW constraints. In such situations, direct wetland and watercourse impacts may not be avoidable, but are minimized in area and subject to appropriate permitting requirements.

Underground transmission involves buried duct banks and splice vaults that could span many feet in length. Thus, an underground facility, depending on its specific route and location, could potentially have more wetland or watercourse impact area than multiple smaller excavations for overhead transmission structure foundations. Such potential impacts are considered in the engineering phase and mitigated as necessary.

Access to overhead transmission structures may require wetland and watercourse crossings. Temporary crossings typically utilize wood matting, known as “swamp mats,” and temporary culverts to reduce impacts to wetlands and watercourses during construction. While temporary impacts to wetlands and watercourses may result from construction, the intent is to prevent and/or minimize permanent impacts to soils, drainage patterns and vegetation.

Proper erosion and sedimentation controls consistent with the 2002 Connecticut Guidelines for Erosion and Sedimentation Control are required to isolate construction areas and minimize the risk of downstream flow of silt into wetland and watercourse areas.

3. Leaks and Spills

Leaks and spills are not applicable to overhead transmission lines. Overhead transmission generally uses the air around the conductors for cooling purposes, and thus, it does not require a dielectric fluid, used as an electrical coolant, like certain underground transmission lines, i.e. HPFF.

HPFF lines have to be properly designed and monitored to minimize the potential leakage of dielectric fluid. Measures to prevent leaks include corrosion coating of the pipe, testing of the coating and backfilling around the pipes.[61] A cathodic protection system is also employed to protect the pipe. Measures to reduce fluid loss consist of containment volumes designed into foundations, pressure gauges and alarms to detect low fluid pressure or frequently operating pumps that might indicate a leak in the system and installation of motor-operated valves and stop-joints to isolate appropriate portions of the system.[62] In addition to these measures employed by both Connecticut utilities, UI continuously monitors HPFF systems by a Supervisory Control and Data Acquisition (SCADA) system.[63]

Solid dielectric cables such as XLPE do not have a fluid for cooling purposes, so there is no risk of leaks.

To protect against fuel spills or oil leakage from construction or maintenance vehicles, a DEEP Stormwater Pollution Control Plan (SWPCP), if required, incorporates best management practices to protect against accidental petroleum-based spills. If a SWPCP is not required for a project, a spill prevention plan serves to minimize such risks.

4. Vegetation

On and off-ROW vegetation has the propensity to cause overhead transmission line outages. FERC's Report on Transmission Facility Outages During the Northeast Snowstorm of October 29-30, 2011 made the following Vegetation Management Recommendations:

- Utilities should take targeted steps to address off ROW danger trees;
- Utilities should employ recognized best practices in managing ROWs;
- Utilities should establish vegetation management when establishing new ROWs;
- Utilities should evaluate and enhance their storm preparedness and response plans; and
- Utilities should report all vegetation-caused bulk electric system outages to NERC.

See Figure 5.

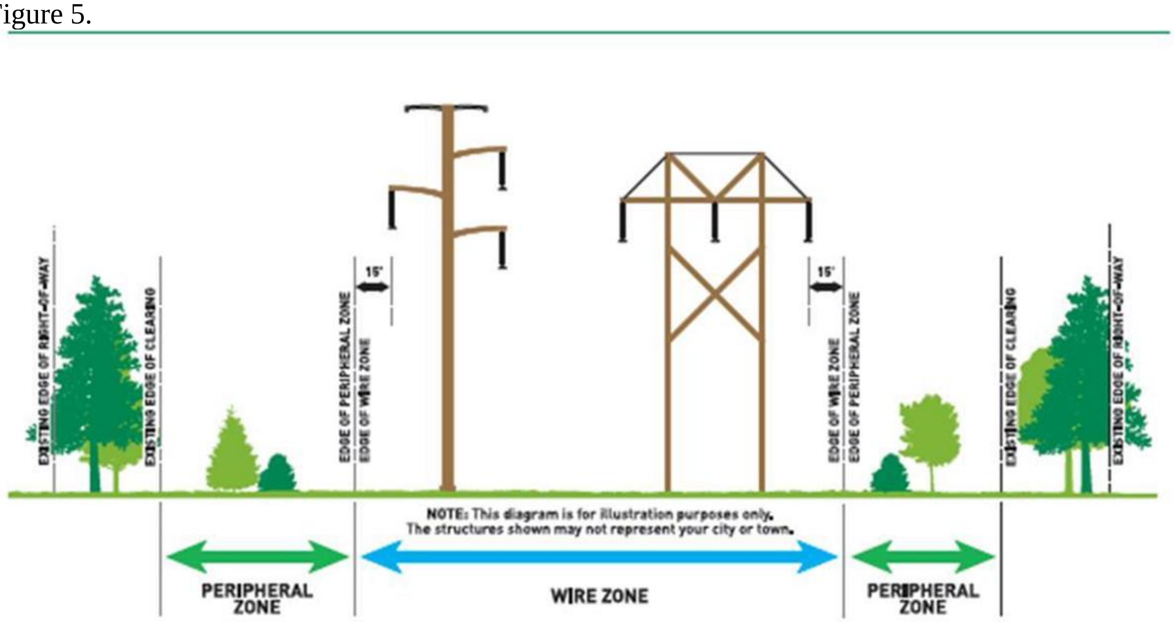

Figure 5 – FERC Vegetation Management Recommendations

[61] Eversource Response 26.
[62] *Id.*
[63] UI Response 26.

Vegetative maintenance could result in visual impacts, and depending on the location of the vegetative maintenance and seasonal timing of such activities, there may also be impacts to habitat of state or federally-listed wildlife species that would have to be considered and mitigated. Vegetative maintenance can also increase the risk of the spread of invasive species. An invasive species mitigation plan may be required particularly to protect sensitive areas, such as wetlands and watercourses.

The nature of the vegetative maintenance is also an important consideration in electric transmission projects. For example, in some areas, it may be possible to cut existing vegetation short and convert the maintained area to a “scrub-shrub” habitat as opposed to full vegetative clearing to ground level. Full vegetative clearing is disruptive to wildlife and susceptible to the risk of spread of invasive species while scrub-shrub habitat is low in height to minimize risk of contact with electric transmission lines and provides wildlife habitat value.

5. Visibility

Concerns regarding visual impacts of overhead transmission are typically related to the heights of overhead structures. There are also visual considerations related to the arrangement of the conductors, which can affect the perceived “width” of the structures. For example, a delta configuration would typically have a more narrow visual profile than a horizontal conductor configuration. The use of guy wires can also affect the visual profile of a transmission structure. The finish of a transmission structure, such as galvanized steel, weathering steel, wood or wood laminate, is an additional aesthetic consideration.

Concerns regarding visual impacts of underground transmission are typically related to the above-ground structures, such as transition structures that convert the underground line to overhead, or termination structures at a substation or switchyard. Visual impacts of such structures could be mitigated, for example, by limiting the height of the structures to be comparable with the heights of other adjacent overhead structures, to the extent allowable by codes.

Tree clearing to create or expand a ROW (accommodate access or construction work pads) is an important consideration in the context of visual impacts as this could result in the reduction (or elimination) of existing vegetative buffers between the transmission project and adjacent homes or sensitive visual receptors.

6. Parks, forests and recreation

Impacts to forest are typically related to tree clearing, including, but not limited to, modification of edge forest and linear perforation. In addition to visual impacts, a new transmission line that traverses a park or recreational resource area may separate or isolate portions of that resource temporarily or permanently, and potentially impact the use of such resource.

To minimize impacts to parks, forests and recreational areas, utilities apply the FERC Guidelines for the Protection of Natural, Historic, Scenic and Recreational Values in the Design and Location of Rights-of-Way and Transmission Facilities.

7. Soils

Excavation may result in encountering subsurface rock or ledge. While mechanical/pneumatic chipping is preferable, there may be projects that require controlled blasting for which a blasting plan is prepared in consultation with the state and local fire marshals. Excavation could also result in the removal and/or disturbance of contaminated soils, which are required to be handled and disposed of in accordance with state and federal regulations. Additionally, dewatering for excavation could result in having to remove potentially contaminated water from excavation holes.

Construction of a transmission line could also traverse and disturb agricultural soils.

E. Compatibility with Existing Electric Supply System

1. ISO-NE Transmission Planning (Needs and Solutions Studies)

ISO-NE administers the New England region's wholesale electricity markets and manages the comprehensive planning of the regional power system. The planning process includes the periodic preparation of a Regional System Plan (RSP) in accordance with the *Open Access Transmission Tariff* and parts of the *Transmission, Markets, and Services Tariff*, approved by FERC. RSPs meet the tariff requirements by summarizing planning activities that include the following:

a) Forecasts of annual energy use and peak loads (i.e., the demand for electricity) for a 10-year planning horizon and the need for resources (i.e., capacity);
b) Information about the amounts, locations, and characteristics of market responses (e.g., generation or demand resources or elective transmission upgrades) that can meet the defined system needs—systemwide and in specific areas; and
c) Descriptions of transmission projects for the region that meet the identified needs, as summarized in an RSP Project List, which includes information on project status and cost estimates and is updated several times each year.

ISO-NE's RSP Project List updates include cost and other information on the following:

a) Transmission solutions in response to the needs identified in the RSP, a needs assessment, or a study of transmission need related to public policy requirements;
b) Elective transmission upgrades, which are transmission projects proposed and funded by private developers; and
c) Generator interconnection upgrades, which are transmission projects required to accommodate new generators.

ISO-NE also has an Asset Condition List, which includes cost and other information on the upgrades or replacements of existing transmission facilities identified by the facility owner.

ISO-NE's Planning Advisory Committee is an open stakeholder forum that provides input and feedback to ISO-NE on the regional system planning process, which involves the following:

a) Developing and reviewing needs assessments;
b) Identifying and prioritizing requests for economic studies to be performed by ISO-NE;
c) Developing solutions studies and competitive solutions;
d) Conducting the public-policy transmission study process; and
e) Developing the RSP and updates to RSP Project List and Asset Condition List.

ISO-NE's Reliability Committee advises on the design and oversight of reliability standards for the New England regional power system.

2. Comparison to other New England utilities

The line voltages of 115-kV and 345-kV used in Connecticut are compatible and consistent with transmission lines across New England. Utilities in the New England region are under the same regional ISO-NE grid and are subject to ISO-NE, NERC, NPCC, and NESC standards, which ensures compatibility. Furthermore, the New England region is part of the "Eastern Interconnection," a larger unified electric power grid that spans from the Rocky Mountains to the East Coast and Canadian Maritimes. New England has 13 interconnections to neighboring electric grids in New York, Quebec and New Brunswick.

3. New large generator interconnections

For interconnection purposes, ISO-NE considers a "large generator" to be greater than 20 megawatts (MW) in capacity. To interconnect a new "large generator" or modify an existing generator (e.g. a power up-rate), a "Large Generator Interconnection Request Form" must be filed with ISO-NE for review and approval.

II. CONCLUSION

Pursuant to CGS §16-50r(b), the Council investigated the life-cycle costs of overhead and underground electric transmission line facilities in Connecticut and held a public comment session on October 19, 2022 at 6:30 p.m. for the convenience of the public. No comments were received at the public comment session.

The estimated first costs (to design, permit and build a line) for the various single-circuit transmission configurations are noted below:

a) 115-kV H-frame - $4,940,500 per mile
b) 115-kV Delta - $4,334,499 per mile
c) 345-kV H-frame - $6,181,801 per mile
d) 345-kV Delta - $6,616,700 per mile
e) 115-kV XLPE - $20,840,500 per mile
f) 115-kV HPFF - $19,740,301 per mile
g) 345-kV XLPE - $23,023,499 per mile
h) 345-kV HPFF - $21,318,100 per mile

An estimated initial weighted average O&M cost of $29,636 per circuit-mile for overhead transmission and $22,937 per circuit-mile for underground transmission was determined by the Council based on the utility data. With an estimated O&M cost escalation compound annual growth rate of about 2 percent, the O&M costs across the 40-year life-cycle study period for these various overhead and underground configurations were determined and are shown in Appendix A.

With an estimated initial energy cost of $100 per MWh (remaining flat for the study period) and loads declining by 0.07 percent and 0.7 percent per year for overhead and underground configurations, respectively, as well as the conductor resistances in ohms per mile and estimated loss factor of 0.31, the cost of electrical losses over the 40-year study period were also determined and are shown in Appendix A for the various transmission configurations.

With the three major components of first costs, O&M costs and electrical energy loss costs (and a discount rate of eight percent), the total net present value (NPV) life-cycle costs (LCCs) for the eight single-circuit transmission configurations over a 40-year study period are listed below:

a) 115-kV H-frame - $7,765,161 per mile
b) 115-kV Delta - $6,955,090 per mile
c) 345-kV H-frame - $9,003,855 per mile
d) 345-kV Delta - $9,585,206 per mile
e) 115-kV XLPE - $28,431,950 per mile
f) 115-kV HPFF - $27,002,057 per mile
g) 345-kV XLPE - $31,350,072 per mile
h) 345-kV HPFF - $29,111,178 per mile

Eversource single-circuit Transmission Line Life-Cycle Costs per circuit mile:

	First Costs	**O&M Costs[64] (initial value per year)**	**Electrical Loss Costs[65] (initial value per year)**	**Total - Net Present Value**
115-kV horizontal H-frame	$4,940,500	$28,857	$60,368	$7,753,271
115-kV delta monopole	$4,334,499	$28,857	$60,368	$6,943,199
345-kV horizontal H-frame	$6,181,801	$28,857	$24,522	$8,991,964
345-kV delta monopole	$6,616,700	$28,857	$24,522	$9,573,315
115-kV XLPE	$20,840,500	$20,155	$21,833	$28,389,467

[64] These are Eversource-specific O&M costs, not weighted average.
[65] These are based on Eversource-specific loss data.

115-kV HPFF	$19,740,301	$20,155	$25,825	$26,959,574
345-kV XLPE	$23,023,499	$20,155	$21,833	$31,307,589
345-kV HPFF	$21,318,100	$20,155	$25,825	$29,068,696

See Appendix A.

UI single-circuit Overhead Transmission Line Life-Cycle Costs per circuit mile:

	First Cost	**O&M Cost[66] (initial value per year)**	**Electrical Loss Cost[67] (initial value per year)**	**Total - Net Present Value**
115-kV vertical monopole	$10,819,493	$38,553	$117,888	$16,036,641

See Appendix B.

Eversource and UI identified the following policies and/or methods that could be implemented to reduce or offset life-cycle costs of overhead and underground electric transmission line facilities:[68]

- Design considerations, such as span length optimization;
- Material installations with less associated O&M costs, such as light duty steel, composite, etc.;
- Maximize the service life of transmission equipment for long-term forecasts (20-30 years);
- Use of technologies for inspections that would reduce the need for outages, such as drones;
- Minimize acquisitions and associated costs of additional ROW by use of existing utility and other linear corridors;
- Optimize line designs in consideration of capital costs and use of ROW space; and
- Engage in competitive bidding processes and long-term contracts, including prequalification of vendors and index-based pricing.

66 These are UI-specific O&M costs, not weighted average.
67 These are based on UI-specific loss data.
68 Eversource Response 33; UI Response 33.

Appendix A – Life Cycle Cost Breakdown – 115-kV H-frame

First Costs			**Losses**			**O&M**		
Poles & Foundations	1098718	Dollars	Conductor	1272 ACSS	54/19 Pheasant	Annual Cost per mile	29636	$/mi-year
Conductor & Hardware	374464	Dollars	Resistance	0.0741	ohm/mi	O&M Cost Escalation	0.02	decimal CAGR
Site Work	855333	Dollars	Peak Line Current	1000	amps			
Construction	1954208	Dollars	Load Growth	-0.0007	decimal CAGR			
Engineering	353586	Dollars	Loss Factor	0.31	dimensionless			
Sales Tax	0	Dollars	Energy Cost	100	$/MWh			
Project Management	304191	Dollars	Energy Cost Escalation	0	decimal CAGR			
Capital Recovery Factor	0.1121	dimensionless						
Year	**Carrying Costs**	**Losses**	**O&M**	**PV Factor**	**PV FC**	**PV O&M**	**PV Losses**	**PV Cost**
0								
1	553830	60283	30228	0.925925926	512806	27989	55818	596613
2	553830	60199	30833	0.85733882	474820	26434	51611	552865
3	553830	60115	31450	0.793832241	439648	24966	47721	512335
4	553830	60031	32079	0.735029853	407082	23579	44124	474785
5	553830	59947	32720	0.680583197	376927	22269	40799	439995
6	553830	59863	33374	0.630169627	349007	21032	37724	407762
7	553830	59779	34042	0.583490395	323155	19863	34880	377898
8	553830	59695	34723	0.540268885	299217	18760	32251	350228
9	553830	59612	35417	0.500248967	277053	17717	29821	324591
10	553830	59528	36126	0.463193488	256530	16733	27573	300837
11	553830	59445	36848	0.428882859	237528	15804	25495	278827
12	553830	59362	37585	0.397113759	219934	14926	23573	258432
13	553830	59279	38337	0.367697925	203642	14096	21797	239535
14	553830	59196	39104	0.340461041	188558	13313	20154	222025
15	553830	59113	39886	0.315241705	174590	12574	18635	205799
16	553830	59030	40683	0.291890468	161658	11875	17230	190763
17	553830	58948	41497	0.270268951	149683	11215	15932	176830
18	553830	58865	42327	0.250249029	138595	10592	14731	163919
19	553830	58783	43173	0.231712064	128329	10004	13621	151954
20	553830	58700	44037	0.214548207	118823	9448	12594	140865
21	553830	58618	44918	0.198655748	110022	8923	11645	130590
22	553830	58536	45816	0.183940507	101872	8427	10767	121066
23	553830	58454	46732	0.170315284	94326	7959	9956	112241
24	553830	58372	47667	0.157699337	87339	7517	9205	104061
25	553830	58291	48620	0.146017905	80869	7099	8511	96480
26	553830	58209	49593	0.135201764	74879	6705	7870	89454
27	553830	58128	50585	0.125186818	69332	6333	7277	82942
28	553830	58046	51596	0.115913721	64197	5981	6728	76906
29	553830	57965	52628	0.107327519	59441	5648	6221	71311
30	553830	57884	53681	0.099377333	55038	5335	5752	66125
31	553830	57803	54754	0.092016049	50961	5038	5319	61318
32	553830	57722	55849	0.085200045	47186	4758	4918	56863
33	553830	57641	56966	0.078888931	43691	4494	4547	52732
34	553830	57561	58106	0.073045306	40455	4244	4205	48904
35	553830	57480	59268	0.067634543	37458	4009	3888	45354
36	553830	57400	60453	0.062624577	34683	3786	3595	42064
37	553830	57319	61662	0.057985719	32114	3576	3324	39013
38	553830	57239	62896	0.053690481	29735	3377	3073	36185
39	553830	57159	64153	0.049713408	27533	3189	2842	33564
40	553830	57079	65437	0.046030933	25493	3012	2627	31133
				LCC Total	7765161			

Appendix A – Life Cycle Cost Breakdown – 115-kV Delta

First Costs			Losses			O&M		
Poles & Foundations	1025312	Dollars	Conductor	1272 ACSS	54/19 Pheasant	Annual Cost per mile	29636	$/mi-year
Conductor & Hardware	343670	Dollars	Resistance	0.0741	ohm/mi	O&M Cost Escalation	0.02	decimal CAGR
Site Work	796971	Dollars	Peak Line Current	1000	amps			
Construction	1563719	Dollars	Load Growth	-0.0007	decimal CAGR			
Engineering	330756	Dollars	Loss Factor	0.31	dimensionless			
Sales Tax	0	Dollars	Energy Cost	100	$/MWh			
Project Management	274071	Dollars	Energy Cost Escalation	0	decimal CAGR			
Capital Recovery Factor	0.1121	dimensionless						
Year	**Carrying Costs**	**Losses**	**O&M**	**PV Factor**	**PV FC**	**PV O&M**	**PV Losses**	**PV Cost**
0								
1	485897	60283	30228	0.9259259	449905	27989	55818	533712
2	485897	60199	30833	0.8573388	416579	26434	51611	494624
3	485897	60115	31450	0.7938322	385721	24966	47721	458408
4	485897	60031	32079	0.7350299	357149	23579	44124	424852
5	485897	59947	32720	0.6805832	330694	22269	40799	393761
6	485897	59863	33374	0.6301696	306198	21032	37724	364953
7	485897	59779	34042	0.5834904	283516	19863	34880	338260
8	485897	59695	34723	0.5402689	262515	18760	32251	313526
9	485897	59612	35417	0.500249	243070	17717	29821	290608
10	485897	59528	36126	0.4631935	225064	16733	27573	269371
11	485897	59445	36848	0.4288829	208393	15804	25495	249691
12	485897	59362	37585	0.3971138	192957	14926	23573	231455
13	485897	59279	38337	0.3676979	178663	14096	21797	214556
14	485897	59196	39104	0.340461	165429	13313	20154	198896
15	485897	59113	39886	0.3152417	153175	12574	18635	184384
16	485897	59030	40683	0.2918905	141829	11875	17230	170934
17	485897	58948	41497	0.270269	131323	11215	15932	158470
18	485897	58865	42327	0.250249	121595	10592	14731	146919
19	485897	58783	43173	0.2317121	112588	10004	13621	136213
20	485897	58700	44037	0.2145482	104248	9448	12594	126290
21	485897	58618	44918	0.1986557	96526	8923	11645	117094
22	485897	58536	45816	0.1839405	89376	8427	10767	108571
23	485897	58454	46732	0.1703153	82756	7959	9956	100671
24	485897	58372	47667	0.1576993	76626	7517	9205	93348
25	485897	58291	48620	0.1460179	70950	7099	8511	86561
26	485897	58209	49593	0.1352018	65694	6705	7870	80269
27	485897	58128	50585	0.1251868	60828	6333	7277	74437
28	485897	58046	51596	0.1159137	56322	5981	6728	69031
29	485897	57965	52628	0.1073275	52150	5648	6221	64020
30	485897	57884	53681	0.0993773	48287	5335	5752	59374
31	485897	57803	54754	0.092016	44710	5038	5319	55067
32	485897	57722	55849	0.0852	41398	4758	4918	51075
33	485897	57641	56966	0.0788889	38332	4494	4547	47373
34	485897	57561	58106	0.0730453	35493	4244	4205	43941
35	485897	57480	59268	0.0676345	32863	4009	3888	40760
36	485897	57400	60453	0.0626246	30429	3786	3595	37810
37	485897	57319	61662	0.0579857	28175	3576	3324	35074
38	485897	57239	62896	0.0536905	26088	3377	3073	32538
39	485897	57159	64153	0.0497134	24156	3189	2842	30186
40	485897	57079	65437	0.0460309	22366	3012	2627	28006
				LCC Total	6955090			

Appendix A – Life Cycle Cost Breakdown – 345-kV H-frame

First Costs			**Losses**			**O&M**		
Poles & Foundations	1314095	Dollars	Conductor	1590 ACSS	54/19 Falcon x2	Annual Cost per mile	29636	$/mi-year
Conductor & Hardware	663053	Dollars	Resistance	0.0301	ohm/mi	O&M Cost Escalation	0.02	decimal CAGR
Site Work	974944	Dollars	Peak Line Current	1000	amps			
Construction	2365318	Dollars	Load Growth	-0.0007	decimal CAGR			
Engineering	499710	Dollars	Loss Factor	0.31	dimensionless			
Sales Tax	0	Dollars	Energy Cost	100	$/MWh			
Project Management	364681	Dollars	Energy Cost Escalation	0	decimal CAGR			
Capital Recovery Factor	0.1121	dimensionless						

Year	Carrying Costs	Losses	O&M	PV Factor	PV FC	PV O&M	PV Losses	PV Cost
0								
1	692980	24488	30228	0.92592593	641648	27989	22674	692311
2	692980	24453	30833	0.85733882	594119	26434	20965	641518
3	692980	24419	31450	0.79383224	550110	24966	19385	594460
4	692980	24385	32079	0.73502985	509361	23579	17924	550863
5	692980	24351	32720	0.6805832	471630	22269	16573	510472
6	692980	24317	33374	0.63016963	436695	21032	15324	473050
7	692980	24283	34042	0.5834904	404347	19863	14169	438379
8	692980	24249	34723	0.54026888	374395	18760	13101	406256
9	692980	24215	35417	0.50024897	346662	17717	12113	376493
10	692980	24181	36126	0.46319349	320984	16733	11200	348917
11	692980	24147	36848	0.42888286	297207	15804	10356	323367
12	692980	24113	37585	0.39711376	275192	14926	9576	299693
13	692980	24079	38337	0.36769792	254807	14096	8854	277758
14	692980	24046	39104	0.34046104	235933	13313	8187	257433
15	692980	24012	39886	0.3152417	218456	12574	7570	238599
16	692980	23978	40683	0.29189047	202274	11875	6999	221148
17	692980	23945	41497	0.27026895	187291	11215	6472	204978
18	692980	23911	42327	0.25024903	173418	10592	5984	189994
19	692980	23878	43173	0.23171206	160572	10004	5533	176108
20	692980	23845	44037	0.21454821	148678	9448	5116	163241
21	692980	23811	44918	0.19865575	137664	8923	4730	151318
22	692980	23778	45816	0.18394051	127467	8427	4374	140268
23	692980	23745	46732	0.17031528	118025	7959	4044	130028
24	692980	23711	47667	0.15769934	109282	7517	3739	120539
25	692980	23678	48620	0.1460179	101187	7099	3457	111744
26	692980	23645	49593	0.13520176	93692	6705	3197	103594
27	692980	23612	50585	0.12518682	86752	6333	2956	96040
28	692980	23579	51596	0.11591372	80326	5981	2733	89040
29	692980	23546	52628	0.10732752	74376	5648	2527	82551
30	692980	23513	53681	0.09937733	68866	5335	2337	76538
31	692980	23480	54754	0.09201605	63765	5038	2161	70964
32	692980	23447	55849	0.08520005	59042	4758	1998	65798
33	692980	23414	56966	0.07888893	54668	4494	1847	61010
34	692980	23382	58106	0.07304531	50619	4244	1708	56571
35	692980	23349	59268	0.06763454	46869	4009	1579	52457
36	692980	23316	60453	0.06262458	43398	3786	1460	48644
37	692980	23284	61662	0.05798572	40183	3576	1350	45109
38	692980	23251	62896	0.05369048	37206	3377	1248	41832
39	692980	23218	64153	0.04971341	34450	3189	1154	38794
40	692980	23186	65437	0.04603093	31899	3012	1067	35978
				LCC Total	9003855			

Appendix A – Life Cycle Cost Breakdown – 345-kV Delta

First Costs			**Losses**			**O&M**			
Poles & Foundations	1789171	Dollars	Conductor	1590 ACSS	54/19 Falcon x2	Annual Cost per mile	29636	$/mi-year	
Conductor & Hardware	627077	Dollars	Resistance	0.0301	ohm/mi	O&M Cost Escalation	0.02	decimal CAGR	
Site Work	904084	Dollars	Peak Line Current	1000	amps				
Construction	2405711	Dollars	Load Growth	-0.0007	decimal CAGR				
Engineering	505960	Dollars	Loss Factor	0.31	dimensionless				
Sales Tax	0	Dollars	Energy Cost	100	$/MWh				
Project Management	384697	Dollars	Energy Cost Escalation	0	decimal CAGR				
Capital Recovery Factor	0.1121	dimensionless							
Year	**Carrying Costs**	**Losses**	**O&M**	**PV Factor**	**PV FC**	**PV O&M**	**PV Losses**	**PV Cost**	
0									
1	741732	24488	30228	0.9259259	686789	27989	22674	737452	
2	741732	24453	30833	0.8573388	635916	26434	20965	683315	
3	741732	24419	31450	0.7938322	588811	24966	19385	633161	
4	741732	24385	32079	0.7350299	545195	23579	17924	586697	
5	741732	24351	32720	0.6805832	504810	22269	16573	543652	
6	741732	24317	33374	0.6301696	467417	21032	15324	503772	
7	741732	24283	34042	0.5834904	432794	19863	14169	466825	
8	741732	24249	34723	0.5402689	400735	18760	13101	432595	
9	741732	24215	35417	0.500249	371051	17717	12113	400882	
10	741732	24181	36126	0.4631935	343565	16733	11200	371499	
11	741732	24147	36848	0.4288829	318116	15804	10356	344276	
12	741732	24113	37585	0.3971138	294552	14926	9576	319053	
13	741732	24079	38337	0.3676979	272733	14096	8854	295684	
14	741732	24046	39104	0.340461	252531	13313	8187	274031	
15	741732	24012	39886	0.3152417	233825	12574	7570	253968	
16	741732	23978	40683	0.2918905	216505	11875	6999	235379	
17	741732	23945	41497	0.270269	200467	11215	6472	218154	
18	741732	23911	42327	0.250249	185618	10592	5984	202194	
19	741732	23878	43173	0.2317121	171868	10004	5533	187405	
20	741732	23845	44037	0.2145482	159137	9448	5116	173701	
21	741732	23811	44918	0.1986557	147349	8923	4730	161003	
22	741732	23778	45816	0.1839405	136435	8427	4374	149236	
23	741732	23745	46732	0.1703153	126328	7959	4044	138332	
24	741732	23711	47667	0.1576993	116971	7517	3739	128227	
25	741732	23678	48620	0.1460179	108306	7099	3457	118863	
26	741732	23645	49593	0.1352018	100283	6705	3197	110185	
27	741732	23612	50585	0.1251868	92855	6333	2956	102144	
28	741732	23579	51596	0.1159137	85977	5981	2733	94691	
29	741732	23546	52628	0.1073275	79608	5648	2527	87784	
30	741732	23513	53681	0.0993773	73711	5335	2337	81383	
31	741732	23480	54754	0.092016	68251	5038	2161	75450	
32	741732	23447	55849	0.0852	63196	4758	1998	69952	
33	741732	23414	56966	0.0788889	58514	4494	1847	64856	
34	741732	23382	58106	0.0730453	54180	4244	1708	60132	
35	741732	23349	59268	0.0676345	50167	4009	1579	55754	
36	741732	23316	60453	0.0626246	46451	3786	1460	51697	
37	741732	23284	61662	0.0579857	43010	3576	1350	47936	
38	741732	23251	62896	0.0536905	39824	3377	1248	44449	
39	741732	23218	64153	0.0497134	36874	3189	1154	41218	
40	741732	23186	65437	0.0460309	34143	3012	1067	38222	
				LCC Total	9585206				

Appendix A – Life Cycle Cost Breakdown – 115-kV XLPE

First Costs			**Losses**			**O&M**		
Ducts & Vaults	6325268	Dollars	Conductor	3000 kcmil	XLPE	Annual Cost per mile	22937	$/mi-year
Conductor & Hardware	4907153	Dollars	Resistance	0.0268	ohm/mi	O&M Cost Escalation	0.02	decimal CAGR
Site Work	2322881	Dollars	Peak Line Current	1000	amps			
Construction	4414236	Dollars	Load Growth	-0.007	decimal CAGR			
Engineering	1750256	Dollars	Loss Factor	0.31	dimensionless			
Sales Tax	0	Dollars	Energy Cost	100	$/MWh			
Project Management	1120706	Dollars	Energy Cost Escalation	0	decimal CAGR			
Capital Recovery Factor	0.1121	dimensionless						
Year	**Carrying Costs**	**Losses**	**O&M**	**PV Factor**	**PV FC**	**PV O&M**	**PV Losses**	**PV Cost**
0								
1	2336220	21529	23395	0.92592593	2163167	21662	19934	2204763
2	2336220	21228	23863	0.85733882	2002932	20459	18200	2041591
3	2336220	20932	24341	0.79383224	1854567	19322	16617	1890506
4	2336220	20640	24827	0.73502985	1717191	18249	15171	1750612
5	2336220	20352	25324	0.6805832	1589992	17235	13851	1621079
6	2336220	20068	25830	0.63016963	1472215	16278	12646	1501139
7	2336220	19788	26347	0.5834904	1363162	15373	11546	1390082
8	2336220	19512	26874	0.54026888	1262187	14519	10542	1287248
9	2336220	19240	27411	0.50024897	1168692	13713	9625	1192029
10	2336220	18972	27960	0.46319349	1082122	12951	8788	1103860
11	2336220	18707	28519	0.42888286	1001965	12231	8023	1022219
12	2336220	18446	29089	0.39711376	927745	11552	7325	946622
13	2336220	18189	29671	0.36769792	859023	10910	6688	876621
14	2336220	17935	30264	0.34046104	795392	10304	6106	811802
15	2336220	17685	30870	0.3152417	736474	9731	5575	751780
16	2336220	17438	31487	0.29189047	681920	9191	5090	696201
17	2336220	17195	32117	0.27026895	631408	8680	4647	644735
18	2336220	16955	32759	0.25024903	584637	8198	4243	597078
19	2336220	16718	33414	0.23171206	541330	7743	3874	552947
20	2336220	16485	34083	0.21454821	501232	7312	3537	512081
21	2336220	16255	34764	0.19865575	464104	6906	3229	474239
22	2336220	16028	35460	0.18394051	429726	6522	2948	439196
23	2336220	15805	36169	0.17031528	397894	6160	2692	406746
24	2336220	15584	36892	0.15769934	368420	5818	2458	376696
25	2336220	15367	37630	0.1460179	341130	5495	2244	348868
26	2336220	15152	38383	0.13520176	315861	5189	2049	323099
27	2336220	14941	39150	0.12518682	292464	4901	1870	299235
28	2336220	14733	39933	0.11591372	270800	4629	1708	277136
29	2336220	14527	40732	0.10732752	250741	4372	1559	256672
30	2336220	14324	41547	0.09937733	232167	4129	1424	237720
31	2336220	14125	42378	0.09201605	214970	3899	1300	220169
32	2336220	13928	43225	0.08520005	199046	3683	1187	203915
33	2336220	13733	44090	0.07888893	184302	3478	1083	188863
34	2336220	13542	44971	0.07304531	170650	3285	989	174924
35	2336220	13353	45871	0.06763454	158009	3102	903	162015
36	2336220	13166	46788	0.06262458	146305	2930	825	150059
37	2336220	12983	47724	0.05798572	135467	2767	753	138988
38	2336220	12802	48679	0.05369048	125433	2614	687	128734
39	2336220	12623	49652	0.04971341	116141	2468	628	119237
40	2336220	12447	50645	0.04603093	107538	2331	573	110443
				LCC Total	28431950			

Appendix A – Life Cycle Cost Breakdown – 115-kV HPFF

First Costs			**Losses**			**O&M**		
Ducts & Vaults	5831008	Dollars	Conductor	2500 kcmil	HPFF	Annual Cost per mile	22937	$/mi-year
Cable & Hardware	5231053	Dollars	Resistance	0.0317	ohm/mi	O&M Cost Escalation	0.02	decimal CAGR
Site Work	2327613	Dollars	Peak Line Current	1000	amps			
Construction	3677883	Dollars	Load Growth	-0.007	decimal CAGR			
Engineering	1666245	Dollars	Loss Factor	0.31	dimensionless			
Sales Tax	0	Dollars	Energy Cost	100	$/MWh			
Project Management	1006499	Dollars	Energy Cost Escalation	0	decimal CAGR			
Capital Recovery Factor	0.1121	dimensionless						
Year	**Carrying Costs**	**Losses**	**O&M**	**PV Factor**	**PV FC**	**PV O&M**	**PV Losses**	**PV Cost**
0								
1	2212888	25465	23395	0.92592593	2048970	21662	23579	2094211
2	2212888	25110	23863	0.85733882	1897195	20459	21528	1939181
3	2212888	24759	24341	0.79383224	1756662	19322	19655	1795639
4	2212888	24414	24827	0.73502985	1626539	18249	17945	1662733
5	2212888	24073	25324	0.6805832	1506054	17235	16384	1539673
6	2212888	23738	25830	0.63016963	1394495	16278	14959	1425731
7	2212888	23406	26347	0.5834904	1291199	15373	13657	1320229
8	2212888	23080	26874	0.54026888	1195554	14519	12469	1222543
9	2212888	22758	27411	0.50024897	1106995	13713	11385	1132092
10	2212888	22440	27960	0.46319349	1024995	12951	10394	1048340
11	2212888	22127	28519	0.42888286	949070	12231	9490	970791
12	2212888	21819	29089	0.39711376	878768	11552	8664	898984
13	2212888	21514	29671	0.36769792	813674	10910	7911	832495
14	2212888	21214	30264	0.34046104	753402	10304	7223	770929
15	2212888	20918	30870	0.3152417	697595	9731	6594	713920
16	2212888	20626	31487	0.29189047	645921	9191	6021	661132
17	2212888	20339	32117	0.27026895	598075	8680	5497	612252
18	2212888	20055	32759	0.25024903	553773	8198	5019	566990
19	2212888	19775	33414	0.23171206	512753	7743	4582	525077
20	2212888	19499	34083	0.21454821	474771	7312	4184	486267
21	2212888	19227	34764	0.19865575	439603	6906	3820	450329
22	2212888	18959	35460	0.18394051	407040	6522	3487	417049
23	2212888	18694	36169	0.17031528	376889	6160	3184	386233
24	2212888	18434	36892	0.15769934	348971	5818	2907	357696
25	2212888	18176	37630	0.1460179	323121	5495	2654	331270
26	2212888	17923	38383	0.13520176	299186	5189	2423	306799
27	2212888	17673	39150	0.12518682	277024	4901	2212	284138
28	2212888	17426	39933	0.11591372	256504	4629	2020	263153
29	2212888	17183	40732	0.10732752	237504	4372	1844	243720
30	2212888	16943	41547	0.09937733	219911	4129	1684	225723
31	2212888	16707	42378	0.09201605	203621	3899	1537	209058
32	2212888	16474	43225	0.08520005	188538	3683	1404	193625
33	2212888	16244	44090	0.07888893	174572	3478	1281	179332
34	2212888	16018	44971	0.07304531	161641	3285	1170	166096
35	2212888	15794	45871	0.06763454	149668	3102	1068	153838
36	2212888	15574	46788	0.06262458	138581	2930	975	142487
37	2212888	15356	47724	0.05798572	128316	2767	890	131974
38	2212888	15142	48679	0.05369048	118811	2614	813	122238
39	2212888	14931	49652	0.04971341	110010	2468	742	113221
40	2212888	14723	50645	0.04603093	101861	2331	678	104870
				LCC Total	27002057			

Appendix A – Life Cycle Cost Breakdown – 345-kV XLPE

First Costs			Losses			O&M		
Ducts & Vaults	6564081	Dollars	Conductor	3000 kcmil	XLPE	Annual Cost per mile	22937	$/mi-year
Cable & Hardware	6298925	Dollars	Resistance	0.0268	ohm/mi	O&M Cost Escalation	0.02	decimal CAGR
Site Work	2296640	Dollars	Peak Line Current	1000	amps			
Construction	4691790	Dollars	Load Growth	-0.007	decimal CAGR			
Engineering	1939625	Dollars	Loss Factor	0.31	dimensionless			
Sales Tax	0	Dollars	Energy Cost	100	$/MWh			
Project Management	1232438	Dollars	Energy Cost Escalation	0	decimal CAGR			
Capital Recovery Factor	0.1121	dimensionless						
Year	**Carrying Costs**	**Losses**	**O&M**	**PV Factor**	**PV FC**	**PV O&M**	**PV Losses**	**PV Cost**
0								
1	2580934	21529	23395	0.92592593	2389754	21662	19934	2431350
2	2580934	21228	23863	0.85733882	2212735	20459	18200	2251394
3	2580934	20932	24341	0.79383224	2048829	19322	16617	2084768
4	2580934	20640	24827	0.73502985	1897064	18249	15171	1930484
5	2580934	20352	25324	0.6805832	1756540	17235	13851	1787627
6	2580934	20068	25830	0.63016963	1626426	16278	12646	1655350
7	2580934	19788	26347	0.5834904	1505950	15373	11546	1532870
8	2580934	19512	26874	0.54026888	1394398	14519	10542	1419460
9	2580934	19240	27411	0.50024897	1291110	13713	9625	1314447
10	2580934	18972	27960	0.46319349	1195472	12951	8788	1217210
11	2580934	18707	28519	0.42888286	1106918	12231	8023	1127173
12	2580934	18446	29089	0.39711376	1024924	11552	7325	1043801
13	2580934	18189	29671	0.36769792	949004	10910	6688	966602
14	2580934	17935	30264	0.34046104	878708	10304	6106	895118
15	2580934	17685	30870	0.3152417	813618	9731	5575	828925
16	2580934	17438	31487	0.29189047	753350	9191	5090	767631
17	2580934	17195	32117	0.27026895	697546	8680	4647	710874
18	2580934	16955	32759	0.25024903	645876	8198	4243	658317
19	2580934	16718	33414	0.23171206	598034	7743	3874	609650
20	2580934	16485	34083	0.21454821	553735	7312	3537	564584
21	2580934	16255	34764	0.19865575	512717	6906	3229	522853
22	2580934	16028	35460	0.18394051	474738	6522	2948	484209
23	2580934	15805	36169	0.17031528	439573	6160	2692	448424
24	2580934	15584	36892	0.15769934	407012	5818	2458	415287
25	2580934	15367	37630	0.1460179	376863	5495	2244	384601
26	2580934	15152	38383	0.13520176	348947	5189	2049	356185
27	2580934	14941	39150	0.12518682	323099	4901	1870	329870
28	2580934	14733	39933	0.11591372	299166	4629	1708	305502
29	2580934	14527	40732	0.10732752	277005	4372	1559	282936
30	2580934	14324	41547	0.09937733	256486	4129	1424	262039
31	2580934	14125	42378	0.09201605	237487	3899	1300	242686
32	2580934	13928	43225	0.08520005	219896	3683	1187	224765
33	2580934	13733	44090	0.07888893	203607	3478	1083	208169
34	2580934	13542	44971	0.07304531	188525	3285	989	192799
35	2580934	13353	45871	0.06763454	174560	3102	903	178566
36	2580934	13166	46788	0.06262458	161630	2930	825	165385
37	2580934	12983	47724	0.05798572	149657	2767	753	153177
38	2580934	12802	48679	0.05369048	138572	2614	687	141872
39	2580934	12623	49652	0.04971341	128307	2468	628	131403
40	2580934	12447	50645	0.04603093	118803	2331	573	121707
				LCC Total	31350072			

Appendix A – Life Cycle Cost Breakdown – 345-kV HPFF

First Costs			**Losses**			**O&M**		
Ducts & Vaults	5813944	Dollars	Conductor	2500 kcmil	HPFF	Annual Cost per mile	22937	$/mi-year
Cable & Hardware	6573099	Dollars	Resistance	0.0317	ohm/mi	O&M Cost Escalation	0.02	decimal CAGR
Site Work	2320802	Dollars	Peak Line Current	1000	amps			
Construction	3735001	Dollars	Load Growth	-0.007	decimal CAGR			
Engineering	1800084	Dollars	Loss Factor	0.31	dimensionless			
Sales Tax	0	Dollars	Energy Cost	100	$/MWh			
Project Management	1075170	Dollars	Energy Cost Escalation	0	decimal CAGR			
Capital Recovery Factor	0.1121	dimensionless						
Year	**Carrying Costs**	**Losses**	**O&M**	**PV Factor**	**PV FC**	**PV O&M**	**PV Losses**	**PV Cost**
0								
1	2389759	25465	23395	0.92592593	2212740	21662	23579	2257981
2	2389759	25110	23863	0.85733882	2048833	20459	21528	2090820
3	2389759	24759	24341	0.79383224	1897068	19322	19655	1936045
4	2389759	24414	24827	0.73502985	1756544	18249	17945	1792738
5	2389759	24073	25324	0.6805832	1626430	17235	16384	1660049
6	2389759	23738	25830	0.63016963	1505954	16278	14959	1537190
7	2389759	23406	26347	0.5834904	1394401	15373	13657	1423432
8	2389759	23080	26874	0.54026888	1291112	14519	12469	1318101
9	2389759	22758	27411	0.50024897	1195474	13713	11385	1220572
10	2389759	22440	27960	0.46319349	1106921	12951	10394	1130266
11	2389759	22127	28519	0.42888286	1024927	12231	9490	1046648
12	2389759	21819	29089	0.39711376	949006	11552	8664	969222
13	2389759	21514	29671	0.36769792	878709	10910	7911	897530
14	2389759	21214	30264	0.34046104	813620	10304	7223	831146
15	2389759	20918	30870	0.3152417	753352	9731	6594	769677
16	2389759	20626	31487	0.29189047	697548	9191	6021	712759
17	2389759	20339	32117	0.27026895	645878	8680	5497	660055
18	2389759	20055	32759	0.25024903	598035	8198	5019	611252
19	2389759	19775	33414	0.23171206	553736	7743	4582	566061
20	2389759	19499	34083	0.21454821	512719	7312	4184	524214
21	2389759	19227	34764	0.19865575	474739	6906	3820	485465
22	2389759	18959	35460	0.18394051	439573	6522	3487	449583
23	2389759	18694	36169	0.17031528	407012	6160	3184	416357
24	2389759	18434	36892	0.15769934	376863	5818	2907	385588
25	2389759	18176	37630	0.1460179	348948	5495	2654	357096
26	2389759	17923	38383	0.13520176	323100	5189	2423	330712
27	2389759	17673	39150	0.12518682	299166	4901	2212	306280
28	2389759	17426	39933	0.11591372	277006	4629	2020	283655
29	2389759	17183	40732	0.10732752	256487	4372	1844	262703
30	2389759	16943	41547	0.09937733	237488	4129	1684	243300
31	2389759	16707	42378	0.09201605	219896	3899	1537	225333
32	2389759	16474	43225	0.08520005	203608	3683	1404	208694
33	2389759	16244	44090	0.07888893	188526	3478	1281	193285
34	2389759	16018	44971	0.07304531	174561	3285	1170	179016
35	2389759	15794	45871	0.06763454	161630	3102	1068	165801
36	2389759	15574	46788	0.06262458	149658	2930	975	153563
37	2389759	15356	47724	0.05798572	138572	2767	890	142230
38	2389759	15142	48679	0.05369048	128307	2614	813	131734
39	2389759	14931	49652	0.04971341	118803	2468	742	122014
40	2389759	14723	50645	0.04603093	110003	2331	678	113012
				LCC Total	29111178			

Appendix B – Life Cycle Cost Breakdown – 115-kV Vertical (UI)

First Costs			**Losses**			**O&M**		
Poles & Foundations	1461542	Dollars	Conductor	1590 ACSS		Annual Cost per mile	38553	$/mi-year
Conductor & Hardware	183304	Dollars	Resistance	0.0622	ohm/mi	O&M Cost Escalation	0.014	decimal CAGR
Site Work	2351990	Dollars	Peak Line Current	2148	amps			
Construction	3627148	Dollars	Load Growth	0.0061	decimal CAGR			
Engineering	1430839	Dollars	Loss Factor	0.35	dimensionless			
Sales Tax	48451	Dollars	Energy Cost	44.66	$/MWh			
Project Management	569124	Dollars	Energy Cost Escalation	-0.0029	decimal CAGR			
UI Costs	1147095							
Capital Recovery Factor	0.1079	dimensionless						
Year	**Carrying Costs**	**Losses**	**O&M**	**PV Factor**	**PV FC**	**PV O&M**	**PV Losses**	**PV Cost**
0								
1	1167423	118985	39093	0.9259259	1080947	36197	110171	1227316
2	1167423	120092	39640	0.8573388	1000877	33985	102959	1137822
3	1167423	121209	40195	0.7938322	926738	31908	96219	1054866
4	1167423	122336	40758	0.7350299	858091	29958	89921	977970
5	1167423	123474	41328	0.6805832	794529	28127	84034	906691
6	1167423	124623	41907	0.6301696	735675	26408	78533	840617
7	1167423	125782	42494	0.5834904	681180	24795	73393	779367
8	1167423	126952	43089	0.5402689	630722	23279	68588	722590
9	1167423	128133	43692	0.500249	584002	21857	64098	669957
10	1167423	129325	44303	0.4631935	540743	20521	59902	621166
11	1167423	130528	44924	0.4288829	500688	19267	55981	575936
12	1167423	131742	45553	0.3971138	463600	18090	52316	534006
13	1167423	132967	46190	0.3676979	429259	16984	48892	495135
14	1167423	134204	46837	0.340461	397462	15946	45691	459100
15	1167423	135452	47493	0.3152417	368021	14972	42700	425692
16	1167423	136712	48158	0.2918905	340760	14057	39905	394721
17	1167423	137984	48832	0.270269	315518	13198	37293	366009
18	1167423	139267	49516	0.250249	292147	12391	34852	339389
19	1167423	140563	50209	0.2317121	270506	11634	32570	314710
20	1167423	141870	50912	0.2145482	250469	10923	30438	291830
21	1167423	143190	51624	0.1986557	231915	10255	28445	270616
22	1167423	144522	52347	0.1839405	214736	9629	26583	250949
23	1167423	145866	53080	0.1703153	198830	9040	24843	232714
24	1167423	147223	53823	0.1576993	184102	8488	23217	215807
25	1167423	148592	54577	0.1460179	170465	7969	21697	200131
26	1167423	149975	55341	0.1352018	157838	7482	20277	185597
27	1167423	151370	56116	0.1251868	146146	7025	18949	172120
28	1167423	152778	56901	0.1159137	135320	6596	17709	159625
29	1167423	154199	57698	0.1073275	125297	6193	16550	148039
30	1167423	155633	58506	0.0993773	116015	5814	15466	137296
31	1167423	157081	59325	0.092016	107422	5459	14454	127334
32	1167423	158542	60155	0.0852	99465	5125	13508	118097
33	1167423	160016	60997	0.0788889	92097	4812	12624	109532
34	1167423	161505	61851	0.0730453	85275	4518	11797	101590
35	1167423	163007	62717	0.0676345	78958	4242	11025	94225
36	1167423	164523	63595	0.0626246	73109	3983	10303	87395
37	1167423	166054	64486	0.0579857	67694	3739	9629	81062
38	1167423	167598	65388	0.0536905	62680	3511	8998	75189
39	1167423	169157	66304	0.0497134	58037	3296	8409	69742
40	1167423	170731	67232	0.0460309	53738	3095	7859	64691
				LCC Total	16036641			