APPENDIX B

Overhead to Underground Conversion

Chapter Structure

A. INTRODUCTION

Over the last decade, major ice storms, wind storms, thunderstorms, and hurricanes have caused billions of dollars of damage to overhead electrical systems across the country. These incidents in turn have affected millions of customers. For example, during a 2002 ice storm, approximately two million or 24% of the 8.5 million residents in North Carolina lost power.[1] Likewise, an estimated 63% of the 1.3 million residents in New Hampshire were without power during the December 2008 ice storm. These are but two examples of incidents that resulted in the consideration of replacing overhead electrical systems with underground ones. With the extensive amount of damage caused by these storms, and the resulting repair and replacement costs, it is only natural to contemplate placing an overhead system underground.

B. OVERHEAD TO UNDERGROUND CONVERSION

There has been a definite trend among utilities across the United States to place new distribution systems underground, especially in residential areas. Many municipalities have passed ordinances requiring this. In turn, property developers and ultimately home owners must pay for the differential costs for placing these systems underground. The main reason for this has been aesthetics, with reliability being of secondary importance. While underground construction can improve reliability by minimizing damage due to high winds, falling trees, and ice and snow storms, it is not immune to all types of damage. For example, damage due to hurricanes, flooding, lightning, earthquakes, rodent, and human damage may be worse for underground

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[1] North Carolina Public Utilities Commission. (November 2003). *The Feasibility of Placing Electric Distribution Facilities Underground*.

construction than for overhead construction. It is true, however, that for a storm such as the one that occurred in New Hampshire in December of 2008, any part of the system that was placed underground would have been impervious to the types of damage seen.

To better understand the requirements to convert an overhead distribution line to underground, one needs to understand the construction of both. The overhead distribution line typically uses two or more "bare" conductors (conductors covered with no rubber or plastic insulation). Air, which is a good insulator (dielectric), surrounds the conductor and allows the heat resulting from the electric current flow to easily dissipate into the surrounding atmosphere. This keeps the conductor below the temperature at which it would be damaged. Overhead type construction has been used for many decades. Due to the requirements of the Rural Utility Service, the construction methods are somewhat standardized and are similar in all parts of the United States. For this reason, bare conductors and installation hardware are widely available and relatively cost effective to install. In order to hold the bare conductors in the air, they are attached to wood, steel, or concrete poles at several hundred foot intervals. The conductors are insulated from the pole by being held in place by polymer or porcelain insulators. These can be mounted directly to the pole or on cross arms which are in turn mounted to it. Safety results from the height the conductors are mounted above the ground rather than the presence of rubber insulation on the conductors. Since air is used as the insulator, continuous rubber insulation on the conductor is not necessary. The result is that this type of construction is very cost efficient and highly durable. Figure B-1 illustrates a typical type of overhead distribution line construction.
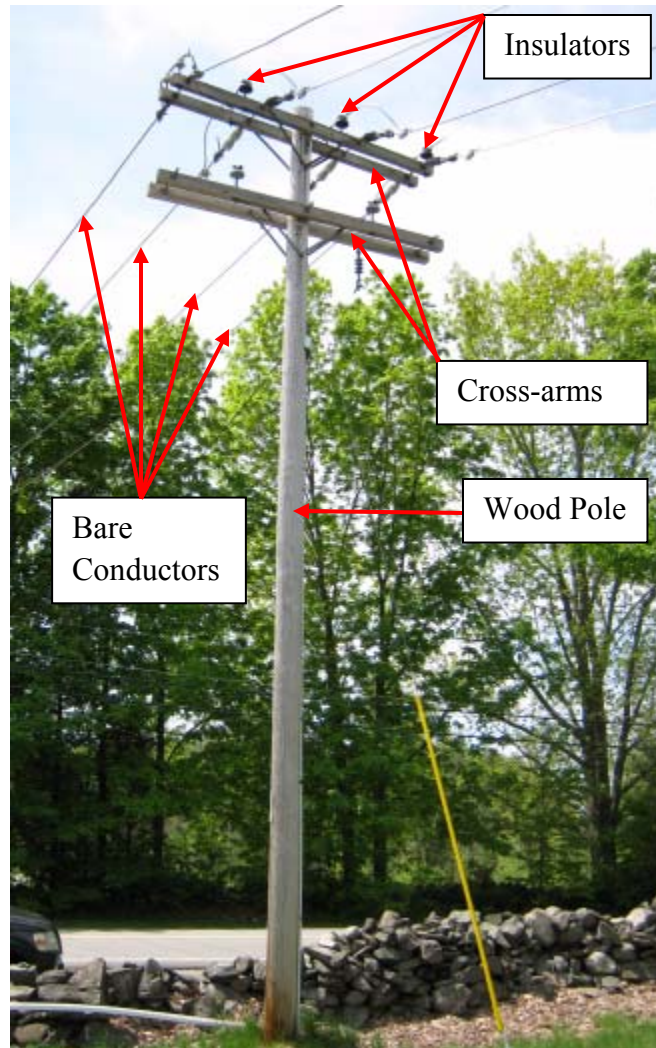
Figure B-1-Typical distribution line bare consisting of conductors attached to insulators mounted on a cross-arm attached to a wooden distribution pole. (Photo by NEI-Location Unknown)

Placing an electrical conductor underground is a much more complex and costly undertaking. First of all, an un-insulated bare conductor cannot be placed underground. While overhead conductors are placed many feet apart from each other and located high above the ground, underground conductors are placed very close together and within a few inches of surrounding earth. It is common in some areas to directly bury conductors. In direct burial, a narrow trench is dug, sometimes only large enough to place the conductor in, and soil is placed directly around it. A direct bury installation is shown in Figure B-2.

Figure B-2-Installing direct buried cable. (Photo courtesy of Southwire)

Another common construction is to bury a pipe (conduit) in the earth and install the electrical conductors inside this pipe. The pipe provides some protection for the conductors and makes future replacement easier than would be possible with the direct burial method. In both cases, since the conductor may be directly in contact with the earth, or directly in contact with a pipe, it cannot be merely a bare conductor (as in the case of overhead conductors). It must instead be covered in some type of insulation. The metal conductor and the various layers of insulation and shields which are necessary constitute an electrical cable. In the case of direct buried cable, the central metal current carrying part of the underground cable may be only an inch or so (the thickness of the insulation) away from surrounding earth. In the case of cables installed in pipe, the metal part of the conductor may only be a slightly further from surrounding earth (the additional distance caused by the thickness of the pipe wall). A typical installation of underground cable in conduit is shown in Figure B-3.

Figure B-3 – Typical underground conduit and cable. (Photo by NEI)

These differences between overhead and underground construction mean that the electrical quantity of capacitance may be up to 75 times higher for an underground line than it will be for an equivalent overhead line. Higher capacitance has the effect of limiting the practical length of a power line. Since capacitance is relatively low for an overhead line, it has little effect on how long the line may be. The higher capacitance of the underground line, however, severely limits its length. Due to the lack of devices capable of switching the capacitive current, the line capacitance limits the length to approximately 15 miles for a typical 35kV underground line. For a 345kV line, the absolute length limit is 26 miles at which point the capacitive current flowing exceeds the current carrying capacity of a typical cable. Currently no 345kV line in the world is longer than 20 miles.

At lower voltages there are other constraints that limit line length more than capacitance. For that reason, typical voltages for an underground distribution line may be in the 7,000 to 15,000 volt range. The conductors must be designed to handle these voltage levels and all of the problems associated with the long term use of the cable. A typical overhead line life is considered to be approximately 50 years. In contrast, underground cable life is usually

considered to be 30-40 years.[2] The installation conditions greatly affect an underground cable's life. Variations in ambient temperature, loading, and soil moisture conditions all affect the life of an underground cable. A typical underground cable is shown in Figure B-4. Note all of the components of the underground cable namely:

- The electrical current carrying conductor in the center.
- A conductor shield surrounding the conductor.
- The electrical insulating material.
- A semi-conducting material (semicon) surrounding the insulation to uniformly distribute the electric charge.
- Concentric wires which are typically used for the neutral or return circuit.
- An outer jacket used to protect the concentric neutral and cable.
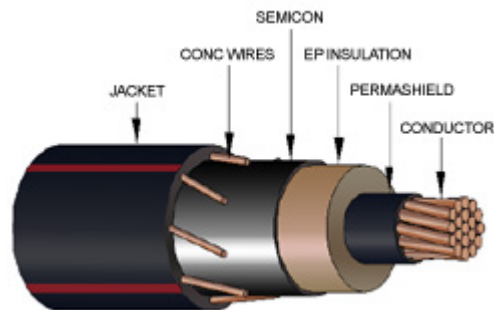

Figure B-4: Typical Underground Distribution Cable. (Courtesy of Kerite)

This complex and relatively expensive cable must then be placed underground. Figure B-5 shows the construction of an underground distribution line in a new residential area where construction in previously undisturbed ground is relatively simple. Typical underground construction involves the following:

- Excavating a trench that is approximately four feet deep and wide enough for the electric power cables
- Installing the cables in plastic (PVC) or steel conduit, which can make future replacement easier than if the cable is direct buried without conduit
- Properly spacing the conduits so heat generated by the cables can be dissipated.
- Carefully backfilling the trench around the conduits with clean, rock free dirt, sand, or concrete
- Placing the top layer of soil, grass, asphalt or concrete

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[2]Rudasill, C.L. and Ward, D. J. (July 1997). "Distribution Underground Cable Evaluation." *IEEE Transactions on Power Delivery*. Vol. 12,No. 3.

Figure B-5 - Conduit and Trench for Underground Distribution
(Photo by NEI-Grand Prairie, Alberta)

Pulling electric power cables into underground conduits requires special equipment. In addition, the length of cable that can be pulled is limited to runs typically less than 1,000 feet. Therefore, above grade switching cabinets or below grade man-holes are required at least every 1,000 feet for access to the power cables during installation and future maintenance.

The fact that the underground cable is hidden from sight and difficult to access makes it more difficult to replace than overhead power lines. While the number of outages due to the distribution system may be far fewer with underground than with overhead lines, the duration of an outage will be far longer with underground systems. If cable damage occurs underground, special equipment and training is needed for linemen to locate the problem. In contrast, the same type of problem may be located in a few minutes by a lineman doing a physical inspection of an overhead line. After the damage in the underground line is located, it may take many hours or days to dig up the line to expose the cables for splicing, or remove the existing damaged cable to replace it with a new one. Alternatively, with an overhead line, the problem may be repaired in a relatively short period of time since all the conductors and hardware are above ground and easily accessible.

If special design techniques are not used, simply placing a line underground may result in more outage time for the customers than would be experienced if the line were overhead. It may take up to 10 times longer to repair a problem on an underground line than it would on an overhead line. To help resolve this issue, two techniques are commonly used. The first is to install an

additional empty conduit next to each line. This allows new cable to be pulled into the spare conduit and connected to restore power to the customer. Afterwards, the old damaged cable is removed from the original conduit. Since this process may still take many hours, the second technique, referred to as a looped system, is often used to minimize outage time for customers fed by an underground system.

Most overhead distribution systems in the United States are radial systems and operate at 12.47kV[3]. A typical radial distribution system shown in Figure B-6 has only one path for current to flow from the source to the customer. If a line is disabled, the resulting outage for all of the customers on that line may persist until the line is replaced. This may take considerable time.
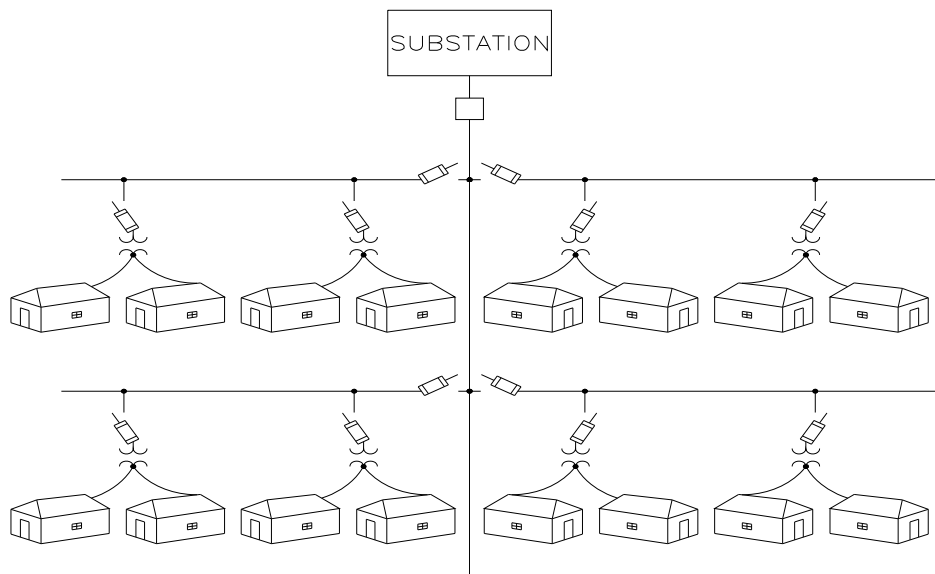

Figure B-6 - Typical radial distribution system.

To expedite power restoration to customers when an underground system is installed, a looped system, rather than a radial system, should be installed. There are several types of looped systems which may be used. One possible type is shown in Figure B-7. With this type of system, power can flow from the source to any customer using either of two different routes. The route used can be changed by opening and closing switches throughout the system. In the event an underground cable fails, linemen can quickly reconfigure the switches in the system to restore power to all customers. Afterward, the linemen can replace the damaged cables without interrupting power to any of the customers, which makes the longer repair time less important.

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[3] Willis, H.L. (2004). *Power Distribution Planning Reference Book*, 2nd Edition. Marcel Dekker, New York, NY.
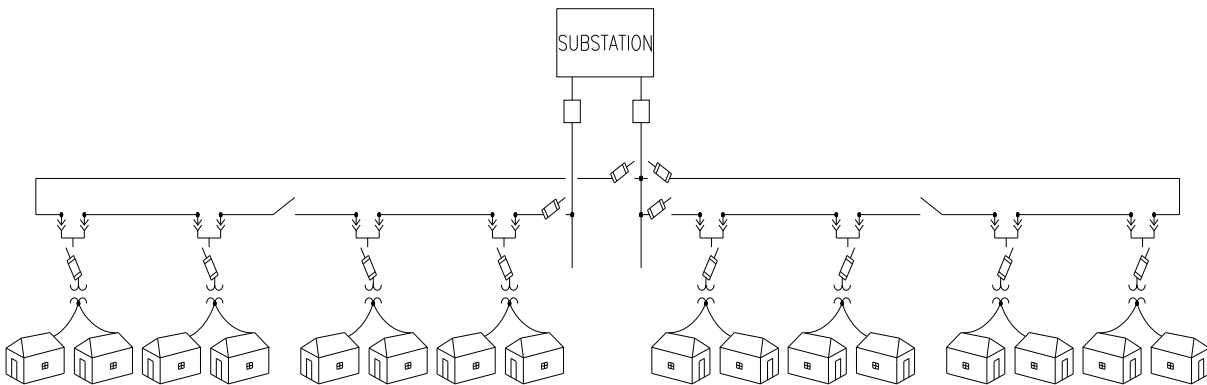
Figure B-7-Looped distribution system.

If an underground distribution system is installed for the sole purpose of reducing outage times, a looped distribution system is necessary. From a reliability standpoint it makes little sense to install underground distribution if a radial system must be used, since it may in actuality increase rather than decrease total outage times.

The placement of a new underground distribution line in a new area is more expensive than installing an overhead line, but is a relatively simple and cost effective process compared to that of moving an existing overhead line underground. If this is planned, several other factors must also be addressed, including:

- Placing lines underground means the utility must obtain new easements from customers and must receive indemnifications for any incidental damage that may occur during the placement of underground lines such as damage to trees.
- The utility will also have some restoration costs for customer property, and these costs may vary greatly from one customer to another.
- Soil conditions can severely impact costs. The shallow level of rock which exists in some areas of New Hampshire may increase the costs of underground construction.
- Overhead lines may have considerable life left and may not need to be replaced for decades.
- While there are many different methods that have been used to fund an overhead to underground conversion, one of the methods is simply incorporating the costs into electrical rates. If this alternative is chosen, the increased cost of underground construction may greatly increase the electrical rates of the customers involved. Some sources predict it could increase rates by 110-150%.[4] [5] [6]

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[4] Florida Public Service Commission. (March 2005). *Preliminary Analysis of Placing Investor-Owned Electric Utility Transmission and Distribution Facilities Underground in Florida.*
[5] North Carolina Public Utilities Commission. (November 2003). *The Feasibility of Placing Electric Distribution Facilities Underground.*

According to data supplied by the New Hampshire utilities,[7][8][9][10] in good soil conditions, the cost of a 34.5 kV line may be in the range of $2,000,000 per mile. If built in granite, that cost could increase by another $500,000 per mile. The cost of an underground distribution line may vary greatly depending on:

- Soil conditions
- Urban versus rural
- Three phase versus single phase
- Cable in conduit versus direct buried
- Concurrent construction with other underground utilities and road work
- Main feeder construction versus lateral construction
- Type of equipment required.

Some utilities have reported construction as low as $200,000 per mile for some single-phase lines.[11] However, the four New Hampshire utilities have provided numbers ranging from as low as $500,000 per mile to $3 million per mile. Under the best conditions, such as no adverse soil or installation problems, the work can be coordinated with the work of other city departments (e.g., road construction), right-of-ways are easily obtainable, and restoration of customer's property is minimal, the average cost per customer in any of the published reports amounts to $3,000. A rough cost calculated by some of the data provided by the New Hampshire electric utilities places that figure in excess of $40,000 per customer. A $3,000 investment using a 15% fixed charge rate would increase the average electric bill by $450 per year or $37.50 per month. On the other hand, the $40,000 figure would increase the average cost by $6,000 per year or $500 per month.

Due to the increased cost and complexity of retrofitting an overhead system to become an underground system, it is less reasonable to consider underground construction in an existing situation. While in all likelihood the cost of placing electrical systems underground will be more expensive than installing them overhead, even in new construction, the differential costs between overhead and underground construction are modest enough that they may be acceptable. The same justification may not apply to installing the system in an established area since the difficulty and differential costs will be much greater.

One other issue that should be discussed is that of timing. To convert the entire electric overhead system in the State of New Hampshire to underground could easily take over 40 years to

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[6] Infrasource Technology. (February 28, 2007). *Undergrounding Assessment Phase 1 Final Report: Literature Review and Analysis of Electric Distribution Overhead to Underground Conversion, for Florida Electric Utilities.*
[7] PSNH. (June 3, 2009). Data Response GN0001. NEI.
[8] Unitil. (May 27, 2009). Data Response GN0001. NEI.
[9] National Grid. (May 29, 2009). Data Response GN0001.NEI.
[10] NHEC. (June 4, 2009). Data Response GN0001.NEI.
[11] City of Fort Collins. (April 28, 2009). Colorado Municipal Utility Conversion from Overhead to Underground, Presentation for the IEEE Rural Electric Power Conference.

accomplish. Considering delays that could come due to permitting, weather, and easement acquisition, the construction time could equal the average cable life of 50 years. This would mean that as soon as all the cable was replaced the project of replacing aged cable would begin. So construction or maintenance on the underground system would become perpetual.

C. UTILITY COST SUMMARY[12]

Table B-1 is a summary of data that was provided by each of the four electric utilities. The data requested from each utility were identical; however, the responses from some of the utilities were not consistent due to the fact that some data was not available due to record keeping and accounting practices. In order to provide more accurate data, the utility may have been required to take a large amount of time and cost to obtain that information. Therefore, in order to provide some continuity of data from one utility to another, assumptions were made by NEI in order to complete the values needed for analysis. Each utility was given the opportunity to review the data and changes were made where requested.

The intent of this data was not to develop detailed cost estimates for the conversion of overhead to underground. Such an effort to provide detailed costs would take a considerable amount of time and money. The results from the data in Table B-1 provide a "ball park" estimate based on numbers independently obtained from each utility. These numbers are used in the main body of the report that discusses the costs of overhead to underground conversion of the electric distribution system. As discussed in the main body of the report, the transmission system was not adversely impacted by the December 2008 ice storm. That fact. along with the major technical and economic issues involved in converting the transmission system from overhead to underground, lead to the conclusion that the costs associated with placing the overhead transmission system to underground was not deemed worthy of further analysis.

Table B-1 provides the following high-level cost estimates for placing the overhead distribution system to underground:

- The first row of the table covers the installation of the underground electric system for each utility. Included in these costs are the conversions of each electrical substation for an underground versus overhead exit along with the cost for the underground sub-transmission line or distribution line.

- The second row of the table covers the cost of removing the overhead sub-transmission line or distribution line along with the present value of the overhead line. It should be noted that the existing overhead system throughout the State of New Hampshire is in relatively good condition and is designed for a perpetual life with proper maintenance.

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[12] All costs discussed in this section are expressed in 2008 dollars, unless otherwise noted.

- The third row of the table covers the costs of converting overhead electric services from the distribution lines to each customer. Included in these costs would be the excavation from the new underground distribution system through each customer's property to the respective meter. In all likelihood, many customers would be required to personally hire an electrician to perform part of this work.

- The fourth row of the table provides the estimated cost per utility for the conversion of the overhead sub-transmission and distribution system. The estimated range in costs is $1.4 billion for National Grid on the low end to $33.6 billion for PSNH on the high end. The total for all four utilities is $43 billion.

- The fifth row lists the approximate number of customers for each utility.

- The sixth row is a high-level cost estimate per customer for the conversion of the distribution system from overhead to underground.

- The seventh row is a high-level cost estimate for the monthly increase of electricity costs based on each utility recovering the investment and replacement of the system in perpetuity using a simple fixed charge rate[13] of 15%.[14] [15]

The interesting fact is that the average cost per customer was in a similar range.

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[13] Fixed Charge Rate is a term used by an electric utility to determine the annual, perpetual cost of an investment that needs to be recovered and includes such things as depreciation, rate of return, taxes and insurance. For example, a 15% fixed charge on a $1000 investment means that an electric utility would need to recover in rates $150 per year or $12.50 per month.

[14] Fixed Charge Rate (FCR) of 15% is chosen with the following formula $(FCR=d/[1-(1+d)^{-N}])$ where 'd' is the discount rate and 'N' is the number of years of payment. We assume d=0.15 from Figure 12.7 (Anders, George J.; Rating of Electric Power Cables; Page 358; 1997.). We assume N=40 for a safe period of payments based on the average lifespan of an underground cable system .

[15] Lai, Loi Lei. (2001). *Power System Restructuring and Deregulation*, 3rd Edition. John Wiley and Sons. New York, NY. Page 299.

Table B-1 – New Hampshire electric utility high level overhead to underground cost summary.

	NG	NHEC	PSNH	Unitil
U/G Distribution Costs - Lines and Subs (millions)	$1,288	$3,845	$29,946	$1,664
Overhead Removal Costs (millions)	$55	$364	$305	$627
U/G Service Costs (millions)	$90	$903	$3,360	$562
Total Cost (millions)	$1,430	$5,110	$33,610	$2,850
Number of Customers	41,156	70,422	492,000	41,264
Average Cost Per Customer	$34,746	$72,563	$68,313	$69,140
Average monthly electric bill increase[16]	$434/mo	$907/mo	$854/mo	$864/mo

National Grid[17] [18] [19] [20] [21] [22]

The National Grid responses for overhead to underground conversion data are shown in Table B-2, Table B-3, and

Table B-4. Their assumptions and comments included:

- No overhead removal costs were provided. Therefore, the removal costs provided by PSNH were used for the cost of removal.

- A $38 million net value was provided for overhead assets. The $38 million stranded costs were included as part of the cost of removal.

- No mileage breakdown was provided to rural versus urban areas, therefore the following assumptions were used:

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[16] Repayment period of 40 years.
[17] National Grid. (May 29, 2009). Data Response GN0001.NEI.
[18] National Grid. (May 29, 2009). Data Response GN0002.NEI.
[19] National Grid. (May 29, 2009). Data Response GN0003.NEI.
[20] National Grid. (May 29, 2009). Data Response GN0004.NEI.
[21] National Grid. (May 29, 2009). Data Response GN0005.NEI.
[22] National Grid. (May 29, 2009). Data Response GN0006.NEI.

- 23 kV – Urban 20% and rural 80% of the 9.7 miles

- 15 kV – 10% 3-Phase Urban, 40% 3 Phase rural, 10% 1 or 2 Phase urban and 40% 1 or 2 phase rural.

Table B-2 – Cost of Overhead to underground conversion-National Grid.

Distribution Voltage Level	Miles of Distribution	Cost Per Mile	Total Cost (millions)
23 kV Sub Trans	9.7[3]	$2,800,000[1]	$5.432
		$1,800,000[2]	$13.968
15 kV			
	833[4]	$2,800,000[1]	$233.24
		$1,800,000[2]	$599.78
1 & 2 Phase		$1,000,000[1]	$83.30
		$750,000[2]	$249.90
Subtotal Lines	**342.7**		**$1,285.62**
Substation Modifications	**Qty**	**Cost Per Unit**	
23 kV Sub Trans	34	$50,000	$1.70
15 kV Dist	21	$50,000	$1.05
Subtotal Subs	**55**		**$2.75**
Total Subs & Lines			**$1,288.37**
[1] Urban [2] Rural			
[3] Assume 23 kV: 20% Urban and 80% Rural			
[4] Assume 15 kV: 10% – 3φ Urban, 40% 3φ Rural, 10% ½ φ Urban, 40% ½ φ Rural			

Table B-3 - Stranded cost and cost of removing overhead electric distribution-National Grid.

Distribution Voltage Level	Miles of Distribution	Cost Per Mile	Total Cost (millions)
23 kV –Sub Trans	9.7[3]	$30,000[1]	$0.058
		$26,000[2]	$0.202
15 kV			
	833[4]	$30,000[1]	$2.499
		$26,000[2]	$8.663
1 & 2 Phase		$15,000[1]	$1.250
		$13,000[2]	$4.332
Distribution Stranded Cost			$38.00*
Total	842.7		$55.004

[1] Urban [2] Rural

[3] Assume 23 kV: 20% Urban and 80% Rural

[4] Assume 15 kV: 10% – 3φ Urban, 40% 3φ Rural, 10% ½ φ Urban, 40% ½ φ Rural

National Grid did not provide removal costs. Therefore, PSNH Estimates were used

Table B-4 - Cost of underground service to the customer- National Grid.

Type of Service	No of Services	Cost of U/G Service	Total Cost (millions)
3 Phase Commercial	16,000[1,3]	$15,000	$48.00
	7,600[2,3]	$15,000	$22.80
120/240 Volt Commercial And Residential	16,000[1,3]	$1,000	$12.80
	7,600[2,3]	$1,000	$6.08
Totals	70,422		$89.68

[1] Urban [2] Rural

[3] Assume: 20% Commercial and 80% Residential

NHEC[23] [24] [25] [26] [27] [28]

The NHEC responses for overhead to underground conversion data are shown in Table B-5,

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[23] NHEC. (June 4, 2009). Data Response GN0001..NEI.

[24] NHEC. (June 4, 2009). Data Response GN0002 .NEI.

[25] NHEC. (June 4, 2009). Data Response GN0003. NEI.

[26] NHEC. (June 4, 2009). Data Response GN0004 .NEI.

[27] NHEC. (June 4, 2009). Data Response GN0005. NEI.

[28] NHEC. (June 4, 2009). Data Response GN0006. NEI.

Table B-6, and Table B-7. The NHEC data was complete and no additional assumptions were required.

Table B-5 - Cost of Overhead to underground conversion-NHEC.

Distribution Voltage Level	Miles of Distribution	Cost Per Mile	Total Cost (millions)
34.5 kV – Sub Trans	5[1]	$1,433,000	$7.165
	36[2]	$992,000	$35.712
15 kV			
	65[1]	$2,876,000	$186.940
	584[2]	$1,776,000	$1,037.184
1 & 2 Phase			
	277[1]	$1,148,000	$317.996
	2,491[2]	$904,000	$2,251.864
Subtotal Lines	**3,458**		**$3,836.861**
Substation Modifications	**Qty**	**Cost Per Unit**	
34.5 kV Sub-Trans	34	$88,000	$2.992
15 kV Dist	75	$71,000	$5.325
Subtotal Lines	**109**		**$8.317**
Total Lines and Subs			**$3,845.178**
[1] Urban [2] Rural			

Table B-6 - Stranded cost and cost of removing overhead electric distribution-NHEC.

Distribution Voltage Level	Miles of Distribution	Cost Per Mile	Total Cost (millions)
34.5 kV – Sub Trans	5	$100,000[1]	$0.50
	36	$100,000[2]	$3.60
15 kV			
	65	$115,000[1]	$7.475
	584	$125,000[2]	$73.00
1 & 2 Phase			
	277	$110,000[1]	$30.47
	2,491	$100,000[2]	$249.10
Total	**3,458**		**$364.145**
[1] Urban [2] Rural			

Table B-7 - Cost of underground service to the customer- NHEC.

Type of Service	No of Services	Cost of U/G Service	Total Cost (millions)
3 Phase Commercial	822[1]	$32,000	$26.304
	1,823[2]	$28,000	$51.044
120/240 Volt Commercial And Residential	4,230[1]	$15,000	$63.45
	63,547[2]	$12,000	$762.564
Totals	**70,422**		**$903.362**
[1] Urban [2] Rural			

PSNH[29] [30] [31] [32] [33] [34]

The PSHN responses for overhead to underground conversion data are shown in tables

Table B-8, Table B-9, and Table B-10. Their assumptions and comments included:

- No line lengths were provided, therefore the numbers in the tables have been assumed.

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[29] PSNH. (June 3, 2009). Data Response GN0001. NEI.
[30] PSNH. (June 3, 2009). Data Response GN0002. NEI.
[31] PSNH. (June 3, 2009). Data Response GN0003. NEI.
[32] PSNH. (June 3, 2009). Data Response GN0004. NEI.
[33] PSNH. (June 3, 2009). Data Response GN0005. NEI.
[34] PSNH. (June 3, 2009). Data Response GN0006. NEI.

- The following percentages were used for calculating underground construction distances: 15 kV – 10% 3 Phase Urban, 40% 3 Phase rural, 10% 1 or 2 Phase urban and 40% 1 or 2 phase rural.

- The number of overhead customers that exist was not provided. With 492,000 meters, it was assumed that 400,000 were overhead services.

- With regard to new services for undergrounding, the following assumptions were made: 70% Urban and 30% rural; and 10% Commercial and 90% residential

Table B-8 - Cost of Overhead to underground conversion-PSNH.

Distribution Voltage Level	Miles of Distribution	Cost Per Mile	Total Cost (millions)
34.5 Sub-Trans[3]	814	$4,000,000	$3,256.00
34.5 Sub-Trans[4]	302	$2,000,000	$604.00
34.5 Dist	3,919	$2,000,000	$7,838.00
15 kV Dist	7,698[5]	$3,000,000[1]	$2,309.40
		$1,500,000[2]	$4,618.80
15 kV		$1,000,000[1]	$769.80
1 & 2 Phase		$500,000[2]	$1,539.60
Subtotal Lines	**12,733**		**$29,935.60**
Substation Mods	Qty	Cost Per Unit	
34.5 kV	186	$30,000	$5.58
15 kV	164	$30,000	$4.92
Subtotal Sub	**350**		**$10.50**
Total Lines and Subs			**$29,946.10**
[1] Urban [2] Rural [3] On ROW [4] Along Street			
[5] Assume 15 kV: 10% – 3φ Urban, 40% 3φ Rural, 10% ½ φ Urban, 40% ½ φ Rural			

Table B-9 - Stranded cost and cost of removing overhead electric distribution-PSNH.

Distribution Voltage Level	Miles of Distribution	Cost Per Mile	Total Cost (millions)
34.5 Sub-Trans[3]	814	$30,000	$24.42
34.5 Sub-Trans[4]	302	$26,000	$7.85
34.5 Dist	3,919	$30,000	$117.57
15 kV Dist	7,698[5]	$30,000[1]	$23.094
		$26,000[2]	$80.059
15 kV		$15,000[1]	$11.547
1 & 2 Phase		$13,000[2]	$40.30
Total	**12,733**		**$304.84**
[1] Urban [2] Rural [3] On ROW [4] Along Street			
[5] Assume 15 kV: 10% – 3φ Urban, 40% 3φ Rural, 10% ½ φ Urban, 40% ½ φ Rural			

Table B-10 - Cost of underground service to the customer- PSNH.

Type of Service	No of Services[1]	Cost of U/G Service	Total Cost (millions)
3 Phase Commercial	28,000[2]	$30,000	$840.00
	12,000[3]	$30,000	$360.00
120/240 Volt Commercial And Residential	324,000[2]	$5,000	$1620.00
	36,000[3]	$15,000	$540.00
Totals	**400,000**		**$3.360**
[1] Assuming 400,000 O/H Services out of 492,000 meters, 70% Urban and 30% rural; and 10% Commercial and 90% residential			
[2]Urban [3]Rural			

Unitil[35] [36] [37] [38] [39] [40]

The Unitil responses for overhead to underground conversion data are shown in Table B-11, Table B-12, and

Table B-13. The Unitil data was complete and no additional assumptions were required.

Table B-11 - Cost of Overhead to underground conversion-Unitil.

Distribution Voltage Level	Miles of Distribution	Cost Per Mile	Total Cost (millions)
35 kV – Sub Trans	22[1]	$2,500,000	$55.00
	88[2]	$2,000,000	$178.00
15 kV 3 Phase	105[1]	$3,000,000	$315.00
	420[2]	$2,200,000	$924.00
15 kV 1/2 Phase	150[1]	$500,000	$75.00
	400[2]	$250,000	$100.00
Subtotal Lines	**1,235**		**$1,647.00**
Substation Mods	Qty	Cost Per Unit	
34.5 kV	65	$100,000	$6.50
15 kV	105	$100,00	$10.50
Sub Total Subs	**170**		**$17.00**
Total Subs & Lines			**$1,664.00**
[1] Urban [2] Rural			

[35] Unitil (May 27, 2009).Data Response GN0001. NEI.
[36] Unitil (May 27, 2009).Data Response GN0002. NEI.
[37] Unitil (May 27, 2009).Data Response GN0003. NEI.
[38] Unitil (May 27, 2009).Data Response GN0004. NEI.
[39] Unitil (May 27, 2009).Data Response GN0005. NEI.
[40] Unitil (May 27, 2009).Data Response GN0006. NEI.

Table B-12 - Stranded cost and cost of removing overhead electric distribution-Unitil.

Distribution Voltage Level	Miles of Distribution	Cost Per Mile	Total Cost (millions)
35 kV – Sub Trans	22[1]	$350,000	$7.70
	88[2]	$350,000	$30.80
15 kV 3 Phase	105[1]	$650,000	$68.25
	420[2]	$650,000	$273.00
15 kV 1/2 Phase	150[1]	$450,000	$67.50
	400[2]	$450,000	$180.00
Total	**1,235**		**$627.25**
[1] Urban [2] Rural			

Table B-13 - Cost of underground service to the customer- Unitil.

Type of Service	No of Services	Cost of U/G Service	Total Cost (millions)
3 Phase Commercial	2,160[1]	$22,080	$47.692
	1,475[2]	$25,275	$37.281
120/240 Volt Commercial And Residential	33,920[1]	$12,550	$425.696
	3,691[2]	$13,780	$50.862
Totals	**41,246**		**$561.531**
[1]Urban [2]Rural			