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Transmission Line Capital Costs

K. R. Hughes
D. R. Brown

May 1995

Prepared for the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

Pacific Northwest Laboratory
Operated for the U.S. Department of Energy
by Battelle Memorial Institute

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Richland, Washington 99352

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Summary

The displacement or deferral of conventional AC transmission line installation is a key benefit associated with several technologies being developed with the support of the U.S. Department of Energy's Office of Energy Management (OEM). Previous benefits assessments conducted within OEM have been based on significantly different assumptions for the average cost per mile of AC transmission line. In response to this uncertainty, an investigation of transmission line capital cost data was initiated. The objective of this study was to develop a database for preparing preliminary estimates of transmission line costs.

An extensive search of potential data sources identified databases maintained by the Bonneville Power Administration (BPA) and the Western Area Power Administration (WAPA) as superior sources of transmission line cost data. The BPA and WAPA data were adjusted to a common basis and combined together. The composite database covers voltage levels from 13.8 to 765 kV, with cost estimates for a given voltage level varying depending on conductor size, tower material type, tower frame type, and number of circuits. Reported transmission line costs vary significantly, even for a given voltage level. This can usually be explained by variation in the design factors noted above and variation in environmental and land (right-of-way) costs, which are extremely site-specific.

Cost estimates prepared from the composite database were compared to cost data collected by the Federal Energy Regulatory Commission (FERC) for investor-owned utilities from across the United States. The comparison was hampered because the only design specifications included with the FERC data were voltage level and line length. Working within this limitation, the FERC data were not found to differ significantly from the composite database. Therefore, the composite database was judged to be a reasonable proxy for estimating national average costs.

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Introduction

The displacement or deferral of conventional AC transmission line installation is a key benefit associated with several technologies that are being developed with the support of the U.S. Department of Energy's Office of Energy Management (OEM). This includes HTS fault current limiters, batteries, SMES, and real-time system control, as well as HTS cable, HVDC, and high-phase-order transmission. In general, the value of displacement or deferral depends on the quantity of conventional AC transmission line affected, its unit capital cost, and the period of deferral.

This study addresses the unit capital cost of conventional AC transmission line. The preparation of Quality Metrics for OEM planning units identified a factor of five difference in the average cost per mile assumed for conventional AC transmission line. The unit cost of conventional AC transmission line does vary by a factor of 10 or more depending on the voltage level, conductor size, and many other design conditions. Therefore, all of the variation noted while preparing Quality Metrics could potentially be explained by different assumptions regarding the design conditions. Still, a factor of five difference across technology applications seems rather large when viewed from a national average perspective.

In response to this issue, the Pacific Northwest Laboratory (PNL),[a] through its Management Analysis Program (MAP), conducted an investigation of transmission line cost data for OEM. The objective of this study was to develop a database for preparing preliminary estimates of transmission line costs based on the key design variables affecting cost. The database would provide a consistent set of cost assumptions for OEM, and other utility programs, that are applicable when conducting evaluations from a national or site-generic perspective. Care should be taken in applying the data in this report for site-specific analyses. In particular, land and environmental costs are highly variable and need to be carefully evaluated in any site-specific study.

The balance of this report is divided into five sections that describe the sources of data, development of a composite database, comparison of data sources, calculation of average costs per mile, and conclusions and recommendations. Raw data are presented in Appendix A. The composite database recommended for preliminary estimating of conventional AC transmission line costs is presented in Appendix B. Adjusted FERC data used for comparison with the composite data are presented in Appendix C.

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Data Sources

An extensive search of secondary information sources was conducted to determine if transmission line cost data already existed in a form useful to this study. While quite a few articles relevant to transmission line costs were identified, the scope of the articles or their orientation was not useful for this endeavor. Many articles dealt with site-specific costs or with the theoretical aspects of cost prediction or cost modeling.

In addition to the database searches, the following organizations were contacted to identify transmission line cost data:

- Electric Power Research Institute (EPRI)
- Energy Information Administration (EIA)
- Federal Energy Regulatory Commission (FERC)
- Edison Electric Institute (EEI)
- Oak Ridge National Laboratory (ORNL)
- Northwest Power Planning Council (NWPPC)
- California Public Utility Commission
- Oregon Public Utility Commission
- Washington Public Utility Commission
- Canadian Electric Association
- The Southern Company
- Tennessee Valley Authority (TVA)
- Southwestern Power Administration (SPA)
- Western Area Power Administration (WAPA)
- Bonneville Power Administration (BPA)
- Utility Data Institute (UDI).

Most of these organizations either did not collect the type of information sought, had site-specific data only, or only had data on transmission line component costs (e.g., conductor costs, cross-arm costs, etc.) as opposed to total transmission line costs based on actual design configurations.

Both BPA and WAPA have extensive transmission line cost data based on their historical construction experience (BPA 1993; WAPA 1994). Each organization has maintained their respective database for a number of years, incorporating annual updates based on data from new installations, new vendor prices, and adjustments to account for inflation. These data are employed by BPA and WAPA to establish preliminary cost estimates for planned transmission line installations.

The WAPA data set contains cost estimates based on conductor size, voltage level, tower material type, tower frame type, and number of circuits. For combinations of these parameters that are actually used, average per-mile cost estimates are given. This data set is presented in Appendix A. The BPA data set contains the same type of information (per-mile cost estimates broken down by conductor size, voltage level, tower material type, tower frame type, and number of circuits). The BPA data set is presented in Appendix A as well.

There are a number of differences between the two data sets. In general, the BPA data set contains per-mile estimates for conductor sizes that are larger than those found in the WAPA data set. The WAPA data are normalized to flat terrain, while the BPA data exist for a variety of terrain types (flat, rolling, 50/50 [half rolling and half mountainous], and mountainous). The WAPA data set contains a separate table with additional cost components, expressed as percentages of principal contracts, that are intended to be added on to the per-mile figures shown (which are for principal contracts only) to arrive at total project cost. These additional cost components include planning, environmental, field data, land and rights, design and specifications, other contracts, and construction supervision. The BPA data have three of these cost components built into the per-mile estimates: field data, design and specifications, and principal contracts. An additional difference between the data sets is the approach for estimating the cost of land and land rights. This component is estimated as a percentage of principal contracts for the WAPA data, while fixed prices based on right-of-way width and geographic location are provided with the BPA data. Similarly, a range of costs is provided for the BPA data for environmental assessments, whereas this is one of the cost components expressed as a percentage of principal contracts for the WAPA data. Lastly, the per-mile figures contained in the raw BPA data set are expressed in 1993 dollars; those in the WAPA data set are in 1994 dollars.

Appendix A also contains transmission line cost data collected by FERC from investor-owned utilities for transmission lines constructed in 1992 (EIA 1994). Whereas the BPA and WAPA data represent federal power marketing agency costs, the FERC data covers costs incurred by private utilities. In addition, the BPA and WAPA data sets are based on experience in the Western United States, while the FERC data represent utilities from across the country.

The FERC data include "land," "structure," and "conductor" cost components, and the corresponding line length and voltage level, but the data do not specify detailed design parameters such as conductor size, number of circuits, or frame type. Therefore, the BPA and WAPA data sets were used to develop the composite data set; the FERC data were used for comparison purposes only. FERC staff indicated that while the intention is to collect data that includes all costs associated with transmission line construction, the data collection forms do not explicitly describe what is to be included with or excluded from each component. For comparison purposes, "land" was presumed to include land, land rights, and environmental costs, while all other costs were assumed to be included in the structure and conductor components.

Composite Database

Several steps were taken to create a composite database from the BPA and WAPA data. These steps are outlined below, and the resulting composite database is presented in Appendix B. These data appear in Appendix B in two formats: as a table of the complete data set, and in tables with the data grouped by tower frame type, tower material type, and the number of circuits.

Each entry in the two databases was adjusted to reflect a common scope of hardware and services, and a common price year. For the BPA data, the per-mile dollar values were adjusted to 1994 dollars, using the Gross Domestic Product (GDP) implicit price deflator. The per-mile figures for the BPA data set were also adjusted to represent what the cost would have been for each configuration if it had been installed on flat terrain, using the appropriate terrain multiplier from the WAPA data set. For the WAPA data set, the original per-mile costs were increased to reflect the following components included in the BPA estimates: field data, design and specifications, and other contracts. These costs were added based on fixed percentages of principal contracts (the reference per-mile figures given in the WAPA data set), using percentages midway between the high and the low percentage figures provided with the WAPA data set.

The next step in creating a composite database was to generate per-mile estimates for each combination of parameters (voltage level, number of circuits, tower frame type, and tower material type) from the BPA and WAPA data that resulted in a "smooth" progression of per-mile cost with increasing conductor size. This was accomplished by fitting a line to the data using least squares regression techniques, with conductor size as the independent variable, and cost per-mile as the dependant variable. An example of this process appears in Figure 1. The example shown in Figure 1 is for 115-kV, single circuit, wood H-frame lines. Appendix B contains per-mile estimates from the composite database for various combinations of design parameters.

Neither the BPA or WAPA data sets included estimated costs for 765-kV transmission lines. The cost estimated for this voltage level was extrapolated from the existing data using the following approach. First, the mean cost per mile was calculated by voltage level, using the composite data set. These data appear in Table 1. The data for 115-kV, 230-kV, 345-kV, and 500-kV transmission lines were extrapolated via linear regression, yielding an estimated average cost of $782,000 per mile at 765-kV.

Table 1 contains the range as well as the mean per-mile cost estimates by voltage level based on the composite database. The range of per-mile costs at a given voltage level reflects variation in conductor size, tower material type, tower frame type, and number of circuits.

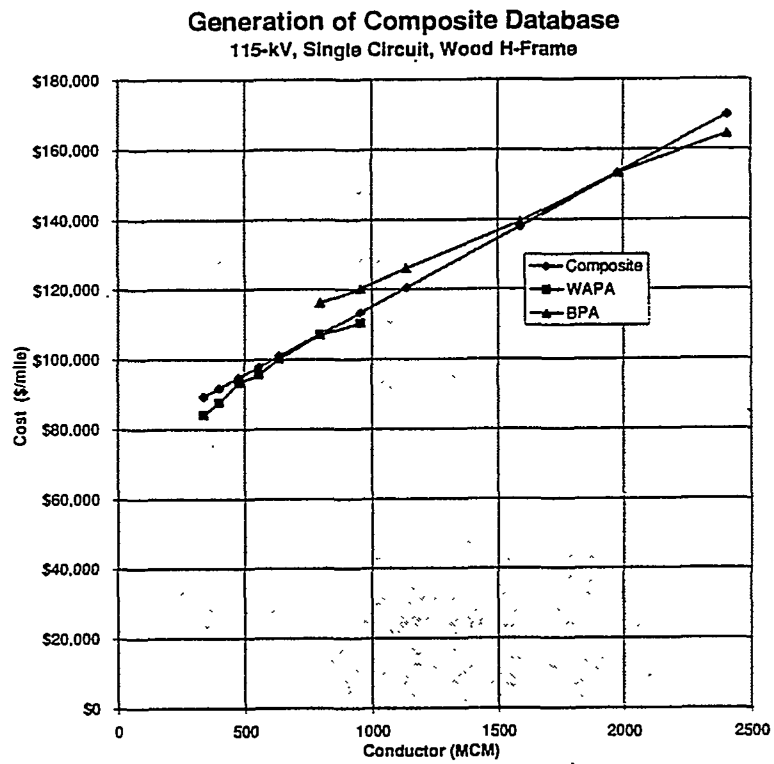

Figure 1. Example of Data Smoothing Used to Create Composite Data Set

Table 1. Mean Per-Mile Transmission Line Costs[a]

Voltage (kV)	Range of per-mile Costs ($000)	Mean per-mile Cost from Composite Database ($000)
13.8	41-50	44
34.5	43-55	48
46	46-56	49
69	60-238	107
115	91-228	124
138	96-308	165
161	105-333	182
230	129-371	235
345	218-503	341
500	364-972	519
765	Extrapolated	782

(a) Based on flat terrain. Does not include land, environmental, planning, or construction supervision costs.

As noted previously, the composite database figures do not include land, environmental, planning, or construction supervision costs. These costs are estimated separately, based on a percentage of the composite database cost per-mile figure, using percentages suggested by WAPA. Alternatively, the land and environmental costs could be estimated using the fixed costs suggested by BPA. The specific land and environmental estimating rules of thumb suggested by WAPA and BPA are presented in Appendix B. Using these two approaches will yield slightly different results, as illustrated in the example below. Note that the per-mile estimates appearing in the composite database are for flat terrain. The appropriate terrain multiplier must be used for a given installation. The example shows how to calculate the total project cost for a given installation.

Transmission Line Installation Project Cost Estimation

This example illustrates the approach used to calculate the total project cost for a transmission line installation, first using the BPA and then the WAPA approaches to accounting for land and environmental costs. As with all of these data, this would serve only as a preliminary scoping estimate, which would be followed by site-specific analyses.

Assume that a utility wants to install 20 miles of 230-kV, single-circuit line using lattice steel towers, 1272-conductor, over rolling terrain, with a 125-ft right-of-way through a non-urban area. The reference cost per-mile for the given design parameters is $183,000, which can be found in Appendix B. This figure would then be modified by the terrain multiplier. For rolling terrain, this is 10%. Therefore, the adjusted cost is $183,000 x 1.10 = $201,000 per-mile. For 20 miles, the total cost would be $4,020,000.

Environmental, land, planning, and construction supervision costs are now added. Using the WAPA approach, a percentage of the reference cost-per-mile is added to account for these factors. With 6.5% for environmental, 5.5% for land, 0.75% for planning, and 7.5% for construction supervision, the grand total project cost would be $4,834,000.

Using the BPA approach, fixed values for environmental and land costs are added. A mid-range price for environmental costs is $50,000. For a 125-ft right-of-way through a non-urban area (averaging the Oregon and Washington values), the land cost would be $25,750 per-mile, or $515,000 for 20 miles. Adding in planning and construction supervision costs using the same percentages as with the WAPA approach, the grand total project cost would be $4,917,000.

An additional step is necessary to estimate the cost of transmission line installations less than 20 miles in length. Figure 2 shows the line length multiplier curve recommended by WAPA. The reference cost for a given configuration is multiplied by the value given by the curve for the length of the line. This is done prior to adding on environmental, land, planning, and construction supervision costs. The use of this curve is illustrated in the example below.

Using the same configuration as before, with a transmission line only 10 miles long, the reference cost from Appendix B is still $183,000. Using Figure 2, the line length multiplier for a 10-mile line is 1.7. Therefore, the modified reference cost is $311,100. For rolling terrain, this would be multiplied by 1.1 to obtain $342,210 per mile. For 10 miles, the total cost would be $3,422,100.

Adding in environmental, land, planning, and construction supervision costs as before yields a grand total project cost of $4,115,000 using the WAPA approach, or $4,012,000 using the BPA approach.

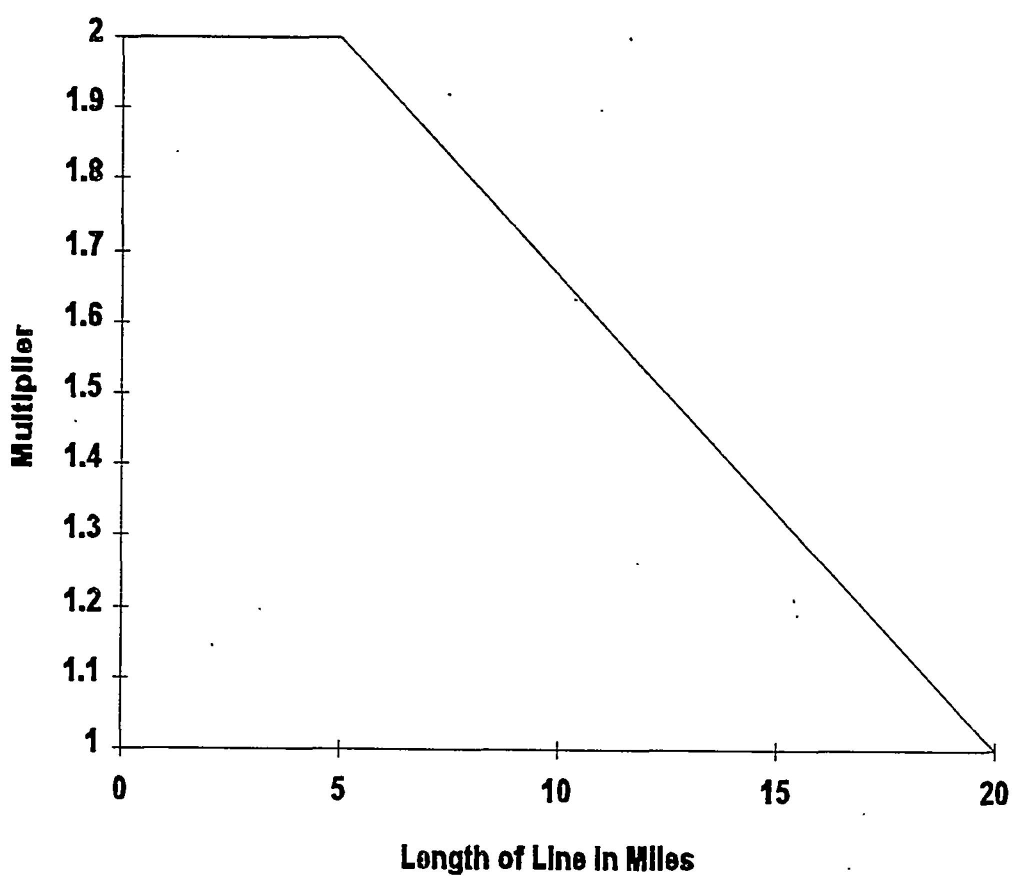

Figure 2. Curve Used to Determine Line Length Multiplier for Transmission Lines Shorter Than 20 Miles in Length

Comparison of Data Sources

The FERC cost data were updated to 1994 dollars using the GDP implicit price deflator to be consistent with the composite data set. In addition, the per-mile costs of lines less than 20 miles long were multiplied by the appropriate value (line length factor) from Figure 2. The adjusted FERC data are presented in Appendix C for each utility.

The table in Appendix C compares the adjusted structure and conductor cost for each line from the FERC data set to the range of values estimated by the composite (BPA and WAPA) data set for the same voltage level. A comparison of the FERC and composite data reveals that a few installations had per-mile costs outside of the corresponding composite data set range. However, the median of the FERC values for each voltage level lies within the composite data set range, as shown in Table 2. Note that the range of values from the composite data set is driven by explicit variations in design configurations, while the FERC data set range results from unspecified configurations that are likely different. Therefore, the results of the comparison must be used cautiously.

An examination of "land" costs reported in the FERC data set revealed a median cost equal to 13% of the combined structure and conductor cost. This is consistent with the WAPA guideline (9-15%) for estimating land and environmental costs as a fraction of hardware-related costs, assuming that the FERC "land" component includes environmental-related costs as well as land and right-of-way costs, as was discussed in the Data Sources Section.

Land and environmental costs are extremely site-specific. Additional data collection and analysis of these two cost components would clarify the variability that exists. However, BPA, WAPA, and FERC data all indicate that land and environmental costs, on average, represent less than 20% of the total cost. Therefore, further analysis of these two cost components should probably be tempered.

Comparison of FERC and composite (BPA and WAPA) data sets identified no significant differences. Therefore, the composite data set appears to be a reasonable proxy for estimating national average transmission line costs.

Table 2. Median Cost-Per-Mile Values for FERC Data Set by Voltage Level

Voltage Level (kV)	FERC Median Cost-per-Mile ($000)	FERC Cost-per-Mile Range ($000)	Range of Values from Composite BPA/WAPA Data Set ($000)
138	161	17-1787	96-308
230	202	51-1356	129-371
345	406	92-440	218-503

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Expected Cost of New Transmission Lines

The North American Electric Reliability Council (NERC) provides estimates of the number of miles of new transmission lines expected to be constructed by 2002 for 230-kV and higher voltage (NERC 1993). These data were used to estimate the total cost of this new construction and the weighted (by expected future construction mileage) average cost per mile. These figures appear in Table 3.

In Table 3, the average cost per-mile by voltage level (from Table 1) was first multiplied by 1.1 to adjust to rolling terrain, and then multiplied by the number of miles NERC estimates to be added by 2002. Land, environmental, planning, and construction supervision costs are added to the base cost figures using the average percentage multipliers (5.5%, 6.5%, 0.75%, and 7.5%, respectively) suggested by WAPA. This yields the grand totals shown.

Table 3. Future Transmission Line Construction Costs

Voltage Level (kV)	230	345	500	765	Weighted Average Cost (by Number of Miles)
Base Cost per-mile ($000)	258	376	571	861	417
Number of Additional Miles	4,365	2,452	4,929	115	N/A
Total Base Cost ($000,000)	1,128	921	2,758	99	N/A
Land ($000)	62	51	152	5	N/A
Environmental ($000)	73	60	179	6	N/A
Planning ($000)	8	7	21	1	N/A
Construction Supervision ($000)	85	69	207	7	N/A
Grand Total ($000,000)	1,356	1,107	3,316	119	N/A
Grand Total per Mile ($000)	311	452	687	1,035	502

Transmission Line Additions - Circuit Miles Additions up to 2002, based on rolling terrain.
Source: North American Electric Reliability Council

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Conclusions and Recommendations

Current transmission line stock and projected capacity additions are usually measured by the number of miles at each of the principal voltage levels. Therefore, the composite database and discussions of transmission line costs are focused on this design variable. However, the other cost drivers included in the BPA and WAPA data sets, namely conductor size, terrain type, tower frame type, tower material type, and number of circuits, could also have been used as classification variables to group per-mile costs. In particular, conductor size would appear to be the single most significant cost driver. The result is that reported costs per mile for a given voltage level vary significantly, but can be explained by these additional design variables, if they are known.

The BPA and WAPA data sets employed in this analysis both represent transmission line costs incurred by federal power marketing agencies in the Western United States. No significant differences were identified when these data sets were compared to the FERC data collected from investor-owned utilities from across the country. Therefore, the composite data set appears to be a reasonable proxy for estimating national average costs.

The extremely site-specific nature of environmental and land (right-of-way) costs make it very difficult to estimate the costs for these components in a generalized manner. Additional data collection and analysis of the costs for these two components would develop a better understanding of the variability that exists. However, BPA, WAPA, and FERC data indicate that these two components typically combine to less than 20% of the total cost, so only a modest analytical effort is recommended.

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References

Bonneville Power Administration (BPA). 1993. "Internal Memorandum: Transmission Line Estimating Data." Portland, Oregon.

Energy Information Administration (EIA). 1994. *Electric Trade in the United States 1992*. DOE/EIA-0531(92), Washington, D.C.

North American Electric Reliability Council (NERC). 1993. *Electricity Supply and Demand - 1993-2002*. Princeton, New Jersey.

Western Area Power Administration (WAPA). 1994. *Conceptual Planning and Budget Cost Estimating Guide*. Golden, Colorado.

Appendix A

Raw Data

Appendix A

Raw Data

This appendix contains the raw data provided by Bonneville Power Administration (BPA) or Western Area Power Administration (WAPA), as indicated in the "Agency" column. The original costs provided by BPA were adjusted from 1993 to 1994 dollars and to reflect Flat terrain. The original costs provided by WAPA were adjusted to include Field Data, Design and Specifications, and Other Contracts. The "Adjusted" costs were used to develop the composite data set presented in Appendix B.

The second table of this appendix presents the raw data collected by Federal Energy Regulatory Commission (FERC) from investor-owned utilities. The adjusted FERC data are presented in Appendix C.

Table A.1. RAW Data

Terrain Lookup Table - Provided with WAPA data.

Flat	Rolling	50/50	Mountainous
0%	10%	18%	25%

Other Factors (as percent additions to base cost) - Provided with WAPA data.

Cost	Low	High
Planning	0.5%	1.0%
Environmental	5.0%	8.0%
Field Data	5.0%	10.0%
Land and Rights	4.0%	7.0%
Design & Specifications	0.5%	1.0%
Other Contracts	4.0%	7.0%
Construction Supervision	5.0%	10.0%

RAW Cost	Adjusted Cost	Voltage (kV)	Conductor Size	Number of Circuits	Terrain Type	Pole Type	Frame Type	Agency
$36,000	$40,950	13.8	1/0	1	Flat	Wood	Single Pole	WAPA
$37,000	$42,088	13.8	2/0	1	Flat	Wood	Single Pole	WAPA
$38,000	$43,225	13.8	3/0	1	Flat	Wood	Single Pole	WAPA
$40,000	$45,500	13.8	4/0	1	Flat	Wood	Single Pole	WAPA
$42,000	$47,775	13.8	266.8	1	Flat	Wood	Single Pole	WAPA
$44,000	$50,050	13.8	336.4	1	Flat	Wood	Single Pole	WAPA
$38,000	$43,225	34.5	1/0	1	Flat	Wood	Single Pole	WAPA
$40,000	$45,500	34.5	2/0	1	Flat	Wood	Single Pole	WAPA
$41,000	$46,638	34.5	3/0	1	Flat	Wood	Single Pole	WAPA
$42,000	$47,775	34.5	4/0	1	Flat	Wood	Single Pole	WAPA
$44,000	$50,050	34.5	266.8	1	Flat	Wood	Single Pole	WAPA
$48,000	$54,600	34.5	336.4	1	Flat	Wood	Single Pole	WAPA
$40,000	$45,500	46	1/0	1	Flat	Wood	Single Pole	WAPA
$41,000	$46,638	46	2/0	1	Flat	Wood	Single Pole	WAPA
$42,000	$47,775	46	3/0	1	Flat	Wood	Single Pole	WAPA
$43,000	$48,913	46	4/0	1	Flat	Wood	Single Pole	WAPA
$46,000	$52,325	46	266.8	1	Flat	Wood	Single Pole	WAPA
$49,000	$55,738	46	336.4	1	Flat	Wood	Single Pole	WAPA
$53,000	$60,288	69	4/0	1	Flat	Wood	Single Pole	WAPA
$55,000	$62,563	69	266.8	1	Flat	Wood	Single Pole	WAPA
$58,000	$65,975	69	336.4	1	Flat	Wood	Single Pole	WAPA
$60,000	$68,250	69	397.5	1	Flat	Wood	Single Pole	WAPA
$64,000	$72,800	69	477	1	Flat	Wood	Single Pole	WAPA
$66,000	$75,075	69	556.5	1	Flat	Wood	Single Pole	WAPA
$70,000	$79,625	69	636	1	Flat	Wood	Single Pole	WAPA
$76,000	$86,450	69	795	1	Flat	Wood	Single Pole	WAPA
$60,000	$68,250	69	4/0	1	Flat	Wood	H-Frame	WAPA
$62,000	$70,525	69	266.8	1	Flat	Wood	H-Frame	WAPA
$65,000	$73,938	69	336.4	1	Flat	Wood	H-Frame	WAPA
$67,000	$76,213	69	397.5	1	Flat	Wood	H-Frame	WAPA
$71,000	$80,763	69	477	1	Flat	Wood	H-Frame	WAPA
$73,000	$83,038	69	556.5	1	Flat	Wood	H-Frame	WAPA
$77,000	$87,588	69	636	1	Flat	Wood	H-Frame	WAPA
$84,000	$95,550	69	795	1	Flat	Wood	H-Frame	WAPA
$89,000	$101,238	69	397.5	1	Flat	Steel	Single Pole	WAPA
$93,000	$105,788	69	477	1	Flat	Steel	Single Pole	WAPA
$96,000	$109,200	69	556.5	1	Flat	Steel	Single Pole	WAPA
$100,000	$113,750	69	636	1	Flat	Steel	Single Pole	WAPA
$105,000	$119,438	69	795	1	Flat	Steel	Single Pole	WAPA
$108,000	$122,850	69	954	1	Flat	Steel	Single Pole	WAPA
$113,000	$128,538	69	1272	1	Flat	Steel	Single Pole	WAPA
$129,000	$146,738	69	397.5	2	Flat	Steel	Single Pole	WAPA
$141,000	$160,388	69	477	2	Flat	Steel	Single Pole	WAPA
$150,000	$170,625	69	556.5	2	Flat	Steel	Single Pole	WAPA
$164,000	$186,550	69	636	2	Flat	Steel	Single Pole	WAPA
$180,000	$204,750	69	795	2	Flat	Steel	Single Pole	WAPA

Table A.1. (contd)

RAW Cost	Adjusted Cost	Voltage (kV)	Conductor Size	Number of Circuits	Terrain Type	Pole Type	Frame Type	Agency
$192,000	$218,400	69	954	2	Flat	Steel	Single Pole	WAPA
$209,000	$237,738	69	1272	2	Flat	Steel	Single Pole	WAPA
$109,900	$102,483	115	398	1	Rolling	Wood	Single Pole	BPA
$119,740	$111,659	115	795	1	Rolling	Wood	Single Pole	BPA
$133,260	$124,267	115	1137	1	Rolling	Wood	Single Pole	BPA
$151,500	$141,276	115	1589	1	Rolling	Wood	Single Pole	BPA
$124,490	$116,089	115	795	1	Rolling	Wood	H-Frame	BPA
$128,810	$120,117	115	954	1	Rolling	Wood	H-Frame	BPA
$135,200	$126,076	115	1137	1	Rolling	Wood	H-Frame	BPA
$149,520	$139,429	115	1589	1	Rolling	Wood	H-Frame	BPA
$164,260	$153,175	115	1979	1	Rolling	Wood	H-Frame	BPA
$176,250	$164,356	115	2406	1	Rolling	Wood	H-Frame	BPA
$140,000	$130,552	115	795	1	Rolling	Steel	Single Pole	BPA
$191,720	$166,661	115	795	1	50/50	Steel	Lattice	BPA
$262,730	$228,389	115	795	2	50/50	Steel	Lattice	BPA
$71,000	$80,763	115	397.5	1	Flat	Wood	Single Pole	WAPA
$74,000	$84,175	115	477	1	Flat	Wood	Single Pole	WAPA
$77,000	$87,588	115	556.5	1	Flat	Wood	Single Pole	WAPA
$82,000	$93,275	115	636	1	Flat	Wood	Single Pole	WAPA
$88,000	$100,100	115	795	1	Flat	Wood	Single Pole	WAPA
$74,000	$84,175	115	336.4	1	Flat	Wood	H-Frame	WAPA
$77,000	$87,588	115	397.5	1	Flat	Wood	H-Frame	WAPA
$82,000	$93,275	115	477	1	Flat	Wood	H-Frame	WAPA
$84,000	$95,550	115	556.5	1	Flat	Wood	H-Frame	WAPA
$88,000	$100,100	115	636	1	Flat	Wood	H-Frame	WAPA
$94,000	$106,925	115	795	1	Flat	Wood	H-Frame	WAPA
$97,000	$110,338	115	954	1	Flat	Wood	H-Frame	WAPA
$109,000	$123,988	115	477	1	Flat	Steel	Single Pole	WAPA
$111,000	$126,263	115	556.5	1	Flat	Steel	Single Pole	WAPA
$114,000	$129,675	115	636	1	Flat	Steel	Single Pole	WAPA
$120,000	$136,500	115	795	1	Flat	Steel	Single Pole	WAPA
$123,000	$139,913	115	954	1	Flat	Steel	Single Pole	WAPA
$130,000	$147,875	115	1272	1	Flat	Steel	Single Pole	WAPA
$142,000	$161,525	115	397.5	2	Flat	Steel	Single Pole	WAPA
$159,000	$180,863	115	477	2	Flat	Steel	Single Pole	WAPA
$173,000	$196,788	115	556.5	2	Flat	Steel	Single Pole	WAPA
$190,000	$216,125	115	636	2	Flat	Steel	Single Pole	WAPA
$212,000	$241,150	115	795	2	Flat	Steel	Single Pole	WAPA
$228,000	$259,350	115	954	2	Flat	Steel	Single Pole	WAPA
$250,000	$284,375	115	1272	2	Flat	Steel	Single Pole	WAPA
$84,000	$95,550	138	397.5	1	Flat	Wood	H-Frame	WAPA
$88,000	$100,100	138	477	1	Flat	Wood	H-Frame	WAPA
$90,000	$102,375	138	556.5	1	Flat	Wood	H-Frame	WAPA
$94,000	$106,925	138	636	1	Flat	Wood	H-Frame	WAPA
$100,000	$113,750	138	795	1	Flat	Wood	H-Frame	WAPA
$103,000	$117,163	138	954	1	Flat	Wood	H-Frame	WAPA
$111,000	$126,263	138	477	1	Flat	Steel	Single Pole	WAPA
$116,000	$131,950	138	556.5	1	Flat	Steel	Single Pole	WAPA
$121,000	$137,638	138	636	1	Flat	Steel	Single Pole	WAPA
$130,000	$147,875	138	795	1	Flat	Steel	Single Pole	WAPA
$135,000	$153,563	138	954	1	Flat	Steel	Single Pole	WAPA
$143,000	$162,663	138	1272	1	Flat	Steel	Single Pole	WAPA
$168,000	$191,100	138	477	2	Flat	Steel	Single Pole	WAPA
$185,000	$210,438	138	556.5	2	Flat	Steel	Single Pole	WAPA
$204,000	$232,050	138	636	2	Flat	Steel	Single Pole	WAPA
$227,000	$258,213	138	795	2	Flat	Steel	Single Pole	WAPA
$247,000	$280,963	138	954	2	Flat	Steel	Single Pole	WAPA
$271,000	$308,263	138	1272	2	Flat	Steel	Single Pole	WAPA
$92,000	$104,650	161	477	1	Flat	Wood	H-Frame	WAPA
$95,000	$108,063	161	556.5	1	Flat	Wood	H-Frame	WAPA
$98,000	$111,475	161	636	1	Flat	Wood	H-Frame	WAPA
$104,000	$118,300	161	795	1	Flat	Wood	H-Frame	WAPA
$108,000	$122,850	161	954	1	Flat	Wood	H-Frame	WAPA
$114,000	$129,675	161	477	1	Flat	Steel	Single Pole	WAPA
$121,000	$137,638	161	556.5	1	Flat	Steel	Single Pole	WAPA
$131,000	$149,013	161	636	1	Flat	Steel	Single Pole	WAPA
$141,000	$160,388	161	795	1	Flat	Steel	Single Pole	WAPA

Table A.1. (contd)

RAW Cost	Adjusted Cost	Voltage (kV)	Conductor Size	Number of Circuits	Terrain Type	Pole Type	Frame Type	Agency
$149,000	$169,488	161	954	1	Flat	Steel	Single Pole	WAPA
$160,000	$182,000	161	1272	1	Flat	Steel	Single Pole	WAPA
$182,000	$207,025	161	477	2	Flat	Steel	Single Pole	WAPA
$201,000	$228,638	161	556.5	2	Flat	Steel	Single Pole	WAPA
$222,000	$252,525	161	636	2	Flat	Steel	Single Pole	WAPA
$247,000	$280,963	161	795	2	Flat	Steel	Single Pole	WAPA
$268,000	$304,850	161	954	2	Flat	Steel	Single Pole	WAPA
$293,000	$333,288	161	1272	2	Flat	Steel	Single Pole	WAPA
$133,080	$124,099	230	795	1	Rolling	Wood	H-Frame	BPA
$137,100	$127,848	230	954	1	Rolling	Wood	H-Frame	BPA
$144,730	$134,963	230	1137	1	Rolling	Wood	H-Frame	BPA
$159,830	$149,044	230	1589	1	Rolling	Wood	H-Frame	BPA
$174,230	$162,472	230	1979	1	Rolling	Wood	H-Frame	BPA
$187,480	$174,828	230	2406	1	Rolling	Wood	H-Frame	BPA
$172,220	$160,597	230	993	1	Rolling	Steel	Lattice	BPA
$176,980	$165,036	230	1114	1	Rolling	Steel	Lattice	BPA
$229,000	$213,546	230	1509	1	Rolling	Steel	Lattice	BPA
$235,960	$220,036	230	1917	1	Rolling	Steel	Lattice	BPA
$252,830	$235,767	230	2406	1	Rolling	Steel	Lattice	BPA
$212,250	$184,507	230	993	1	50/50	Steel	Lattice	BPA
$217,320	$188,915	230	1114	1	50/50	Steel	Lattice	BPA
$261,860	$227,633	230	1509	1	50/50	Steel	Lattice	BPA
$268,720	$233,596	230	1917	1	50/50	Steel	Lattice	BPA
$285,250	$247,966	230	2406	1	50/50	Steel	Lattice	BPA
$236,240	$220,297	230	1589	2	Rolling	Wood	H-Frame	BPA
$310,480	$289,527	230	1114	2	Rolling	Steel	Single Pole	BPA
$358,670	$334,465	230	1589	2	Rolling	Steel	Single Pole	BPA
$285,390	$266,130	230	993	2	Rolling	Steel	Lattice	BPA
$293,840	$274,010	230	1114	2	Rolling	Steel	Lattice	BPA
$344,200	$320,971	230	1509	2	Rolling	Steel	Lattice	BPA
$357,690	$333,551	230	1917	2	Rolling	Steel	Lattice	BPA
$382,570	$356,752	230	2406	2	Rolling	Steel	Lattice	BPA
$333,200	$289,648	230	993	2	50/50	Steel	Lattice	BPA
$342,360	$297,611	230	1114	2	50/50	Steel	Lattice	BPA
$376,160	$326,993	230	1509	2	50/50	Steel	Lattice	BPA
$389,650	$338,720	230	1917	2	50/50	Steel	Lattice	BPA
$415,210	$360,939	230	2406	2	50/50	Steel	Lattice	BPA
$119,000	$135,363	230	795	1	Flat	Wood	H-Frame	WAPA
$122,000	$138,775	230	954	1	Flat	Wood	H-Frame	WAPA
$128,000	$145,600	230	1272	1	Flat	Wood	H-Frame	WAPA
$123,000	$139,913	230	477	1	Flat	Steel	Single Pole	WAPA
$133,000	$151,288	230	556.5	1	Flat	Steel	Single Pole	WAPA
$143,000	$162,663	230	636	1	Flat	Steel	Single Pole	WAPA
$155,000	$176,313	230	795	1	Flat	Steel	Single Pole	WAPA
$166,000	$188,825	230	954	1	Flat	Steel	Single Pole	WAPA
$179,000	$203,613	230	1272	1	Flat	Steel	Single Pole	WAPA
$207,000	$235,463	230	477	2	Flat	Steel	Single Pole	WAPA
$222,000	$252,525	230	556.5	2	Flat	Steel	Single Pole	WAPA
$240,000	$273,000	230	636	2	Flat	Steel	Single Pole	WAPA
$261,000	$296,888	230	795	2	Flat	Steel	Single Pole	WAPA
$280,000	$318,500	230	954	2	Flat	Steel	Single Pole	WAPA
$302,000	$343,525	230	1272	2	Flat	Steel	Single Pole	WAPA
$119,000	$135,363	230	795	1	Flat	Steel	Lattice	WAPA
$132,000	$150,150	230	954	1	Flat	Steel	Lattice	WAPA
$150,000	$170,625	230	1272	1	Flat	Steel	Lattice	WAPA
$170,000	$193,375	230	1565	1	Flat	Steel	Lattice	WAPA
$191,000	$217,263	230	795	2	Flat	Steel	Lattice	WAPA
$216,000	$245,700	230	954	2	Flat	Steel	Lattice	WAPA
$248,000	$282,100	230	1272	2	Flat	Steel	Lattice	WAPA
$285,000	$324,188	230	1565	2	Flat	Steel	Lattice	WAPA
$192,000	$218,400	345	795	1	Flat	Steel	Lattice	WAPA
$209,000	$237,738	345	954	1	Flat	Steel	Lattice	WAPA
$231,000	$262,763	345	1272	1	Flat	Steel	Lattice	WAPA
$260,000	$295,750	345	1565	1	Flat	Steel	Lattice	WAPA
$323,000	$367,413	345	795	2	Flat	Steel	Lattice	WAPA
$353,000	$401,538	345	954	2	Flat	Steel	Lattice	WAPA
$391,000	$444,763	345	1272	2	Flat	Steel	Lattice	WAPA

Table A.1. (contd)

RAW Cost	Adjusted Cost	Voltage (kV)	Conductor Size	Number of Circuits	Terrain Type	Pole Type	Frame Type	Agency
$442,000	$502,775	345	1565	2	Flat	Steel	Lattice	WAPA
$366,300	$375,738	500	3578	1	Flat	Steel	Lattice	BPA
$421,760	$432,627	500	5607	1	Flat	Steel	Lattice	BPA
$431,230	$402,128	500	3578	1	Rolling	Steel	Lattice	BPA
$480,590	$448,157	500	5607	1	Rolling	Steel	Lattice	BPA
$449,250	$390,530	500	3578	1	50/50	Steel	Lattice	BPA
$521,860	$453,649	500	5607	1	50/50	Steel	Lattice	BPA
$654,860	$569,265	500	5607	1	50/50	Steel	Single Pole	BPA
$803,450	$824,151	500	5607	2	Flat	Steel	Lattice	BPA
$881,680	$904,396	500	6039	2	Flat	Steel	Lattice	BPA
$862,530	$884,753	500	7218	2	Flat	Steel	Lattice	BPA
$916,170	$854,341	500	5607	2	Rolling	Steel	Lattice	BPA
$1,001,500	$933,912	500	6039	2	Rolling	Steel	Lattice	BPA
$975,860	$910,003	500	7218	2	Rolling	Steel	Lattice	BPA
$961,170	$835,538	500	5607	2	50/50	Steel	Lattice	BPA
$1,045,840	$909,141	500	6039	2	50/50	Steel	Lattice	BPA
$1,020,540	$887,148	500	7218	2	50/50	Steel	Lattice	BPA
$1,061,100	$922,406	500	5607	2	50/50	Steel	Single Pole	BPA
$290,000	$329,875	500	795	1	Flat	Steel	Lattice	WAPA
$306,000	$348,075	500	954	1	Flat	Steel	Lattice	WAPA
$327,000	$371,963	500	1272	1	Flat	Steel	Lattice	WAPA
$358,000	$407,225	500	1565	1	Flat	Steel	Lattice	WAPA
$389,000	$442,488	500	1780	1	Flat	Steel	Lattice	WAPA
$492,000	$559,650	500	795	2	Flat	Steel	Lattice	WAPA
$513,000	$583,538	500	954	2	Flat	Steel	Lattice	WAPA
$546,000	$621,075	500	1272	2	Flat	Steel	Lattice	WAPA
$599,000	$681,363	500	1565	2	Flat	Steel	Lattice	WAPA
$652,000	$741,650	500	1780	2	Flat	Steel	Lattice	WAPA

Table A.2. FERC RAW Data

Company	Voltage Level (kV)	Line Length (Miles)	Land Cost ($000)*	Structure Cost ($000)*	Conductor Cost ($000)*	Total ($000)*
Appalachian Power	$138	6.8	315	1445	772	2532
Carolina Power and Light	$138	15.78	-	204	153	357
Central Illinois Public Service	$138	34.32	1732	2986	3158	7875
Central Power and Light	$138	59.6	151	93	-	244
Cinicinatti Gas and Electric	$138	3.15	-	-	-	-
Columbus Southern Power	$138	2.53	359	275	2964	3599
Commonwealth Edison	$138	31.85	-	371	159	530
Consolidated Edison New York	$138	4.31	-	8166	6478	14644
Consumer Power	$138	37.1	576	3273	2786	6635
Dayton Power and Light	$138	2.23	-	-	-	-
Del Marva Power and Light	$138	4.63	-	-	-	2544
Duquesne Light	$138	7.16	149	1296	1406	2851
Florida Power and Light	$138	238.88	304	5419	4748	10450
Georgia Power	$138	0.7	-	-	-	-
Hawaiian Electric	$138	0.24	-	-	-	-
Houstaon Lighting and Power	$138	-	-	-	-	-
Idaho Power	$138	1.36	-	101	87	188
Illinois Power	$138	9.88	83	362	309	754
Indiana Michigan Power	$138	19.58	878	968	1092	2938
Indianapolis Power and Light	$138	10.47	-	-	-	-
Kentucky Power	$138	1.02	-	167	240	406
Nevada Power	$138	17.34	331	1877	459	2666
Ohio Edison	$138	-	1	97	22	121
Ohio Power	$138	6.66	443	1828	1231	3502
Oklahoma Gas & Electric	$138	4.48	1031	4320	1960	7311
Peoples Electric Co-op	$138	12.43	-	-	-	1540
Public Service Co. of Oklahoma	$138	10.84	347	652	865	1865
Public Service Electric and Gas Co.	$138	-	75	17229	6641	23945
PSI Energy Inc.	$138	4	66	692	372	1130
Southern Indiana Gas and Electric	$138	7.08	-	591	356	946
Texas Utilities Electric	$138	277.06	-	-	-	-
Utilicorp United Inc.	$138	0.2	20	199	108	327
Wes Penn Power	$138	5.3	1160	2016	708	3884
West Texas Utilities	$138	35.59	159	1032	835	2026
Wisconson Electric Power	$138	11.83	-	1677	1118	2795
Philidelphia Electric	$220	-	4952	8510	4692	18154
Alabama Power	$230	5.05	-	1485	440	1925
Appalachian Power	$230	91.42	3934	9837	7655	21426
Baltimore Gas & Electric	$230	4.5	991	3540	2789	7320
Florida Power and Light	$230	76.11	11	2105	1600	3716
Florida Power	$230	0.34	-	93	58	151
Georgia Power	$230	7.4	-	-	4134	4134
Louisiana Power and Light	$230	31.1	23	4806	3315	8145
Mississippi Power and Light	$230	3.03	619	683	323	1626
Montana Power	$230	4.7	580	914	426	1920
Nevada Power	$230	6.28	1025	4578	2377	7980
Northern States Power	$230	0.05	-	65	64	129
PG&E	$230	17.59	-	-	-	-
Pennsylvania Power and Light	$230	22.23	-	293	3971	4264
Patomic Electric Power	$230	0.57	-	42	146	188
Public Service Co. of Colorado	$230	655.06	3567	31131	20258	54959
Public Service Electric and Gas Co.	$230	10.41	8294	10644	5127	24065
Puget Sound Power and Light	$230	22.81	789	1373	2360	4522
PSI Energy Inc.	$230	3	-	1799	1199	2998
South Carolina Electric and Gas	$230	8	413	784	1101	2278
Virginia Electric and Power	$230	19.79	2194	4919	3383	10495
Boston Edison	$345	0.05	-	-	-	-
Consolidated Edison New York	$345	-	36	239	-	275
Consumers Power	$345	20	247	5631	2731	8609
Ohio Edison	$345	-	-	303	108	411
Oklahoma Gas & Electric	$345	-	10	117	2	109
Public Service Co. of Colorado	$345	346.7	1499	21888	8291	31678
Saint Joseph Light and Power	$345	102.99	-	-	2594	2594
Texas Utilities Electric	$345	37.68	-	-	-	-
Wisconson Electric Power	$345	76.3	1629	14085	15382	31096
Public Service Electric and Gas Co.	$500	-	22		-	22

*Note: All costs are total - not per mile.

Appendix B

Composite Data

Appendix B

Composite Data

This appendix contains the composite data set generated as described in the report. The first table contains the entire data set together; the subsequent tables contain the same data organized by specific design configurations. To arrive at an estimate for total project cost, look up the composite cost in either of these tables for the configuration of interest. Then, refer to the final two pages in this appendix, which contain the additional costs (terrain factor, line length factor, land, environmental, planning, and construction supervision) that must be added to the composite per-mile cost to arrive at a total project cost. For land and environmental costs, both the Bonneville Power Administration (BPA) and the Western Area Power Administration (WAPA) approaches are provided.

Table B.1. Composite Data Set

Composite Cost ($000)	Voltage (kV)	Conductor Size	Number of Circuits	Terrain Type	Pole Type	Frame Type	Reference Number/Sheet	Source
41	13.8	123	1	Flat	Wood	Single Pole	60	WAPA
42	13.8	138	1	Flat	Wood	Single Pole	61	WAPA
43	13.8	155	1	Flat	Wood	Single Pole	62	WAPA
46	13.8	174	1	Flat	Wood	Single Pole	63	WAPA
48	13.8	267	1	Flat	Wood	Single Pole	64	WAPA
50	13.8	336	1	Flat	Wood	Single Pole	65	WAPA
43	34.5	123	1	Flat	Wood	Single Pole	66	WAPA
46	34.5	138	1	Flat	Wood	Single Pole	67	WAPA
47	34.5	155	1	Flat	Wood	Single Pole	68	WAPA
48	34.5	174	1	Flat	Wood	Single Pole	69	WAPA
50	34.5	267	1	Flat	Wood	Single Pole	70	WAPA
55	34.5	336	1	Flat	Wood	Single Pole	71	WAPA
46	46	123	1	Flat	Wood	Single Pole	72	WAPA
47	46	138	1	Flat	Wood	Single Pole	73	WAPA
48	46	155	1	Flat	Wood	Single Pole	74	WAPA
49	46	174	1	Flat	Wood	Single Pole	75	WAPA
52	46	267	1	Flat	Wood	Single Pole	76	WAPA
56	46	336	1	Flat	Wood	Single Pole	77	WAPA
60	69	174	1	Flat	Wood	Single Pole	78	WAPA
63	69	267	1	Flat	Wood	Single Pole	79	WAPA
66	69	336	1	Flat	Wood	Single Pole	80	WAPA
68	69	398	1	Flat	Wood	Single Pole	81	WAPA
73	69	477	1	Flat	Wood	Single Pole	82	WAPA
75	69	557	1	Flat	Wood	Single Pole	83	WAPA
80	69	636	1	Flat	Wood	Single Pole	84	WAPA
86	69	795	1	Flat	Wood	Single Pole	85	WAPA
68	69	174	1	Flat	Wood	H-Frame	91	WAPA
71	69	267	1	Flat	Wood	H-Frame	92	WAPA
74	69	336	1	Flat	Wood	H-Frame	93	WAPA
76	69	398	1	Flat	Wood	H-Frame	94	WAPA
81	69	477	1	Flat	Wood	H-Frame	95	WAPA
83	69	557	1	Flat	Wood	H-Frame	96	WAPA
88	69	636	1	Flat	Wood	H-Frame	97	WAPA
96	69	795	1	Flat	Wood	H-Frame	98	WAPA
96	138	398	1	Flat	Wood	H-Frame	106	WAPA
100	138	477	1	Flat	Wood	H-Frame	107	WAPA
102	138	557	1	Flat	Wood	H-Frame	108	WAPA
107	138	636	1	Flat	Wood	H-Frame	109	WAPA
114	138	795	1	Flat	Wood	H-Frame	110	WAPA
117	138	954	1	Flat	Wood	H-Frame	111	WAPA
126	138	1137	1	Flat	Wood	H-Frame	Special 14	WAPA
131	138	1272	1	Flat	Wood	H-Frame	Special 15	WAPA
141	138	1509	1	Flat	Wood	H-Frame	Special 16	WAPA
144	138	1589	1	Flat	Wood	H-Frame	Special 24	WAPA
159	138	1979	1	Flat	Wood	H-Frame	Special 17	WAPA
176	138	2406	1	Flat	Wood	H-Frame	Special 18	WAPA
105	161	477	1	Flat	Wood	H-Frame	112	WAPA
108	161	557	1	Flat	Wood	H-Frame	113	WAPA
111	161	636	1	Flat	Wood	H-Frame	114	WAPA
118	161	795	1	Flat	Wood	H-Frame	115	WAPA
123	161	954	1	Flat	Wood	H-Frame	116	WAPA
131	161	1137	1	Flat	Wood	H-Frame	Special 19	WAPA
136	161	1272	1	Flat	Wood	H-Frame	Special 20	WAPA
145	161	1509	1	Flat	Wood	H-Frame	Special 21	WAPA
148	161	1589	1	Flat	Wood	H-Frame	Special 25	WAPA

Table B.1. (contd)

Composite Cost ($000)	Voltage (kV)	Conductor Size	Number of Circuits	Terrain Type	Pole Type	Frame Type	Reference Number/Sheet	Source
163	161	1979	1	Flat	Wood	H-Frame	Special 22	WAPA
180	161	2406	1	Flat	Wood	H-Frame	Special 23	WAPA
101	69	398	1	Flat	Steel	Single Pole	120	WAPA
106	69	477	1	Flat	Steel	Single Pole	121	WAPA
109	69	557	1	Flat	Steel	Single Pole	122	WAPA
114	69	636	1	Flat	Steel	Single Pole	123	WAPA
119	69	795	1	Flat	Steel	Single Pole	124	WAPA
123	69	954	1	Flat	Steel	Single Pole	125	WAPA
126	69	1114	1	Adjusted	Steel	Single Pole	Special 1	Composite
129	69	1272	1	Flat	Steel	Single Pole	126	WAPA
126	138	477	1	Flat	Steel	Single Pole	133	WAPA
132	138	557	1	Flat	Steel	Single Pole	134	WAPA
138	138	636	1	Flat	Steel	Single Pole	135	WAPA
148	138	795	1	Flat	Steel	Single Pole	136	WAPA
154	138	954	1	Flat	Steel	Single Pole	137	WAPA
159	138	1114	1	Flat	Steel	Single Pole	Special 2	Composite
163	138	1272	1	Flat	Steel	Single Pole	138	WAPA
130	161	477	1	Flat	Steel	Single Pole	139	WAPA
138	161	557	1	Flat	Steel	Single Pole	140	WAPA
149	161	636	1	Flat	Steel	Single Pole	141	WAPA
160	161	795	1	Flat	Steel	Single Pole	142	WAPA
169	161	954	1	Flat	Steel	Single Pole	143	WAPA
176	161	1114	1	Adjusted	Steel	Single Pole	Special 3	Composite
182	161	1272	1	Flat	Steel	Single Pole	144	WAPA
147	69	398	2	Flat	Steel	Single Pole	151	WAPA
160	69	477	2	Flat	Steel	Single Pole	152	WAPA
171	69	557	2	Flat	Steel	Single Pole	153	WAPA
187	69	636	2	Flat	Steel	Single Pole	154	WAPA
205	69	795	2	Flat	Steel	Single Pole	155	WAPA
218	69	954	2	Flat	Steel	Single Pole	156	WAPA
217	69	993	2	Flat	Steel	Single Pole	Special 4	Composite
230	69	1114	2	Flat	Steel	Single Pole	Special 5	Composite
238	69	1272	2	Flat	Steel	Single Pole	157	WAPA
191	138	477	2	Flat	Steel	Single Pole	165	WAPA
210	138	557	2	Flat	Steel	Single Pole	166	WAPA
232	138	636	2	Flat	Steel	Single Pole	167	WAPA
258	138	795	2	Flat	Steel	Single Pole	168	WAPA
281	138	954	2	Flat	Steel	Single Pole	169	WAPA
278	138	993	2	Flat	Steel	Single Pole	Special 6	WAPA
295	138	1114	2	Flat	Steel	Single Pole	Special 7	WAPA
308	138	1272	2	Flat	Steel	Single Pole	170	WAPA
207	161	477	2	Flat	Steel	Single Pole	171	WAPA
229	161	557	2	Flat	Steel	Single Pole	172	WAPA
253	161	636	2	Flat	Steel	Single Pole	173	WAPA
281	161	795	2	Flat	Steel	Single Pole	174	WAPA
305	161	954	2	Flat	Steel	Single Pole	175	WAPA
301	161	993	2	Flat	Steel	Single Pole	Special 8	WAPA
320	161	1114	2	Flat	Steel	Single Pole	Special 9	WAPA
333	161	1272	2	Flat	Steel	Single Pole	176	WAPA
218	345	795	1	Flat	Steel	Lattice	187	WAPA
238	345	954	1	Flat	Steel	Lattice	188	WAPA
239	345	993	1	Flat	Steel	Lattice	Special 11	WAPA
250	345	1114	1	Flat	Steel	Lattice	Special 12	WAPA
263	345	1272	1	Flat	Steel	Lattice	189	WAPA
289	345	1509	1	Flat	Steel	Lattice	Special 13	WAPA
296	345	1565	1	Flat	Steel	Lattice	190	WAPA
315	345	1780	1	Flat	Steel	Lattice	Special 10	WAPA
329	345	1917	1	Flat	Steel	Lattice	Special 26	WAPA
376	345	2406	1	Flat	Steel	Lattice	Special 27	WAPA

Table B.1. (contd)

Composite Cost ($000)	Voltage (kV)	Conductor Size	Number of Circuits	Terrain Type	Pole Type	Frame Type	Reference Number/Sheet	Source
367	345	795	2	Flat	Steel	Lattice	200	WAPA
402	345	954	2	Flat	Steel	Lattice	201	WAPA
445	345	1272	2	Flat	Steel	Lattice	202	WAPA
503	345	1565	2	Flat	Steel	Lattice	203	WAPA
167	115	795	1	50/50	Steel	Lattice	12	BPA
228	115	795	2	50/50	Steel	Lattice	13	BPA
220	230	1589	2	Rolling	Wood	H-Frame	30	BPA
569	500	5607	1	50/50	Steel	Single Pole	49	BPA
1061	500	5607	2	50/50	Steel	Single Pole	59	BPA
91	115	398	1	Adjusted	Wood	Single Pole	A	Composite
94	115	477	1	Adjusted	Wood	Single Pole	A	Composite
98	115	557	1	Adjusted	Wood	Single Pole	A	Composite
101	115	636	1	Adjusted	Wood	Single Pole	A	Composite
108	115	795	1	Adjusted	Wood	Single Pole	A	Composite
114	115	954	1	Adjusted	Wood	Single Pole	A	Composite
122	115	1137	1	Adjusted	Wood	Single Pole	A	Composite
141	115	1589	1	Adjusted	Wood	Single Pole	A	Composite
89	115	336	1	Adjusted	Wood	H-Frame	B	Composite
92	115	398	1	Adjusted	Wood	H-Frame	B	Composite
95	115	477	1	Adjusted	Wood	H-Frame	B	Composite
98	115	557	1	Adjusted	Wood	H-Frame	B	Composite
101	115	636	1	Adjusted	Wood	H-Frame	B	Composite
107	115	795	1	Adjusted	Wood	H-Frame	B	Composite
113	115	954	1	Adjusted	Wood	H-Frame	B	Composite
120	115	1137	1	Adjusted	Wood	H-Frame	B	Composite
126	115	1272	1	Adjusted	Wood	H-Frame	B	Composite
135	115	1509	1	Adjusted	Wood	H-Frame	B	Composite
138	115	1589	1	Adjusted	Wood	H-Frame	B	Composite
153	115	1979	1	Adjusted	Wood	H-Frame	B	Composite
170	115	2406	1	Adjusted	Wood	H-Frame	B	Composite
134	115	795	1	Adjusted	Steel	Single Pole	C	Composite
124	115	477	1	Adjusted	Steel	Single Pole	C	Composite
127	115	557	1	Adjusted	Steel	Single Pole	C	Composite
129	115	636	1	Adjusted	Steel	Single Pole	C	Composite
139	115	954	1	Adjusted	Steel	Single Pole	C	Composite
144	115	1114	1	Adjusted	Steel	Single Pole	C	Composite
148	115	1272	1	Adjusted	Steel	Single Pole	C	Composite
129	230	795	1	Adjusted	Wood	H-Frame	E	Composite
133	230	954	1	Adjusted	Wood	H-Frame	E	Composite
142	230	1272	1	Adjusted	Wood	H-Frame	E	Composite
139	230	1137	1	Adjusted	Wood	H-Frame	E	Composite
149	230	1509	1	Adjusted	Wood	H-Frame	E	Composite
151	230	1589	1	Adjusted	Wood	H-Frame	E	Composite
162	230	1979	1	Adjusted	Wood	H-Frame	E	Composite
174	230	2406	1	Adjusted	Wood	H-Frame	E	Composite
154	230	795	1	Adjusted	Steel	Lattice	F&G	Composite
164	230	954	1	Adjusted	Steel	Lattice	F&G	Composite
183	230	1272	1	Adjusted	Steel	Lattice	F&G	Composite
201	230	1565	1	Adjusted	Steel	Lattice	F&G	Composite
166	230	993	1	Adjusted	Steel	Lattice	F&G	Composite
174	230	1114	1	Adjusted	Steel	Lattice	F&G	Composite
198	230	1509	1	Adjusted	Steel	Lattice	F&G	Composite
214	230	1780	1	Adjusted	Steel	Lattice	F&G	Composite
222	230	1917	1	Adjusted	Steel	Lattice	F&G	Composite
252	230	2406	1	Adjusted	Steel	Lattice	F&G	Composite
254	230	477	1	Adjusted	Steel	Single Pole	H	Composite
261	230	557	1	Adjusted	Steel	Single Pole	H	Composite
268	230	636	1	Adjusted	Steel	Single Pole	H	Composite
282	230	795	1	Adjusted	Steel	Single Pole	H	Composite

Table B.1. (contd)

Composite Cost ($000)	Voltage (kV)	Conductor Size	Number of Circuits	Terrain Type	Pole Type	Frame Type	Reference Number/Sheet	Source
296	230	954	1	Adjusted	Steel	Single Pole	H	Composite
324	230	1272	1	Adjusted	Steel	Single Pole	H	Composite
310	230	1114	1	Adjusted	Steel	Single Pole	H	Composite
352	230	1589	1	Adjusted	Steel	Single Pole	H	Composite
254	230	795	2	Adjusted	Steel	Single Pole	I&J	Composite
265	230	954	2	Adjusted	Steel	Single Pole	I&J	Composite
289	230	1272	2	Adjusted	Steel	Single Pole	I&J	Composite
310	230	1565	2	Adjusted	Steel	Single Pole	I&J	Composite
268	230	993	2	Adjusted	Steel	Single Pole	I&J	Composite
277	230	1114	2	Adjusted	Steel	Single Pole	I&J	Composite
306	230	1509	2	Adjusted	Steel	Single Pole	I&J	Composite
336	230	1917	2	Adjusted	Steel	Single Pole	I&J	Composite
371	230	2406	2	Adjusted	Steel	Single Pole	I&J	Composite
364	500	795	1	Adjusted	Steel	Lattice	KLM	Composite
367	500	954	1	Adjusted	Steel	Lattice	KLM	Composite
367	500	993	1	Adjusted	Steel	Lattice	KLM	Composite
369	500	1114	1	Adjusted	Steel	Lattice	KLM	Composite
372	500	1272	1	Adjusted	Steel	Lattice	KLM	Composite
376	500	1509	1	Adjusted	Steel	Lattice	KLM	Composite
376	500	1565	1	Adjusted	Steel	Lattice	KLM	Composite
380	500	1780	1	Adjusted	Steel	Lattice	KLM	Composite
382	500	1917	1	Adjusted	Steel	Lattice	KLM	Composite
390	500	2406	1	Adjusted	Steel	Lattice	KLM	Composite
408	500	3578	1	Adjusted	Steel	Lattice	KLM	Composite
440	500	5607	1	Adjusted	Steel	Lattice	KLM	Composite
370	500	795	2	Adjusted	Steel	Lattice	NOP	Composite
385	500	954	2	Adjusted	Steel	Lattice	NOP	Composite
414	500	1272	2	Adjusted	Steel	Lattice	NOP	Composite
442	500	1565	2	Adjusted	Steel	Lattice	NOP	Composite
462	500	1780	2	Adjusted	Steel	Lattice	NOP	Composite
821	500	5607	2	Adjusted	Steel	Lattice	NOP	Composite
861	500	6039	2	Adjusted	Steel	Lattice	NOP	Composite
972	500	7218	2	Adjusted	Steel	Lattice	NOP	Composite

Table B.2. Composite Cost for Wood Single Pole, Single-Circuit Transmission Lines

Pole Type	Steel
Frame Type	Lattice
Number of Circuits	1

Composite Cost ($000)	Voltage (kV)			
Conductor Size	115	230	345	500
795	167	154	218	364
954	N/A	164	238	367
993	N/A	166	239	367
1114	N/A	174	250	369
1272	N/A	183	263	372
1509	N/A	198	289	376
1565	N/A	201	296	376
1780	N/A	214	315	380
1917	N/A	222	329	382
2405	N/A	252	376	390
3578	N/A	N/A	N/A	408
5607	N/A	N/A	N/A	440

Table B.3. Composite Cost for Wood H-Frame, Single-Circuit Transmission Lines

Pole Type	Wood
Frame Type	H-Frame
Number of Circuits	1

Composite Cost ($000)	Voltage (kV)				
Conductor Size	69	115	138	161	230
174	68	N/A	N/A	N/A	N/A
266.8	71	N/A	N/A	N/A	N/A
336.4	74	89	N/A	N/A	N/A
397.5	76	92	96	N/A	N/A
477	81	95	100	105	N/A
556.5	83	98	102	108	N/A
636	88	101	107	111	N/A
795	96	107	114	118	129
954	N/A	113	117	123	133
1137	N/A	120	126	131	139
1272	N/A	126	131	136	142
1509	N/A	135	141	145	149
1589	N/A	138	144	148	151
1979	N/A	153	159	163	162
2406	N/A	170	176	180	174

Table B.4. Composite Cost for Wood H-Frame, Single-Circuit Transmission Lines

Pole Type	Wood
Frame Type	H-Frame
Number of Circuits	2

Composite Cost ($000)	Voltage (kV)
Conductor Size	230
1589	220

Table B.5. Composite Cost for Steel Single Pole, Single-Circuit Transmission Lines

Pole Type	Steel
Frame Type	Single Pole
Number of Circuits	1

Composite Cost ($000)	Voltage (kV)					
Conductor Size	69	115	138	161	230	500
397.5	101	N/A	N/A	N/A	N/A	N/A
477	106	124	126	130	254	N/A
556.5	109	127	132	138	261	N/A
636	114	129	138	149	268	N/A
795	119	134	148	160	282	N/A
954	123	139	154	169	296	N/A
1114	126	144	159	176	310	N/A
1272	129	148	163	182	324	N/A
1589	N/A	N/A	N/A	N/A	352	N/A
5607	N/A	N/A	N/A	N/A	N/A	569

Table B.6. Composite Cost for Steel Single Pole, Double-Circuit Transmission Lines

Pole Type	Steel
Frame Type	Single Pole
Number of Circuits	2

Composite Cost ($000)	Voltage (kV)				
Conductor Size	69	138	161	230	500
397.5	147	N/A	N/A	N/A	N/A
477	160	191	207	N/A	N/A
556.5	171	210	229	N/A	N/A
636	187	232	253	N/A	N/A
795	205	258	281	254	N/A
954	218	281	305	265	N/A
993	217	278	301	268	N/A
1114	230	295	320	277	N/A
1272	238	308	333	289	N/A
1509	N/A	N/A	N/A	306	N/A
1565	N/A	N/A	N/A	310	N/A
1917	N/A	N/A	N/A	336	N/A
2406	N/A	N/A	N/A	371	N/A
5607	N/A	N/A	N/A	N/A	1061

Table B.7. Composite Cost for Steel Lattice, Double-Circuit Transmission Lines

Pole Type	Steel
Frame Type	Lattice
Number of Circuits	1

Composite Cost ($000)	Voltage (kV)			
Conductor Size	115	230	345	500
795	167	154	218	364
954	N/A	164	238	367
993	N/A	166	239	367
1114	N/A	174	250	369
1272	N/A	183	263	372
1509	N/A	198	289	376
1565	N/A	201	296	376
1780	N/A	214	315	380
1917	N/A	222	329	382
2406	N/A	252	376	390
3578	N/A	N/A	N/A	408
5607	N/A	N/A	N/A	440

Table B.8. Composite Cost for Steel Lattice, Double-Circuit Transmission Lines

Pole Type	Steel
Frame Type	Lattice
Number of Circuits	2

Composite Cost ($000)	Voltage (kV)		
Conductor Size	115	345	500
795	228	367	370
954	N/A	402	385
1272	N/A	445	414
1566	N/A	503	442
1780	N/A	N/A	462
5607	N/A	N/A	821
6039	N/A	N/A	861
7218	N/A	N/A	972

Table B.9. Additional Costs to Add to Per-Mile Principal Contracts Costs from Composite Data Set

Terrain Cost Adjustment Multiplier:

Flat	Rolling	50/50	Mountainous
0%	10%	18%	25%

Additional Cost Multipliers:

Cost	Low	High
Planning	0.5%	1.0%
Construction Supervision	5.0%	10.0%

Note: Field Data, Design and Specifications, and Other Contracts cost multipliers were already added into the composite data set.

Land and Environmental Costs - WAPA Approach

Cost	Low	High
Environmental	5.0%	8.0%
Land and Rights	4.0%	7.0%

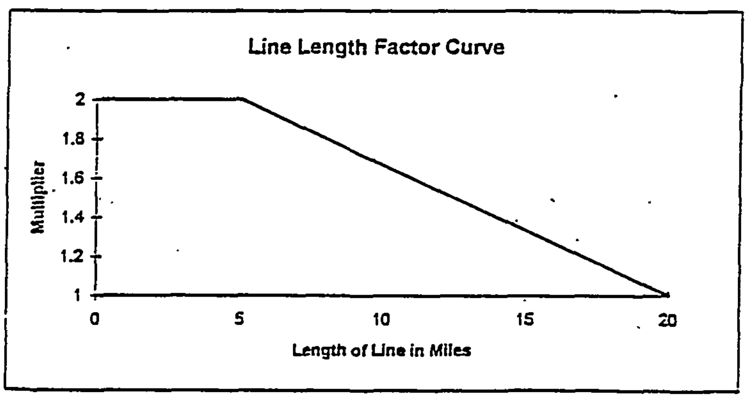

Table B.10. Land Environmental Costs - BPA Approach

Environmental Costs

Assessment Type	*Total Project Cost*
Environmental Assessment (No Significant Impact)	\$5,000 - \$100,000
Environmental Impact Statement (Significant Impact)	\$100,000 - \$750,000

Land Costs

Right-of-Way Width (ft)	Non-Urban Areas East of Cascades		Urban Areas (All West of Cascades)	
	Oregon (\$000)	Washington (\$000)	Oregon (\$000)	Washington (\$000)
50	9.7	10.9	60.6	90.9
75	14.5	16.4	90.9	136.4
90	17.5	19.6	109.1	163.6
100	19.4	21.8	121.2	181.8
105	20.4	22.9	127.3	190.9
110	21.3	24.0	133.3	200.0
115	22.3	25.1	139.4	209.1
120	23.3	26.2	145.5	218.2
125	24.2	27.3	151.5	227.3
130	25.2	28.4	157.6	236.4
135	26.2	29.5	163.6	245.5
140	27.2	30.5	169.7	254.5
145	28.1	31.6	175.8	263.6
150	29.1	32.7	181.8	272.7

Appendix C

Adjusted FERC Data

Appendix C

Adjusted FERC Data

This appendix contains adjusted Federal Energy Regulatory Commission (FERC) data for comparison with the range of costs estimated by the composite (BPA and WAPA) database. The raw FERC data in Appendix A were updated to 1994 dollars using the Gross Domestic Product (GDP) implicit price deflator and adjusted by the appropriate line length multiplier specified in Figure 2.

Table C.1. Adjusted FERC Data

Company	Voltage Level (kV)	Line Length (Miles)	Composite Cost of Structure and Conductor per Mile ($000)	Structure and Conductor Cost Range from WAPA and BPA for Same Voltage $(000)
Appalachian Power	138	6.8	182	96-308
Carolina Power and Light	138	15.78	19	96-308
Central Illinois Public Service	138	34.32	188	96-308
Central Power and Light	138	59.6	-	96-308
Cincinatti Gas and Electric	138	3.15	-	96-308
Columbus Southern Power	138	2.53	674	96-308
Commonwealth Edison	138	31.85	17	96-308
Consolidated Edison New York	138	4.31	1787	96-308
Consumers Power	138	37.1	172	96-308
Dayton Power and Light	138	2.23	-	96-308
Del Marva Power and Light	138	4.63	-	96-308
Duquesne Light	138	7.16	214	96-308
Florida Power and Light	138	238.88	45	96-308
Georgia Power	138	0.7	-	96-308
Hawaiian Electric	138	0.24	-	96-308
Houston Lighting and Power	138	-	-	96-308
Idaho Power	138	1.36	73	96-308
Illinois Power	138	9.88	43	96-308
Indiana Michigan Power	138	19.58	108	96-308
Indianapolis Power and Light	138	10.47	-	96-308
Kentucky Power	138	1.02	209	96-308
Nevada Power	138	17.34	120	96-308
Ohio Edison	138	-	-	96-308
Ohio Power	138	6.66	256	96-308
Oklahoma Gas & Electric	138	4.48	737	96-308
Peoples Electric Co-op	138	12.43	-	96-308
Public Service Co. of Oklahoma	138	10.84	91	96-308
Public Service Electric and Gas Co.	138	-	-	96-308
PSI Energy Inc.	138	4	140	96-308
Southern Indiana Gas and Electric	138	7.08	76	96-308
Texas Utilities Electric	138	277.06	-	96-308
Utilicorp United Inc.	138	0.2	806	96-308
Wes Penn Power	138	5.3	273	96-308
West Texas Utilities	138	35.59	55	96-308
Wisconson Electric Power	138	11.83	161	96-308
Philadelphia Electric	220	-	-	129-371
Alabama Power	230	5.05	201	129-371
Appalachian Power	230	91.42	201	129-371
Baltimore Gas & Electric	230	4.5	740	129-371
Florida Power and Light	230	76.11	51	129-371
Florida Power	230	0.34	234	129-371
Georgia Power	230	7.4	-	129-371
Louisiana Power and Light	230	31.1	275	129-371
Mississippi Power and Light	230	3.03	175	129-371
Montana Power	230	4.7	150	129-371
Nevada Power	230	6.28	609	129-371
Northern States Power	230	0.05	1356	129-371
PG&E	230	17.59	-	129-371
Pennsylvania Power and Light	230	22.23	202	129-371
Patomic Electric Power	230	0.57	173	129-371
Public Service Co. of Colorado	230	655.06	83	129-371
Public Service Electric and Gas Co.	230	10.41	972	129-371
Puget Sound Power and Light	230	22.81	172	129-371
PSI Energy Inc.	230	3	526	129-371
South Carolina Electric and Gas	230	8	138	129-371
Virginia Electric and Power	230	19.79	435	129-371
Boston Edison	345	0.05	-	218-503
Consolidated Edison New York	345	-	-	218-503
Consumers Power	345	20	440	218-503
Ohio Edison	345	-	-	218-503
Oklahoma Gas & Electric	345	-	-	218-503
Public Service Co. of Colorado	345	346.7	92	218-503
Saint Joseph Light and Power	345	102.99	-	218-503
Texas Utilities Electric	345	37.68	-	218-503
Wisconson Electric Power	345	76.3	406	218-503
Public Service Electric and Gas Co.	500	-	-	364-972

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