ECONOMIC IMPLICATIONS OF BURIED ELECTRIC UTILITIES

–Final Report–

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Executive Summary

On September 29th, 2003 Hurricane Juan, one of the most damaging hurricanes to ever impact made landfall at Halifax resulting in more that $24 million in Halifax Regional Municipality (HRM) owned infrastructure and property damage as well as significant economic and personal losses resulting from the associated damages to infrastructure and utilities. It took, in some parts of HRM, up to two weeks for businesses, institutions and residents to return to normal. In the next 14 months, HRM would be struck by two more storm events that resulted in above-average number of power outages and substantial power infrastructure repair costs. The majority of the outages resulted from downed power transmission and distribution lines due to high winds, fallen trees and branches, ice and snow.

HRM is the only community of its size in Canada where electrical utilities in new subdivisions are still permitted overhead and along streets. Other communities have moved to have these utilities installed either underground or along backlots.

With increasing global average temperatures, the frequency and intensity of extreme storm events is expected to increase, in many estimates by up to two-fold. With this scenario, HRM's projected growth and HRM's vulnerability to these extreme events, damages, disruptions and economic losses are expected to increase. As a result, there is a need to explore measures to minimize future financial and social costs such as implementing climate change adaptation measures into our infrastructure planning and design. Given that infrastructure decisions such as utilities have high capital costs and long-term community implications, making decisions in the face of climate uncertainty requires a close examination of the costs not only from an economic perspective but from a long-term social perspective as well.

This report builds on the *Underground Utilities Feasibility Study for Halifax Regional Municipality* by incorporating recent information on the expected impacts of climate change in HRM and how these factor into a cost benefits assessment for burying electrical utilities. The study concludes that the incremental economic cost for burying electrical utilities in new subdivisions is $3,800 per lot. However, when non-economic benefits such as: reduced outages; improvements in the urban forest; improvement in aesthetics; increase in property value; and improved air quality are factored in the result is an estimated **net benefit** of $10,000 per lot (assumed a 3% discount rate and a life of 40 years).

1. INTRODUCTION

Shortly after midnight on Monday, September 29th 2003, Hurricane Juan, one of the most damaging of hurricanes to ever impact Canada, made landfall in Nova Scotia. Hurricane Juan caused severe damage to the Halifax Regional Municipality (HRM) resulting in more than $24 million in HRM owned infrastructure and property damage.[1] In addition to these costs borne by the Municipality, Nova Scotia Power Inc. (NSPI) incurred costs of $12.6 million as a result of the storm or approximately 11% of earnings that year.[2] Within 14 months, Nova Scotia had been struck by two more storms (February (White Juan) and November 2004) that resulted in an above-average number of power outages and substantial power infrastructure repair costs. The majority of the outages resulted from downed power transmission and distribution lines due to high winds, fallen trees and branches, ice and snow.

With climate change and increasing global average temperatures, the frequency and intensity of extreme storm events is expected to increase.[3] Damages and insurance claims are expected to increase correspondingly and perhaps increase more significantly as coastal and other at-risk populations grow. International insurance companies such as Munich Re have already documented an upward trend in weather-related disasters and the associated damages.[4]

Given HRM's projected population growth and its recent experience with storm-related infrastructure repair and replacement as well as lost productivity associated with these events, there is a desire to explore possible means of minimizing future damages both from financial and social cost perspectives. In particular, there is an interest in including climate change adaptation strategies in infrastructure and community development plans. Infrastructure decisions are associated with high capital costs and long-term community implications. As such, making infrastructure decisions in the face of climate uncertainty requires a comprehensive understanding of the benefits and costs associated with the available options.

The purpose of this paper is to provide decision-making insight on including climate change considerations in cost benefits assessments. In this case, the balance between costs and benefits associated with the installation of underground power distribution cables for new residential development as compared with overhead distribution lines. As installation of underground utilities can be considered a climate change adaptation measure, a particular emphasis is placed on determining if climate uncertainty and possible damages associated with an increase in extreme events impact the decision to develop a policy of requiring the burial of power lines underground in new urban and suburban developments.

1 Halifax Regional Municipality. 2004. *District 13 Newsletter, Winter 2004.* http://www.halifax.ca/districts/dist13/2004Dist13Newsletter.pdf

2 Emera. 2003. *Emera Reports Third Quarter Earnings of $11.5 Million: $4.0 Earnings Impact from Hurricane Juan.* http://www.emera.com/mediactr/20031107.shtml

3 Francis, D. and Hengeveld, H. 1998. Extreme Weather and Climate Change. Report to Environment Canada.

4 Environment Canada. 2003. The Challenge of Climate Change and Extreme Weather in Atlantic Canada. http://www.atl.ec.gc.ca/weather/severe/climatechange_e.html

1.1 ABOUT THIS REPORT

The remainder of this report is presented in four sections:

- Section 2 presents the conceptual framework for the analysis and provides an overview of the benefit and cost categories examined.
- Section 3 explores the cost factors that affect the decision to place utility wires above or below ground.
- Section 4 presents ranges of benefits associated with burying utility lines; however, the focus is not on quantification, but rather on thorough consideration of all factors and the identification of those that are key to decision-making.
- Section 5 presents the analysis of cost-effectiveness from a utility perspective and the quantification of direct and indirect benefits that accrue under a societal perspective. Key findings of the paper are provided along with a policy recommendation.

2. CONCEPTUAL FRAMEWORK

Infrastructure investments trigger a myriad of benefits and costs, many of which accrue differentially to households, businesses, utilities and the municipality. This is certainly the case when comparing the merits of aboveground and underground power distribution networks, where the costs and benefits of each alternative will differ. In this paper, we assess the status quo practice of placing power lines overhead with a policy of buried lines in new residential developments in HRM. We place a particular emphasis on exploring if the inclusion of infrastructure damages under alternative future climate scenarios impacts the decision to bury power lines.

Under this scenario, we are really interested in the incremental change in moving from the status quo practice of overhead power lines to burying the lines. That is, we explore the incremental costs versus the incremental benefits of buried power lines versus overhead lines. Of course, the perspective of the costs and benefits differs, and what is a benefit to a household or society is not necessarily a benefit to a utility. Thus, we can differentiate decision-making information on the costs and benefits of overhead versus underground power lines on the basis of two perspectives, namely the *utility* and *society*, where society includes the municipality, households and businesses.

Important decision-making information can then be presented as follows:

- **From the utility's perspective**, in order for an alternative to be selected it must be cost-effective in its own right. This is to say that the option with lower capital, operation and maintenance, and event-related repair costs becomes the preferred choice. This is especially true in a regulatory environment that leans toward a lowest cost of service model. Cost-effectiveness examines purely financial aspects of decision-making including capital costs, operation and maintenance costs, and storm-related expenditures. The infrastructure choice hinges on the cost difference between the baseline (aboveground power distribution lines) and the alternative (below ground power cables). Costs are assessed on an annualized basis in keeping with private sector decision-making.

- **From a societal perspective**, the decision rule for selecting the preferred power supply option is to assess if incremental benefits exceed the incremental costs of underground lines versus overhead lines:

  - *Costs* include financial costs, which are the same as the utility costs. Other possible costs of underground lines are associated with an increased urban forest could include incremental damages to buildings and other property during storm events as well as root impacts on underground services such as concrete pipes;

  - *Benefits* are many and varied. Some benefits result directly from the substitution of underground cables for aboveground power distribution infrastructure, including a possible reduction in accidents from pole-car conflicts and reduced human contact injuries depending on streetlighting requirements e.g. some jurisdictions may require street lights on every pole. Level of service improvements are also likely when lines are buried resulting in avoided losses in economic value. Other important benefits stem from an incremental increase in tree canopy enabled by burying lines and reducing the need for tree height and pruning polices.

In keeping with the previous two stages, the assessment of the balance between costs and benefits takes both utility and community perspectives. From the utility perspective, the investment must be cost-effective in its own right. From the community perspective, for an alternative to be selected, the investment must be economically efficient which would mean that it is plausible that the costs of the investment would be less than the monetized benefits. A major focus here is that environmental, health and societal benefits are real and verifiable and can be credibly compared to the costs.

3. COST ANALYSIS

As mentioned above, the incremental costs of burying power lines consist of three components:

- *Capital costs* are those related to one time infrastructure expenditures for buried lines, and include assumptions about the relative useful service life of the two alternatives;
- *Regular operation and maintenance costs,* which includes the sub-categories of vegetation management and system O&M; and,
- Storm related costs, which in the baseline will be increasing in frequency and intensity and thus have an upward trajectory;

Where possible, we present per lot (or new house) costs to provide guidance on the incremental costs and benefits for new housing developments of moving to buried utilities lines. We adopt this per household viewpoint throughout the remainder of the report.

3.1 CAPITAL COSTS

Capital Costs Estimated

Capital costs estimates associated with the installation of underground power distribution networks vary widely depending largely on terrain and whether the installation takes place in a new or existing development. For new development, capital costs are typically on the order of two to three times those for aboveground networks.[5] The higher costs are due largely to trenching and/or boring requirements as well as the requirement for concrete reinforced duct banks, differences in transformer cost and increased complexity of switching and controls. It should be noted that the duct banks have the added advantage that they can be constructed to accommodate not only electrical service but communications (telephone, cable) services which are also vulnerable to extreme events when installed overhead as well.

Credible ranges of costs for underground distribution networks for new developments are summarized in Exhibit 3.1 below. We observe that the average incremental capital cost (that is the incremental costs for underground systems versus overhead is likely in the order of $3,780 per house, with a distribution ranging between $4,640 (maximum) and $2,900 (minimum) (see chart below). Exhibit A.1 provides more detail on the range of costs from international and Canadian studies. Generally, we find that these estimates for Halifax align with other Canadian and international studies.

Much of the apparent cost variation is a function of the system design, particularly the extent to which infrastructure is buried underground. Options exist for (progressing from least to most expensive):

- Burial of only secondary lines (line drops to individual houses);

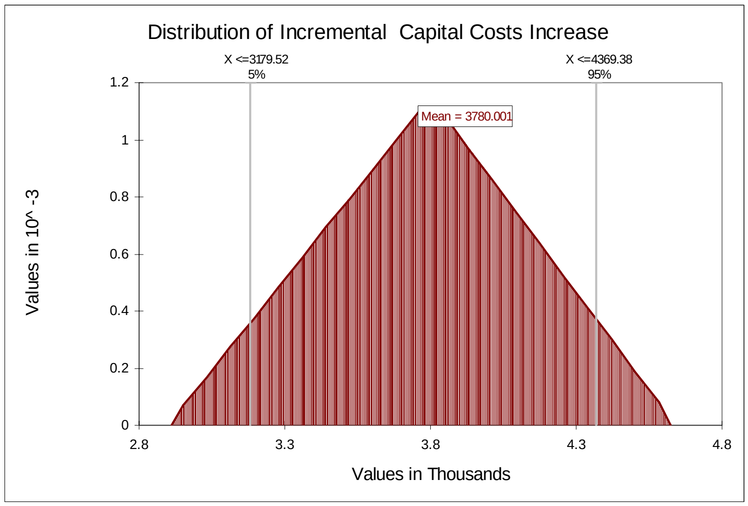
[5] Canadian Electrical Association (CEA). 1992. Underground Versus Overhead Distribution Systems. Document #: CEA 274 D 723

- Burial of secondary and primary cables leaving arterial routes and collectors with overhead infrastructure; and,
- Burial of the entire system.

Even within this last category there are at least two alternatives: pad-mounted transformers (the less expensive of the two options) and underground vaults. Thus, we can expect a fair degree of cost variation due to differing design assumptions, and therefore it is prudent to pursue the entire range of costs in the cost comparison.

Exhibit 3.1
Likely Distribution of Incremental Capital Cost (One-time)
Per New Household (2005$)

Source:	Capital Costs
Dillon Consulting	$4,640
Kinectrics HRM Study	$3,800
Kinectrics HRM Study	$2,900
Mean	**$3,780**



Useful Service Life

Another important incremental cost factor is the assumption regarding the useful service lives of system components. Given the high capital costs associated with electric power distribution systems, a variation in service life of ten or 20 years can make an appreciable difference in the relative incremental capital costs. There is little consistency in estimates of useful service life for below and aboveground systems in the literature (Exhibit 3.2). What is certain is that the anticipated service life of a system is highly dependent on its design, the equipment used and external factors such as the environment in which it is situated.

In the HRM study by Kinectrics, the assumption was made that the useful life of the infrastructure under both a buried and overhead scenario are equal and in the range of 40 years. We adopt this perspective.

Exhibit 3.2
Expected Service Life of Below- and Aboveground Distribution Systems

Study	System Service Life (Years)*	
	Aboveground	**Belowground**
Putting Cables Underground[6]	30-60[7]	>50
Virginia State Corporation Commission Report[8]	60	40
North Carolina Feasibility Study[9]	>50	<30

* These do not factor in increased extreme events.

Other Capital Cost factors

In addition to differences in useful service life, it is possible that differences in system capacity, quality and potential for cost-effective expansion exist. For example, underground systems are generally constructed with larger conductors in anticipation of future load and to allow for lower current rating because of the poor heat dissipation attributes of the underground environment.[10] The costs of adding incremental capacity given the presence of available ducts is comparable to that of installing new overhead line.[11] Furthermore, the larger conductors with higher current rating generally result in reduced line losses.[12] These benefits, while not directly impacting capital costs, should be accounted for in order to compare below and aboveground systems on an equal basis.

Conclusion: What can we say about the incremental capital costs? Capital costs are most definitely higher with buried power lines. We conclude that on average buried systems will have a one-time cost in the order of $4,350 more per lot (with a deviation of plus or minus $2000). Service life is most likely undifferentiated between underground and overhead lines.

3.2 OPERATION & MAINTENANCE COSTS

Operation and maintenance (O&M) costs associated with electric power distribution systems comprise of:

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[6] Putting Cables Underground. 1998. Report of the Putting Cables Underground Working Group to the Minister for Communications, Information Technology and the Arts. Australia.

[7] Source: Sinclair Knight Merz. 1998. Consultancy to Investigate Potential Benefits From Putting Cables Underground. A study completed in support of the Putting Cables Underground Working Group. Australia.

Note: Service life range depends on system component under consideration; however, 30 to 60 years is the typical range presented for most components.

[8] Virginia State Corporation Commission. 2005. Placement of Utility Distribution Lines Underground. Report to the Governor and the General Assembly of Virginia.

[9] North Carolina Utilities Commission Public Staff. 2003. The Feasibility of Placing Electric Distribution Facilities Underground. Report to the North Carolina Natural Disaster Preparedness Task Force.

[10] Kinectrics. 2005. Underground Utilities Feasibility Study for HRM. Report #: 10986-001-RA-001-R01.

[11] CEA. 1992. Underground Versus Overhead Distribution Systems. Document #: CEA 274 D 723

[12] Putting Cables Underground. 1998. Report of the Putting Cables Underground Working Group to the Minister for Communications, Information Technology and the Arts. Australia.

- *Vegetation management*, which includes a decrease in costs for the utilities (or on a cost-shared basis rate payers and/or the municipality) when lines are buried.

- *System O&M*, which includes annual costs for preventative and reactive maintenance that may or may not represent cost increases under the buried scenario.

We note that system reliability is discussed independently in Section 4.1 with respect to avoided lost productivity (i.e. lost economic output when power is down); however, costs associated with repairs from outages (reactive maintenance) excluding that related to major storms (discussed in Section 3.3) are included in the consideration of system O&M costs in this section.

As with capital costs, many of the recent North American studies providing information on O&M costs reference the same base studies and thus come to similar conclusions.[13] For this reason, the accuracy of the assessment is not necessarily corroborated by the number of sources coming to the same conclusions. We therefore make judgements with respect to the most plausible range of values for vegetation costs and system O&M.

3.2.1 Vegetation Management Costs

Vegetation management is cited across all studies reviewed as the greatest and most certain O&M cost reduction associated with undergrounding distribution systems. Notable examples from the literature include:

- The Virginia State Corporation Commission estimated annual utility savings of $50 million assuming all tree pruning is avoided by undergrounding the distribution system.[14]

- The North Carolina Utilities Commission indicates that tree pruning is among the most costly activities associated with overhead systems citing costs ranging from $7,000 to $70,000 (USD) depending on the number and size of trees, the amount of trimming, the location (urban/rural), and ease of access.[15]

- An Australian consulting study supporting the larger "Putting Cables Underground" study cites a median vegetation management cost of $194 (AUD) per circuit kilometre.[16] Costs can rise to $285 (AUD) per kilometre for areas with high tree density and quick rejuvenation and can be as low as $107 (AUD) per kilometre for areas with low tree densities, low growth trees and easily accessible overhead lines.[17]

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[13] For example, the Edison Electric Institute paper "Out of Sight, Out of Mind?" references the North Carolina and Virginia Power Commission papers and the report prepared for LIPA undertaken by Navigant Consulting references all three. Furthermore, the Virginia Power Commission study references the North Carolina report.

[14] Virginia State Corporation Commission. 2005. Placement of Utility Distribution Lines Underground. Report to the Governor and the General Assembly of Virginia.

[15] North Carolina Utilities Commission Public Staff. 2003. The Feasibility of Placing Electric Distribution Facilities Underground. Report to the North Carolina Natural Disaster Preparedness Task Force.

[16] Sinclair Knight Merz. 1998. Consultancy to Investigate Potential Benefits From Putting Cables Underground. A study completed in support of the Putting Cables Underground Working Group. Australia.

[17] Sinclair Knight Merz. 1998. Consultancy to Investigate Potential Benefits From Putting Cables Underground. A study completed in support of the Putting Cables Underground Working Group. Australia.

Overall the Australian study estimated annual vegetation management savings of approximately $40 per house.[18]

While there seems to be agreement that this O&M cost is a real cost-savings under a scenario with buried utilities, can we say the same for HRM? Our research indicates that vegetation management is likely a cost-savings with buried utilities in HRM:

- Historical NSPI vegetation management costs for metropolitan Halifax averaged in the order of $768,000 over the 2000 to 2001 period, or about $5.60 per household per year (in 2005$ and assuming 144,435 households).[19]
- The Nova Scotia Utility and Review Board set NSPI's 2006 vegetation management contribution at $3.6 million or approximately $7.66 per customer in Nova Scotia. Note that this figure includes transmission and distribution vegetation management and therefore may be over stated. Countering this overstatement is the fact that NSPI and HRM reached a mediated agreement in late 2005 regarding new developments, which may involve some form of cost sharing. That said, it is plausible that vegetative costs would be somewhat higher in the more heavily treed urban HRM relative to new developments given that transmission lines are wide open and don't need a lot of tree clearing.
- Kinectrics determined that for HRM the incremental per lot reductions in vegetation management ranged between $3.10 for new urban suburban developments and $6.00 for new suburban developments.

Conclusion: What can we say about vegetation costs? Vegetation management O&M costs are significantly reduced when power lines are buried, and translate into a savings ranging between three and eight dollars per new house, with an average in the order of $5.52 per household per year.

3.2.2 System O&M Costs

International experience concerning differences in System O&M costs between overhead and underground systems provides a wide range of guidance on the possible incremental costs of buried versus underground lines:

- The Virginia State Corporation Commission commissioned a survey and observed that while costs were wide ranging, many utilities indicated cost savings with going to underground lines and therefore the overall impact on O&M costs of installing an underground system on a state-wide basis would be insignificant;[20]

[18] Putting Cables Underground. 1998. Report of the Putting Cables Underground Working Group to the Minister for Communications, Information Technology and the Arts. Australia.

[19] Note: These figures include some areas outside HRM.

[20] Virginia State Corporation Commission. 2005. Placement of Utility Distribution Lines Underground. Report to the Governor and the General Assembly of Virginia.

- An Edison Electric Institute study reports costs per mile varying from $287 to $1,123 for overhead systems and from $473 to $6,953 for underground systems also based on Virginia data;

- The North Carolina experience suggests substantially higher costs for underground systems as compared with overhead; however, care must be taken in directly comparing these figures with the Virginia results as the North Carolina values are based on three-year averages and include "[storm-related] service restoration";

- The Sinclair Knight Merz study found that the range of total O&M costs between low and high cost situations, universally favoured underground systems; the median values suggest a cost ratio of two to one in favour of underground systems. The range in cost is substantial, reflecting differences in asset age, condition and maintenance/rehabilitation history as well as differences in the operational cost structure of utilities.[21]

- The Putting Cables Underground study determined that savings of approximately $36 per house would be attained by installing underground networks.[22]

All studies seem to indicate that O&M cost savings can't be expected. This potential is dependent on the type of system installed, the specific system design and how well it is adapted to the external environment. As well, reactive maintenance costs are expected to diminish over the long-term due to increased public awareness, employee training and experience, and technology development.

For Canada, two studies provide insight on the incremental *system O&M* costs:

- The Canadian Electrical Association found (through utility surveys) that routine O&M costs for underground systems are on average between one quarter and one half those of overhead systems.[23] It is not clear if O&M includes vegetation management or not, and thus this estimate is not that useful as a cost predictor.

- Kinectrics determined that for HRM the incremental system O&M costs per house ranged between $11.25 for urban suburban developments and $44.44 for suburban developments.

- While currently not a cost factor, there is a growing recognition among insurers that climate change brings increased risks. As a result, there is a possibility that insurance premiums will increase overtime if practices do not reflect climate change risks. This could therefore result in increased premiums for utilities that do not take mitigation measures.

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[21] Sinclair Knight Merz. 1998. Consultancy to Investigate Potential Benefits From Putting Cables Underground. A study completed in support of the Putting Cables Underground Working Group. Australia.

[22] Putting Cables Underground. 1998. Report of the Putting Cables Underground Working Group to the Minister for Communications, Information Technology and the Arts. Australia.

[23] CEA. 1992. Underground Versus Overhead Distribution Systems. Document #: CEA 274 D 723

Conclusion: What can we conclude about system O&M costs? While the literature is mixed with respect to the incremental O&M costs, to be conservative it is likely that system O&M costs will increase with buried lines. While the range from the Kinectrics report is large, we weigh the range in the lower end to account for the potential for cost savings indicated in the literature. Therefore, we would expect average costs to be bounded by the range of $0, $11.25 and $44.44. This implies an average of about $18.50 per household per year.

3.3 STORM-RELATED EXPENDITURES

With climate change and increasing global average temperatures, the frequency and intensity of extreme storm events is expected to increase.[24] If this occurs damage to infrastructure can be expected to rise, and consequently the cost savings from buried utilities would also rise. In this section we first explore this point and then determine if we can attribute storm related cost savings to buried utility lines.

The Frequency of Extreme Events

Broadly categorized, extreme storm events include tropical storms and hurricanes, extratropical storms (large low pressure systems that commonly form and travel along the boundaries between contrasting air masses in the middle and high latitudes), and thunderstorms. Each of these has unique characteristics and results from specific climatological circumstances and thus each is affected independently by climate change. While no single event can be attributed to climate change, projections of climate change in Atlantic Canada point to increased ocean temperatures and corresponding increases in weather event intensity.[25] Hurricane Juan is a testament to the implications of increased ocean temperatures as it was made possible in part by higher than average ocean temperatures off the south coast of Nova Scotia.[26]

While projections of increased storm frequency and intensity are difficult to quantify, modelling undertaken by Environment Canada suggests that historical storm return periods are essentially expected to halve by 2050 (Exhibit 3-3). This would mean that what was a "one-hundred year storm" (e.g. Hurricane Juan) would become a "fifty-year storm", doubling the probability that a storm of that magnitude will occur within a hundred-year time period. Exhibit 3-4 summarizes some climate projections for HRM.

Conclusion: What can we say about the frequency of extreme events due to climate change? It is very likely that a one-hundred year event will become a fifty-year event. This suggests a doubling of probability of infrastructure damages resulting from weather related events.

[24] Francis, D. and Hengeveld, H. 1998. Extreme Weather and Climate Change. Report to Environment Canada.

[25] Environment Canada. 2003. The Challenge of Climate Change and Extreme Weather in Atlantic Canada. http://www.atl.ec.gc.ca/weather/severe/climatechange_e.html. Also IPCC, 2007. *Climate Change 2007: The Physical Science Basis. Summary for Policy Makers*. 21pp.

[26] Ibid.

Exhibit 3-3
24-Hour Precipitation Extremes, Halifax Nova, Scotia[27]

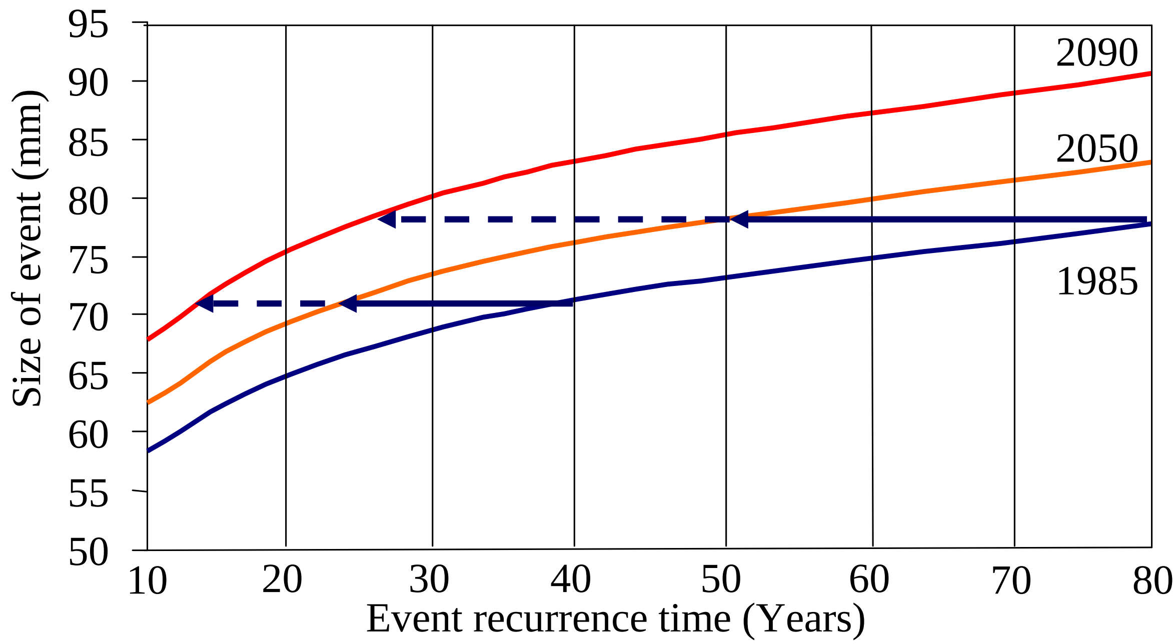


Exhibit 3-4
Climate Projections for HRM[28]

Climate Variable	Mean Change By 2080s	Variability / Frequency By 2080s	Knowledge Gap
Sea Level	50 cm rise globally	Not Available	Regional variations on mean and extreme amount unknown.
Synoptic Storms	Not Applicable	Increase in intense storms. Decrease in weak storms. (North of 30N)	Specific number and intensity of future storms over HRM unknown.
Tropical Cyclones	Increase in peak wind speed	Unknown	Increase in frequency unknown.
Ozone (Smog)	Unknown	Increase in production of smog with increase in maximum temperature.	Projections of ozone production increase unavailable.
Cloud Cover	Values vary widely from model to model globally.	Unknown	Specifics of cloud cover change unknown.
Waves	Increase in mean Significant Wave amount over North Atlantic	Increase in Significant Wave occurrence (return period of 20 year wave height reducing to 8-16yrs).	Need more specifics regionally.
Ice Storms (ZR)	Most recent work for Ontario and Quebec	Increase in frequency expected by 2050	Specifics of frequency change over HRM unknown.

27 Lines, G. Climate Change in Halifax Regional Municipality. Presentation to HRM Planning, September 22, 2006. Climate Change Section, Meteorological Service of Canada, Atlantic Operations, Environment Canada.

28 Ibid.

Damages Associated With Extreme Events

Damages and insurance claims are expected to increase concomitantly with increased storm frequency and intensity, and perhaps as significantly as coastal and other at-risk populations grow. This certainty is plausible for HRM given that the population grew by 4.7 percent between 1996 and 2001 and continues to grow at greater than average regional rates.[29] Indeed, research suggests that an additional 100,000 residents will live and work in the Halifax area by 2028.[30] As the population and economy expand, the level of infrastructure investment and the potential ramifications of extreme storm events will likely continue to increase.

Every year, HRM is impacted by storm events that affect the electric power distribution systems. Since 1997, Nova Scotia Power Inc. has experienced three storms that threatened the continuity of electricity supply in the province: the 1997 ice storm, Hurricane Juan, and the November 13/14 storm of 2004.[31] In 2003, a record number of storms with record strength affected HRM. Much of the available data concerning the cost implications of storm events comes from this recent experience, and in particular from Hurricane Isabel and Hurricane Juan (considered a 100-year storm). Little information is available concerning the November 13/14, 2004 storm, or the winter storm, “White Juan”, which impacted HRM in 2004.

As presented in Exhibit 3-5, NSPI incurred 100-year storm costs, which were substantially lower than those experienced by three utilities for a storm of smaller magnitude. The magnitudes of the cost differentials would suggest that the number of customers impacted and the recovery costs are not necessarily linearly related. Some repairs may be more costly (and possibly take more time) than others while affecting the same number of customers. It should be noted that the costs presented are related to the number of impacted customers, not the total number of customers. Nevertheless, we can conclude that storm events do have a cost that is above and beyond routine system O&M costs, including damages from “normal” storm events. We therefore use the ranges in Exhibit 3-5 below to account for the risk that damages will be avoided in the case with buried distribution lines. We note however that these are lower bound costs, since we don’t know the full extent of the storm damages experienced by all utilities, and are not confident that the storm costs adequately capture the full range of costs experienced by the NSPI.

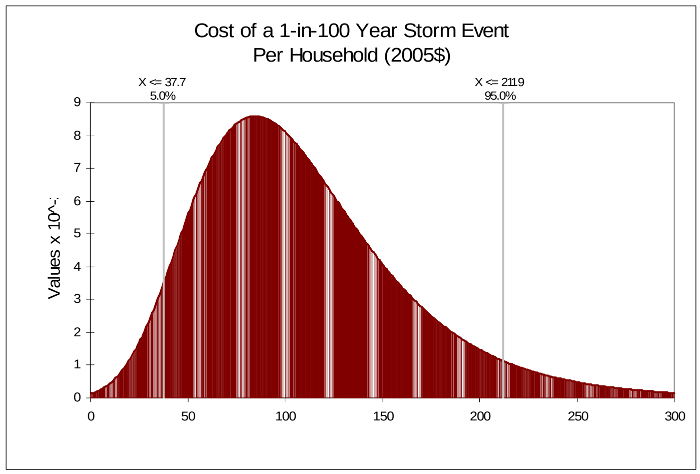
[29] Halifax Regional Municipality. 2006. Economic Strategy – Project Overview. http://www.halifax.ca/economicstrategy/index.html

[30] Halifax Regional Municipality. 2006. Regional Planning: HRM Region. http://www.halifax.ca/regionalplanning/Region/region.html

[31] The Liberty Consulting Group. 2005. Report on Nova Scotia Power Company’s Transmission System and Outage Communications. Report Presented to the Nova Scotia Utility and Review Board.

Exhibit 3-5
Incremental Storm Costs Utility Restoration Costs
1-in-100 Year Storm Events[32]

	Hurricane Isabel			**Hurricane Juan**
	Utility A	**Utility B**	**Utility C**	**NSPI**
Peak Number of Customer Outages	480,883	427,000	1,800,000	300,000
Days Required to Restore to Full Service	8	7.5	15	14
Total Restoration Cost ($ Million CAD)	$105.0	$39.0	$166.0	$12.6
Average Cost per Customer	$218	$91	$92	$42



Conclusion: What can we say about storm related infrastructure costs? Storm related costs avoided due to burying power lines likely range between $42 and $218 per customer for the one-hundred year storm. With an increasing storm frequency expected, these costs would likely translate into an annual benefit (of avoided storm damage) in the order of $4.38 per year. This assumes a risk-based valuation approach, where the 1/100 year costs are doubled under climate change due to a doubling in the probability of an extreme event. These can be translated into an annual benefit (or cost-risk with overhead lines) simply by subtracting the future probability (1/50) from the current probability of the event (1/100) multiplied the damages. This is essentially the measure of the increased value of the risk.

32 Power System Outage Response, LLC. 2004. A Report to the Nova Scotia Utility and Review Board on Nova Scotia Power Inc.'s Response to Hurricane Juan.

3.4 SUMMARY OF COSTS

Incremental capital and operating costs were developed for a scenario that includes burying power lines underground versus overhead installation in a new residential development. The summary of incremental costs using available data and assumptions are provided in Exhibit 3-6. To capture the significant uncertainties in the costs, we provide a range of values centred on a central value, which may or may not be a mean value within the range. These cost estimates are assembled in the final two chapters under the societal and utility perspectives. They are also compared with a range of associated benefits.

Exhibit 3-6
Summary of Capital and Operating Costs (2005$)
Incremental Change with Buried versus Overhead (basecase)

	Range of Costs			**Perspectives**	
	Central	Low	High	Utility	Societal
Capital Costs (one-time)	**$3,780**	$2,900	$4,640	√	√
Vegetation (annual)	**-$5.52**	-$3.00	-$8.00	√	√
System O&M (annual)	**$11.25**	$0	$44.44	√	√
Storm Expenditure (annual)	**-$1.09**	-$0.42	-$2.18	√	√

4. BENEFITS ANALYSIS

In Section 2 we identified that benefits will accrue to society under a scenario with buried utility lines versus overhead lines. Recall that some benefits result directly from the substitution of underground cables for above-ground power distribution infrastructure, including a reduction in accidents from pole-car conflicts and reduced human contact injuries. Benefits related to level of service improvements are also likely when lines are buried, reliability increases and power outages occur less frequently. Other important benefits stem from an incremental increase in tree canopy enabled by burying lines, reducing the need for tree height and pruning polices and diversification of the plant mix afforded by eliminating the need to plant "dwarf" species. This may translate to increased property values afforded by a mixed urban forest.

Exhibit 4.4 provides a graphical representation of the full range of likely benefits. What is surprising is the sheer range of benefits that accrue outside of the narrowly focused cost purview of the utility. At first glance, this mapping of benefits indicates that societal benefits likely had an interest in influencing utilities to bury utility lines. We test this terse observation in Chapter 4.

4.1 SUBSTITUTION FOR UNDERGROUND CABLES

4.1.1 Reduction in Accidents From Pole-Car Conflicts

A substantial reduction in the number of pole-car conflicts is expected with the installation of underground power distribution systems. According to one Australian study, avoidable costs associated with motor vehicle accidents resulting from collisions with poles is in the order of $112 million (all figures in CDN. 2005$). Approximately 13.5 percent of these costs are associated with property damage with the remainder being attributable to health care and/or mortality. On a per customer basis, the annual benefit from installing an underground system is approximately $92, with the health component being approximately $79. This study clearly indicates a significant source of benefit.

The Kinectrics report estimates that pole-accidents could be reduced in the order of $11 to $21 dollars per year per new house. That said, there is doubt about this benefit since street lights would be required regardless and thus there may not be a reduction in pole-car conflicts.

Conclusion: What can we say about pole-car conflicts? We find evidence that significant benefits arise from a reduction in the incidence of pole-car accidents. Further, this benefit can be monetized, and could range between $0, to reflect the assumption of no reductions in pole-car conflicts and $21 dollars per new house per year.

4.1.2 Reduced Human Contact Injuries

The literature concerning electrical contact accidents provides conflicting evidence; however, overall it points to a reduction in the number of such accidents in the long-term for underground systems. The Australian *Putting Cables Underground* study found that potential changes in the number of electrocutions resulting from undergrounding cables are not quantifiable.[33] A supporting study had indicated that while the quantity of data available was limited, the information suggested that the incidence of accidental electrocutions could increase when electricity cables are moved underground. In a U.S. article on the benefits of urban underground power delivery, it was found that underground lines are far safer than overhead lines.[34] This is further supported by additional information provided to the Australian study that indicated that underground networks generally require less maintenance than overhead networks which in the long run would lead to fewer accidents given that overhead and underground systems are equally safe to work with. The Australian study further identified that the safety of consumers remains unchanged.

We also note that Kinectrics did not value the reduction in human contract nor assign any qualitative weight.

Conclusion: What can we say about reduced human contact injuries? Most likely there is not a large benefit associated with electrocution when distribution systems are buried versus overhead. While the benefit may be positive, it is likely small.

4.2 LOSS OF SERVICE IMPROVEMENTS (RELIABILITY)

To determine a loss of service reduction benefit attributable to burying power lines, we must first demonstrate that loss of service improvements are plausible and then provide a means to value those improvements in dollar terms. Reliability is predominantly a level of service consideration. If the level of service is improved, higher infrastructure costs to some degree can be justified. However these costs ought to be offset by any savings that accrue to the utility and to customers from a reduction in lost service.

Underground systems are generally recognized as being subject to fewer interruptions. The CEA indicates that reliability considerations universally favour underground configurations.[35] Similarly, Hydro Québec echoes this assertion indicating that over 40 percent of its power outages result from fallen branches or trees in proximity to overhead distribution lines and that in some areas this figure is even more significant.[36]

System reliability is a function of the frequency and duration of service interruptions. The industry standard measurements for these two parameters are the system average interruption frequency index (SAIFI) and the customer average interruption duration index (CAIDI). The product of these two indices yields a third metric, the system average interruption duration index (SAIDI). Some sources indicate that while the number of interruptions may decrease (improvements in SAIFI), the average duration of outages (CAIDI) and thus the overall

[33] Putting Cables Underground. 1998. Report of the Putting Cables Underground Working Group to the Minister for Communications, Information Technology and the Arts. Australia.

[34] Maney, C.T. 1996. Benefits of Urban Underground Power Delivery. IEEE Technology and Society Magazine, Spring 1996.

[35] Canadian Electrical Association (CEA). 1992. Underground Versus Overhead Distribution Systems.

Document #: CEA 274 D 723

[36] Hydro Québec. 2006. Live in a Wirefree Neighbourhood: Undergrounding Offers Clear Advantages. http://www.hydroquebec.com/livingwirefree/avantages.html

performance of the system (SAIDI) suffers as a result of undergrounding.[37] However, this claim is disputed by British experience that suggests that in terms of hours of interruption, underground systems have an advantage by a factor of two to one.[38] Kinectrics suggest that the increased duration of outages in underground systems results from poor system design and that a well designed open-loop system using faulted circuit indicators allows power restoration to affected customers through a switching operation before any repair is completed.[39] As such, faults may be corrected more quickly than in an overhead system.

Based on this discussion we can conclude that undergrounding reduces losses. Two cost savings (benefits) are obtained as a result of increased reliability attributable to burying power lines:

- **Avoided lost electricity value on the part of the utility.** The utility loses revenue from a loss of service, which has a value. The value is simply the revenue lost less the cost of production. Revenue is simple enough to calculate but the cost of the production is less straight forward. Regulated utilities such as NSPI are entitled to charge a profit on their cost of production, which for NSPI is in the order of 11%.[40] While we could use this number as the lost value, when reviewing the balance sheet for Emera we notice a number of fixed costs that are subtracted from the revenue, which likely should not be included in the lost service measure.

  Why? We observe that the lost service is a very small increment of the overall revenue, and thus fixed costs are already likely covered by the yearly sales and the actual loss is simply the variable costs of the electricity, which is primarily fuel. This would mean that the actual benefit is not entire revenue or just 11% of the sales (i.e. the profit) but rather some number in between. Therefore, stripping out fixed costs we find that the loss of service value is in the order of 55% of revenue (average 2003 to 2005 in Exhibit 4.1). Exhibit 4.1 provides the source information used to determine this ratio.

Exhibit 4.1
Loss of Service Value Calculation

	2005	2004	2003
Electric Revenue	$1,168	$1,134	$1,147
Fuel For Generation	$432	$350	$363
Operating Maintenance and general	$248	$245	$259
Net Earnings	$122	$128	$128
Earnings/Revenue	10%	11%	11%
Loss of Service Value: Fuel and Operating/Revenue	**58%**	**52%**	**54%**

[37] Numerous reports cite this difficulty including the Virginia State Corporation Commission report, the Florida Public Service Commission report, the North Carolina Utilities Commission report, the Putting Cables Underground report (Australia) and several literature reviews which reference the aforementioned studies.

[38] Sinclair Knight Merz. 1998. Consultancy to Investigate Potential Benefits From Putting Cables Underground. A study completed in support of the Putting Cables Underground Working Group. Australia.

[39] Kinectrics. 2005. Underground Utilities Feasibility Study for HRM. Report #: 10986-001-RA-001-R01.

[40] This comes from EMERA's 2005 Annual Financial Report. It is the average over the 2003 to 2005 period of net earnings over electricity sales. .

Source: Emera 2005 Annual Financial Report

We now have to determine on a per house basis the reduction in the lost revenue when power lines are buried:

- The North American experience with avoided lost electricity value is varied with some studies not reporting any savings while others report fairly sizeable savings. For example, the Virginia State Corporation Commission reported annual avoided lost sales from day-to-day outages resulting from the switch to underground infrastructure of $12 million or roughly $3.32 (CDN 2005$) per customer per year. The Australian study, "Putting Cables Underground" assessed annual avoided lost electricity sales savings of approximately $4.26 (AUD) per house.

- The Kinectrics study for HRM determined avoided lost electricity costs (revenue) for a (modelled) typical suburban residential area to be in the order of $17 per household in both suburban and urban residential areas.

Conclusion. What can we say about improved reliability in terms of the value of electricity sales? We find that a reduction in value of lost electricity production is a benefit attributable to burying power lines and that this benefit has a significant dollar value. Assuming the Kinetrics lost service revenue estimates ($17 per household per year), in conjunction with the NSPI value of production estimates (~55%), implies that on a per household basis the value of reducing lost service is in the order of $8.57 per household per year. This would be a benefit under both utility and societal perspectives.

- **Avoided lost value to utility customers**. Since customers value the level of service, any interruptions will have an associated loss. The value of avoided lost productivity depends on the customer type, the outage frequency and duration, the magnitude of the interrupted load and the time of day and week that the outage occurs. While there is not much in the literature on this benefit, we can nevertheless assign a value based on numbers provided in the Kinectrics study.

  The value to the customer of the avoided interruption is related to the price they are willing-to-pay to avoid the interruption and not the price paid for electricity. In Exhibit 4.2 we develop an indicator of the yearly value of a reduction in service interruptions. Based on information from Kinectrics:

  - With both suburban and urban circuits, interruptions can be expected to decrease when moving to buried lines, with reductions per household in the range of 2.8 to 4.92 hours per year.

  - These reductions can be valued assuming a range of electricity rates for residential and commercial users in the order of $2 to $16/kw per hour interrupted. We use this range as a proxy for the values placed on a reduction in service interruptions, and assuming the residential prices do not reflect the value.

  - On a per household basis, the value is estimated to be in the order of $23 to $41 annually (Exhibit 4.2).

Exhibit 4.2
Annual Value of a Reduction in Lost Service Interruptions

	Suburban	**Urban**
Interruptions in Hours - Overhead	4,100	16,600
Interruptions in Hours - Buried	321	863
Reduction in Interruptions (hours)	3,779	15,737
Customers on Circuit	1,350	3,200
Hour Reductions per house (reduction/customers)	2.80	4.92
Range of Value ($/kw per hour interrupted)	[$2,$7.5,$16]	
Reduction in Service Interruptions Value of Savings ($7.5/kw-h times reductions	**$23**	**$41**

Source : Kinectrics and Marbek, estimated.

Conclusion: What can we say about the value of lost service interruptions to consumers? Improvements in the level of service can be expected when power lines are buried. It is very likely that consumer's value this improvement in service interruptions. The value is likely positive and significant and ranges between $23 and $41 per household per year.

4.3 LOSS OF SERVICE IMPROVEMENTS (INCREASED STORM EVENTS)

Under a climate change scenario with an increase in extreme events, we can also expect the two loss of service benefits to provide an incremental benefit with buried versus overhead lines. We first need to establish if in fact the baseline of service interruptions changes with storm events:

- According to NSPI documents, the SAIFI decreased from 5.5 to 2.6 interruptions per year from 1998 to 2002; the 2003 SAIFI was 4.0 as a result of Hurricane Juan. The SAIDI averaged around five hours over the 1998 to 2002 period and was close to 40 hours in 2003 due to Hurricane Juan. The CAIDI ranged from 1.0 to 2.5 hours (average 1.75) per interruption with the exception of 2003 during which it rose to 10.0. Thus, to customers the impact under a storm event is an increase in a storm event of 8.25 hours of interruption (i.e. 10 minus 1.75).

This information implies that service interruptions will increase with increased storm frequency. Under a buried line scenario, we would therefore expect reductions in loss of service interruptions, which can be valued in dollar terms. As discussed in the previous section, a reduction in service interruptions will trigger benefits from a reduction in lost electricity value to both customers and the utility:

- **For the utility**, the benefit with buried lines and increased storm events would simply be the avoided lost electricity value (revenue minus operating costs as discussed above). Exhibit 4.3 provides an elaboration of how we can value this benefit:
    - *Probability of Event:* In Section 3.3 we determined that the probability of an extreme event under climate change would double, and thus the 1-in-100 storm would become the 1-in-50 storm event. The annual probability change would therefore be from 1/100 to 1/50 or from 1% to 2% (the savings is a reduction in the probability of 1%).

- *Value of Lost Sales.* This is then multiplied by the value of lost sales (net of operating costs), assuming that under an extreme event and with buried lines customer service interruptions represented a net reduction in lost sales of 8.25 hours per customer (CAIDI Change). This is then adjusted to account for baseline interruptions with underground lines (that is there are 93% fewer disruptions with buried lines versus overhead - see Exhibit 4.2). Multiplying this by the cost of electricity ($2/kw per hour interrupted) and factoring for the cost of the electricity (54%), the value per customer of burying the power lines is $0.08 annually, which is clearly a small benefit.

- **For the customer** the same logic holds. The value of the avoided loss of service interruption is simply the value of the service interruption with buried lines multiplied by the probability of a reduction in storm related costs. (See Exhibit 4.3 for elaboration).

Exhibit 4.3
Value of the Loss of Service (Storm Events)

Per Storm Event		
	Utility Value	**Customer Value**
CAIDI Average (hours)	1.75 (range 1.0 to 2.5)	
CAIDI Storm (hours)	10	
Difference (hours) Gained when Lines Buried	8.25	
Baseline Savings with Buried versus Overhead	93%	
Avoided Hours	7.71	
Value of Reduced electricity	$15	$247.99
Value Net of Operating Costs (55%)	$8.48	
Annual Value of Event		
Reduced Probability of a Storm Event	1%	1%
Annual Value	$0.08	$2.48

Conclusion: What can we say about reductions in service interruptions with increased extreme events and buried power lines? While there is likely a positive benefit that has value, it is likely small and in the order of $2.54 per household per year.

4.4 TREE-RELATED BENEFITS

Many environmental and health benefits derive wholly from incremental increases in tree cover (combination of number of trees, tree size, and tree health) resulting from increased growing space and allowed growth due to underground utilities. Consultations with HRM arborists by Kinectrics suggest that there would be room for an additional large tree per house in suburban neighbourhoods as a result of installing the distribution network underground. Furthermore, by eliminating the height restrictions, small trees (currently mandated) could be replaced by large trees. Tree benefits will not be realized immediately but would grow with the trees until they reach maturity at which point they will plateau for the duration of the tree's life.

Benefits for which we are able to credibly assign a dollar value and which are tree-related include:

- *Energy Benefits* related to reduced heating and cooling loads'
- *Air Benefits*, where trees reduce PM and ozone, and therefore reduce the incidence of adverse health outcomes; and
- *Other Urban Forest benefits*, which can include reducing water run-off thereby decreasing volumes to sewers and pollutant run-off to surface waters.

Each is discussed below. Exhibit 4.4 provides more detail of the range of benefits.

4.4.1 Energy Benefits

Trees modify the micro-climate through shading, evapo-transpiration, and wind speed reduction resulting in residential climate-control energy cost savings (summer and winter) and a general reduction in summer ambient air temperatures.[41] The energy savings attributable to trees varies by site and region depending on tree type, size, health and leaf and branch density. Savings are greatest in regions with the largest heating and cooling loads.

According to studies undertaken in Chicago, increasing tree cover by ten percent can reduce total heating and cooling energy use from five to ten percent or between $50 and $90 (USD).[42] This translates to approximately 1.3% per tree ($10) for heating and 7% ($15) for cooling with a corresponding peak cooling demand reduction of about 6% (0.3 kW).[43] The cost of peak load reduction using trees is estimated at $63/kW as compared with California's $150/kW benchmark.[44]

In addition to directly impacting residential climate control energy consumption, trees contribute to ambient air cooling, reducing the urban heat island effect and resulting in a myriad of secondary health and comfort benefits.

The Kinectrics report values the possible heating and cooling benefits at around $10 per household per year ($9.85 for suburban and $10.63 for urban.

Conclusion. What can we say about heating and cooling benefits related to an increased urban forest? We can conclude that this benefit is positive and is in the order of $10 per household per year.

[41] McPherson. 2004.

[42] McPherson et al. 1994

[43] Ibid.

[44] McPherson. 2004.

4.4.2 Air Benefits

Air quality benefits associated with trees stem from:

- Avoided electricity generation emissions due to reductions in building cooling energy requirements;
- A general reduction in ambient air temperature which reduces smog formation and evaporative hydrocarbon emissions from parked vehicles; and,
- Direct removal of pollutants.

Trees provide direct air quality benefits by absorbing gaseous pollutants (e.g. ozone, nitrogen oxides and sulphur dioxide) through leaf surfaces (primarily through stomata, as well as through adsorption of gases to plant surfaces and uptake through bark pores), intercepting particulate matter (such as dust, ash, pollen and smoke) on plant surfaces and, releasing oxygen through photosynthesis. The amount of gaseous pollutants and particulates removed by trees depends on tree size and architecture as well as local meteorology and pollutant concentrations. Uptake rates are high when pollutant concentrations and leaf surface areas are also high and species with hair or rough leaf twig and bark surfaces are efficient interceptors.

Different contaminants follow different pathways once intercepted. Adsorbed sulphur moves through the entire tree and into the soil through its roots (diffusion). Heavy metals, chloride and fluoride tend to adhere to leaf surfaces until they fall from the tree. Materials adhering to tree surfaces may be re-suspended in the air as a result of wind action or can be washed off in rain water contaminating soil or runoff.

Trees also emit biogenic volatile organic compounds (BVOCs) such as isoprenes and monoprenes that can contribute to ozone formation. The contribution of BVOCs from city trees to ozone formation depends on complex geographic and atmospheric interactions that have not been studied in most cities.

Various studies cite actual savings by trees in specific cities. Trees in Chicago (1991) were estimated to remove 15 tonnes of carbon monoxide (CO), 89 tonnes of nitrogen dioxide (NO_2), 191 tonnes of ozone, and 212 tonnes of particulate matter less than 10 microns (PM_{10}).[45] The value of this pollution removal was approximately $1 million in Chicago's urban core and $9.2 million across the Chicago area.[46] Trees in Brooklyn (1994) were estimated to remove about 208 tonnes of air pollution at a value of $1.1 million. A study of standardized pollution removal by trees in various cities yielded fairly consistent results. Differences between cities are thought to be due to differences in pollution levels, meteorology, length of growing season and forest leaf area. Such estimates of air quality improvement likely underestimate the total effect of the urban forest on reducing ground-level pollutants because they do not account for the effect of the forest canopy in preventing upper air pollution from reaching ground level air space;

[45] McPherson. 1994.

[46] Ibid.

however, if there are substantial air pollution sources below canopy level, the canopy may in fact concentrate pollution by minimizing dispersion.[47]

Kinectrics provide a rough calculation of the costs of the air quality benefits, using pollution control costs as a proxy. The value of the removed pollution by trees is equivalent to the engineering costs of removing the same amount from an industrial source, such as an electric generating facility. We observe that this is a minimum value, since the value of removed air pollution is better measured as a reduction in the value of the reduced risk of an adverse health outcome. That said, due to project scope limitations, we adopt the Kinectrics approach, where the air quality value is in the order of $0.21 to 0.81 dollars per household per year.

Conclusion. What can we say about tree-related air quality benefits? We conclude that air quality benefits are real and measurable, but are small in terms of overall value. On a per household basis, the average value is likely less than one dollar per year, and in the range of $0.21 to$ 0.83.

4.4.3 Other Urban Forest Benefits

Water benefits from increased size and health of the urban forest include reductions in runoff volume and reduced pollutant loading of receiving water bodies. Trees delay the onset of peak flows during rainstorm events and reduce runoff volumes through interception by leaves and branch surfaces.[48] Some of the intercepted rain evaporates, some runs to the ground along branches and stems (stemflow) and some drips off (throughfall).[49] Root growth and decomposition increase the capacity and rate of soil infiltration and transpiration increases soil. Small storms are responsible for the highest levels of pollutant wash-off and are also those most greatly impacted by interception by vegetation.[50] As a result, urban forests generally produce more benefits through water quality protection than through flood control.[51] There are also infrastructure benefits, where reduced run-off decrease loads on sewer infrastructure.

Typically, crown storage of water ranges between 6.7 and 13.4 cubic metres per tree.[52] The amount of rainfall intercepted depends on tree architecture, rainfall patterns and local climate. Tree crown characteristics that influence interception include trunk, stem and surface areas, textures, number and size of gaps, foliation period and dimensions (height and diameter). Trees with coarse textured surfaces retain more rainfall than ones with smooth surfaces. Large trees generally intercept more rainfall than small trees because of greater surface areas and higher evaporation rates. Trees with fewer foliage gaps have lower flow-through rates. Species that are in leaf when rainfall is plentiful are more

[47] Bytnerowicz et al. 1999.

[48] McPherson. 2004.

[49] Ibid.

[50] Ibid.

[51] Ibid.

[52] Ibid.

effective than deciduous species that have dropped their leaves. Rainfall in Halifax is fairly evenly distributed across the 12 months.

Additional water benefits result indirectly from reductions in required electricity generation. Approximately 2.3 litres of cooling water are saved per kWh energy saved from coal-fired generators and it is estimated that approximately one cubic meter of water could be saved per year as a result of one strategically planted shade tree in a Midwest community.[53]

Conclusion. What can we say about other tree-related benefits? An improved urban forest can lead to a number of important benefits. For such example is water benefits, where the increased size and health of the urban forest reduces runoff volume and can reduce pollutant loading to receiving water bodies and volumes to sewer systems.

4.5 AESTHETIC BENEFITS – PROPERTY VALUE INCREASE

Aesthetic benefits or those benefits that improve the quality of place of a given area are difficult to quantify, but are nonetheless real and verifiable. We would expect aesthetic benefits to accrue to individuals with buried lines because of the improved viewscape and urban forest. Indeed, one of the most frequently cited reasons that people plant trees is for beautification. Trees provide colour, texture and form to the landscape and soften the hard geometry of urban settings. Research on the aesthetic quality of residential streets has demonstrated that trees exert the strongest positive influence on scenic quality.[54]

One means by which the aesthetic benefits of both increased tree cover and hidden utility lines are observed is through increased property values. For example,

- The *Putting Cables Underground* study found that property value increased only relative to other areas that did not have underground distribution systems and decreased proportionately to the number of properties with underground utilities.[55] However, the relative value of having an underground distribution system increased with the quality of the view and the value of the lot.[56] Depending on the situation, expected increases in property value ranged from negligible to five percent of the property value.[57]

- The Valuer General of Victoria suggested that while property value did indicate a preference, it was a poor indicator of willingness to pay.[58] What this study did not attempt to evaluate however, was the potential increase in property values facilitated by putting cables underground due to the increase in yard trees.

[53] McPherson, E.G., Simpson, J.R., Peper, P.J., Maco, S.E., Gardner, S.L., Cozad, S.K. and Xiao, Q. 2005. Midwest Community Tree Guide: Benefits, Costs and Strategic Planting. USDA Forest Service, Newtown Square, Pennsylvania.

[54] McPherson, E.G., Simpson, J.R., Peper, P.J., Maco, S.E., Gardner, S.L., Cozad, S.K. and Xiao, Q. 2005. Midwest Community Tree Guide: Benefits, Costs and Strategic Planting. USDA Forest Service, Newtown Square, Pennsylvania.

[55] Putting Cables Underground. 1998. Report of the Putting Cables Underground Working Group to the Minister for Communications, Information Technology and the Arts. Australia.

[56] Ibid.

[57] Ibid.

[58] Ibid.

- Studies comparing sales prices of residential properties with different levels of tree resources indicate that people are willing to pay between three and seven percent more for properties with ample tree resources versus those with few or none.[59] One of the most comprehensive studies undertaken found that based on real sales data each large front-yard tree was associated with an approximately one percent increase in sales price.[60]

  Based on this discussion we can place a dollar estimate on the property value increase attributable to the aesthetic value held by individuals when power lines are buried and trees are more prevalent. This value is simply the one-time property value increase followed by an annual increase associated with the one-time increase. Marbek's estimates of these costs are provided below:

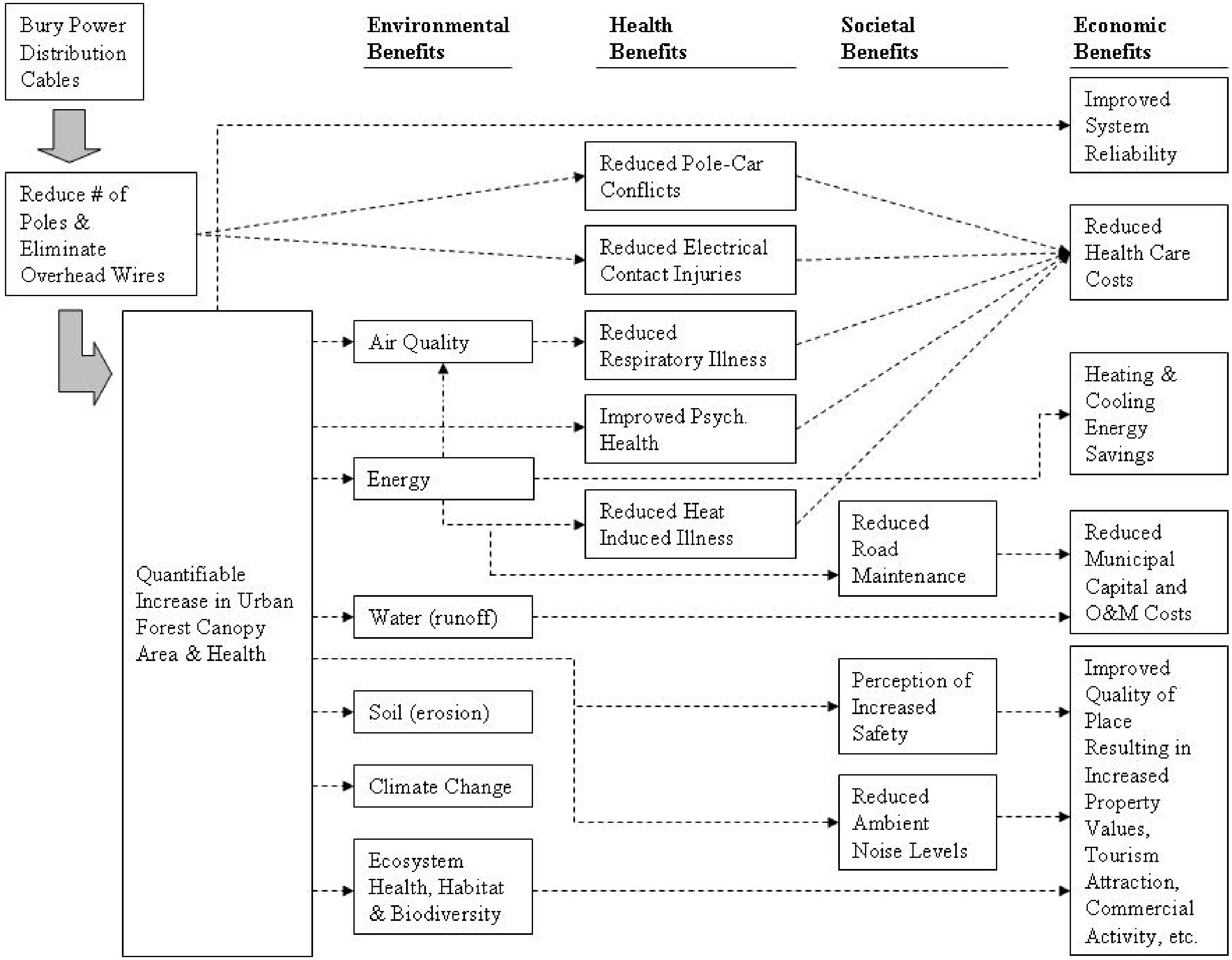
  - Average Value of Halifax Residential Property in 2005 (2001 Stat Can Census grown at 5% appreciation per year) = $163,225
  - Estimated one-time increase in value (3% increase due to buried lines) = $4,897
  - Annual increase in value due to property appreciation (One-time increase appreciates at annual property value rate (5%)) = $245

Conclusion: What can we say about property value increases? We observe that the property value increase when power lines are buried is likely very significant, and indeed one of the most important benefits. Studies indicate that property value increase could be in the order of one to seven percent. Assuming a modest 3% increase in the average price of a home in Halifax results in a one time increase of ~$5,000, which then grows over time at some property appreciation rate. Assuming a conservative appreciation rate for residential property of ~5% per year would result in an additional benefit of ~$245 per year.

[59] McPherson, E.G., Simpson, J.R., Peper, P.J., Maco, S.E., Gardner, S.L., Cozad, S.K. and Xiao, Q. 2005. Midwest Community Tree Guide: Benefits, Costs and Strategic Planting. USDA Forest Service, Newtown Square, Pennsylvania

[60] Ibid.

Exhibit 4-4: Benefit Overview



4.6 SUMMARY AND EVALUATION OF BENEFITS

The following benefit conclusions are real and verifiable when utility lines are buried:

Pole- Substitution Benefits

- What can we say about pole-car conflicts? We find evidence that significant benefits arise from a reduction in the incidence of pole-car accidents. Further, this benefit can be monetized, and could range between $0 and $21 dollars per new house per year.

- What can we say about reduced human contact injuries? Most likely there is not a large benefit associated with electrocution when distribution systems are buried versus overhead. While the benefit may be positive it is likely small

Improved Reliability Benefits

- What can we say about improved reliability in terms of the value of electricity sales? We find that a reduction in value of lost electricity production is a benefit attributable to burying power lines and that this benefit has a significant dollar value. Assuming the Kinectrics lost service revenue estimates ($17 per household per year), in conjunction with the NSPI value of production estimates (~55%), implies that on a per household basis the value of reducing lost service is in the order of $8.57 per household per year. This would be a benefit under both utility and societal perspectives.

Improved Reliability Benefits under Increased Storm Events

- What can we say about the value of lost service interruptions to consumers? Improvements in the level of service can be expected when power lines are buried. It is very likely that consumers value this improvement in service interruptions. The value is likely positive and significant and ranges between $23 and $41 per household.

Tree-Related Benefits from Improved Urban Forest

- What can we say about heating and cooling benefits related to an increased urban forest? We can conclude that this benefit is positive and in the order of $10 per household per year.

- What can we say about tree-related air quality benefits? We conclude that air quality benefits are real and measurable, but are small in terms of overall value. On a per household basis, the average value is likely less than one dollar per year, and in the range of $0.21 to$ 0.83.

  What can we say about other tree-related benefits? An improved urban forest can lead to a number of important benefits. For such example is water benefits, where the increased size and health of the urban forest reduces runoff volume and can reduce pollutant loading to receiving water bodies and volumes to sewer systems.

- What can we say about property value increases? We observe that the property value increase when power lines are buried is likely very significant, and indeed one of the most important benefits. Studies indicate that property value increase could be in the order of one to seven percent. Assuming a modest 3% increase in the average price of a home in Halifax results in a one time increase of ~$5,000, which then grows over time at some property appreciation rate. Assuming a conservative appreciation rate for residential property of ~5% per year would result in an additional benefit of ~$245 per year.

Exhibit 4.5 provides an overview of the range of the dollar values of these benefits as well as a summary of how the benefits accrue to both the utility and societal perspectives.

Exhibit 4.5
Summary of Benefits
Range of Dollar Values and Perspectives

	Range of Values (2005$)			**Perspective**	
	Low	**Central**	**High**	**Utility**	**Social**
Pole-Accidents	$0	$11	$20.74		✓
Reliability – Supply Value	$6.05	$9.77	$9.88	✓	✓
Reliability – End-use Value	$23.33	$32.15	$40.98		✓
Storms – Supply Value	$0.08	$0.08	$0.09	✓	✓
Storms – End-use Value	$2.11	$2.48	$2.85		✓
Air Pollution	$0.21	$0.52	$0.83		✓
Heating and Cooling	$9.85	$10.24	$10.63		✓
Property Value (one-time)	$1,632.25	$4,896.76	$8,161.27		✓
Property Value (annual)	$48.97	$244.84	$571.29		✓

5. WEIGHING THE COSTS & BENEFITS

In this section we look at a number of scenarios to see if burying power lines makes sense from a utility and a societal perspective. We also investigate if the inclusion of damages from extreme events has an impact on the decision criteria. The time frame adopted in the analysis is 40 years, which is roughly the productive life of both underground and buried utilities.

5.1 UTILITY PERSPECTIVE

For the utility the decision rule is if the cost of burying utility lines is cost-effective, meaning it is less expensive that overhead lines looking only at narrowly attributed construction and maintenance costs. Our simulations show that under the utility perspective and using the available information, burying the utility line is not cost-effective, even with the doubling of the probability of an extreme event. This conclusion holds across a full range of sensitivity testing and alternative assumptions about costs and discount rates. Indeed, even if the 1-in-100 year event becomes a 1-in-25 event, the conclusion holds. This is not to say, however, that a policy to bury lines does not make economic sense, but rather from the narrow utility cost-effectiveness perspective the costs are greater than the costs of current overheading practice.

Exhibit 5.1
Utility Perspective
Cost-Effectiveness Per Household for New Development
A Doubling of the Storm Event Probability (1-100 becomes 1-50)
(2005$: 40 years @ 0 to 3% discount rate)

Percentile	Value in 2005$ assuming discount rate of 0, 2% and 3%
20%	-$4,190
50%	-$3,815
80%	-$3,427

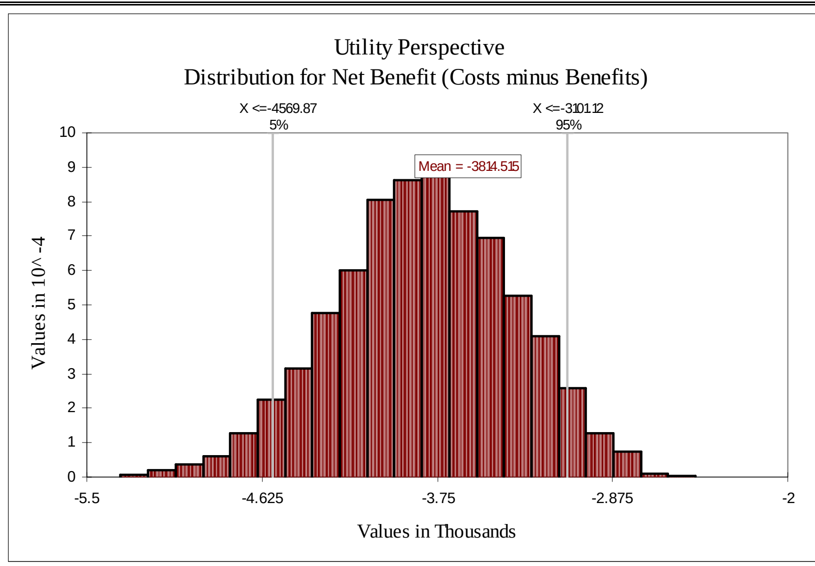
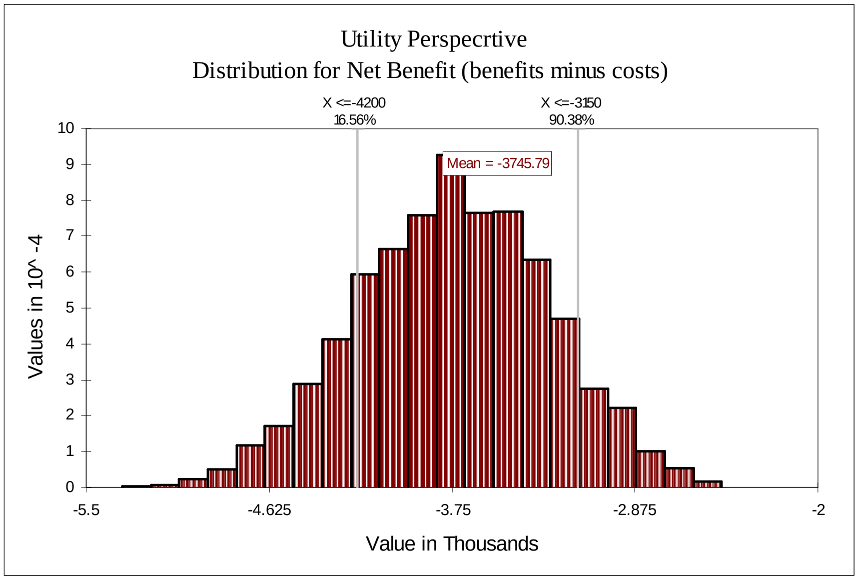


Exhibit 5.2
Utility Perspective
Cost-Effectiveness Per Household for New Development
A Quadrupling of the Storm Event Probability (1-100 becomes 1-25)
(2005$: 40 years @ 0 to 3% discount rate)

Percentile	Value in 2005$ assuming discount rate of 0, 2% and 3%
20%	-$4,400
50%	-$3,745
80%	-$3,613



Conclusion: From a utility cost-effectiveness perspective, it is not to invest in burying power lines in new urban and suburban developments, even with an increased frequency of extreme events. This is not to say, however, that a policy to bury lines does not make economic sense, but rather from the narrow utility perspective the costs are greater than the current practice.

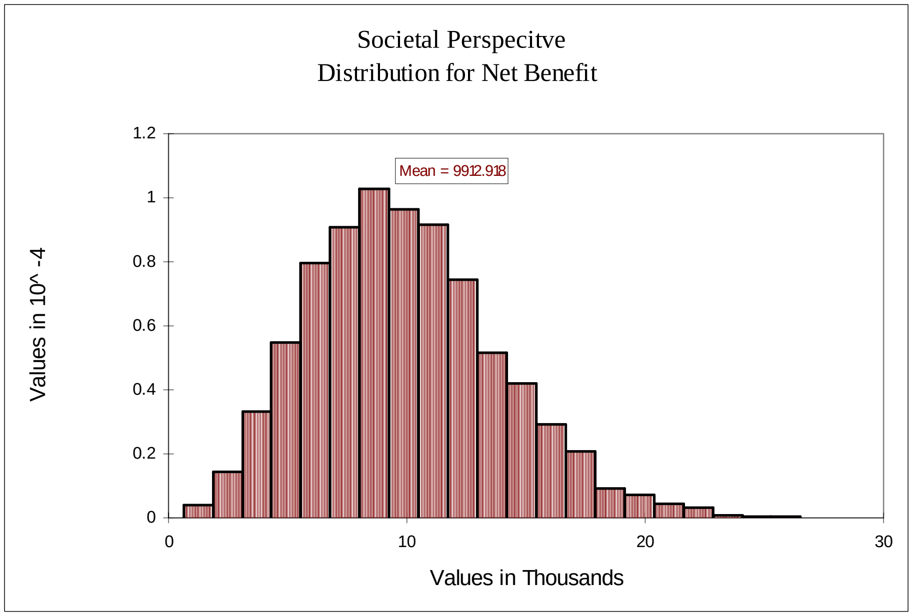
5.2 SOCIETAL PERSPECTIVE: BALANCE OF BROADER BENEFITS & COSTS

From a societal perspective burying utility lines is desirable if the net benefit is positive, meaning that the societal costs are greater than the societal benefits. Our simulations show that when a societal perspective is adopted, burying power lines underground in new developments is economically efficient, where the benefits outweigh the costs. This conclusion holds across a variety of assumptions about costs benefits and discount rates. For example, a discount rate assumption of 20% still produces a positive net benefit. If we assume no benefits from avoiding increased storm damages, there is still a positive net benefit. The largest driver in the positive net benefit is the property value increase, which is a proxy for a preference to live in communities with more trees and no visible utility lines.

Conclusion: There is an economic argument for burying utility lines when a societal perspective is adopted. The net benefit remains positive across a wide range of assumptions about costs, benefits and discount rates.

Exhibit 5.3
Societal Perspective
Net Benefit (costs minus benefits) Per Household Basis for New Development A
A Doubling of the Storm Event Probability (1-100 becomes 1-50)
(2005$: 40 years @ 0 to 3% discount rate)

Percentile	Value in 2005$ assuming discount rate of 0, 2% and 3%
20%	$6,469
50%	$9,912
80%	$13,087



6. CONCLUSION

Three main conclusions emerge from this paper:

1. There is a wedge between the regulated private utility perspective and the public societal (or community perspective) when considering burying power lines in new residential developments. From a utility perspective, based on available data and information the costs of burying power lines likely exceed the costs of the current practice of overhead power lines, and there is no economic incentive to change practices. **This argument changes entirely when a broader societal perspective is considered, and the costs of burying power lines are more than outweighed by the benefits.**

2. The positive net benefit under the societal perspective implies that municipalities develop polices that require underground power lines in new residential developments. However, given the wide distribution of benefits, polices should consider some form of cost-sharing given that benefits accrue to:

   - *Utilities*, in the form of reduced vegetation management costs (and the Municipality) and avoided storm damages;
   - *Developers*, in the form of higher prices for new developments and therefore higher profit levels;
   - *Homeowners*, through reduced heating and cooling costs, higher property values and increased service reliability; and,
   - *Community (including rate payers)*, through clean-air and other environmental benefits.

   Exhibit 6.1 provides a snap-shot of the distribution of costs and benefits by category and importantly an indication of who accrues the costs and the benefits. As can be seen, the net benefit on a per household (or new lot) basis is in the order of $10,000 over the 40 year life of the infrastructure (assuming 3% discount rate and in 2005$). The actual distribution of the costs and benefits will depend on the extent to which costs can be passed on to rate payers by utilities, or reflected in the new house price by developers versus homeowners.

3. While an increased frequency of storm events and infrastructure damages can be expected under future climate change scenarios, the influence of these increased damages on the choice to bury power lines versus overheading is small. This does not imply that lines should not be buried in new residential developments, but rather that other benefits have a far greater influence on decision-making than those related to extreme events. That is, the policy choice to require underground utilities in new residential developments can be justified on a host of factors, including damages related to extreme events.

Exhibit 6.1
Distribution of Cost and Benefits
2005$ Discounted over 40 years at 3%

	Sum of Annual Values	Likely Distribution of Costs and Benefits			
Costs		Utility	Developers	Homeowners	Community
Capital Costs	$3,718	✓	✓	✓	✓
Vegetation Management	-$160	✓		✓	✓
System O&M	$539	✓		✓	✓
Storm Expenditure (Extreme Event)	-$95	✓		✓	✓
Total Costs	**-$4,001**				
Benefits					
Pole-Accidents	$455				✓
Reliability – Supply Value	$248	✓			✓
Reliability – End-use Value	$933			✓	✓
Storms – Supply Value	$7.38	✓			✓
Storms – End-use Value	$215			✓	✓
Air Pollution	$15				✓
Heating and Cooling	$297			✓	✓
Property Value (one-time)	$4,816		✓		
Property Value (on-going)	$6,828			✓	
Total Benefits	**$13,818**				
Net Benefit (Benefits minus Costs)	**$9,816**				

7. BIBLIOGRAPHY

Geiger, J. 2003. Tree Values Quantified. The Desert Arborist. July/August 2003, p.12.

Geiger, J. 2004. The Large Tree Argument: The Case for Large Trees vs. Small Trees. Western Arborist, Volume 30, No. 1: 14-15.

Johnson, B.W. 2006. Out of Sight, Out of Mind? A Study on the Costs and Benefits of Undergrounding Power Lines. Prepared for the Edison Electric Institute.

Kinectrics. 2005. Underground Utilities Feasibility Study for Halifax Regional Municipality. Report #: 10986-001-RA-001-R01.

Maney, C T. 2006. Benefits of Urban Underground Power Delivery. IEEE Technology and Society Magazine, Spring 1996.

McPherson, E.G. 2004. Benefits of Trees: Watershed, Energy and Air.

McPherson, E.G. and Muchnick, J. 2005. Effects of Street Tree Shade on Asphalt Concrete Pavement Performance. Journal of Arboriculture, Volume 31, No. 6: 303-310.

McPherson, E.G., Simpson, J.R., Peper, P.J., Maco, S.E., Gardner, S.L., Cozad, S.K. and Xiao, Q. 2005. Midwest Community Tree Guide: Benefits, Costs and Strategic Planting. USDA Forest Service, Newtown Square, Pennsylvania.

Nowak, D.J., Crane, D.E., Stevens, J.C. and Ibarra, M. 2002. Brooklyn's Urban Forest. USDA Forest Service, Newtown Square, Pennsylvania.

Putting Cables Underground Working Group. 1998. Putting Cables Underground. Report of the Putting Cables Underground Working Group to the Minister for Communications, Information Technology and the Arts. Australia.

Sinclair Knight Merz. 1998. Consultancy to Investigate Potential Benefits From Putting Cables Underground. A study completed in support of the Putting Cables Underground Working Group. Australia.

Virginia State Corporation Commission. 2005. Placement of Utility Distribution Lines Underground. Report to the Governor and the General Assembly of Virginia.

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APPENDIX A

Capital Cost Estimates Associated with Installing Underground Distribution Networks

Exhibit A-1
Capital Cost Estimates Associated with Installing Underground Distribution Networks

Location / Source	Development Type	Typical Capital Cost	Range	
			Low	High
Costs Per Meter				
Placement of Utility Distribution Lines Underground. 2005. Report of the State Corporation Commission to the Governor and the General Assembly of Virginia.	Existing Development	$497	NA	NA
Out of Site, Out of Mind? A Study on the Costs and Benefits of Undergrounding Overhead Power Lines. 2006. Johnson, B.W. Edison Electric Institute.	Existing Development, Florida	$506	NA	NA
	Existing Development, Virginia Investor Owned Utilities	$743	NA	NA
	Existing Development, Long Island Power Authority	$981	NA	NA
	Existing Development, Tahoe-Donner	$740	NA	NA
Underground Utilities Feasibility Study for Halifax Regional Municipality. 2005. Kinectrics.	New Development, Entire Network Underground	$370	NA	NA
	New Development, Arterial/Collector OH	$280	NA	NA
Costs Per House				
Placement of Utility Distribution Lines Underground. 2005. Report of the State Corporation Commission to the Governor and the General Assembly of Virginia.	Existing Development	$27,000	NA	NA
Putting Cables Underground. 1998. Report of the Putting Cables Underground Working Group to the Minister for Communications, Information Technology and the Arts. Australia.	Existing Development	$6,342	$3,016	$12,665
CEA. 1992. Underground vs. Overhead Distribution Systems. Document # CEA 274 D 723	New Suburban Development	$1,900[61]	NA	NA
Hydro Quebec	New (Suburban) Development	$4,000[62]	$1,640	$6,760
Underground Utilities Feasibility Study for Halifax Regional Municipality. 2005. Kinectrics.	New Suburban Development, Entire Network Underground	$3,800	NA	NA
	New Suburban Development, Arterial/Collector OH	$2,900	NA	NA

[61] The suburban development case study indicates that the underground option increases long-term costs by nine percent, which could be paid for by a capital contribution of $1,900 per residence or a 0.0063 $/kW-h increase in rates.

[62] This figure is based on Hydro Québec's assertion that their $2,000 credit for connecting a detached house to the reference system (distribution network) in new developments covers approximately 50 percent of the costs incurred by the applicant (customer, builder, municipality). This hook-up cost is intended to reimburse the applicant for costs that would have been incurred by the utility had it installed an aboveground network. The figure of $4,000 is arrived at by the inclusion of "basic civil engineering costs" estimated (by Hydro Québec) at $2000.

Source: http://www.hydroquebec.com/distribution/en/produits_services/enfouissement.html