Toronto-Hydro Electric System Limited

EB-2018-0165

Norman Hann Compendium

Panel 1

RESPONSES TO ND HANN INTERROGATORIES

INTERROGATORY 1:

Reference(s): **Exhibit 1B, Tab 1, Schedule 1, p. 3 of 34, lines 9-24**

THESL uses the term "extreme weather" throughout the evidence. What is THESL definition of Extreme Weather?

RESPONSE:

The term "extreme weather" refers to weather considered to be unexpected, unusual, severe, unseasonable, or at the edges of the historical distribution (i.e. range) of weather that has been experienced. From an operational perspective, an extreme weather event is any abnormal weather that directly results in or has the potential to result in a large outage and/or a large number of outage events (high wind/gusts, high freezing rain accumulation, heavy rain accumulation, abnormally high temperatures for an extend period of time, etc.). Where the term "extreme weather" is used in the evidence, its context should be considered, as it may reference a particular environmental factor (e.g. wind, rainfall, temperature) or a combination of factors that put Toronto Hydro's distribution system at risk.

RESPONSES TO ND HANN INTERROGATORIES

INTERROGATORY 2:

Reference(s): **Exhibit 1B, Tab 1, Schedule 1, p. 3 of 34, lines 9-24**

If it is based on wind speed, accumulated glace ice, amount of water on the ground, etc. what are the values? [sic]

RESPONSE:

Please refer to Toronto Hydro's response to interrogatory 1B-Hann-1.

RESPONSES TO ND HANN INTERROGATORIES

INTERROGATORY 3:

Reference(s): **Exhibit 1B, Tab 1, Schedule 1, p. 10 of 34, line 14-16**

What is impact on SAIDI and SAIFI if the feeders and interruptions for the "densely populated downtown core are removed from 2009-2017? [sic]

RESPONSE:

Feeders within Toronto Hydro's service territory do not have specific boundary limits or categorization in regards to customer density, and it is not possible to distinguish which customers were interrupted in these specific areas based on the outage data collected by Toronto Hydro.

RESPONSES TO CONSUMERS COUNCIL OF CANADA INTERROGATORIES

INTERROGATORY 12:

Reference(s): Exhibit 1B, Tab 1, Schedule 1, p. 11

The evidence states that 24% of the utility's asset base continues to operate beyond useful life, and an estimated 9% will reach that point by 2025. Please explain how these numbers were calculated. Specifically, what process does THESL use to determine whether assets are beyond their useful life? How does THESL define "beyond useful life"?

RESPONSE:

Unless otherwise specified, the term "Useful Life" used throughout Toronto Hydro's application refers specifically to an asset's Mean Useful Life ("Mean UL").

Derivation of Mean Useful Life

For each of its major system asset types, Toronto Hydro derives a Mean UL from the estimated Useful Life Ranges provided in the 2009 Kinectrics report, "Toronto Hydro-Electric System Useful Life of Assets".[1] The Useful Life Range is defined in part by a Minimum Useful Life ("MIN UL") and a Maximum Useful Life ("MAX UL"), where the MIN UL is "the age when a small percentage of assets reaches physical end-of-life" and "the failure rate starts increasing exponentially," and the MAX UL is the "age when most assets reach physical end-of-life." The Mean UL is the "arithmetic average value of the end-of-life year data" and is equal to the mid-point between the MIN UL and MAX UL.[2]

[1] Toronto Hydro has provided a copy of this report as Appendix A to its response to interrogatory 2B-SEC-38.
[2] Kinectrics Report, "Asset Depreciation Study for the Ontario Energy Board" (July 8, 2010) at pages 10 and 159.

<u>Assessing Assets Past Useful Life</u>

Toronto Hydro considers an asset to be operating "beyond" or "past useful life" if it remains in service at an age that is greater than its Mean UL. Toronto Hydro calculates the percentage of Assets Past Useful Life ("APUL") by comparing the age demographics of its asset population to the Mean UL for each asset class or type.

Please refer to Exhibit 2B, Section E2.2.2.1 for additional information about the Assets Past Useful Life (APUL) metric.

your response, you said 12.5 millimetre radial ice, 400 Newtons per metre squared was the CSA standard. Is that "and" or is that "or." Is it 12 millimetres ice and 400 Newtons, or it is "or"?

MR. TAKI: It is "and."

MR. HANN: And?

MR. TAKI: Yes.

MR. HANN: Thank you. In my question I asked that you calculate the wind speed and kilometres per hour. This wasn't done. I would like to ask for an undertaking to have that done.

MR. TAKI: It is 85 kilometres an hour.

MR. HANN: It is 85 kilometres an hour based on what equation?

MR. KEIZER: Mr. Hann, I am going to interrupt, because a number of your interrogatories are very technical.

MR. HANN: Sorry, I can't hear you.

MR. KEIZER: I said a number of your interrogatories are very technical, and this is a proceeding for purposes of determining and establishing rates.

So I guess if I could understand how the formula for the determination of the kilometres per hour relates to the determination of rates, that would be very helpful.

MR. HANN: That is the basis for my other questions, because I asked how many times the wind speed has exceeded the design capacity of the poles and the conductor.

And I have also asked similar-type questions related

RESPONSES TO ND HANN INTERROGATORIES

INTERROGATORY 6:

Reference(s): **Exhibit 1B, Tab 1, Schedule 1, pp. 13, 14 of 34, lines 3-9 and 1 Table 1 Months of Extreme Weather (January 1 2017 through June 2018)**

What are the design loads for wind in KPH and/or ice in mm including overload factors?

RESPONSE:

For overhead systems, 12.5 mm radial thickness of ice, 400 N/m^2 horizontal wind loading, and -20 degree Celsius temperature are used to determine loads and maximum tensions. These values are based on CSA C22.3 No. 1 "Overhead Systems" standard.

RESPONSES TO ND HANN INTERROGATORIES

INTERROGATORY 7:

Reference(s): **Exhibit 1B, Tab 1, Schedule 1, pp. 13, 14 of 34, lines 3-9 and 1 Table 1 Months of Extreme Weather (January 1 2017 through June 2018)**

Provide evidence including dates of events where the actual loads of wind and/or glace ice exceeded the design loads.

RESPONSE:

Toronto Hydro tracks customer outages due to weather events by cause codes such as Adverse Environment and Tree Contacts. However, it does not specifically track the information requested. For weather events that resulted in significant impacts to Toronto Hydro's distribution system, please refer to Appendix C – Forensic Analysis of Weather Related Power Outage Events of Exhibit 2B, Section D, Appendix D and Exhibit 1B, Tab 1, Schedule 1, Table 1. For comparable storm data for the previous 18 months, please refer to Toronto Hydro's response to interrogatory 1B-BOMA-6.

Toronto Hydro designs its system in line with standard utility practice. For overhead systems, the system is designed to the CSA C22.3 No. 1 "Overhead Systems" standard. For underground systems, the system is designed to the CSA C22.3 No.1 "Underground Systems" standard. These include requirements for combined loads of ice, wind, and temperature, as provided in Toronto Hydro's response to interrogatory 1B-Hann-6.

RESPONSES TO ND HANN INTERROGATORIES

INTERROGATORY 8:

Reference(s): **Exhibit 1B, Tab 1, Schedule 1, p. 15 of 34, lines 9-15**

Why does the system not withstand the design loads including overload factor?

RESPONSE:

Please see Toronto Hydro's response to interrogatory 1B-Hann-7.

Due to the effects of climate change, weather events are becoming more frequent and have increased reliability risks for Toronto Hydro's distribution system. To better understand the risks related to increases in extreme and severe weather due to climate change, Toronto Hydro completed a vulnerability assessment of its infrastructure (Exhibit 2B, Section D, Appendix D). Following this study, Toronto Hydro developed a climate change road map, along with initiatives relating to climate data validation, review of equipment specifications, and review of the load forecasting model. For further information on these initiatives and Toronto Hydro's ongoing efforts to renew and enhance its system to changes in the weather and climate, please refer to Exhibit 2B, Section D2.1.2.

RESPONSES TO ND HANN INTERROGATORIES

INTERROGATORY 11:

Reference(s): Exhibit 1B, Tab 1, Schedule 1, p. 15 of 34, line 1-3

Did the extreme weather events in 2017 or the aging of the urban forest and in particular invasive species such as the Norway Maple with a life span of 20-40 years, result "in a 72 percent increase 1 in the number of customer interruptions attributed to tree contacts compared to the average of the previous five years." [sic]

RESPONSE:

The customer interruptions referenced all occurred during weather events and weather was a primary cause of the interruptions. Toronto Hydro does not have information that would suggest the aging of the urban forest or the presence of invasive species such as the Norway Maple was a significant contributor to the "72 percent increase" in the number of customer interruptions in 2017 relative to the average of the previous five year.

Toronto Hydro does recognize that the City of Toronto's tree canopy, along with factors such as age, invasive species, and disease, is a risk to system reliability. Toronto Hydro manages this risk through programs such as the Preventative and Predictive Overhead Line Maintenance program, and in particular the Vegetation Management segment (Exhibit 4A, Tab 2, Schedule 1, Section 7), the Overhead System Renewal program (Exhibit 2B, Section E6.5), and the Area Conversion program (Exhibit 2B, Section E6.1).

RESPONSES TO ND HANN INTERROGATORIES

INTERROGATORY 12:

Reference(s): Exhibit 1B, Tab 1, Schedule 1, p. 15 of 34, line 1-3

Is the aging urban forest the issue, since trees that were planted in "fields" in the 1960's in Etobicoke, Scarborough and North York are now 50 years older, taller and in some cases weaker due to age, disease and infestations? If not, please explain why.

RESPONSE:

Please refer to Toronto Hydro's response to interrogatory 1B-Hann-11.

RESPONSES TO ND HANN INTERROGATORIES

INTERROGATORY 17:

Reference(s): **Exhibit 1B, Tab 1, Schedule 1, p. 9 of 34, no line numbers reference below**

Reference: We emphasize the importance of including U.S. distributors into any benchmark evaluation involving Toronto Hydro (or any other extreme outlier in the Ontario dataset). While an Ontario only dataset is appropriate for the clear majority of Ontario distributors, an Ontario-only dataset will not produce reliable results for Toronto Hydro, due to its outlier status within that dataset. This outlier status is shown by the fact that Toronto Hydro has over double the number of customers than the next largest distributor (prior to Alectra Utilities being formed), except for the extremely rural Hydro One Networks. Additionally, Toronto Hydro's "congested urban" variable is over three times as large as the next closest Ontario peer.

Please provide segregated SAIFI, SAIDI with and without MED data for the downtown congested and horseshoe.

RESPONSE:

Toronto Hydro does not track reliability down to the "congested urban" area as defined by the PSE study. Feeders run in and out of the various "congested urban" area and as such, it is not possible to distinguish which customers were interrupted in these specific areas based on the outage data collected by Toronto Hydro.

RESPONSES TO ND HANN INTERROGATORIES

INTERROGATORY 22:

Reference(s): **Exhibit 1B, Tab 2, Schedule 4, p. 11 of 21, Figure 12: SAIDI Cause Code 1 Breakdown (Excluding MEDs)**

Since THESL "tracks the cost code as a measure of continuous improvement 5 in the execution of its capital expenditure and maintenance plans ". [sic]

a) How many defective equipment interruptions occurred,

b) How many fuse links were replaced during unplanned interruptions?

c) How many fused switches were replaced during unplanned interruptions?

d) How many poles were replaced during unplanned interruption? From 2013-2017.

RESPONSE:

a) 2,922 outages were caused by defective equipment from 2013-2017. Please see Table 1 for a detailed breakdown.

Table 1: Outages Caused by Defective Equipment from 2013-2017

	2013	2014	2015	2016	2017	Total
Outages Caused By Defective Equipment	636	711	572	519	484	2,922

b) Toronto Hydro does not track the number of fuse links replaced specifically during unplanned outages and as such, is unable to provide the requested information.

c) Over the 2013-2017 period, 167 overhead disconnect switches were replaced due to outages caused by defective equipment.

d) Over the 2013-2017 period, 48 poles were replaced due to outages caused by defective equipment.

RESPONSES TO ND HANN INTERROGATORIES

INTERROGATORY 23:

Reference(s): **Exhibit 1B, Tab 2, Schedule 4, p. 11 of 21, Figure 12: SAIDI Cause Code 1 Breakdown (Excluding MEDs)**

What is the definition of Defective Equipment cause used by the reporting staff, was it a blown fuse or a switch operating as it should have due to a fault on the line that was attributed to defective equipment? [sic]

RESPONSE:

Defective Equipment is a cause code defined by the Ontario Energy Board's Electricity Reporting & Record Keeping Requirements document[1] as follows:

> *"Customer interruptions resulting from distributor equipment failures due to deterioration from age, incorrect maintenance, or imminent failures detected by maintenance."*[1]

The OEB's requirements further specify how outages should be categorized into the various cause codes based on the cause.

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[1] "Electricity Reporting & Record Keeping Requirements", p. 13, Ontario Energy Board, 2018, URL: <https://www.oeb.ca/sites/default/files/RRR-Electricity-20181129-1.pdf>

RESPONSES TO ND HANN INTERROGATORIES

INTERROGATORY 27:

Reference(s): Exhibit 1B, Tab 2, Schedule 4, p. 12 of 21, lines 1-9

What was the performance of the section of the lines/feeders before and after the capital improvements? Please provide the dates, Number of interruption, number of customer interruptions, duration of interruption by line/feeder and year.

RESPONSE:

Toronto Hydro does not track the reliability impacts of specific section of lines/feeders before and after a capital project. The results of capital investments targeting performance are affected by numerous factors, including but not limited to:

- Toronto Hydro's Outage Management System, which tracks outages at a feeder level;
- Scope/size/type of the capital project (i.e. some projects are minor, while others rebuild a large section of a feeder);
- Multiple projects carried out on the same feeder over a period of time (e.g. small projects being done year after year on a feeder);
- External factors (e.g. foreign interference or adverse weather); and
- The continuously changing size and configuration of feeders that may redistribute customers from one feeder to another.

RESPONSES TO ND HANN INTERROGATORIES

INTERROGATORY 33:

Reference(s): **Exhibit 1B, Tab 2, Schedule 5, p. 1 of 1, OEB Appendix 2-G Service Reliability Indicators 2013 - 2017**

THESL uses SAIFI as a measure of aging and deteriorating assets, please explain why SAIFI including MEDs is showing a downward trend (excluding 2013) in an environment of increasing storms and aging assets?

RESPONSE:

SAIFI is not a measure of aging and deteriorating assets, although aging and deteriorating assets may impact SAIFI. The Ontario Energy Board's Electricity Reporting & Record Keeping Requirements document[1] defines SAIFI as "an index of system reliability that expresses the number of times per reporting period that the supply to a customer is interrupted." [1]

Further, Toronto Hydro uses more than just reliability (such as the SAIFI measure) when assessing aging and deteriorating assets. Toronto Hydro must also consider the age and the condition of assets. Please refer to Exhibit 2B, Section D3 for details on Toronto Hydro's Asset Lifecycle Optimization approach.

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[1] "Electricity Reporting & Record Keeping Requirements", p. 12, Ontario Energy Board, 2018, URL: https://www.oeb.ca/sites/default/files/RRR-Electricity-20181129-1.pdf

Even though Toronto Hydro's assets continue to age and deteriorate, and adverse weather events are unpredictable, the following factors have contributed to improved reliability:

- as described in the System Renewal Programs presented in Exhibit 2B, Section E6 as well as the System Enhancements Programs presented in Exhibit 2B, Section E7.1, Toronto Hydro invests in renewing and enhancing the existing distribution system to reduce the impacts and duration of outages due to storms; and

- through inspections and maintenance, assets that are at risk of imminent failure can be identified and replaced prior to them failing thereby preventing an unplanned outage. For more details, please refer to the Reactive and Corrective Capital program presented in Exhibit 2B, Section E6.7.

RESPONSES TO ND HANN INTERROGATORIES

INTERROGATORY 38:

Reference(s): **Exhibit 1B, Tab 3, Schedule 1, Appendix A, p. 31 of Toronto Hydro 2018 Customer Engagement Customer Feedback Portal Report Segmentation and Demographics**

What are the actual number of interruptions, and customer interruptions 2008-2017 for defective equipment?

RESPONSE:

Please see Table 1 below for number of interruptions and customer interruptions for defective equipment from 2008-2017.

Table 1: Reliability Impact of Defective Equipment (Outage Incidents & CI)

Year	Number of Outage Incidents	Total Customers Interrupted
2008	803	582,999
2009	718	517,980
2010	724	488,566
2011	696	434,578
2012	557	453,218
2013	636	382,908
2014	711	387,519
2015	572	433,324
2016	519	370,901
2017	484	344,853

RESPONSES TO ND HANN INTERROGATORIES

INTERROGATORY 39:

Reference(s): **Exhibit 1B, Tab 3, Schedule 1, Appendix A, p. 48 in Appendix 2.1 Toronto Hydro 2018 Customer Engagement Customer Feedback Portal Report (p. 372 in pdf)**

In multiple locations in the evidence photos show “storms” with “trees”. How does capital replacement storm hardening eliminate these interruptions due to tree contact?

RESPONSE:

Capital replacements that harden the system against extreme weather will not eliminate interruptions due to tree contacts. Toronto Hydro does however have a number of programs that are aimed at reducing the number of tree contacts through design changes such as tree proof conductors (please refer to Exhibit 2B, Section E6.5 - Overhead System Renewal), as well as converting infrastructure that is more prone to tree contacts, or that makes it more difficult to resolve interruptions due to tree contact (please refer to Exhibit 2B, Section E6.1 - Area Conversions).

RESPONSES TO ND HANN INTERROGATORIES

INTERROGATORY 41:

Reference(s): **Exhibit 1B, Tab 4, Schedule 2, p. 10, Figure 2 Toronto Hydro's SAIFI Performance 2005-2024 13 of report point 3**

Customer interruptions in SAIFI are dependent on a number of factors, what is the comparison of actual number of interruptions that have occurred on the assets from 2005 projected to 2024, segregated by 1-50, 51-500. 501 to 1000, 1001 to 5000 and greater than 5000 customers interrupted by a device? Please provide in table and chart format. [sic]

RESPONSE:

Please see Table 1 and Figure 1 for 2005-2017 results. Toronto Hydro does not forecast customer interruptions. Toronto Hydro does not currently have this data finalized for 2018.

Table 1: Number of Outage Incidents (By CI of Incident)

	1-50 CI	51-500 CI	501-1000 CI	1001-5000 CI	>5000 CI
2005	853	425	147	298	39
2006	744	394	164	314	41
2007	709	409	105	321	47
2008	665	397	127	304	39
2009	610	373	101	248	44
2010	618	334	101	255	37
2011	638	323	107	277	42
2012	535	285	87	203	42
2013	650	342	81	236	38

	1-50 CI	51-500 CI	501-1000 CI	1001-5000 CI	>5000 CI
2014	676	335	99	224	32
2015	470	315	92	233	43
2016	503	241	75	213	47
2017	439	213	75	204	54

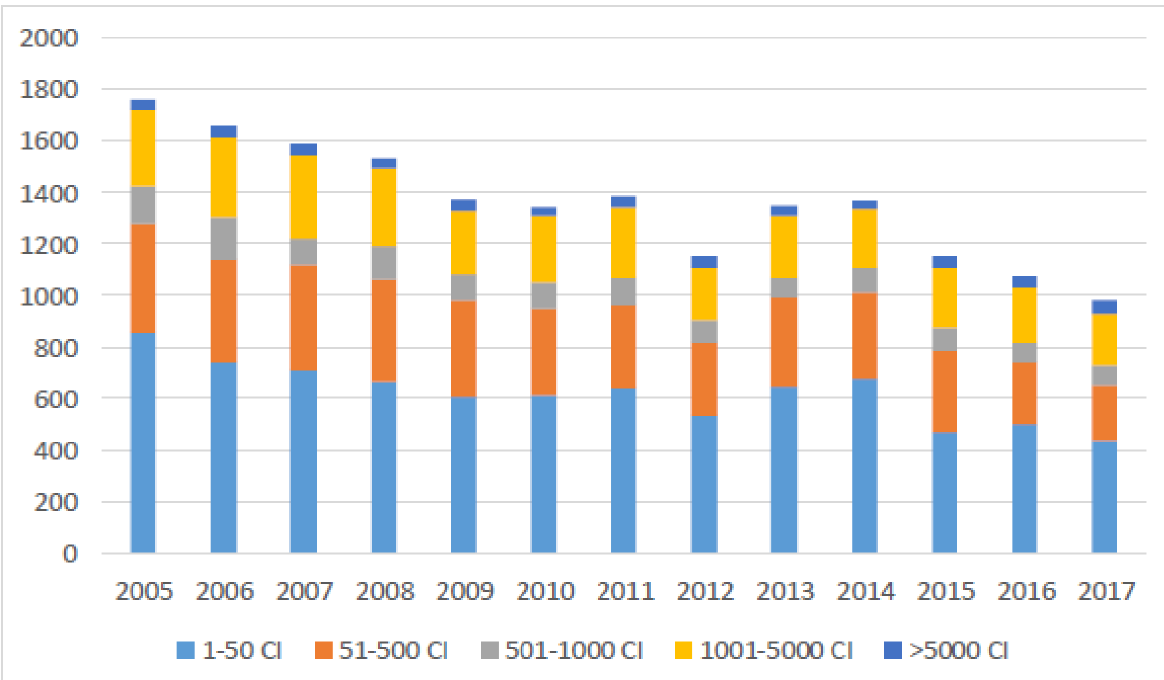


Figure 1: Number of Outage Incidents (By CI of Incident)

RESPONSES TO ND HANN INTERROGATORIES

INTERROGATORY 42:

Reference(s): **Exhibit 1B, Tab 1, Schedule 1, p. 31 of 34, lines 6-13**

How many pole top transformers fail each year listed by year of manufacture from 2008 to 2017?

RESPONSE:

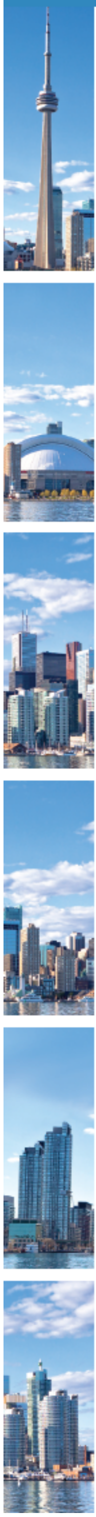
Exhibit 2B, Section E6.5, Figure 7 at page 9 provides the age distribution for failed overhead transformers for the period of 2013-2017, based on the subset of pole top transformers investigated by Toronto Hydro's Quality Program. However, as a result of information system limitations, Toronto Hydro is unable to provide the information requested going back to 2008.

Exhibit 2B, Section E6.5, Figure 4 also provides the total number of interruptions caused by pole-top transformers for the period of 2013-2017. The following table provides the same information for the prior period of 2008-2012.

Table 1: Pole Transformer Failures from 2008-2012 (Toronto Hydro ITIS Database)

Year	Number of Failures
2008	72
2009	65
2010	95
2011	79
2012	55

Toronto Hydro's Performance



Outcomes and Performance Measurement

Customers want to know that Toronto Hydro's 2020 to 2024 performance will provide them with value for money. We're proposing to report on **44** performance measures that will track how well we're doing.

For more on Toronto Hydro's Performance, See Exhibit 1B: Outcomes and Performance

Toronto Hydro Outcome	OEB Reporting Category	Performance Measures
Customer Service	Service Quality	9
	Customer Satisfaction	5
Safety	Safety	7
Reliability	System Reliability	6
	Asset Management	4
Financial	Cost Control	5
	Financial Ratios	3
Public Policy	Conservation and Demand Management	1
	Connecting Renewable Generation	2
Environment	Environment	2
Total Performance Measures		**44**

Past Performance and Continuous Improvement

Our previous plans are working and our performance is improving.

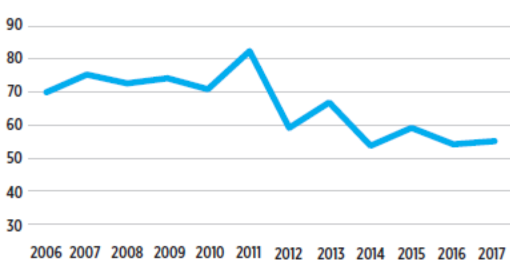
We're getting faster at connecting new customers. And we're exceeding industry standards for meeting scheduled appointments, answering calls on time and providing accurate bills.

We're also making the grid more reliable. Outages that aren't related to major events, like wind and ice storms, are becoming shorter and less frequent.

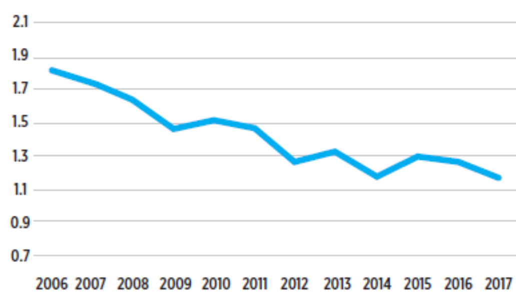
Performance Categories	Measures	2013	2014	2015	2016	2017	Industry
Service Quality	New Residential/Small Business Services Connected on Time	94.2%	91.5%	96.9%	97.7%	**98.3%**	90.0%
	Scheduled Appointments Met On Time	99.6%	99.8%	99.9%	99.5%	**99.4%**	90.0%
	Telephone Calls Answered On Time	82.0%	71.9%	76.8%	64.7%	**77.9%**	65.0%
Customer Satisfaction	Billing Accuracy	–	96.6%	97.5%	98.8%	**99.2%**	98.0%

System Reliability

Duration of Outages (minutes per year)*



Frequency of Outages (number per year)*



*Excludes Loss of Supply from Hydro One and Major Event Days

4.1 Deteriorating Infrastructure

Toronto Hydro operates in a mature, congested urban environment, which presents significant cost and operating challenges. For instance, Figure 4, below, provides an example of aging box construction feeders from the pre-amalgamation City of Toronto.

In undertaking its capital and operational work, the utility contends with complexities including:

- The intensification of development (such as condominium complexes, transit extensions, and community redevelopments);
- Limited space for utility equipment installation, over a century of construction by various agencies in the public right-of-way and on private properties, often with missing or inaccurate historical records;
- Coordination with other City and utility reconstruction programs; and
- A densely populated downtown core, served by a complex arrangement of equipment that is unique in its span and configuration in Ontario's distribution sector.

Figure 4: Box Construction in a Backyard with Leaking Equipment

Extreme weather events in 2017 resulted in a 72 percent increase in the number of customer interruptions attributed to tree contacts compared to the average of the previous five years. Similarly, in 2018, Toronto Hydro experienced four extreme storms during the first half of the year, leaving nearly 160,000 customers without electricity.

Figure 7: Damage due to Weather Events

Climate change affects different parts of the distribution system in different ways. The overhead system is susceptible to extreme winds, freezing rain and wet snow resulting in damage and outages. Broken trees and the weight of ice and snow accretions can bring lines, poles and associated equipment to the ground. Figure 7, above, are some examples of line damage caused by the recent weather-related events in the City of Toronto. The underground system is vulnerable to flooding from extreme rainfall. For instance, extreme rainfall in April and May of 2017 caused a number of Toronto Hydro's vaults and cable chambers in the underground system to flood. One particular network vault in Toronto's downtown core experienced severe flooding, causing a network protector to fail. This resulted in a lengthy outage in the financial district with significant disruption to customers, a closure of a busy arterial road during afternoon rush hour, and significant public and media attention.

In addition to extreme weather events, Toronto experiences a wide range of weather conditions that may not be classified as extreme, but nevertheless have the potential to adversely affect the distribution system at various times during the year. Heat, high winds, heavy rainfall, freezing rain, and heavy snowfall cause major system damage. They also make restoration more challenging, and prolong outages.

4.4 Workforce Retirements

Toronto Hydro employees are essential in executing planned and reactive work programs that are necessary to maintain the distribution system's integrity, mitigate unacceptable risks in the areas of reliability and safety, and operate the system. Toronto Hydro is in the midst of a significant renewal of its workforce, with approximately 23 percent of its workforce (or approximately 340 FTEs) forecasted to retire between 2020 and 2024. Of that number, approximately 80 percent are from the utility's staffing categories that directly maintain and operate the distribution system (e.g. certified and skilled trades, designated and technical professionals, and supervisory positions). These personnel are critical to maintaining and operating the distribution system in a safe and efficient manner, and filling these roles can be especially challenging and can take up to six years to train. Recruitment and retention are particularly challenging in Toronto's competitive job market and with quickly escalating costs of living in the City and neighbouring communities.

4.5 Technology Advancements

Technology advancements are a major challenge in the electricity distribution sector globally, and is in many ways greater for distributors in major urban centres. A prominent example of that challenge is the complexity of integrating distributed energy

The risk to the utility's deteriorating infrastructure is compounded by increases in the frequency and magnitude of extreme weather. Toronto Hydro continues to emphasize plans and programs that facilitate and improve its system resiliency, and ability to respond to these events.[41]

With more than 1,800 distributed energy resources connected to Toronto Hydro's system,[42] reducing risks to the grid requires Toronto Hydro to enhance its visibility of them and put in appropriate safety equipment and protocols. To this end, the utility plan includes a number of investments to assist in managing evolving system requirements and technological landscape.[43]

6.3 Operating, Maintenance & Administration ("OM&A" or "Operational") Plan

Toronto Hydro's operational plan is organized into 21 programs, each of which advances similar outcomes in similar ways. Some programs work directly with the distribution system, such as preventative maintenance, emergency response, and the control centre.[44] Other programs provide support to operations and customers, such as fleet, facilities, and supply chain,[45] customer service and support,[46] human resources, finance, and information technology.[47] All these programs are necessary to safely and reliably

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[41] These programs include the Control Operations Reinforcement program (Exhibit 2B, Section E8.1), Area Conversions (Exhibit 2B, E6.1), System Enhancements (Exhibit 2B, E7.1), and Overhead System Renewal (Exhibit 2B, Section E6.5).

[42] There are likely dozens, perhaps even hundreds more of these micro-generation, storage, and other devices that are installed without notice to Toronto Hydro, the operation of which by the customer can affect the distribution system and other customers connected to it (e.g. power quality fluctuations, back-flow of power, spikes up and down in demand).

[43] See Exhibit 2B, Section E7.1 (System Enhancements); Exhibit 2B, Section E7.2 (Energy Storage Systems); Exhibit 2B, Section E7.3 (Network Condition Monitoring and Control); and Exhibit 2B, Section E8.1 (Control Operations Reinforcement program).

[44] See Exhibit 4A, Tab 2, Schedules 1-10.

[45] See Exhibit 4A, Tab 2, Schedules 11-13.

[46] See Exhibit 4A, Tab 2, Schedules 14 and 19.

[47] See Exhibit 4A, Tab 2, Schedules 15-18, 20-21.

RESPONSES TO ND HANN INTERROGATORIES

INTERROGATORY 44:

Reference(s): **Exhibit 2B, Section D, Appendix D, Toronto Hydro-Electric System Limited Climate Change Vulnerability Assessment Application of the Public Infrastructure Engineering Vulnerability Assessment Protocol to Electrical Distribution Infrastructure Final Report - Public 6031-8907 June 2015, Table ES-1 Climate Parameters and Probability of Occurrence**

What are THESL design standards including overload factor for wind and ice with overload factoring KPH and mm?

RESPONSE:

Please refer to Toronto Hydro's response in 1B-Hann-6.

RESPONSES TO ND HANN INTERROGATORIES

INTERROGATORY 45:

Reference(s): **Exhibit 2B, Section D, Appendix D, Toronto Hydro-Electric System Limited Climate Change Vulnerability Assessment Application of the Public Infrastructure Engineering Vulnerability Assessment Protocol to Electrical Distribution Infrastructure Final Report - Public 6031-8907 June 2015, Table ES-1 Climate Parameters and Probability of Occurrence**

What are the dates, actual wind or Ice values have exceeded the design standards including overload the from 2008-2017? [sic]

RESPONSE:

Please refer to Toronto Hydro's response to interrogatory 1B-Hann-7.

RESPONSES TO ND HANN INTERROGATORIES

INTERROGATORY 46:

Reference(s): **Exhibit 2B, Section D, Appendix D, Toronto Hydro-Electric System Limited Climate Change Vulnerability Assessment Application of the Public Infrastructure Engineering Vulnerability Assessment Protocol to Electrical Distribution Infrastructure Final Report - Public 6031-8907 June 2015, Table ES-1 Climate Parameters and Probability of Occurrence**

What were the actual historical dates from the earliest available data to 2018 that the wind and Ice climate parameter values in Table ES-1 were reached or exceeded?

RESPONSE (PREPARED BY AECOM/RSI):

Thresholds for ice breaking points were based on studies on power outages and the comprehensive study for Public Safety Canada. These included all outages beginning from the late 1940s, with the information based on archives, climate reports, weather maps, media coverage and a database of communications tower failures for all of Southern Ontario and for US states bordering on the Northern Great Lakes.

For specific dates of significant ice storm events, please refer to the report prepared for Public Safety Canada (at the time known as the Office of Critical Infrastructure Protection and Emergency Preparedness, by Klaassen et al. (2003).[1] In addition to the events listed

[1] This report can be accessed at the following link https://www.publicsafety.gc.ca/lbrr/archives/qc%20926.45.c22%20e78%202003-eng.pdf

in Klaassen et al. (2003), we also note substantial evidence that some of the thresholds used in this study were also exceeded during the December 2013 ice storm event in the Greater Toronto Area.

RESPONSES TO ND HANN INTERROGATORIES

INTERROGATORY 47:

Reference(s): **Exhibit 2B, Section D, Appendix D, Toronto Hydro-Electric System Limited Climate Change Vulnerability Assessment Application of the Public Infrastructure Engineering Vulnerability Assessment Protocol to Electrical Distribution Infrastructure Final Report - Public 6031-8907 June 2015, Figure ES-1 Example Maps Based on Risk Ratings for High Heat, Freezing Rain and Lightning**

It appears from the maps that there may be a coorelation between tree density and High Ambient Temperatures, Freezing Rain and Lighting risk rating. Please provide a vegetation density map as well from the 1960.s and 2014. [sic]

RESPONSE (PREPARED BY AECOM/RSI):

The Risk Assessment Matrix (p805-806) should be used alongside the commentary in Section 5 of the report (pg 695-706 of PDF) to interpret observed mapping trends in Figure ES-1.

AECOM did not produce vegetation density maps because the scope of the study did not include mapping historic vegetation density. Forensic assessment was limited to analysis of climate and outage data.

RESPONSES TO ND HANN INTERROGATORIES

INTERROGATORY 48:

Reference(s): **Exhibit 2B, Section D, Appendix D, Toronto Hydro-Electric System Limited Climate Change Vulnerability Assessment Application of the Public Infrastructure Engineering Vulnerability Assessment Protocol to Electrical Distribution Infrastructure Final Report - Public 6031-8907 June 2015**

How often has THESL experienced," ice storms (up to 25 mm) and high winds (up to 90 km/h) in the past." Please provide yearly data in a table format.

RESPONSE:

Please refer to Toronto Hydro's response to interrogatory 1B-Hann-7.

RESPONSES TO ND HANN INTERROGATORIES

INTERROGATORY 49:

Reference(s): **Exhibit 2B, Section D, Appendix D, Toronto Hydro-Electric System Limited Climate Change Vulnerability Assessment Application of the Public Infrastructure Engineering Vulnerability Assessment Protocol to Electrical Distribution Infrastructure Final Report - Public 6031-8907 June 2015**

a) How does this statement "These events are projected to continue in the future, but continue to occur on a less than annual, or even decadal frequency." prove as stated throughout the evidence that "extreme storms" are more frequent?

b) Is it the processes from design to construction to maintenance that need to be re-evaluated and addressed in light of the changing urban environment, especially the growth, aging and disease of the urban forest? If yes, what action is being undertaken?

RESPONSE:

a) The statement quoted refers to the general category of "Freezing Rain, Ice Storms, High Winds and Tornados – Overhead and Feeder Assets." Please refer to Exhibit 2B, Section D, Appendix D, Table 3-2 for a breakdown of projected climate parameters that contribute to extreme weather conditions similar to the recent extreme weather events listed in Exhibit 2B, Section A4, Table 4. The projections are that the occurrence of these parameters will increase in the future. Please refer to Exhibit 2B,

Pg 686 Toronto Hydro_CIR_Appl_Exhibit 2B_20180815 Exhibit 2B,
23 Section D, Appendix D, Table 3-2

Section D, Appendix D for more details.

b) Following the study referenced, Toronto Hydro developed a climate change adaptation road map, along with initiatives relating to climate data validation, review of equipment specifications, and review of the load forecasting model. As part of this road map, Toronto Hydro reviewed and updated major equipment specifications in 2016 to adapt to climate change, including the adoption of breakaway links in tree-covered areas for residential customers with overhead service connections, intended to facilitate faster restoration after extreme weather and prevent damage to customer-owned service masts. For more information on Toronto Hydro's climate adaptation road map please refer to Exhibit 2B, Section D2.1.2.

Additionally, Toronto Hydro recognizes that the City of Toronto's tree canopy, along with factors such as age, invasive species, and disease, is a risk to system reliability. Toronto Hydro manages this risk through programs such as the Preventative and Predictive Overhead Line Maintenance program, and in particular the Vegetation Management segment (Exhibit 4A, Tab 2, Schedule 1, Section 7), the Overhead System Renewal program (Exhibit 2B, Section E6.5), and the Area Conversion program (Exhibit 2B, Section E6.1).

RESPONSES TO ND HANN INTERROGATORIES

INTERROGATORY 51:

Reference(s): **Exhibit 2B, Section D, Appendix D, p. 10, 11**

Fuses and Circuit breakers are in typical stations. What work has been done to coordinate the fuses on the feeders to prevent interruptions that should be captured that affect only a few customers going back to the station switch and taking out many customers?

RESPONSE:

Toronto Hydro's Construction Standards and Standard Design Practice prescribe fusing requirements for feeders to ensure protection coordination with station circuit breakers and to limit the number of customers impacted by an interruption. Construction Standards and Standard Design Practice are adhered to in all construction on Toronto Hydro's distribution system.

Prior to the execution of any capital or maintenance work at a station, Toronto Hydro reviews station and feeder protection to ensure proper coordination of protective devices such as breakers and fuses. In addition, prior to connecting a customer-owned substation to its system, Toronto Hydro reviews the customer's breaker and fuse specifications to ensure coordination with protective devices on Toronto Hydro's distribution system and to minimize the number of customers impacted by an interruption.

RESPONSES TO ND HANN INTERROGATORIES

INTERROGATORY 52:

Reference(s): **Exhibit 2B, p. 17**

Load projections are provided by Former Toronto and Horseshoe stations. Please provide the Number of interruptions, number of customer interruptions and durations and customer durations by station feeders for 2008-2017 in table format.

RESPONSE:

Based on the load projection referenced in the question, Toronto Hydro is able to provide the information requested broken down by Former Toronto and Horseshoe stations for 2008-2017.

Table 1: Number of Interruptions

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Former Toronto	230	192	174	197	132	186	140	137	145	126
Horseshoe	1,618	1,563	1,990	1,741	1,464	1,784	1,749	1,219	1,304	1,097

Table 2: Number of Customer Interruptions

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Former Toronto	178,580	154,448	194,336	168,098	94,683	126,464	108,655	106,197	91,943	89,369
Horseshoe	1,024,692	970,705	1,034,847	975,297	906,076	915,837	909,515	974,789	967,244	1,001,473

Table 3: Sum of Durations of Interruptions

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Former Toronto	32,720	23,395	30,046	32,125	22,713	58,708	28,744	21,779	31,523	32,669
Horseshoe	307,013	298,080	393,321	363,515	290,002	378,735	345,700	268,776	259,653	227,824

Table 4: Number of Customer Hours Interrupted

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Former Toronto	124,960	223,196	188,931	213,381	139,716	135,539	145,891	120,008	160,113	191,061
Horseshoe	722,926	723,540	709,656	793,428	592,699	691,883	590,646	668,804	562,694	561,400

Table 3-1 PIEVC Version 10 Probability Scores based on Method B

Score	Probability	
0	< 0.1 %	< 1 in 1,000
1	1 %	1 in 100
2	5 %	1 in 20
3	10 %	1 in 10
4	20 %	1 in 5
5	40 %	1 in 2.5
6	70 %	1 in 1.4
7	> 99 %	> 1 in 1.01

3.2 Summary of Results

24 climate parameters covering temperature, precipitation, wind and lightning hazards were considered within the climate analysis. However, four of them were not carried forward in the vulnerability assessment due to data availability issues or relevance[14]. Table 3-2 provides a summary of the climate data results. Relevant climate parameters and infrastructure thresholds (climate parameters) to be used in this study are listed. For these climate parameters, historical and future probabilities of occurrence, as well as PIEVC probability scores for annual and study period probabilities are presented.

Table 3-2 Climate Parameters and Thresholds, Occurrence Probabilities and PIEVC Scoring

Climate Parameter	Threshold	Annual Probability (Historical; **Projected 2030** and ***2050***)	Probability of Occurrence Study Period (2015-2050)	PIEVC Scoring		
				Historical	2030's & 2050's	Study Period
Daily Maximum Temperatures	25°C	66 per year; **84 per year**, ***106 per year***	100%	7	7	7
	30°C	16 per year; **26 per year**, ***47 per year***	100%	7	7	7
	35°C	0.75 per year; **3 per year**, ***8 per year***	100%	6	7	7
	40°C	~0.01 per year[15]; **0.3 to 2 days per year**, ***1-7 days per year***	~100%	1	**4 - 7**	7
High Daily Avg Temperature	30°C	0.07 per year[16]; **N/A**, ***1.2 days per year***	~100%	3	7	7
	35°C	Zero occurrences historically; ***zero occurrences projected***	0%	0	0	0
Heat Wave	3 days max temp over 30°C	0.88 per year; **>1 for both**	100%	6	7	7
High Night time Temperatures	Nighttime low ≥23°C	0.70 per year; **7 per year**, ***16 per year***	~100%	6	7	7
Extreme Rainfall	100 mm in <1 day + antecedent	0.04 per year; ***extreme precipitation expected ↑, percentage unknown***	~75%-85%	2	3	6

[14] The climate parameters not evaluated in the vulnerability assessment were high daily average temperature above 35°C (relevance), 6 hr+ freezing rain (relevance, as no ice accretion threshold was known), Minor ice accretion and deicing agents (complex interaction, no projection data available) and tree growth, pest and disease (complex interaction, no data available).
[15] Based on data from Toronto City Center station rather than Pearson Airport.
[16] Based on 4 occurrences since 1961 at Pearson Airport; see discussion in text for further details.

Climate Parameter	Threshold	Annual Probability (Historical; Projected 2030 and 2050)	Probability of Occurrence Study Period (2015-2050)	PIEVC Scoring		
				Historical	2030's & 2050's	Study Period
Ice Storm/Freezing Rain	15 mm (tree branches)	0.11 per year; **>0.13 per year**, ***>0.16 per year***	>99%	3	3	7
	25 mm ≈ 12.5 mm radial	0.06 days per year; **>0.07 per year**, ***>0.09 per year***	>95%	2	3	7
	60 mm ≈ 30 mm radial	High Risk: 0.007 events per year; **>0.008 per year**; ***>0.01 per year*** Low Risk: 0.002 events per year; **> 0.0023 per year**; ***0.003 per year***	High: ~25% Low: ~8%	0-1	0-1	2-4
	6 hours + freezing rain	0.65 days per year; **~0.75 per year**, ***~0.94 per year***	100%	5	6	7
High Winds	70 km/h+ (tree branches)	21 days per year; **N/A**, ***24 to 26 per year***	100%	7	7	7
	90 km/h	2 days per year; **N/A**, ***>2.5 per year***	100%	7	7	7
	120 km/h	~0.05 days per year; ***likely ↑, but % unknown***	~85% or higher	2	2	7
Tornado	EF1+	1-in-6,000; ***Unknown, no consensus***	~0.6%	0	0	1
	EF2+	1-in-12,000; ***Unknown, no consensus***	~0.3%	0	0	0
Lightning[17]	Flash density per km km^2	1.12 to 2.24 per year per km^2; ***Expected increase, % change unknown***	~50-70%(Lg); ~10-20% (Sm)	Lg - 2 Sm - 0	n/a	Lg – 6 Sm - 3
Snowfall	Days w/ >10 cm	1.5 days per year; ***Trend decreasing but highly variable***	100%	7	7	7
	Days w/ > 5cm	5 days per year; ***Trend decreasing but highly variable***	100%	7	7	7
Frost		229 frost free days; **249 frost free days**, ***273 frost free days***	100%	7	7	7
Complex Interactions	Minor ice accretion + deicing agents	***Projections unavailable***	N/A		N/A	
Complex Interactions	Changes in tree growth, disease conditions	***Projections unavailable***	N/A		N/A	

3.3 Data Sufficiency and Recommendations

The primary sources of information used in this climate data work were:

- Environment Canada Weather Station Data;
- IPCC AR5 quality controlled GCM output;
- TRCA environmental data and observations (TRCA 2014).

The climate data available for this study was judged to be sufficient to cover the majority of climate related stresses to electrical distribution systems (stemming from temperature, precipitation and wind). The study area of the City of Toronto also benefited from having good quality, long-term climate data that covered most areas of the city for these types of climate parameters. While further studies, in-depth analyses, and data quality improvements can be made (see Chapter 7), the climate data that was available was sufficient to support the risk assessment.

[17] Note that "Lg" and "Sm" refer to large and small transformer stations, see Appendix B for more details.

High Temperature

Days with peak temperatures above 40°C and days where average ambient temperatures exceed 30°C on a 24h basis are the two significant climate parameters rated as high risk for transmission and municipal stations. Days with peak temperatures above 40°C are currently a very rare occurrence, but are expected to occur on an almost annual basis by the 2030's and on an annual basis by the 2050's. Similarly, high ambient temperatures exceeding 30°C on a 24h basis are currently a rare occurrence, but may occur on an annual basis by the 2050's. In both cases, high electrical demand, coupled with loss of cooling efficiency, will cause station power transformers to overheat. In the most severe of cases, demand cannot be maintained without damaging station power transformers, which have an average replacement cost of around $500 K[21]. A coping mechanism employed by electrical utilities is to shed electrical load (load shedding), which entails instituting temporary outages in various sectors of the city in order to reduce load demand. For buildings and residents dependent on air-conditioning for cooling purposes, this represents a significant public health risk at a time of extreme heat events.

This high risk is especially relevant for transmission and municipal stations with low excess capacity by the 2030's and 2050's. As such, during periods of high demand, these stations have less excess capacity with which to meet electrical demand.

Freezing Rain and Ice Storms

There are three significant thresholds to consider for freezing rain and ice storm effects on the electrical distribution system. First, preliminary forensic analyses of outages from freezing rain indicate that 15+ mm of freezing rain is a trigger for the breaking of tree branches and limbs. These pose a threat to overhead feeder systems, and these freezing rain amounts have resulted in widespread outages in Toronto in the past due to tree contacts. The next threshold is 25 mm of freezing rain, which is the CSA design requirement for overhead electrical systems. Theoretically, overhead feeder systems, as well as the overhead exit lines at stations are supposed to withstand 25 mm of freezing rain (12.5 mm of radial ice accretion). However, such quantities of freezing rain and ice accretion on overhead infrastructure bring them to their structural design limits, which are further exacerbated by breaking tree branches and wind. Finally at 60 mm of freezing rain, the weight of ice accretion on overhead lines and station exit lines exceeds their design limit, and will likely cause them to collapse.

It should be noted that the high risk ratings for 15 mm and 25 mm of freezing rain on overhead feeder systems and station exit lines is based on probability of occurrence for the study period (probability scores of 7, event will occur during the study period)[22]. From an annual probability perspective, freezing rain events at 15mm and 25mm of freezing rain would actually result in medium risk ratings. As can be seen from Table 3-2 in Chapter 3, the current annual probability of occurrence of 15 mm of freezing rain is 0.11 days / year (1 in 9 year return period), and is projected to increase to 0.16 days / year (1 in 6 year return period) by the 2050's. The current annual probability of 25 mm of freezing rain is 0.06 days / year (1 in 17 year return period), and is projected to increase to 0.09 days per / year (1 in 11 year return period) by the 2050's.As the projected trend for 15 mm and 25 mm freezing rain events is increasing in the future, the interaction of these two climate parameters with overhead feeder systems and station exit lines are maintained as a high risk.

Similarly, it was found that 60 mm freezing rain events would actually fall into a medium risk category (study period probability of 4, annual probability of 1, severity score of 7). However, major ice storms are part of a pattern of risk that is similar to 25 mm freezing rain events. For this reason, it is maintained in the high risk category

High Winds

High winds and wind gusts at 90 km/h and 120 km/h were judged to be a high risk to overhead feeder systems. These wind speeds reach and exceed the design limits of conductor connections to support poles, and the poles

[21] Estimate provided through correspondence with Toronto Hydro staff.
[22] A comparison for freezing rain/ice storm lasting at least 6hr+ based on annual probability versus study period probability does not change the high risk rating.

themselves. Further compounding impacts is the potential for flying debris, such as broken tree branches and limbs, to further bring down overhead feeder systems.

The threats from high winds and gusts above 120 km/h were judged to be high risk due to wind forces on station overhead exit lines (exceeding design standard for poles). Furthermore, there is the potential for flying debris to damage station equipment at outdoor stations.

As is the case for freezing rain, it should be noted that the high risk ratings wind over 120 km/h were on overhead feeder systems and station exit lines is based on probability of occurrence for the study period (probability scores of 7, event will occur during the study period)[23]. However, from an annual probability perspective, events producing 120 km/h high winds would actual result in low and medium-low risk ratings for station and overhead feeder systems respectively. This is because the current annual probability of 120 km/h wind events is 0.05 days per year (1 in 20 year return period). This frequency is expected to increase during the study horizon, although the projected value is not known. These significant wind events are similar to the case of tornadoes, in that they are infrequent but can lead to significant damage to large areas of the distribution system if they occur (low probability, high severity events). As they are however expected to be more frequent than tornadoes, the 120 km/h wind – overhead systems interaction is maintained as high risk in this study.

Lightning

Lightning strikes on station equipment, notably power transformers, were rated as a high risk. Lightning arrestors at stations are designed to direct lightning surge currents to ground and protect electrical equipment. However, failure of the lightning arrestors can result in damaged equipment from lightning strikes and potentially causing an outage to an entire service area.

Human Resources

Heavy freezing rain events constitute a high risk for Toronto Hydro personnel. First, slippery surfaces make travel to and from work, and out to worksites dangerous for field crews. Second, field crews also have to contend with a layer of ice over electrical equipment, trees, and other overhead structures such as buildings. As such, the risk of injury to workers from freezing rain events remain even after the storm has passed due to the continuous ice loads on overhead power lines and trees, which may cause them to break without warning.

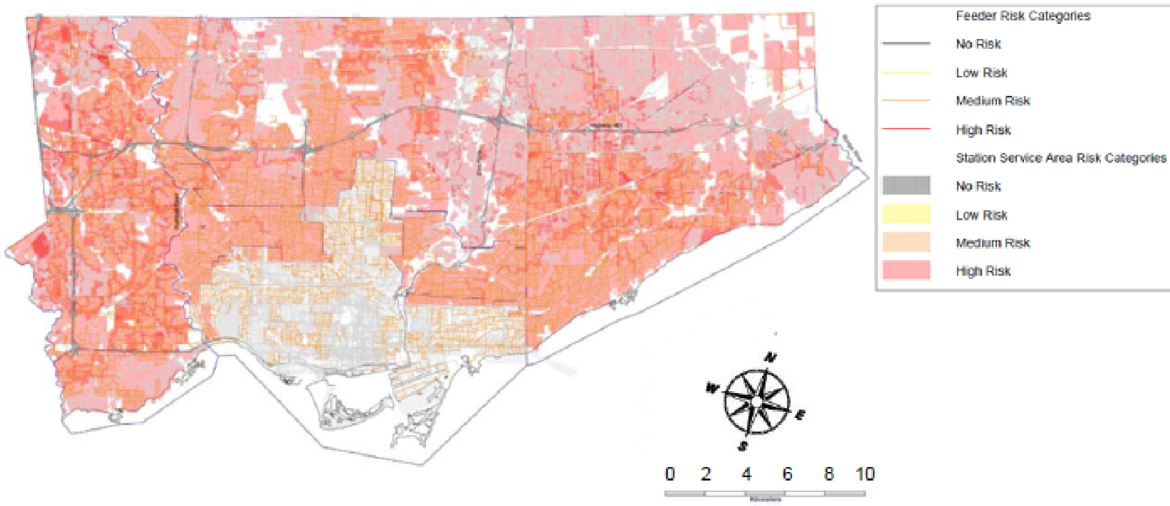
5.4 Special Cases – High Severity, Low Probability Events

Tornadoes

Tornadoes represent a high severity, low probability event. As mentioned in Chapter 3, while the likelihood of a tornado event touching down at a specific point or location is extremely small, the likelihood of a tornado occurring somewhere in the City of Toronto over study period (2015 – 2050) is in fact considerable. Furthermore, due to the lake breeze effect, northern portions of the city tend to have a high probability of seeing a tornado event, although it does not preclude an occurrence closer to the lakeshore. Tornadoes were judged to have catastrophic consequences on all above ground infrastructure, while underground infrastructure may become inaccessible due to windblown debris.

[23] A comparison for freezing rain/ice storm lasting at least 6hr+ based on annual probability versus study period probability does not change the high risk rating.

Figure 5-4 Risk Map, Electrical Distribution Systems Potentially Affected by Lightning Strikes



There are several caveats that should be mentioned with respect to interpreting mapping results, due in large part to the fact that risk ratings were evaluated based on general system characteristics. Localized site characteristics that may mitigate or worsen risk ratings were not adequately captured in the mapping exercise. They include:

- Local geographic characteristics, assets and features. There may be local site characteristics such the tree canopy cover, types of trees, presence of buildings or other overhead structures, which may exacerbate weather events (e.g. wind) or shelter infrastructure from impacts. The presence of low lying areas (e.g. bowls, flood plains) was also not considered. This level of detail, provided by a full site inspection and digital terrain mapping, were not available for this project. Such information would be useful in refining the risk ratings and mapping for extreme rainfall, freezing rain and wind;

- Areas with lower drainage capacity due to configuration of city storm drainage infrastructure. This type of information requires a very detailed understanding of city infrastructure, which was not available for this study. Furthermore, this level of data is most useful when combined with digital terrain mapping in order to identify low lying areas with problematic drainage. Finally, future projections as to how city infrastructure might evolve over time were also not available for this project;

- The moderating effect of Lake Ontario. As noted in Chapter 3, the lake can play a significant role in influencing temperature and humidity along the lakeshore. For example, the lake effect can moderate temperatures during heat waves and can reduce the possibilities of freezing rain or snow falling on areas closer to the lakeshore. The extent and intensity of the lake effect can vary depending on the event and weather conditions. It was not possible to estimate the geographic extent of the lake effect, or by how much the probability scoring for certain climate parameters may be affected. As such, the lake effect's moderating influence was not taken into account sufficiently in the risk assessment and mapping exercise;

- Local electrical configurations and characteristics. There are likely cases where location specific electrical equipment may make certain feeder or station systems inherently more robust or redundant than would be the case of the general class of equipment. For example, additional feeder ties, loops or circuits could make certain feeders more redundant in the event of a downed power line. The age of equipment, their future replacement schedule will also have an effect on their risk rating. This level of detail is not captured at level of analysis undertaken in this study;

- For the extreme rainfall risk map, it should be noted that the mapping of transmission stations includes all stations. Information identifying the location of the stations whose batteries and switchgear are located below grade was not available. Further analysis is required to identify the precise locations of transmission with below grade assets in order to get a better mapping of flood related risks.

In spite of these shortcomings, the mapping exercise represents a useful first approximation of spatial nature of electrical system vulnerabilities to climate change. Furthermore, this mapping information can be more easily combined with other layers of information such as technical hazard information (e.g. flood mapping), physical locations (e.g. emergency resource centres, hospitals, transportation networks) and social vulnerability indices (e.g. age, income, population density, etc.) from other sources (e.g. TRCA, City of Toronto) to produce further mapping studies and in depth analyses to suit the needs of other policy makers.

demand for cooling, and may place greater stress on cables and lead to increasing occurrences of cable failures. Therefore, high heat impacts on cable was deemed to be a vulnerability.

8. *Extreme rainfall / underground feeders*

a. Feeders: Water treeing of the cables, flooding

Further action recommended. Climate change related stresses (i.e. higher temperature, higher loading, flooding from extreme rainfall) will continue to stress underground cables and constitute a vulnerability for Toronto Hydro.

b. Non-submersible equipment failure in vault type stations below ground in the Horseshoe Area (Former Toronto has a high risk result)

Further action recommended. While Toronto Hydro is gradually replacing vault type non-submersible equipment with submersible versions, non-submersible vault type equipment is likely to remain in the system over the study period.

c. Above ground vault stations, access to the vault station and to the station equipment could be limited due to localized flooding of streets around the vault station, or at the station itself

No further action required. This impact does not relate to station load or capacity. The consequence is that the access to the vault stations or the stations equipment could be temporarily impeded. Impact is localized and temporary, and was not judged to warrant further action beyond current practices.

d. Network feeders: old N/W protectors are not submersible

Further action recommended. The old N/W protector may not operate properly if flooded. However, failure of the N/W protector will not automatically result in an interruption to the customer, since network systems are highly redundant. Toronto Hydro is installing new N/W protectors that are submersible, but there may still be older non-submersible N/W protectors in the systems, particularly in downtown over the study period. Further study could be undertaken to evaluate the cost of replacing old network protectors prior to the end of their expected lifecycle against the frequency and consequence of old N/W protectors being flooded.

9. *High winds (120 km/h) / padmount stations on distribution network (Former Toronto)*

No further action required. The damaged equipment will result in an overall or some loss of service capacity and function. However, it is judged that flying debris is too much of a random occurrence to warrant further action.

10. *High temperature maximum above 35°C & above 40°C, average temp >30°C and heat wave / Overhead power lines (radial and loop)*

Further action recommended. Higher temperatures will have impacts on the overall capacity of the power lines. In the downtown area, there are critical, constrained areas (i.e. built up zones) where added conductor/transformer capacity may be difficult to implement.

11. *High nighttime temperatures / Overhead power lines (radial)*

No further action required. Night time temperatures with minimum ≥ 23°C in and of itself is not a significant concern for Toronto Hydro in terms of electrical service provision as peak demand has subsided. However, it is important to note that high daily temperatures in combination with high night time temperatures are a concern. This has been considered under different climate-infrastructure interaction, average temperature over 30°C on a 24 h basis, so this particular interaction does not warrant further action.

12. Freezing rain - ice Storm 15 mm and high winds 70 km/h / Overhead feeders in loop configuration

Further action recommended. The risk assessment of radial systems resulted in a high risk rating for this interaction. In overhead loop systems, it was hypothesized that their more redundant configuration would reduce customer interruptions, affect fewer clients or cause outages of shorter durations, thus yielding a high-medium risk rating of 35. However, the frequency of freezing rain events are projected to increase slightly by the end of the study horizon compared to present day (see table 3-2). The tree canopy may also be weakened by increased disease threats. Finally, freezing rain events tend to be widespread, and there is no reason to believe that both branches of an overhead loop circuit might not be equally susceptible to damage. For all of these reasons, all overhead power lines, irrespective of electrical configuration, were deemed as vulnerable.

13. Freezing rain/ice storm 60 mm ≈ 30 mm radial (major outages) / overhead lines (radial and loop)

Further action recommended. See explanation for freezing rain and stations (item 5 above).

14. Lightning / overhead power lines (radial and open loop) and SCADA system

Further action recommended. It is difficult to predict the increase of lightning strikes for the study period; however it is interesting to note that the probability of a lightning strike in an area of 0,015 km^2 anywhere within the City of Toronto is very high for the study period. At the moment, lightning strike intensity, the number of lightning arrestors/km and arrestor performance are not monitored by Toronto Hydro. Given this uncertainty, and since lightning strikes are currently a frequent source of outages, lightning strikes were judged to be a continued vulnerability.

15. Snow > 5 cm and snow > 10 cm / overhead power lines (radial)

No further action required. The number of snow days is highly variable. The trend seems to be decreasing, but snow days will still occur annually. During the workshop, Toronto Hydro mentioned having problems regarding insulator tracking leading to pole fires especially at higher voltages (13.8 kV and 27.6 kV) and switch failures. However, Toronto Hydro is already monitoring and dealing with this issue.

6.3 Civil Structures

16. Extreme rainfall, freezing rain/ice storm 15 mm & 25 mm & 6hrs+ (combination of events) / civil structures: underground feeders (Former Toronto)

Further action recommended. Vaults and chambers already suffering from degradation issues will deteriorate more rapidly over time. From THESL (Toronto Hydro, 2014a): *As below-grade structures age, the greatest concern becomes structural strength. Structural deficiencies affecting vaults include degradation of concrete and corrosion of supports such as beams and rebar. Once degradation and corrosion sets in, conditions can deteriorate rapidly and in many cases from one season to the next. Of particular concern is the winter season when moisture and water enter in below-grade structures, freezes and thaws, and carries with it salt that has been used at grade to melt ice and snow.*

While maintenance can reduce the rate of deterioration, incidence of extreme rainfall, snowfall, freezing rain and the application of road salt will persist throughout the study period and continue to contribute to the premature aging of civil structures. While, it could not be determined in the study whether premature aging of civil structures will be exacerbated by a changing climate, this issue will persist over the study period and is therefore judged as an on-going vulnerability

17. Snow > 5 cm and snow > 10 cm / civil structures: underground feeders (Former Toronto)

No further action required, but combinations of climates events require additional study. As days with snow will probably decrease, the snow days alone were not judge to be a significant vulnerability. However, snow days will still occur over the study period, and in combination with extreme rainfall, freezes and thaw, freezing rain, and the continued application of road salt, premature degradation of civil structures was judged to be an

7 Conclusions

The Phase 2 study presents a climate change based vulnerability assessment of electrical distribution infrastructure. It seeks to inform future investigations, planning and investment decisions on system and component vulnerabilities, and to support efforts to enhance the resilience of the electrical system. This chapter presents Step 5 of the Protocol and covers electrical distribution system vulnerabilities within the City of Toronto, adaptation options and areas of further study.

7.1 Vulnerabilities to a Changing Climate

The Phase 2 employed a high level risk based screening methodology to determine where infrastructure vulnerabilities to climate change may be present. All high risk infrastructure-climate parameter interactions, as well as medium risk interactions assessed as vulnerable through the engineering analysis comprise the vulnerabilities identified for Toronto Hydro's electrical distribution system to a changing climate. These vulnerabilities can be divided into five groups based on how climate parameters affect the system. The following paragraphs summarize these vulnerabilities, while table 7-1 provides more detailed information by infrastructure-climate parameter interactions.

High Ambient Temperatures – Station and Feeder Assets

High ambient temperatures create problems for the distribution system because of the compounding effect of high demand (e.g. for cooling) and high ambient temperature affecting equipment cooling and electrical transmission efficiency. Two specific climate parameters were of most significant concern, daily peak temperatures exceeding 40°C (excluding humidity) and daily average temperatures exceeding 30°C. In these cases, the climate analysis found that such extreme temperatures have occurred only rarely in the past, but are projected to occur on an almost semi-annual to annual basis by the 2030's and 2050's respectively. Through preliminary demand and supply growth projections completed for this study, these vulnerabilities were identified based on the notion that extreme heat will generate electrical demand for cooling in areas where station excess capacity is projected to be marginal. Furthermore, such temperature extremes may cause equipment, notably power transformers, to operate beyond their design specifications and increases the likelihood of failure. It is anticipated that vulnerability to high heat events will be concentrated in the Former Toronto area, although there are several horseshoe station service areas which would also be vulnerable.

Freezing Rain, Ice Storms, High Wind and Tornadoes – Overhead Station and Feeder Assets

Freezing rain, ice storms, high wind and tornado events cause immediate structural issues for overhead distribution assets, as they have the capacity to exceed the design limits of equipment and their supports. Outages may result from damage to equipment arising from direct forces applied by climate parameters (e.g. wind, weight of ice) or by other objects (e.g. tree branches, flying debris). These kinds of events affect outdoor station and feeder assets, which are largely concentrated in the horseshoe service area. It is important to emphasize that Toronto Hydro has experienced problems related to freezing rain, ice storms (up to 25 mm) and high winds (up to 90 km/h) in the past. These events are projected to continue in the future, but continue to occur on a less than annual or even decadal frequency. More severe ice storms (60 mm), high winds (over 120 km/h) and tornadoes (EF1+) have been extremely rare in the past, and while there is a lack of scientific consensus on projected future frequencies for these extreme events, they are likely to remain rare in the future. Nevertheless, the damages caused by these kinds of events can be severe. Therefore, they were judged as ongoing and future vulnerabilities for Toronto Hydro.

Extreme Rainfall – Underground Feeder Assets

Extreme rainfall events may potentially flood underground feeder assets, which are largely concentrated in the Former Toronto and northeastern horseshoe areas. Toronto Hydro is aware of these issues in relation to its assets and has programs to replace non-submersible equipment with submersible type equipment, to relocate equipment where possible. However, due to the large quantity of underground feeder assets across the city, replacement and reinforcement of underground assets will be a gradual and ongoing activity for Toronto Hydro over the study period. As such, some underground feeder assets may remain an area of vulnerability for Toronto Hydro.

Snowfall, Freezing Rain - Corrosion of Civil Structures

The degradation of civil structures (i.e. concrete and steel), which is accelerated by humidity and the presence of de-icing salts, was identified as a potential area of vulnerability to climate change. Corrosion is already an ongoing issue for Toronto Hydro and current assets have a design lifespan which accounts to a great extent for corrosion issues. However, it is not clear from this study whether the climate change stresses will exacerbate the problem. While snowfall days are generally expected to decrease with a warming climate, they will continue to occur annually through to the 2050's. As a result, and in combination with freezing rain events, the application of de-icing salts will also be applied annually through the study horizon. Nonetheless, it should be emphasized that corrosion represents a long-term and on-going vulnerability for Toronto Hydro.

Lightning – Overhead Feeder Assets

Based on workshop feedback and an examination of Toronto Hydro's ITIS outage data, Toronto Hydro recognizes that lightning impacts are a significant source of outages on the distribution system today. While there have been advances in predicting lightning activity, there was insufficient data available on lightning strike intensity and arrester performance to suggest how future lighting activity may affect the electrical system. For these reasons, this study suggests that lightning activity will continue to be an area of vulnerability.

7.2 Adaptation Options

Adaptation options are suggested for all the infrastructure-climate parameter interactions identified as vulnerabilities. The Protocol classifies adaptation options in four possible categories:

- remedial engineering actions which aim to strengthen or upgrade the infrastructure;
- management actions to account for changes in the infrastructure capacity;
- continued monitoring of performance of the infrastructure and impacts; and
- further study required to address gaps in data availability and data quality.

Adaptation options by infrastructure-climate parameter interaction are presented in Table 7-1.

Table 7-1 Vulnerabilities and Adaptation Options by Infrastructure Asset, Climate Parameter

Affected infrastructure	Climate Parameter	Adaptation Option	Details
Stations, Communications and Protection Systems			
1. Transmission stations, municipal stations, protection and control systems Critical component: batteries	High temperature above 25°C	Further study required	Toronto Hydro has experienced problems with station batteries failing short of expected lifespans (i.e. approximately 10 years). Operating batteries in rooms where the ambient temperatures increases above 25°C is a contributing factor to premature battery failure (Toronto Hydro, 2014c). As battery rooms are not temperature controlled, Toronto Hydro could monitor how ambient temperatures of rooms within stations housing batteries fluctuate during the warmer summer months and evaluate whether additional measures are needed (e.g. review of battery technical specifications, including aging factor) to reduce battery degradation.

Affected infrastructure	Climate Parameter	Adaptation Option	Details
2. Transmission stations, municipal stations Critical component: power transformers	High temperature above 35°C, 40°C Average daily temperature > 30°C Heat wave High nighttime temperatures	Further study required	Given the increased frequency of high heat conditions in the future, coupled with continued demand growth, infrastructure owners (Toronto Hydro and Hydro One), could conduct a could conduct a further study evaluating the technical and financial feasibility of installing transformers with a higher capacity, or installing more transformers at stations (shared load) where space permits. Another possibility is to evaluate the technical and financial feasibility of increasing the design standard for current power transformer equipment, for example, by designing to a daily average ambient temperature higher than 30 °C (35 °C) and maximum temperature with a higher temperature than 40°C (45 °C). Finally, these measures should be complemented by continued demand side management /energy conservation programs.
3. Transmission stations: only outdoor stations 4. Municipal stations: Horseshoe area outdoor stations Critical component: Overhead exit lines (for freezing rain and high winds parameters)	Freezing rain/ice storm : 25 mm, 60 mm High winds : 120 km/h and tornadoes	Management actions and further study required .	Major freezing rain, ice storm, high wind and tornado events are not expected to be an annual occurrence in the future, but will still likely occur over the study period. Station exit lines, either overhead ones or where underground cables surface, are a particular point of vulnerability, as downed exit lines can sever power supply to the entire service area. Toronto Hydro could monitor the frequency of damage to station exit lines and poles across a range of potential weather threats (freezing rain, high winds) to evaluate whether this critical portion of the distribution network requires strengthening. Toronto Hydro could also consider a station by station study of surroundings to identify areas around stations susceptible to generating flying debris (e.g. trees, buildings). Emphasis should also be placed on optimizing the emergency response and restoration procedures to reduce system down time. Note that Toronto Hydro is already undertaking a review and enhancement where necessary of response planning, dispatching operations, prioritization of restoration activities, coordination with other utilities, response team training and preparation.
Arresters (for lightning parameter)	Lightning	Monitoring activities	Lightning events and strikes are difficult to predict, but are likely to increase in frequency and intensity. However, lightning strike intensity and arrester performance is not currently monitored. Given the importance of lightning strikes as a cause of outages, it is recommended that the lightning activities (e.g. frequency, intensity), soil resistivity (i.e. decreased soil moisture from longer and hotter summers) and impacts on the system could be more closely monitored to provide more information regarding the risks of lightning strikes. For example, where high voltage arresters are installed, counters (if not already present) could also be installed to check if a particular phase or transmission line suffers from an exceptionally high number of overvoltages leading to arrester operation. Lightning strikes on the building housing stations could be investigated to determine whether they resulted in any overvoltage impacts. If further studies on lightning activity result in a better definition of lightning characteristics and impacts, or if monitoring indicates a higher rate of failure, a review of actual design practices could be undertaken.

Affected infrastructure	Climate Parameter	Adaptation Option	Details
		Feeders, Communication and Protection Systems	
5. Underground feeders Critical component: cables and power transformers	High temperature above 35°C, 40°C Average daily temperature > 30°C Heat wave High nighttime temperatures	Monitoring activities	For power transformers, see discussion above on station power transformers (see row 2). For cables, increased temperature operation tends to reduce the dielectric strength of the cables. Toronto Hydro is currently trialing cable diagnostic testing techniques as a method of detecting vulnerabilities in cables. If cable testing techniques prove reliable in detecting potential failures, Toronto Hydro could consider extending diagnostic techniques to all cables to monitor heat stress impacts on cables to evaluate whether high design standards or more frequent replacement is required.
6. Underground feeders : Submersible type Critical component: cables	Extreme rainfall: 100 mm <1 day + antecedent	Monitoring activities	The presence of water can lead to an electrical failure of the cables (water treeing) and/or reduce the dielectric strength of cables. Cable diagnostic testing can be employed to monitor the degradation of underground cables. This study also supports Toronto Hydro's program to replace and renew older cable assets with moisture and tree resistant underground conductors such as TRXLPE cables. The development of flood risk mapping, coupled with historical registry of flood related equipment failures could enhance the identification of areas for priority intervention.
7. Underground feeders: Vault type – Below ground Critical component: non-submersible equipment	Extreme rainfall: 100 mm <1 day + antecedent	Remedial engineering actions	Toronto Hydro is currently upgrading non-submersible equipment located in below grade vaults with submersible equipment, or relocating them above grade. The development of flood risk mapping, coupled with historical registry of flood related equipment failures could enhance the identification of areas for priority intervention.
8. Underground feeders: 13.8 kV Network systems	Extreme rainfall: 100 mm <1 day + antecedent	Remedial engineering actions	Many old network protectors are not submersible, particularly in the downtown area. The current Toronto Hydro standard is to use submersible network protectors when replacing old equipment. Further study could be undertaken to evaluate the benefit and cost of replacing old network protectors prior to their end of life versus replacement at their end of life (i.e. potential for flood damage and outages prior to replacement).
9. Overhead feeders (Radial and loop) Critical component: power transformers and conductors	High temperature above 35°C High temperature maximum above 40°C Average daily temperature > 30°C Heat wave	Monitoring activities	Climate change is projected to increase the frequency of high heat conditions in the future. Coupled with continued demand growth, this is projected to increase heat stresses on overhead distribution feeder assets. However, unlike the case with station transformers, where projected heat and capacity reveal a clear vulnerability in terms of supply capacity, it is not clear whether high temperatures will have the same impact across the distribution feeder system (i.e. are there bottlenecks to supplying electricity during periods of high heat at certain stations or across the grid?). Toronto Hydro should continue to monitor key grid operational indicators for distribution transformers, such as load currents, billing data, transformer oil and ambient temperatures. This information can be used to help evaluate whether distribution line capacities are sufficient to handle increased electrical loads.
10. Overhead feeders (Radial and loop) Critical component: conductors	Freezing Rain/Ice storm: 15 mm and high winds 70 km/h	Management actions and remedial engineering actions	Toronto Hydro is already experiencing outages caused by tree contacts and is planning to increase its vegetation management activities. This study supports the need for increased tree trimming practices around overhead power lines and use of tree proof conductors in areas where outages due to tree contacts have been frequent.
11. Overhead : Radial and Loop Critical component: poles	Freezing rain/ice storm: 25 mm High winds: 90 km/h and 120 km/h, tornadoes	Management actions and further study required	See recommendations for stations above on freezing rain and tornadoes (see row 3).

Affected infrastructure	Climate Parameter	Adaptation Option	Details
12. Overhead power lines (radial and open loop) and SCADA system	Lightning	Monitoring activities	See recommendations for stations above on lighting (see row 3).
Civil structures			
13. Civil structures: Underground feeders (Former Toronto)	Extreme rainfall, freezing rain/ice storm 15 mm & 25 mm & 60 mm (combination of events)	Further study required	While maintenance can mitigate the risks of civil structures deterioration, changing climate conditions (e.g. freezing rain, rainfall, freeze-thaw) may exacerbate premature degradation issues. However, it could not be determined in this study whether current design standards are sufficient to withstand future climate - salt and moisture related degradation. Further study could be undertaken to estimate salt/moisture corrosion effects in relation to climate change.
14. Civil structures: transmission and municipal stations, underground feeders	Frost	Further study required	The nature of the frost heave impacts to civil structures was not sufficiently evaluated within this study. Further study can be undertaken to identify whether there are any specific location, ground condition and structure combinations which contribute to frost heave impacts.
Human Resources			
15. Human Resources	Heat, freezing rain, wind and tornadoes	Management actions	Toronto Hydro applies an occupational health and safety manual. Toronto Hydro is already conducting a review of its procedures in light of future extreme events to determine whether modifications in procedure or training are needed.

7.3 Other Areas of Study

Additional climate and infrastructure related areas of further study that can be used to enhance the understanding of electrical system vulnerabilities to climate change are listed below.

Climate

- Increase monitoring of important climate parameters across the city. For both the climate assessments and forensic analyses, a lack of observational data made understanding climate risk challenging and introduced uncertainties, particularly for specific climate parameters such as wind gusts, hourly rainfall measurements, and freezing precipitation accumulations. New monitoring would provide important benefits, including:
    - Addressing gaps in historical data;
    - Facilitating comparisons between sites across the city;
    - Improving the spatial resolution of the climate monitoring network, increasing the likelihood of capturing important meteorological events; and,
    - Providing additional data to assist in detecting new and emerging trends sooner than would be possible using the current network.
- Enhance details about weather impacts contained in the ITIS database. Although information contained within the database was extremely useful and yielded important insights, there were still gaps in the details of weather related outages which limited the evaluation of impacts;
- Refine and expand forensic investigations (see **Appendix C**) completed in this Phase 2 study. Several climate parameters, individual climate events and impacts were not investigated thoroughly due to the scope of the present study. In particular, further analyses could be done on:
    - Lake modified air and lake breeze influences on atmospheric hazards, especially extreme temperatures, ice accretion events, and severe thunderstorms (including extreme rainfall, downbursts/microbursts, and tornadoes);
    - December 2013 ice storm and other ice accretion events, particularly to help refine understanding of apparent variations in impacts between different sections of the city.

hours to more than a day. Similarly, precipitation events are generally associated with thunderstorms during the warm season and low pressure systems in the cool season (snow storms, ice storms, etc.). It should become quickly apparent that several event types can occur simultaneously, resulting in multiple cause power outage events.

Identification of event type is critical in understanding what types of impacts to expect at different times of year, including duration of the event, potential challenges for response and maintenance, presence of simultaneously occurring hazards, and for some event types what antecedent conditions to monitor to help anticipate or forecast weather related impacts. During the late spring and summer, for example, a number of significant thunderstorm events tend to be proceeded by high temperature and humidity combinations which themselves may have generated impacts on the system. While individual events are indeed complex, infrastructure operators can begin to understand the antecedent conditions to help increase readiness for such events.

Event type identification is also critical to climatological analyses and the development of adaptation responses. More localized, short duration events present significant challenges for assessing future climate vulnerability and risk, but less complex climate elements, such as temperature, are far less difficult to analyze, and confidence in both the consistency of historical data as well as certainty in projected trends are much greater.

Adaptation responses, particularly those regarding maintenance and operations, must take into account the nature of the events generating impacts. How much lead time can one expect for storm warnings, if any? What hazards may be posed to repair crews, or restrict access to damage locations? For example, a number of recent press releases indicated that full repair efforts have been postponed based on the timing of high winds, with crews waiting for the "worst to pass" before executing major restoration efforts (see "Superstorm Sandy" analysis below). More sophisticated operations and management actions such as these are critical to optimizing response to severe weather events.

C.1.2 Brief Note on Impacts Data

Staff at Toronto Hydro kindly provided outage incident data for this analysis, which proved invaluable for determining the types and magnitude of events which were responsible for significant power outage events. However, this type of cross-disciplinary forensic analysis was not the original intent of the failure database, and as such there were a number of challenges which presented themselves when using the data.

Most notably, it became clear that data collection was inconsistent throughout the period of record. While the database contains events from the years 2000 to 2013 inclusive, earlier events have dozens of reports per date, while more recent major outage events do not. In 2013, the July 8th flood and December 21st-22nd ice storm, which Toronto Hydro staff indicated were among the worst in their history, have very few listings in the database. This is likely due to changes in reporting practices, which apparently began in 2007 judging from the frequency of weather events with 20+ reports each, but this requires confirmation Toronto Hydro staff.

This emphasizes the need for the standard forensic practice of consulting and comparing multiple sources of data. For example, impacts data can be used to indicate if event intensity, such as high winds, could have been significantly higher than meteorological measurements may indicate. Conversely, meteorological data can be used to either guide and/or refine the search for impacts data, or even correct coding or other errors in impacts data.

C.2 Toronto Hydro Outage Data

As indicated above, outage data from Toronto Hydro were interrogated to identify significant outage events which could be used for further study. Days with 20 or more reports were identified, and these were further refined by checking for potentially related reports on days before and after identified event dates. While it is fairly clear that data from 2007 to 2013 were collected under different reporting requirements, 2000-2006 appear to be consistent, and so data for this period will be evaluated here.

A total of 46 weather events were identified with this methodology. Just over half (54%) of these events occurred over fairly extended periods of 12 to 48 hours; this has implications for maintenance and repair response measures. For fall wind storms and winter precipitation events, this quite literally meant several consecutive hours of either high winds or precipitation generating impacts, while for summer events this likely represents two or more episodes of thunderstorm activity within a one to two day period.

C.2.1 "Worst" Years

In terms of the "worst" years, we have two measures; total number of events, total number of damage reports for these events, and number of damage reports per event. The years 2000 and 2005 are tied for the most events in a given year (9). In terms of total reports for all events combined, 2000 has the highest at 6—followed by 2003. In terms of average event severity, the total number of reports was divided by the number of events in a given year as a rough measure of "average" severity for a given year. The year 2003 had the highest average, with an average of just over 84 reports per event. Even though 2000 and 2005 contain single major events, their averages fall well below those seen in 2003, 69 and 56 reports per event respectively.

The year 2000 followed two main themes. A series of severe winter storms in February were responsible for multiple reports and were characterized by either freezing rain or heavy wet snow and rainfall combinations, both characteristic of "warm" winter storms producing heavy precipitation at temperatures near or at 0°C[1]. This was followed by late spring to summer severe thunderstorm events, including the May 12-13, 2000 event, as well as a thunderstorm event on July 14, 2000, which generated over 100 reports through mainly lightning related damage.

The year 2005 was characterized by high heat and humidity during the summer months, which either directly contributed to infrastructure underperformance as well as severe thunderstorm events, most

[1] At temperatures at or just below freezing, atmospheric water content is at its highest while still being able to support ice formation; hence temperatures near zero are associated with either freezing rain or high density, wet snow capable of physically coating and loading overhead lines and trees.

notably the August 19th, 2005 storm. This was followed in the fall by a series of wind storms which produced scattered outages throughout the GTA, which was among several areas across Ontario which were impacted by intense fall windstorms (e.g. over 100,000 Hydro One customers lost power during the November 6, 2005 synoptic storm; Hydro One 2005).

Finally, in 2003, Toronto Hydro was impacted by a similar combination of event types, with two winter storms in rapid succession in February, followed by severe thunderstorm activity during the late spring and summer, followed by large scale wind events from late September to mid-November.

All of the so-called "worst" years identified here have the following in common:

- Repeated events, often with only days between similar types of incidents
- Two or three "modes" of high impact weather events in the same year, specifically:
    - "warm" winter storms, meaning they were associated with temperatures at or just below 0°C with some combination of heavy snow, freezing rain or even rainfall mid-winter;
    - Severe thunderstorms and high heat and humidity during the summer;
    - Multiple fall season large scale (synoptic) wind storms;
- One major event which produced over 150 damage reports

These findings can help with better planning and anticipation of particularly high impact years. For example, periods of very high heat and humidity should be watched closely, as they are occasionally followed by severe thunderstorm events when the heat "breaks" with the passage of a cold front or other air mass change. Fall and spring large scale wind storms will occasionally occur in series, as occurred between September 29th and November 13th 2005[2], repeatedly impacting the same area. These findings appear to be consistent with recent experiences; in 2013, Toronto Hydro suffered two major weather related outage events, one in the summer from a severe thunderstorm event producing extreme rainfall, followed in the winter by a freezing rain event.

It may also be possible to anticipate a particularly severe damage year since the "major" events producing over 150 reports tend not to occur in isolation but usually occur in years with a number of less severe but still significant events, although the consistency of this pattern requires further research.

C.2.2 "Worst" Events for 2000 to 2006 Period

The two events with the greatest number of reports, May 12-13, 2000 and August 19, 2005, were both subject to detailed analyses. Another three events (Jan 31-February 4, 2003; July 14, 2000 and July 21-22, 2002) produced over 100 reports, with September 19, 2003 coming very close at 99 reports.

What is of particular interest is the number of severe thunderstorm related reports which were accompanied by mainly lightning related outages. Even for storms which included extreme rainfall and high winds related impacts, lightning appeared to be the dominant factor in producing outages. The July

[2] A fourth synoptic storm occurred on November 15 to 16, 2005 but did not cause significant impacts to Toronto Hydro's infrastructure, instead tracking to the north east and affecting Georgian Bay and the "Nickel Belt," causing over 50,000 Hydro One customers to lose power.

21-22, 2002 event is particularly noteworthy. Although we do not have detailed lightning information, such information is available from the national lightning detection network, and the frequency and amperage of lightning experienced during this thunderstorm series could be investigated to determine what made this particular lightning storm so damaging to the system in comparison to any number of other events. A summary of all events identified through this method is provided in **Table C.2.**

C.3 Fall and Winter Storms

C.3.1 December 20-22, 2013 Ice Storm

The December 2013 ice storm in south central Ontario has been deemed the worst ice storm in Toronto Hydro's history in terms of impacts to the city's distribution system. It is estimated that at the peak of event during the overnight hours between December 21st and 22nd, ~300,000 customers were without power. The most recent estimates of total damage incurred by Toronto Hydro's distribution system has been placed at nearly $15 million, specifically for restoration and repair (Toronto Star: March 31, 2014).

The storm also impacted several other adjacent LDC's, including:

- Enersource (Mississauga), 91,000 customers affected (Mississauga.ca 2014);
- Hydro One Brampton, 15,500 customers (Brampton Guardian, Dec 30, 2013);
- PowerStream (York Region[3]) 92,000 customers (Markham Economist and Sun, December 31, 2013);
- Veridian (Pickering/Ajax/Port Hope) 40,000 (Veridan Connections Press Release, Dec 22, 2013);
- Whitby 13,000 (Oshawa This Week, Dec 22, 2013)
- Oshawa Public Utilities Company ~30,000; and,
- Rural areas of Clarington (Hydro One) ~46,000 (Ajax News Adviser, Dec 23, 2013)

Meteorological data from both Environment Canada and Toronto Region Conservation Authority stations were analyzed to estimated ice accretion totals and rates in and around the GTA, which were then compared to impacts on electrical distribution infrastructure in the area.

C.3.1.1 Impacts and Meteorological Conditions: City of Toronto

Figure C.1 compares estimated ice accretion values at Pearson and Buttonville Airports with the total number of customers affected reported by Toronto Hydro. While ice accretion values were not directly reported by any of the stations evaluated, they can be estimated by combining hourly observations of precipitation type with daily rainfall totals. Freezing rainfall and drizzle totals were estimated by first determining the fraction of precipitation falling as freezing rain or drizzle (since liquid rainfall and snow were also reported on some days). Accretion rates were then weighted by precipitation type (1 for rain, 0.5 for moderate rain, and 0.1 for drizzle, based relative accretion rates from Klaassen et al. 2003), which were then further developed into estimated hourly average accretion rates. These were then summed for each day between December 20th and December 23rd for both Pearson Airport and

[3] PowerStream also suffered the complete outage of their website, which had not been designed to receive the traffic volumes which it encountered during the event (Markham Economist and Sun, December 31, 2013).

C.3.2.2 Case Study Specific Findings for January 31st-Febraury 4th

Galloping was indicated during the second storm, mainly in Toronto's west end, from what were likely a combination of ice accretions of on the order of 10 mm or less, but with winds gusting to the 70 to 80 km/h range. This is fairly close to the "15mm + 70 km/h" wind threshold indicated in previous work (CSA 2010), but may have been associated with lower ice accretion values but higher wind speeds. Additional cases would be needed to understand if galloping due to combined ice-wind loads occur in a range of wind speed and ice accretion combinations, but this case does indicate the potential for forecasting such problems when combined with monitoring of ice accretion.

Additional ice accretion, from either drizzle or light snow, coupled with several hours of reported fog or haze, is also highly likely for this event, but additional date related to this event is needed to diagnose actual accretion amounts and their causes. One should also consider that heavier precipitation may have occurred further east in North York and Scarborough, where the majority of ice accretion related impacts were reported. Indeed, several ITIS damage reports from those locations indicated ongoing snow and/or freezing rain for times when conditions at Pearson did not indicate *any* ongoing precipitation (e.g. two reports of snow in North York on the night of January 31st correspond with reports of "haze" at Toronto Pearson for the same time period). High wind and galloping conditions are likely better captured by records at Pearson Airport, since many of those incidents were reported much closer in Etobicoke.

When considering the types of impacts reported for this even, it is suggested that fog ice accretion may have slightly different characteristics than freezing rain ice accretion, which may result in slightly different impacts; i.e. when ice accretes due to fog and light drizzle in a humid environment, does it coat equipment differently than more rapidly accreting freezing rain? Did this lead to more localized problems associated with shorts and arching, in contrast to failures associated with direct physical impacts from ice loading and tree contacts? The role temperature fluctuations during and following periods of precipitation should also be investigated further. The degree of temperature variability for this event was much greater for this even when compared to the December 2013 ice storm, which again may have affected the type and degree of impacts (see **Table C.3**).

C.3.3 Large Scale Wind Storms

Large scale wind storms were identified through the Toronto Hydro Outage data for the 2000-2006 period. The maximum wind gusts reported during these storms were then compared to the number of outage events reported in the ITIS database and were also compared to the cause description, mainly identifying whether or not tree contacts were mentioned. The results of this comparison are described in **Table C.4** and illustrated in **Figure C.8.** Large scale, long duration wind events associated with low pressure systems were chosen instead of summer severe wind events associated with severe thunderstorms, since wind measurements at Pearson and Island airports were more likely to be representative of wind conditions at the damage sites for the large scale storms.

For the majority of events, a threshold wind speed of around 90 km/h emerges. A recent event on November 1, 2013, described in Toronto Hydro press releases but not well captured in ITIS, bears this out, in which 3,500 customers lost power during a wind storm which produce gusts up to 91 km/h at Pearson Airport.

It is notable that one of the most significant events, September 19, 2003 with 99 damage reports, also had the lowest reported gust at 72 km/h and is a pronounced outlier on the graph (bottom bar in **Figure C.8**), and the only other event which occurred in September shows the 2nd lowest wind speed value at 78 km/h.

To further investigate this wind speed relationship, the month of November 2005 was "back checked" to see how well a threshold of ~90 km/h was able to predict impacts to the Toronto Hydro system (**Table C.5** and **Figure C.9**). A total of 53 outage incidents were reported in ITIS for this month, with the largest number reported on November 6th and into the early morning hours of November 7th (35 reports). As indicated in **Table C.4**, these correspond with gusts of up to 89 km/h. Incidents were reported on 6 other days, with the second greatest number occurring on November 9th (9 reports). That day saw snow during the morning hours, followed by severe thunderstorm activity which resulted in one tornado in the City of Hamilton. Damage from thunderstorms is expected to be localized and therefore low wind speeds measured at Pearson airport are not surprising. The day with the third greatest number of reports also shows the second highest gust reported that month.

There are a number of potential reasons for this apparent seasonal difference between wind speed thresholds, most likely the effects of deciduous trees being still in full leaf, but, other considerations, such ground softness due temperatures remaining above freezing, must be considered given the very small sample size present here. However, data do appear indicate that threshold winds for damage increased from ~70 km/h during early fall up to ~90 km/h for late fall and winter windstorm events, and the causes listed for these impacts hint at a relationship to tree contacts.

We should mention that spring low pressure systems are also capable of producing high winds, but these do not seem to be as significant as fall season large scale wind storms. Spring severe wind storms also tend to have embedded thunderstorms, which act to further localize winds and complicate efforts to determine the representativeness of measurements. Examples of this event type include the April 20 to 21, 2000 and April 12, 2001 storms. March 9-10, 2002 is the only significant spring wind storm in the 2000-2006 period, but this event was also accompanied by severe thunderstorm activity which produced much more significant impacts in other parts of Ontario, including the loss of multiple Hydro One electrical transmission towers.

C.3.3.1 Superstorm Sandy: October 29-30, 2012

So-called "Superstorm" Sandy, responsible for major devastation in several major east coast cities in the United States, also produced impacts in Canada, including one fatality from windblown debris. Toronto Hydro estimated about 60,000 customers had lost power during the storm (T.H. Press Releases, Toronto Star 2012). Adjacent LDE Enersource reported approximately 6,000 customers lost power during the event, with 6 crews beginning restoration efforts at around 6PM on October 29th (Mississauga News 2012). Causes for these outages included the loss of three hydro poles. ORNGE air crews had also been grounded at 2 pm October 29th due to high winds (Toronto Star 2012).

Toronto Hydro had been initially criticized for not immediately declaring Level 3 status for this event and beginning repairs; however, the vice president of grid management indicated attempting repairs during the storm would have been futile and dangerous for repair crews (Toronto Star 2012). "There's nothing we could have done between 2 am and 6 am." Press releases issued as early as 6 PM on October 29th warned customers that repairs may be impossible during high winds.

A map depicting impacts and rainfall measurements for the event is provided in **Figure C.10**. Unfortunately, outage incident data appears to be incomplete for this time period (the event having occurred after 2006), and media reports for the city of Toronto lack specific damage and failure location descriptions. This is in sharp contrast to media reports from the City of Mississauga (Mississauga News 2012), the source of all media damage reports indicated in **Figure C.10**.

With the exception of one incident, wind damage reports from ITIS all appear in the southern half of the City of Toronto, and these also correspond very well with media reports of wind damage in Mississauga, as well as the difference in measured severity between Pearson (80 km/h max gust) and Toronto Island (91 km/h). There are simply too few available rain related damage reports to determine if important thresholds were reached for direct overland flooding related damage, and a comparison between Buttonville and Pearson to determine if antecedent rainfall played an important role appears to be negative. Both areas experienced similar amounts of antecedent rainfall on October 28th, followed by wind gusts of similar magnitudes on October 29th; however, only areas located southwest and southeast of Pearson reported any notable wind damage.

Toronto Hydro press releases, including those issued as early as 9:30 PM on October 29th, before the peak of the storm, in indicated trees and tree limb contact with overhead wires as the main cause of the outages (T.H. 2012). The October 30th 10:39 PM press release specifically indicated, "Toronto Hydro estimates that more than 85 per cent of outages were caused by tree contacts with power line[s]" Further indicating that repairs are expected to exceed $1 million and that other jurisdictions, which have far less tree cover, were not expected to be as heavily impacted. On the evening of October 30th, the worst affected area was roughly bounded by "Talwood Drive (north), Eglinton Ave E (south), Bayview Ave (west) and Don Mills Rd (east)"

The preponderance of tree and tree related damage in the southern portions of Toronto and Peel, coupled with the transition from wind gust regimes from 80 km/h to 90 km/h, further supports the findings from the analysis of large scale wind storms indicating wind speed thresholds of 90 km/h, again likely related to tree contacts. Budget and time limitations prevent further analysis of this event (e.g. search for impacts in Durham region) for the time being, but further research is strongly indicated.

C.4 Severe Summer Thunderstorm Events

C.4.1 July 8, 2013 Extreme Rainfall Event

"Little India resident Kurt Krausewipz, said the 'thick heavy sheets of rain,' reminded him of monsoon season in Southeast Asia." (Toronto Star, July 9, 2013)

The flash flood event on July 8th, 2013 was responsible for the largest 24 hour rainfall amount ever reported at Pearson Airport. The event was notable for a number of important impacts, including the stranding hundreds of GO transit commuters for 5 hours on a flooded train in the Don Valley (Toronto and Toronto Island Airport is 4.1 degrees for the four high heat days, and the difference between North York Climate Station and Toronto Island is slightly less at 3.1 degrees.

Figure C. 13 shows an example of a high heat day (July 16, 2006) in which impacts began to be reported in North York at two different transformer stations. Interestingly enough, two of the four reports are listed as "Adverse Weather/Tree Contacts", and we are unsure of the nature of these reported causes. Either they have been mistakenly coded, or tree contacts may have occurred due to line sag, but details on the specific impact characteristics are lacking. The small number of reports indicated in North York for this date and the inter-comparison in **Table C.6**, coupled with results from the literature review and discussions with practitioners, provide additional evidence that negative impacts to the distribution system begin to appear as temperatures approach ~35°C.

This case, however, provides an excellent example of the temperature gradient often present across the City of Toronto during extreme heat days, with slightly higher temperatures occurring further from the lake. During the summer, the temperature difference between land and lake often result in the production of a lake breeze, in which cooler, heavier air over the lake flows inland, the leading edge of that air often acting as a miniature cold front. This can result in notable temperature gradients across the city, and can also trigger and/or enhance thunderstorm activity at the boundary between lake air and air further inland.

Although time and resources did not allow for more detailed assessment, a greater number of days in which extreme heat impacted the Toronto Hydro distribution system should be further investigated to help refine this threshold further. Further analysis is also needed to ensure that the impacts of other air mass boundaries (i.e. large scale fronts) are not skewing the results presented here, as similar temperature gradients can be produced through other mechanisms unrelated to the effects of the lake.

C.6 Final Conclusions

In summary, the forensic analyses resulted in the following conclusions:

- Although data sufficiency and time allotted to the project prevented the thorough investigation of many of the events identified through this forensic analysis, several avenues of future research were identified which could lead directly to improved operational maintenance and management measures, including improved forecasting of climatic impacts to assist in anticipation and preparation for significant events.
- In some cases, it was clear that Toronto Hydro operations and maintenance crews were making effective use of forecasts to help plan and optimize repair and response, such as allowing severe weather conditions to pass before full repair operations were initiated.
- In most cases, and particularly for those in which localized differences in impact severity were evident, further analysis was stymied by a lack of observational data. Even with the inclusion of additional observational data provided by TRCA (2014), spatial gaps in observations prevented the assessment and diagnosis of conditions in certain locations (e.g. December, 2013 ice storm

damage in Scarborough lacking ice accretion or temperature measures; August 19, 2005 severe thunderstorm wind speed measurements in southern portions of the city).

- The majority of power outage events identified in the 2000-2006 period were extended events lasting up to 48 hours, representing the need for sustained operational response, but the characteristics of these events differed depending on season:
    - Extended warm season events consisted of 2 or more acute weather events in quick succession, and were a combination of related hazards producing impacts (e.g. extreme heat followed by thunderstorm activity)
    - Cool season and shoulder season events tended to last several hours; when storms occurred in succession, they tended to be separated by periods of one or more days
    - The years with the greatest reported impacts to the distribution system were characterized by multiple moderate to major outage events occurring in different seasons (e.g. significant severe thunderstorm event during the summer followed by one or more wind storms during the fall season)
- Thresholds determined for wind speed and ice storm damage agree well with previous work and research, and these also appear to be *directly* related to tree contact related impacts rather than direct climatic loading of infrastructure through wind or ice accretion.
    - The 70 km/h threshold for wind gusts, originally provided by Toronto Hydro staff during Phase I, appears to be correlated with tree damage, particularly during the warm portions of the year when deciduous trees are in full leaf, resulting in secondary impacts to the distribution system; further research is needed to confirm this relationship
    - The 90 km/h threshold appears to be both related to the baseline climatic loading used in design of civil infrastructure components (see CSA 2010) as well as tree damage after deciduous trees have shed their leaves
    - The lower bound of 15 mm for freezing rain totals resulting in tree contacts with overhead systems agree well with the findings from Klaassen et al. (2003)
    - Freezing rain totals of less than 15 mm, however, may cause impacts when combined with high humidity environments near the 0°C boundary. This can specifically result in flashovers and other related impacts. While not as severe as direct damage to overhead lines and other equipment, these types of impacts can be numerous, widespread, and localized, presenting particular challenges for restoration efforts
- Overall, larger metropolitan LDCs appear to be more vulnerable to climatic events than smaller LDCs, particularly when considering overall restoration times; this is likely due a culmination of factors, not the least of which include the state and age of equipment, difficulty of access for system repair in an urban environment, and the relative proportion of staff available with respect to total number of customers and the size of a geographical area of responsibility.
- Certain regions within the city appear to be more susceptible to weather related power outages; potential regional differences in vulnerability should be investigated further. It is not clear at this time if these vulnerabilities are due to aging infrastructure, proximity to aged canopies, difficult to access infrastructure (e.g. back-lots) or some other combination of factors.

- There were several cases in which events tended to follow one-another in series, with either the restoration following a major event being hampered by subsequent smaller events, or several moderate events resulting in prolonged, multi-day outage cases where new damage occurred immediately following recovery from previous events
- Extreme rainfall impacts are worst with warm season severe thunderstorms. These were characterized by highly localized events impacting only a portion of the City, generating rainfall accumulations of over 100 mm, the majority of which (>50%) falling on during a period of *one hour*. Rainfall impacts with longer the longer duration, larger scale events investigated here (e.g. "Superstorm Sandy") appeared to be minor.
- Changes in tree health conditions such as disease and pests may also be playing a role in increasing sensitivity to damage, as suggested by analyses of the December 2013 ice storm. These represent very complex interactions, since the extent of certain disease and pests will also be affected by changing climate regimes, and their interaction with the structural integrity of trees and limbs is still unknown.
- Even for winter events, which are ostensibly much less localized in nature than warm season storms, localized differences in infrastructure impacts were evident, and without additional data, the causes for these disparities were not entirely clear. In one case (December 21-22, 2013) a small scale weather feature was explicitly identified as having very likely been a major contributor to the case overall, and similar findings are expected if similarly in-depth analyses are conducted of other high impact winter storms.
- Differences in impacts due to storm structure and other localized meteorological factors were evident in some cases (e.g. separation of precipitation and wind related impacts Aug 19, 2005). While these are to be expected, they may also assist in response to events when combined with remote sensing data, such that response crews may be better informed as to the type of impacts they may encounter following a severe storm.
- Events were not only characterized by impacts to the distribution system, but tended to consist of multiple, often severe impacts to other buildings and infrastructure, including transportation, and communication infrastructure. These impacts compounded effects on the distribution system by further complicating operational response.
- Smaller events which barely generated more than 20 damage reports, such as July 1, 2001 (lightning and rainfall) or April 28, 2002 (high winds), should be studied to understand where the lower damage thresholds may lie and/or which areas within the city or infrastructure types/categories are the *most* vulnerable
- The presence of Lake Ontario directly impacts the behaviour of certain weather hazards, generating differences in risk across the city; it generally moderates temperatures, warming areas adjacent to the lake during the cool season and cooling areas near the lake during the summer. This effect either mitigates or exacerbates the severity of hazards depending on the type of hazard (e.g. areas downtown are kept cooler during extreme heat days, but the leading edge of the lake breeze also plays a role in enhancing severe thunderstorm hazards for other portions of the city).

RESPONSES TO ND HANN INTERROGATORIES

INTERROGATORY 55:

Reference(s): **Exhibit 2B, pg. 35, 36**

a) What is the CSA standard for wind load with overload?

b) If they are 120 km/h or greater, why are "wind gusts at 90 km/h and 120 km/h were judged to be a high risk to overhead feeder systems." since the system is design to withstand this external loading?

RESPONSE:

a) Please see Toronto Hydro's response to 1B-Hann-6.

b) Wind gusts at 90km/h and 120km/h can cause damage to vegetation which can represent a risk to Toronto Hydro's system. For more details, please refer to Exhibit 2B, Section D, Appendix D, Appendix C – Forensic Analysis of Weather Power Outage Events.

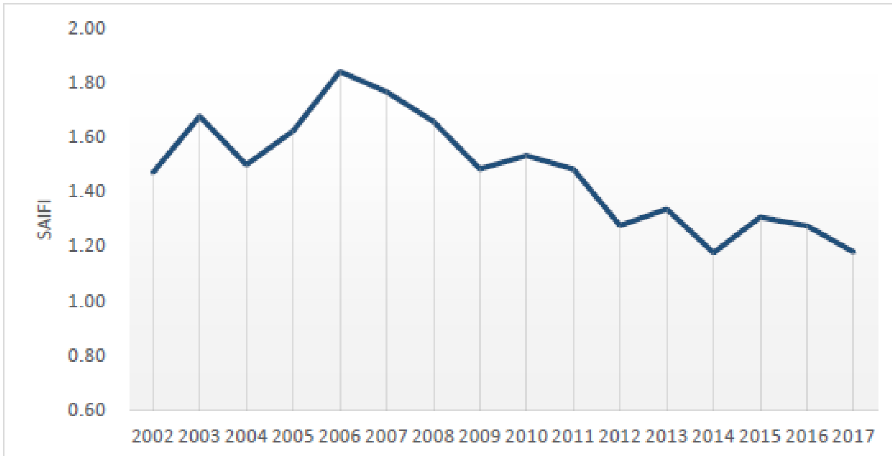


Figure 6: Historical SAIFI (Excluding MEDs and Loss of Supply)

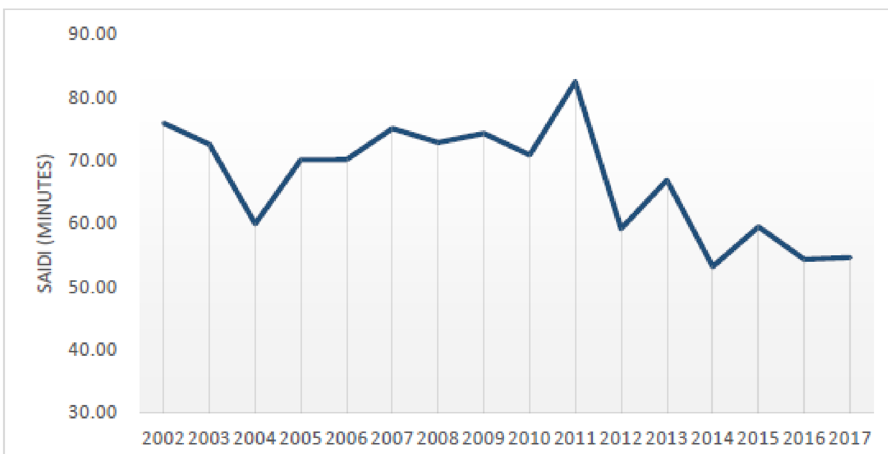


Figure 7: Historical SAIDI (Excluding MEDs and Loss of Supply)

Toronto Hydro has seen improvements in the frequency and duration of outages caused by defective equipment. However, defective equipment continues to be by far the largest contributor to SAIFI, at 36 percent, and SAIDI, at 44 percent. In light of the age, condition, and legacy asset related risks discussed above, Toronto Hydro concluded that a shift to a more reactive renewal approach would – in addition to being a more costly approach to renewal over the long-term – result in a decline in reliability over the near- and long-terms, with potentially significant impacts for customers in areas in population will require additional accommodation, commercial spaces and services.[10] This growth is also reinforced by the projected GDP growth anticipated for the City, which is expected to be around 2 percent per annum for the period of 2020-2024.

As illustrated in Figure 2, from 2007 to 2017, Toronto Hydro connected approximately 88,000 customers, representing a 13 percent increase in its customer base (average of 1.3 percent per year), and approximately 49,000 customers from 2012 to 2017, representing a 7 percent increase (average of 1.4 percent per year). Similar levels of growth are expected for the 2020-2024 period, as described in the Customer Forecast Section.[11] These additional customers were connected to Toronto Hydro's distribution system as a result of the investments in the Load Connection segment.

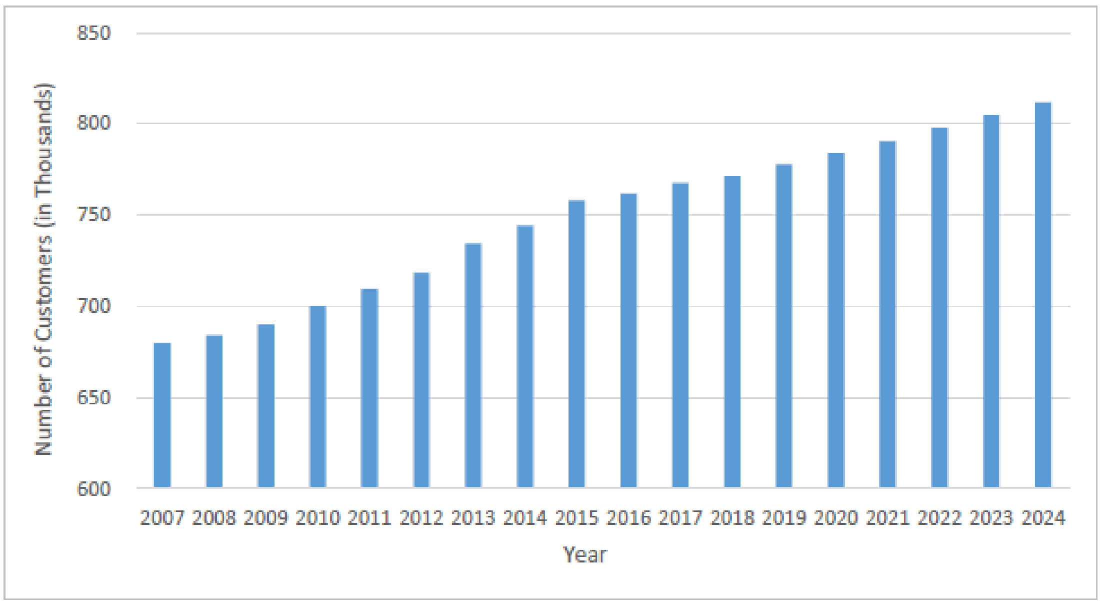


Figure 2: Historical and Forecast Number of Toronto Hydro Customers

Customer connections can be in the form of a basic connection, or a connection requiring expansion work. The types of connections Toronto Hydro performs can generally be divided into two categories as follows:

10 As of 2017, Toronto continues to lead in the number of major buildings under construction, ranking second in tall building construction after New York (Toronto Economic Bulletin, May 25, 2018).
11 Exhibit 3, Tab 1, Schedule 1.

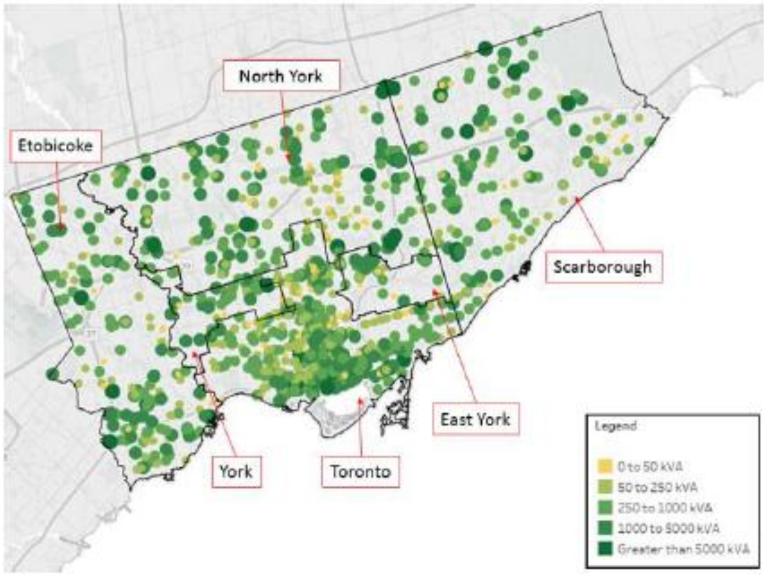


Figure 1: Load Additions in the City of Toronto during the 2013-2017 Period

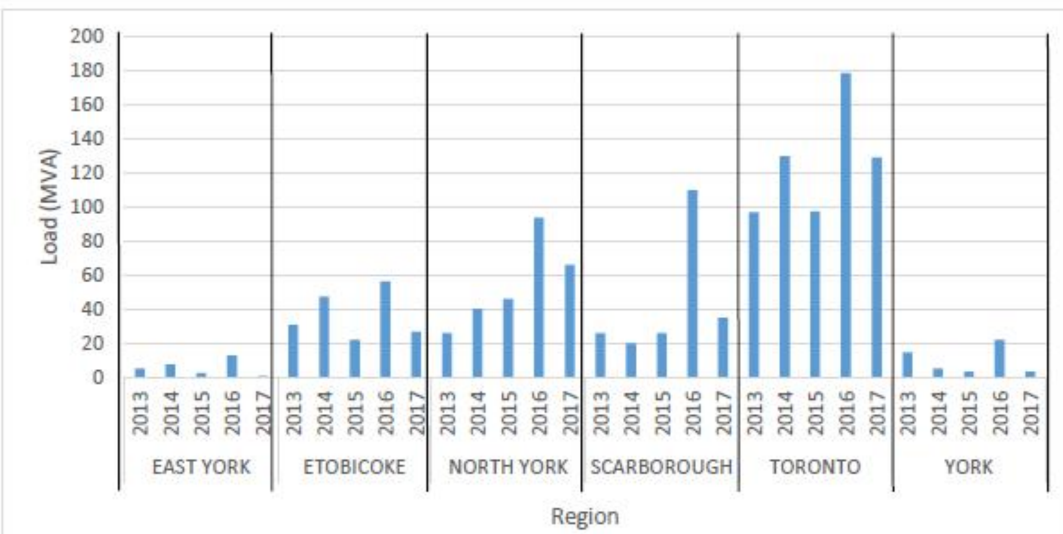


Figure 2: Load Additions by Region during the 2013-2017 Period

The City of Toronto is experiencing an increase in development which is expected to continue throughout the 2020-2024 period. Table 4 below provides a summary of the projects submitted to the City of Toronto's Planning Division between 2012 and 2016, and Figure 3 is a map of the residential units proposed over this period.

Table 4: Proposed Projects in the City of Toronto (2012-2016)[8]

	Built	Active	Under Review	Total in Pipeline	% of Total
City of Toronto	1,156	743	624	2,523	
Growth Areas					
Downtown and Central Waterfront	**187**	**129**	**132**	**448**	**17.8**
Centres	**28**	**34**	**26**	**88**	**3.5**
Etobicoke Centre	6	10	3	19	21.6
North York Centre	14	9	9	32	36.4
Scarborough Centre	4	3	1	8	9.1
Yonge-Eglinton Centre	4	12	13	29	33.0
Avenues	**174**	**154**	**147**	**475**	**18.8**
Other Mixed Use Areas	**79**	**82**	**55**	**216**	**8.6**
All Other Areas	**688**	**344**	**264**	**1,296**	**51.4**

Source: City of Toronto, City Planning Division: Land Use Information System II

Development projects with activity between January 1, 2012 and December 31, 2016. Built projects are those which became ready for occupancy and/or were completed. Active projects are those which have been approved, for which building permits have been applied or have been issued, and/or those which are under construction. Projects under review are those which have not yet been approved or refused and those which are under appeal.

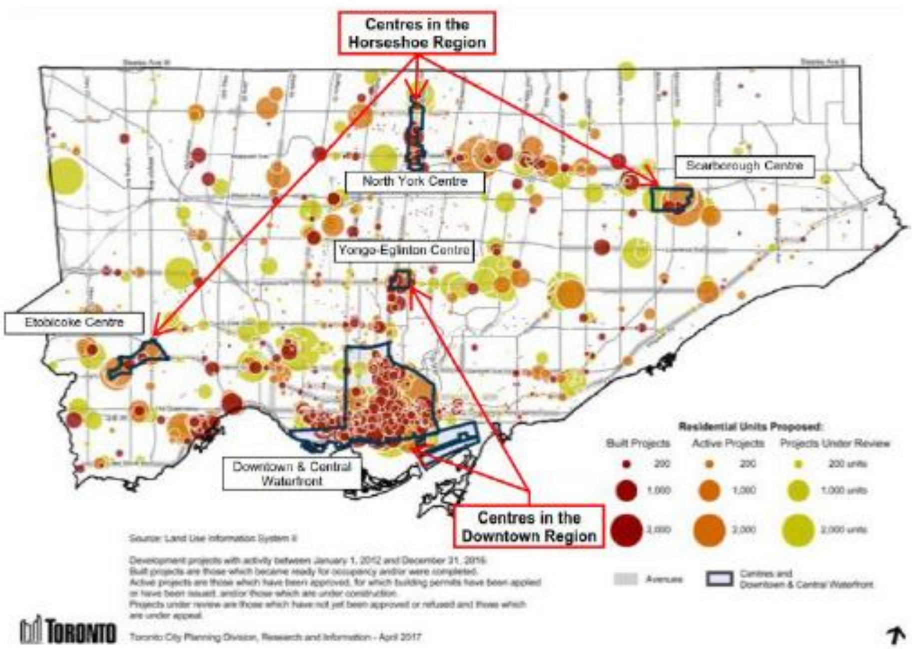


Figure 3: Residential units proposed (2012-2016)

[8] *Supra* Note 8.

As illustrated in Figure 3, the majority of the growth is focused on the downtown system, particularly the downtown and Central Waterfront area, where 42,556 residential units have been built as of the end of 2016 and 141,079 units are in the pipeline for future development. Another area experiencing strong growth in the downtown system is the Yonge-Eglinton Centre, with 1,329 units built by 2016 and 12,975 units in the pipeline.

In the Horseshoe system, Etobicoke Centre, North York Centre, and Scarborough Centre have experienced development growth which are expected to continue: (i) in the Etobicoke Centre area, 970 units were built and 7,261 remain in the development pipeline; (ii) in the North York Centre area, 4,052 units were built and 8,819 remain in the pipeline; and (iii) in the Scarborough Centre area, 853 units were built and 1,591 remain in the pipeline.[9]

Of the total projects proposed over the 2012-2016 period, 123,710 residential units and 3,046,196 m^2 of proposed non-residential Gross Floor Area ("GFA") are currently in the development pipeline as active projects.[10] Based on a load estimate of 2 kVA per residential unit[11] and 0.07 kVA per m^2 of non-residential GFA,[12] Toronto Hydro expects that these projects will result in up to an estimated 460 MVA of new load during an estimated 3 to 7 years after the end of the 2020-2024 period. This estimated load addition does not take into account load subtractions to the distribution system due to redevelopments. Therefore the actual net new load may vary. Furthermore, the actual load added to the distribution system will depend on customer load factors and the system coincidence factors.

Therefore, the utility can expect a steady stream of customer service requests for new connections over the 2020-2024 period and beyond.[13] To meet these requests in a timely and cost-effective manner, and maintain reliability and quality of service for existing customers, Toronto Hydro must invest in infrastructure upgrades and load transfers to alleviate capacity constraints. In particular, the utility must focus its efforts in the downtown area where concentrated growth is straining the distribution system by overloading station buses, feeders, and transformers.

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[9] *Supra* note 8.
[10] *Supra* note 8.
[11] OEB, Backgrounder – May 1 electricity price change (2016). Available: https://www.oeb.ca/oeb/_Documents/Press%20Releases/bg_RPP-TOU_20160414.pdf
[12] H. Joshi, "Load Estimates," in Residential, Commercial and Industrial Electrical Systems: Network and Installation, Volume 2, 1st ed. (McGraw-Hill, 2008), pp. 3.
[13] Canada Mortgage and Housing Corporation reports that from 2007 to 2016, an average of approximately 14,700 residential units were built each year. This information confirms that active residential projects will likely be completed in the 2020-2024 rate period. (City of Toronto (2017). "How Does the City Grow?" *Supra* Note 8)

The failure risk of these assets is mitigated through the Preventative and Predictive Underground Line Maintenance program;[3] however, environmental conditions can accelerate the deterioration and failure of these assets prior to their next inspection due to the nature of their surroundings.

Toronto Hydro investigated 257 underground transformers failures that occurred between 2012 and 2017. The results of this analysis (see Figure 12 and Figure 13) show that 35 percent[4] of the failed underground transformers failed at or beyond useful life and that the number of failed units increases with transformer age. Therefore, if not proactively replaced, transformers on Toronto Hydro's distribution system which are at or beyond their useful life of 33 or 35 years are at an increased risk of failing.

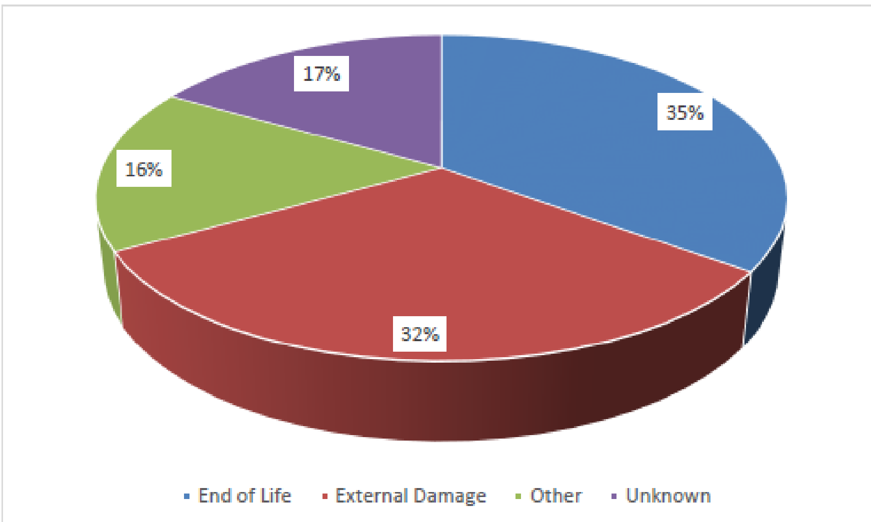


Figure 12: Root Cause Distribution for Failed Underground Transformers from 2012 to 2017

[3] See Exhibit 4A, Tab 2, Schedule 2.
[4] Corrosion, which is known to accelerate degradation and reduce the life of assets, represents 5 percent of these failures and is included in External Damage (see Figure 12).

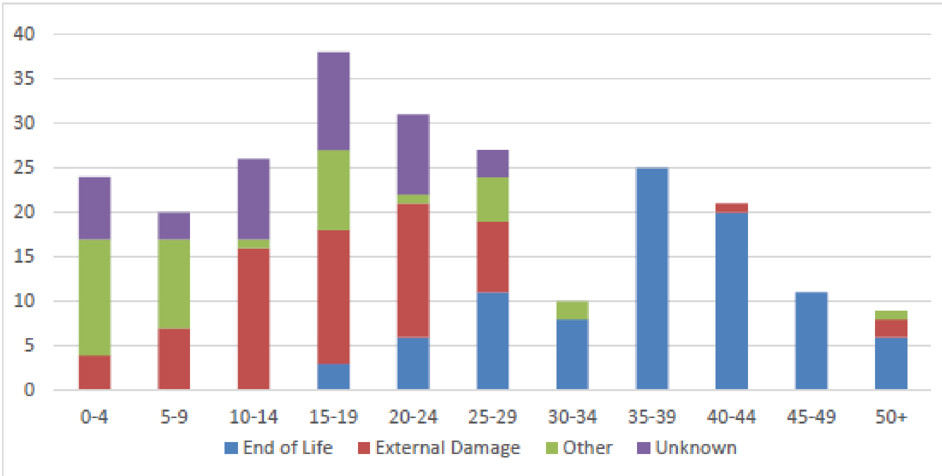


Figure 13: Age of Transformers at Time of Failure

Figure 14 shows the current age distribution of underground transformers in the Horseshoe area and what it will be in 2024 without investment. As of 2017, 19 percent of underground transformers in the Horseshoe area (i.e. 3,505 units) were at or beyond useful life. There are also a high number of transformers approaching their useful life (i.e. 33 years for submersibles and 35 years for padmount and vault). Without any replacement, the percentage of assets at or beyond their useful life will increase by more than 50 percent and reach 29 percent (5,355) by 2024. An increase in the number of transformers at or beyond their useful life will increase the risk of units failing and will erode and eventually reverse the improvements in reliability made in recent years. Additionally, without sufficient replacement, Toronto Hydro will face a backlog of transformers requiring replacement beyond 2024.

RESPONSES TO ND HANN INTERROGATORIES

INTERROGATORY 56:

Reference(s): **Exhibit 2B, p. 36**

Do the lightning storms cause "electrical" or "mechanical" interruptions? E.g. how many lightning arrestors were damaged, vs fuse links replaced, how many poles were replaced during lightning storms due to a lightning strike vs trees falling on the conductor? Did the lightning storms actually cause the damage to the assets?

RESPONSE:

Lightning storms apply large electrical stresses to Toronto Hydro's infrastructure and can damage distribution equipment.

Table 1 below provides quantities of electrical distribution equipment damaged by lightning storms which required replacement from 2011-2018 per Toronto Hydro's records. Please note that the data set below may not be complete as these records only account for equipment returned for investigation.

Table 1: Equipment Failures due to Lightning Storms from 2011-2018

Equipment Type	# of Units Damaged
Cable, MV	1
Lightning Arrestor	2
Pole	1
Switch, 3PH Manual Loadbreak	1
Switch, SCADA Loadbreak	1
Transformer, Padmount	4

Equipment Type	# of Units Damaged
Transformer, Polemount	23
Transformer, Submersible	4

RESPONSES TO ND HANN INTERROGATORIES

INTERROGATORY 57:

Reference(s): **Exhibit 2B, pg 49**

Why does THESL state throughout the evidence and public consultation that there are and will be more extreme weather while the consultants report states "These events are projected to continue in the future, but continue to occur on a less than annual or even decadal frequency. More severe ice storms (60 mm), high winds (over 120 km/h) and tornadoes (EF1+) have been extremely rare in the past, and while there is a lack of scientific consensus on projected future frequencies for these extreme events, they are likely to remain rare in the future."?

RESPONSE:

Please refer to Toronto Hydro's response to interrogatory 2B-Hann-49 part (a).

RESPONSES TO ND HANN INTERROGATORIES

INTERROGATORY 60:

Reference(s): **Exhibit 2B, Pg no number Pg 770 of pdf**

a) Is there a recurring weather cycle of say 7 years?

b) Is this related to tree growth/trimming? Reference "It may also be possible to anticipate a particularly severe damage year since the "major" events producing over 150 reports tend not to occur in isolation but usually occur in years with a number of less severe but still significant events, although the consistency of this pattern requires further research".

RESPONSE (PREPARED BY AECOM/RSI):

a) The period of record available for consistent power outage incident data (2000-2006 inclusive) was of insufficient length to determine if a regular multi-year cycle is present. Due to the focus in the analyses on individual case studies and the fact that it did not include assessment of multi-year cycles, no investigation of recurring weather cycles is possible under the constraints of the original assessment, scope, and available data.

Furthermore, current Best Practices employed for the calculation of return-periods for extreme weather events is to treat events within each individual year as statistically independent. This means that the occurrence of an event in one year does not affect the probability of the same type of event occurring in other years.

For more detailed descriptions of return-period calculation methods for climatic extremes, see the *National Building Code of Canada, Appendix C "Climatic and Seismic Information"* (NRC 2015), or *CSA PLUS 4013-12 TECHNICAL GUIDE - Development, interpretation, and use of rainfall intensity-duration-frequency (IDF) information: Guideline for Canadian water resources practitioners* (CSA 2012).

b) Determination of any links to tree growth cycles or Toronto Hydro's tree maintenance program is well beyond the scope of work. To fully examine this question would require an analysis of the interaction between high-impact weather events and Toronto Hydro's maintenance and response programs. The purpose of the forensic assessment was to help determine impact thresholds for the purposes of the PIEVC risk assessment and was not meant to assess Toronto Hydro staff's performance in responding to these events.

To clarify, the statement quoted in this question is in reference to the "clustering" of similar high-impact events in adjacent days or weeks within the same season. The appendix of the Project Report provides an example of this regarding large-scale windstorms; "Fall and spring large scale wind storms will occasionally occur in series" with the September 29 to November 13, 2005 wind storm *series* provided as an example.

RESPONSES TO ND HANN INTERROGATORIES

INTERROGATORY 61:

Reference(s): **Exhibit 2B, Pg no number Pg 770 of pdf**

Did the consultant challenge what the actual root cause was of lightning reported interruptions? What was the result of that challenge? Reference "Lightning - Customer interruptions due to lightning striking the distribution system, resulting in an insulation breakdown and/or flash-overs Pg 25 of RRR_Electricity_20130101" [sic]

RESPONSE (PREPARED BY AECOM/RSI):

No. None of the statements within the forensic analysis were meant to *challenge* the stated mechanism associated with lightning related interruptions. The forensic analysis found indications that even in cases where other damage mechanisms are present (i.e., wind, extreme rainfall), that lightning related impacts were still a major contributor to the total number of outage incidents associated with a given weather event.

From the Report Appendix: "Even for storms which included extreme rainfall and high winds [sic] related impacts, *lightning appeared to be the dominant factor in producing outages*." [emphasis added]

RESPONSES TO ND HANN INTERROGATORIES

INTERROGATORY 72:

Reference(s): Exhibit 2B, Section E2, p. 22, p. 23, lines 1-21, lines 1-17

a) How many poles (by year) failed due to age from 2008 to 2017 on days without storms?

b) How many poles (by year) failed on days with storms where the pole was broken due to strictly wind or ice load on the conductor?

RESPONSE:

a) The following table provides the number of pole failures that resulted in interruptions on non-major event days. Please note that in addition to the poles listed in the table, Toronto Hydro identifies a number of other poles each year that have either failed or are determined to be at the end of their serviceable life, but that have not caused an interruption. For more information on this, please refer to Toronto Hydro's response to interrogatory 4A-Hann-87.

Table 1: Pole Failures (2008-2018 with no Major Event Days)

Year	Number of Failures
2008	12
2009	8
2010	4
2011	8
2012	6
2013	4
2014	19
2015	12

2016	3
2017	7
2018	7

b) Toronto Hydro does not have that information, as Toronto Hydro's systems do not track failures on the basis of "strictly wind or ice load on the conductor."

RESPONSES TO ND HANN INTERROGATORIES

INTERROGATORY 73:

Reference(s): **Exhibit 2B, Section E2, p. 22, p. 23, lines 1-21, lines 1-17**

In the photo in Figure 12: "Deterioration 1 at the base of a pole" provided,

a) What is the estimated % reduction in load carrying capacity? What is the estimated % reduction of load carrying capacity for the "approximately 11,000 poles in each of the 6 HI4 ("material deterioration") and HI5 ("end-of-serviceable life") condition bands."?

b) For the conductor sizes and class of pole used by THESL,
   i) what are the maximum span the poles can be set at according to maximum design loads with overload?
   ii) What is the average span on the THESL system?

RESPONSE:

a) The photo of the pole in Exhibit 2B, Section E2, p. 23, Figure 12 was included for illustrative purposes. For this reason, the estimated percent reduction in load carrying capacity of this specific pole cannot be provided.

   Toronto Hydro has not calculated percent reduction in load carrying capacity for the approximately 11,000 poles in HI4 and HI5 bands. Such a calculation would be complex as multiple variables are involved such as span between poles, conductor tension, pole height, and pole strength.

b)

i) The maximum allowable span between poles for regular span construction is 38 metres. The maximum allowable span between poles for long-span construction is 60 metres, which is only constructed when regular span construction cannot be achieved.

ii) The average span between poles is 27 metres.

RESPONSES TO ND HANN INTERROGATORIES

INTERROGATORY 74:

Reference(s): **Exhibit 2B, Section E2, p. 24, lines 2-7**

a) How many pole top transformers (by year) failed due to age from 2008 to 2017 on days without storms or high temperatures?

b) How many pole top transformers (by year) failed on days with storms where the transformer failed without any external forces?

c) How many transformers (by year) failed on high temperature days?

RESPONSE:

a) Toronto Hydro is unable to provide the data as specifically requested (i.e. for the length of time, excluding storms and high temperatures, by age) due to system and data limitations. However, the combination of information provided in (i) Exhibit 2B, Section E6.5, Figure 7 at page 9, (ii) part (b) of this response, and (iii) part (c) of this response, may be used to infer what the data set would look like.

   i) Exhibit 2B, Section E6.5, Figure 7 at page 9, provides the analysis that was conducted as part of Toronto Hydro's Quality Program on a substantial subset of failed pole top transformers from 2013-2017. That analysis divides failures by age and Toronto Hydro has no reason to believe that a broader subset of data (either by number of transformers investigated, or broader period of time e.g., 2008-2017) would yield different results.

ii) Part (b) of this response shows that an extremely low number of transformers (i.e. approximately only 1 per year) fail during storm events without any external forces being applied. As a result, the findings of the analysis discussed in (i) are not expected to change materially if failures during storms are excluded.

iii) Part (c) of this response shows that relatively few transformers (i.e. 8 annually on average) fail during high temperature days. As a result, the findings of the analysis discussed in (i) are not expected to change materially if failures during high temperature days are excluded.

b) Please see the table below. Toronto Hydro has experienced one transformer failure annually (on average) where the transformer failed, during a storm event, but did so without any external forces being applied.

Table 1: Number of Pole Top Transformer Failures

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Number of Failures	0	3	2	0	3	2	2	0	0	1

Notes: For the purposes of this response, Toronto Hydro has interpreted the terms "storm" and "failures" to mean: (i) "Storms" are major events that occurred on "Major Event Days" as defined in Exhibit 1B, Tab 2, Schedule 4, at page 5; and (ii) "Failures" are interruptions caused by defective (transformer) equipment on Major Event Days.

c) Please see the table below. Toronto Hydro does not have a definition for "high temperature day". For the purposes of this response, Toronto Hydro is providing the number of transformer failures that resulted in an interruption, categorized by the ambient temperature on the day of the interruption (i.e. recorded temperature in Toronto) for what could commonly be considered to be "high temperatures" in Toronto.

Table 2: Number of Transformer Failures by Ambient Temperature

Temperature Range	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Greater than 30ºC	1	0	28	7	9	9	2	5	11	7

RESPONSES TO ND HANN INTERROGATORIES

INTERROGATORY 76:

Reference(s): **Exhibit 2B, Section E4, p. 13, lines 6-15**
Pag 939, pg 1317 line 12-21

a) How does Feeder Automation operations input to MAIFI reporting?

b) What impact did Feeder Automation have from 2015-2018 on MAIFI?

RESPONSE:

a) The goal of feeder automation is to reduce outage restoration time by allowing faster sectionalization of feeders. The speed with which this is achieved in each instance will determine how outages are reported (i.e. depending on whether an outage is sustained or momentary, it would be counted as SAIFI or MAIFI, respectively).

b) The impact of the Feeder Automation program on MAIFI during 2015-2018 was not tracked.

- On Day 1, page 101, lines 10-11, the witness stated that the 2016 Asset Condition Assessment results were based on early 2016 data. Upon detailed review and as noted in the response to undertaking JTC 2.13, these results were actually based on data from the end of 2016.

- On Day 2, page 115, lines 25-27, the witness stated that the threshold for change requests for OM&A expenses is $25,000, whereas this threshold is actually $50,000.

- On Day 2, page 155, lines 9-10, whereupon Mr. Hann asked if the changes from central to unit metering account for 4 % of the increase in customer numbers on average per year, the witness responded that this rate of increase is for the entire period. Upon detailed review, Toronto Hydro confirms that the relevant changes actually account for 4% of the increase per year.

- On Day 3, page 22, line 23 and page 23, lines 1 and 12, the witness acknowledged the description of the calculation of the vacancy budget for the 2020-2024 rate period as suggested by counsel for the Schools Energy Coalition. However, upon detailed review, Toronto Hydro notes that more accurately, the vacancy lag in the plan is based on historical average vacancy by division by employee category multiplied by the average compensation for each employee category within the same division.

- On Day 3, page 55, lines 7-9, the witness identified the per customer electronic bill savings on paper, printing, and postage costs combined as $0.87, whereas the actual savings is $0.88.

- On Day 3, page 81, lines 21-22, the witness stated that the function of Vice President, Internal Audit and Corporate Compliance is included under the "Corporate Stewardship – CEO" shared service allocated from Toronto Hydro Corporation to Toronto Hydro. Upon detailed review, Toronto Hydro confirms that this function is not included in that shared service.

- On Day 3, page 108, line 18, the witness identified the capital budget of the Fleet & Equipment Services program for the 2020-2024 rate period as $45.2 million, whereas the actual budget figure is $42.5 million, as noted in Exhibit 2B, Section E8.3, Table 1 of the Application.

Please contact me directly if you have any questions or concerns.

Respectfully,

Andrew J. Sasso
Director, Regulatory Affairs
Toronto Hydro-Electric System Limited

cc: Lawrie Gluck, OEB Case Manager
Michael Miller, OEB Counsel
Parties of Record
Amanda Klein, Toronto Hydro
Daliana Coban, Toronto Hydro
Charles Keizer, Torys LLP

saying the new customers were predominantly connected in the downtown areas, as in they are new customers.

MR. HANN: So they're all new customers?

MR. LYBEROGIANNIS: Yes. And if I can take you to part D of that, part D says changes in metering from central to unit metering only account for 4 percent of the increase in the customer numbers on average.

MR. HANN: Per year?

MR. LYBEROGIANNIS: Subject to check, that is for the entire period.

MR. HANN: So that has an impact on SAIFI, correct? So if your denominator goes up 4 percent per year --

MR. LYBEROGIANNIS: No, Mr. Hann, the denominator does not go up 4 percent per year.

MR. HANN: If you go from one customer to 300 customers because of a change in central metering, it goes up, right?

MR. LYBEROGIANNIS: No, Mr. Hann. The denominator for SAIFI and SAIDI is approximately -- let's say 750,000 customers.

MR. HANN: Yes.

MR. LYBEROGIANNIS: Between 2007 and 2015, there's been some growth in that number, which would be a subset of the 750-odd-thousand customers. It is 4 percent of that subset that is attributed to changes in metering.

MR. HANN: Thank you.

MR. KEIZER: Do you have an idea how much longer you're going to be, Mr. Hann?

RESPONSES TO ND HANN INTERROGATORIES

INTERROGATORY 85:

Reference(s): **Exhibit 4A, Tab 2, Schedule 1, p. 11 line 10-26, 12 line 1-25 of 40 Pg 25 , 26 (sic)**

How does the inspector know how old the equipment is (especially if it has been replaced during an interruption)?

RESPONSE:

In respect of pole-mounted transformers, switches, conductor wires, and auxiliary equipment on distribution poles, inspectors are not required to know the age of equipment when performing Overhead Line Patrols, and it is not possible to always verify equipment age from the ground. In such circumstances, inspectors visually inspect equipment and perform infrared thermography scans to assess their condition during a patrol. In respect of distribution poles, age information can be ascertained on the pole itself if it is visible.

RESPONSES TO ND HANN INTERROGATORIES

INTERROGATORY 86:

Reference(s): **Exhibit 4A, Tab 2, Schedule 1, p. 11 line 10-26, 12 line 1-25 of 40 Pg 25 , 26 (sic)**

a) What does a deficiency in a switch look like as a result of aging?

b) Or a conductor?

c) Is there corrosion on new and old equipment?

RESPONSE:

a) Deficiencies are not always caused by aging equipment and can be caused by external factors such as the environment an asset is installed in and the conditions to which it is subjected to. Please see Exhibit 4A, Tab 2, Schedule 1, pages 20-21 for a list of common failure modes for overhead switches and a picture of an example of a defect for a broken switch insulator.

b) As per part a), deficiencies are not always caused by aging. Common deficiencies for conductor wires include sagging wires, broken/frayed wires, and wires in close proximity to vegetation.

c) Corrosion may appear on both older and younger assets and is not always dependent on the age of the equipment.

RESPONSES TO ND HANN INTERROGATORIES

INTERROGATORY 87:

Reference(s): **Exhibit 4A, Tab 2, Schedule 1, p. 11 line 10-26, 12 line 1-25 of 40 Pg 25 , 26 (sic)**

How many wood poles have failed (by year 2008-2017) without external forces being applied e.g. motor vehicle, trees etc. ? to put another way, just due to wind or ice and no other influences? [sic]

RESPONSE:

Toronto Hydro does not have the granularity of data available to provide distribution poles that have failed "just due to wind or ice and no other influences". However, please note that Exhibit 4A, Tab 2, Schedule 1, page 13 states that Toronto Hydro, through its pole inspection program, has condemned for replacement on average over 290 wood poles annually.

RESPONSES TO ND HANN INTERROGATORIES

INTERROGATORY 88:

Reference(s): **Exhibit 4A, Tab 2, Schedule 1, p. 13 of 40, line 1-3**

How many "aged" poles were there between 2015 and 2017 that THESL deemed needed replacement?

RESPONSE:

Approximately 80 percent of all wood poles inspected and deemed in need of replacement between 2015 and 2017 were beyond their useful life of 45 years. Age alone, however, is not the only criteria used when considering a pole for replacement. Please refer to Exhibit 4A, Tab 2, Schedule 1, Page 12, for more information.

RESPONSES TO ND HANN INTERROGATORIES

INTERROGATORY 89:

Reference(s): **Exhibit 4A, Tab 2, Schedule 1, p. 15 of 40, line 19-23**

What is the Average BM cost by year 2008-2017 of Overhead Line Patrols and Pole Inspections Segment Costs compared to THESL? [sic]

RESPONSE:

Toronto Hydro has not done a benchmarking study for Overhead Line Patrols and Pole Inspections Segment costs for the period specified. See Exhibit 1B, Tab 2, Schedule 1, Appendix B, page 7 for Toronto Hydro's Unit Cost Benchmarking Study which considers the unit prices for the Overhead Line Patrols and Wood Pole Testing and Treatment activities.

RESPONSES TO ND HANN INTERROGATORIES

INTERROGATORY 95:

Reference(s): Exhibit 4A, Tab 2, Schedule 2, p. 24 of 34, line 19-24

There are 4000 deficiencies per year 2015 -2017.

a) How many impact on the operation of the devices and system reliability and how many are like "warning signage have2 been vandalized,"? [sic]

b) How many are addressed immediately e.g. new warning sign, new locks etc.?

RESPONSE:

a) Approximately 30 percent of the deficiencies cited in Exhibit 4A, Tab 2, Schedule 2, Figure 14 can have an impact on the operability of an asset and lead to system reliability, safety, and environmental risks if not addressed. The remaining deficiencies consist of missing or damaged nomenclature and warning signage.

b) Please see Table 1 below for the number of nomenclature deficiencies that are addressed through "find it and fix it" practices over the 2015-2018 period for Toronto Hydro's padmounted equipment.

Table 1: "Find it and Fix it" Nomenclature Deficiencies (Padmounted Equipment)

Year	2015	2016	2017	2018
Units	0	214	228	132

RESPONSES TO ND HANN INTERROGATORIES

INTERROGATORY 103:

Reference(s): **Exhibit 4A, Tab 2, Schedule 9, p. 16, 17 of 37**
Figure 2: lines 9-17 Number of Deficiencies Processed

Figure 2: Number of Deficiencies Processed shows about 6000 to 8000 Executable work deficiencies annually. Even with cancelled inquiries the value does not reach 29000.

a) Please explain what the 29000 deficiencies are.

b) Also, how many of the Executable Work are significant, in that they may affect the reliability of the system. (e.g. not missing signs)

RESPONSE:

a) Please see chart below.

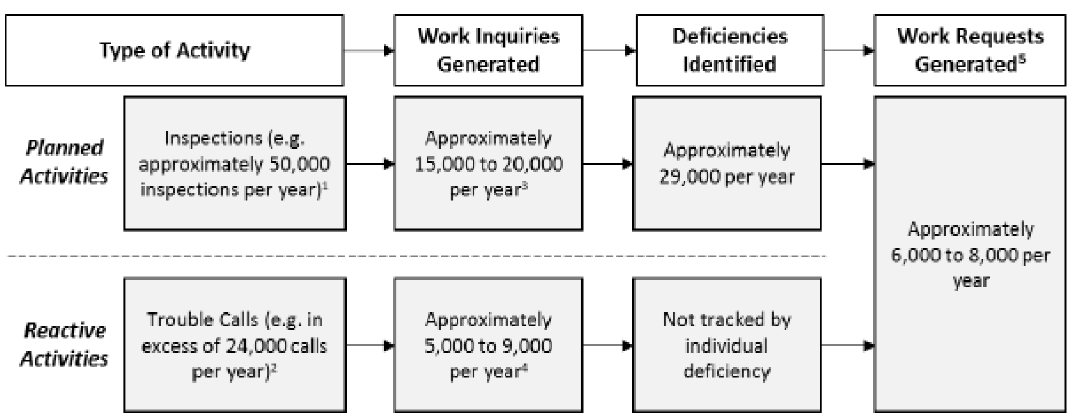


Figure 1: Number of Deficiencies Processed

Note 1: See Exhibit 4, Tab 2, Schedules 1, 2, and 3. Other planned maintenance activities such as line patrols are not captured in the 50,000 figure.

Note 2: See Exhibit 4A, Tab 2, Schedule 5, Emergency Response. Trouble calls in the table is used as a broad term and includes any reactive activity including emails and phone calls received by the Maintenance Planning function described in Exhibit 4A, Tab 2, Schedule 5, Asset and Program Management.
Note 3: For Planned inspections, a Work Inquiry is defined as an inspection with at least one deficiency (e.g. corrosion, oil leak) identified.
Note 4: For Reactive activities, a Work Inquiry is defined as any report (e.g. system response report, defective equipment tracking system entry, email, phone call) that indicates the presence of a potential deficiency.
Note 5: Although the relationship between Work Inquiries and Deficiencies is "1 to 1" or "1 to Many", the relationship between Work Inquiries (and Deficiencies) and Work Requests may be "1 to 1", "1 to Many" or "Many to 1".

As shown above, the 29,000 deficiencies identified are from planned inspections. The 6,000 to 8,000 executable work deficiencies are generated from a combination of planned and reactive activities. Figure 2 in the reference should have more appropriately been entitled "Work Inquiries". In the process of preparing this response, Toronto Hydro also identified a data error in the 2015 results. Please see an updated figure below.

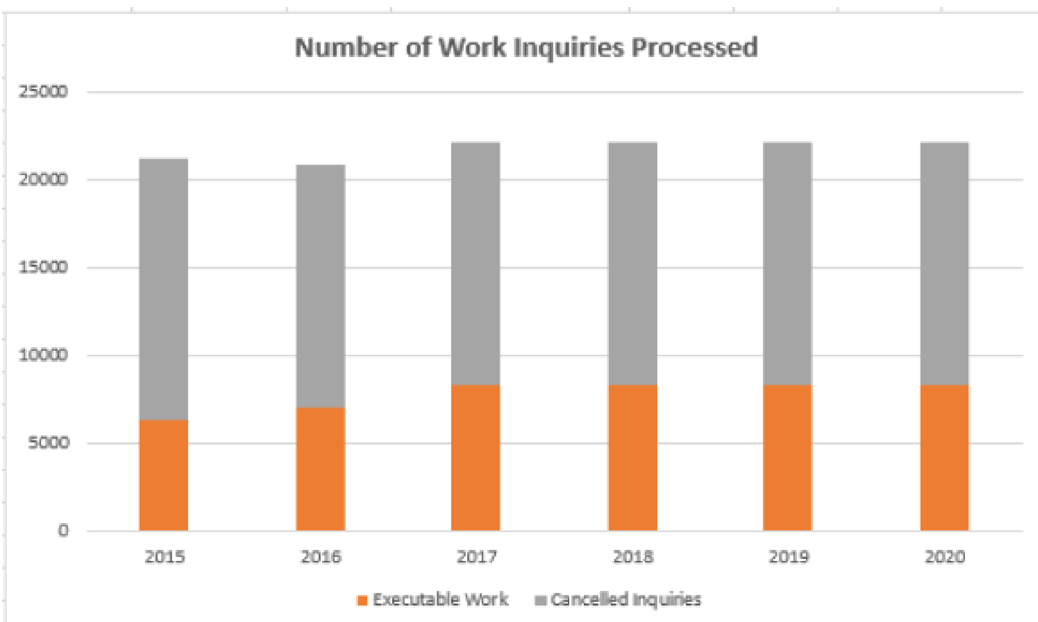


Figure 2: Work Inquiries Processed

b) Table 1 below identifies the percentage of executable work that may impact reliability. To determine the "Work with potential reliability impacts" Toronto Hydro excluded the following from the "Total Work": Trip Hazard; Nomenclature; Light Replacement; Paint; Dirt; Lighting; Obtain Test Sheet; Phone/Emergency Phone; Abandoned Equipment; Bollards; Bolts; Decommissioned; Door; Door Gap; Graffiti; Keys/Locks/Lock Boxes; Ladder; Stub Poles.

As shown the table below, over 80 percent of executable work has the potential to impact system reliability. Please note that although the excluded items may not impact reliability, Toronto Hydro still considers these items to be "significant". These items have the potential to result in unacceptable public and worker safety, environmental, legal, and other consequences and as such are "significant".

Table 1: Work with potential impact to system reliability

	2013	2014	2015	2016	2017
Work with potential reliability impacts	5,996	5,341	6,182	5,846	6,729
Total Work	6,903	5,624	6,494	7,134	8,347
Ratio (%)	87%	95%	95%	82%	81%

RESPONSES TO ND HANN INTERROGATORIES

INTERROGATORY 116:

Reference(s): **Exhibit 4B, Tab 2, Schedule 3 – 2016 Tax Return REDACTED, UPDATED, p. 22 of the PDF file, lines 1-11, section 242**

What is THESL's the definition of a storm day?

RESPONSE:

"Storm days" is used to broadly refer to adverse weather events including those described in Exhibit 2B, Section A4, page 13. These may include, but are not limited to, any storm events with high winds, heavy rain, freezing rain, etc.

Please also refer to Toronto Hydro's response to interrogatory 1B-Hann-1.

Recent extreme weather events (see Table 4, below) have repeatedly and pervasively affected Toronto Hydro's customers. Extreme weather events in 2017 resulted in a 72 percent increase in the number of customer interruptions attributed to tree contacts compared to the average of the previous five years. Similarly, in 2018, Toronto Hydro experienced four extreme storms during the first half of the year.

These circumstances drive Toronto Hydro to continue emphasizing plans and programs that facilitate and improve its system resiliency and ability to respond to these events. This is reflected in the fact that all of the utility's investment categories include at least some investments that support this objective. System Renewal work – and especially the renewal of legacy asset types – will contribute to system hardening by improving asset health and introducing updated equipment design and construction standards that are better suited to the changing operating environment. Grid modernization efforts in the System Access,[5] System Renewal, [6] System Service,[7] and General Plant[8] categories will help the utility respond to major events more effectively. Neglecting to make these investments during the 2020-2024 period could leave the utility ill-prepared for the effects of climate change, leading to a potential decline in service and higher costs related to reactive and emergency scenarios.

Table 4: Extreme Weather Events since the Beginning of 2017

Event	Description
Freezing Rain (February 2017)	• Approximately 2-6 mm of freezing rain followed by additional heavy rain. • Estimated 9,200 customers out at peak; all customers restored within 24 hours of the start of the freezing rain event.
High-water/flooding (May - June 2017)	• Heavy rainfall in southern Ontario exceeded the yearly average for an entire summer. • Numerous incidents of high-water/flooding reported across Toronto. • No customers were directly impacted during this 55-day incident due to the utility's proactive damage assessment and DPM mitigation measures, including flood mitigation efforts.

[5] For example, replacing end-of-life meters with next-generation smart meters.
[6] For example, replacing end-of-life stations assets with assets equipped with modern SCADA-enabled remote monitoring and control capabilities.
[7] For example, installing remote sensing capabilities in network vaults to detect floods before they damage equipment.
[8] For example, creating a fully functional dual control centre (refer to Section E8.1).

RESPONSES TO ND HANN INTERROGATORIES

INTERROGATORY 117:

Reference(s): **Exhibit 4B, Tab 2, Schedule 3 – 2016 Tax Return REDACTED, UPDATED, p. 22 of the PDF file, lines 1-11, section 242**

Did the storm hardening using covered cables prevent vegetation interruptions?

RESPONSE:

Using tree proof conductors can reduce vegetation interruptions such as tree/brush contacts. However, they will not prevent customer interruptions as a result of downed lines caused by trees. Please see Exhibit 2B, Section D2.1.2 for further details on climate, weather, and storm hardening.

To keep pace with the growing city and ensure appropriate distribution system capacity, the utility plans to continue actively investing through the following programs, further described in Section E:

- Customer Connections (Section E5.1);
- Stations Expansion (Section E7.4);
- Load Demand (Section E5.3); and
- Generation Protection Monitoring & Control (Section E5.5).

D2.1.2 Climate and Weather

Climate change is a significant factor influencing Toronto Hydro's planning and operations. Scientists worldwide overwhelmingly agree that the planet is warming. By the year 2050, Toronto's climate is forecasted to be significantly different than the already changing climate seen today. For example, in Toronto, daily maximum temperatures of 25°C are expected to occur 106 times per year as opposed to 66 times per year currently. Daily maximum temperatures over 40°C, which have historically been an anomaly, are projected to occur up to seven times per year by 2050.[1] A warmer climate will also allow the atmosphere to hold more moisture, which is expected to lead to more frequent and severe extreme weather events such as ice storms and extreme rainfall events. These extreme events can cause major disruptions to Toronto Hydro's distribution system.

In addition to extreme weather events, Toronto experiences a wide range of weather conditions that may not be classified as extreme, but nevertheless have the potential to adversely affect the distribution system at various times during the year. Heat, high winds, heavy rainfall, freezing rain, and heavy snowfall have the potential to cause major system damage and extensive outages. Not only are these weather conditions projected to occur more frequently and with greater severity in the future due to climate change, trends from the past 20 years suggest that these changes are already affecting the system. Figure 6 below contains two charts depicting cumulative rainfall and the number of high wind days (i.e. with wind gusts exceeding 70 kilometres per hour) in Toronto over the past 20 years. With respect to rainfall, seven of the 10 highest rain fall years have occurred in the last 10 years. Similarly, six of the 10 years with the greatest number of days of wind gusts above 70 kilometres per hour have also occurred in the last 10 years (these years are highlighted in red).

[1] See Appendix D – Toronto Hydro-Electric System Limited Climate Change Vulnerability Assessment by AECOM (June 2015)

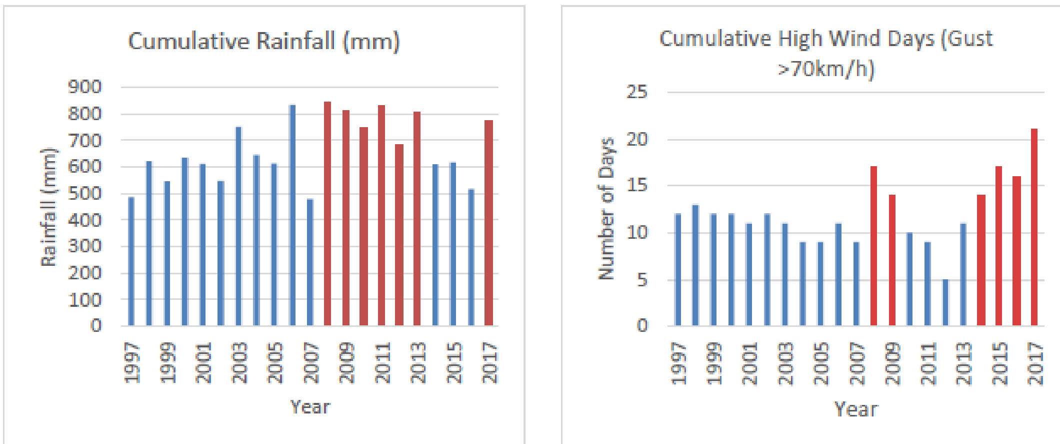


Figure 6: Cumulative Rainfall (left) and Number of High Wind Days (right) in Toronto[2]

These weather trends have increased reliability risks for Toronto Hydro's distribution system. Parts of the underground system are sensitive to significant rainfall, and in particular flooding, while the overhead system in general is sensitive to high winds, freezing rain and wet snow events resulting in damage and outages (e.g. from vegetation impact in proximity to overhead lines). In extreme cases, broken trees and the weight of ice and snow accretions bring lines, poles and associated equipment to the ground.

The aforementioned reliability risks are significant, as evidenced by examples of events that occurred in 2017. April and May of 2017 saw significant rainfall, causing a number of Toronto Hydro's vaults and cable chambers in the underground system to flood. From the perspective of the overhead system, high wind events in 2017 resulted in a 72 percent increase in the number of customer interruptions attributed to tree contacts compared to the average of the previous five years. Similarly, 2018 has seen significant storms and related damage, with four major events occurring during the first half of the year.

To better understand the risks related to increases in extreme and severe weather due to climate change, in June 2015, Toronto Hydro completed a vulnerability assessment following Engineers Canada's Public Infrastructure Engineering Vulnerability Committee ("PIEVC") protocol.[3] The

[2] Weather data compiled using Toronto Lester B. Pearson INTL A for January 1997 to June 2013 and Toronto INTL A for July 2013 to December 2017. Available from: Government of Canada, Weather, Climate and Hazard Historical Data online: <http://climate.weather.gc.ca/historical_data/search_historic_data_e.html>

[3] See Appendix D to Section D.

assessment identified areas of vulnerability to Toronto Hydro's infrastructure as a result of climate change. Following this study, a climate change adaptation road map was developed, along with initiatives relating to climate data validation, review of equipment specifications, and review of the load forecasting model.

Existing codes, standards, and regulations were developed with regard to historical weather data and do not always account for ongoing and future changes to the climate. In efforts to close this gap, Toronto Hydro now utilizes climate data projections for temperature, rainfall, and freezing rain in its equipment specifications and station load forecasting. Further, Toronto Hydro reviewed and updated major equipment specifications in 2016 to adapt to climate change, including:

- Revisions to submersible transformer specifications to require stainless steel construction and testing of the equipment's ability to withstand fully flooded conditions;
- Replacement of air-vented, padmounted switches with new standard SF_6 sealed-type, padmounted switches to remove risk of failure due to ingress of dirt and road contaminants on the live (i.e. energized) surface;
- Initiation of trials of solid dielectric transformers that do not contain oil and are designed to withstand extreme environmental conditions underground; and
- Adoption of breakaway links in tree-covered areas for residential customers with overhead service connections, intended to facilitate faster restoration after extreme weather and prevent damage to customer-owned service masts.

As part of the climate change adaptation roadmap, Toronto Hydro conducted analyses between 2016 and 2017 to better understand how assets and operational practices could be impacted by climate change:

1) An asset impact review that looked at how each type of asset is affected by the different aspects of climate change. Resulting recommendations for each type of asset were used to alter maintenance and asset management programs.
2) An industry review of climate adaptation best practices that included an evaluation of other major utilities as well as published papers. Vegetation management practices, system hardening practices, design criteria, and maintenance practices were areas identified as being affected by climate change.
3) An emergency restoration analysis to evaluate various strategies in the event of a failure in the underground electrical distribution infrastructure when load switching or re-routing is

not feasible. Restoration methods that utilities, specialized companies, and manufacturers have developed in this field were reviewed in order to restore the network as quickly and efficiently as possible. Evaluations and trials of the proposed methods will be investigated and tested prior to being implemented as a standard practice.

The following 2020-2024 program activities will contribute to Toronto Hydro's ongoing efforts to renew and enhance its system to increase resiliency to changes in the weather and climate, thereby supporting the continued delivery of outcomes expected by existing and future customers:

- As assets are replaced in the Overhead System Renewal program (Exhibit 2B, Section E6.5), Toronto Hydro will install taller poles with armless construction and tree-proof wire to reduce vegetation contact risks.
- Stainless steel submersible transformers will replace existing units as the utility carries out its Underground System Renewal – Horseshoe program (Exhibit 2B, Section E6.2).
- Underground System Renewal – Horseshoe program will also replace air-vented padmounted switches with SF_6 sealed-type padmounted switches to mitigate risk of failure due to ingress of dirt and road contaminants on the live surface.
- The Network System Renewal program (Exhibit 2B, Section E6.4) will replace non-submersible automatic transfer switches and remote power breakers with submersible equipment to tolerate flooding.
- The Network System Renewal program will also replace other end-of-life and deteriorated non-submersible protectors with submersible protectors to protect against flooding.
- The Network Condition Monitoring & Control program (Exhibit 2B, Section E7.3) will help the utility detect flooding in network vaults before it damages equipment.
- The Network Circuit Reconfiguration segment under the Network System Renewal program (Exhibit 2B, Section E6.4) will help the utility improve system restoration capabilities in the event of outages.
- Installation of flood mitigation systems at stations identified as being vulnerable to flooding will occur under the Stations Renewal program (Exhibit 2B, Section E6.6).
- New switchgear installed in the Stations Renewal or Station Expansion (Exhibit 2B, Section E6.6 and E7.4) programs will be specified to mitigate flood risk where appropriate (e.g. installing air-tight SF_6 switchgear or other engineered solutions).

RESPONSES TO ND HANN INTERROGATORIES

INTERROGATORY 118:

Reference(s): **Exhibit 4B, Tab 2, Schedule 3 – 2016 Tax Return REDACTED, UPDATED, p. 26 of the PDF file, lines 5-15, section 242**

Was the methodology developed by a subcontractor tested against the 25 years 1993 to 2017, using data from 1968 to 1992 or any period of time (eg 10 year periods) that would be reasonable to test the methodology? If yes, how did the predicted data correlate with the actual results?

RESPONSE:

Yes, the methodology was tested. For the details of the methodology, data assumptions, and correlation with actual results, please follow the link provided in Exhibit 2B, Section B2.1 for the Central Toronto IRRP – Appendices, see Appendix B: Toronto Hydro Spatial Load Forecast Methodology, October 2012, pages 9 to 12.

B2 Regional Planning Processes

The regional planning process is an important input to distribution system planning and the regional planning process is informed by Toronto Hydro's plans. The regional planning process for Toronto is characterized by:

- a large load that is dynamic in the city area;
- a significant number and density of transmission lines and stations;
- the presence of large generation; and
- a customer base that has experienced, and is sensitive to, major events that disrupt continuity of service.

To facilitate infrastructure planning, the IESO divides Ontario into planning regions. As planning considerations change, the boundaries of these regions are revised. In recent years, Toronto Hydro's service area was split between Central Toronto and Northern Toronto. Metro Toronto was also a descriptor of the planning region. More recently, regional planning considers Toronto Hydro Service area, the City of Toronto on a consolidated basis: the Toronto Region. Planning documents and reports that have been developed, issued, and relied upon during the 2015-2018 period, and that inform the utility's plans, make refer to the region using these various names.

B2.1 Toronto Integrated Regional Resource Plan

The Toronto Region used to be divided into two sub-regions for ease of planning: Central Toronto and the Northern sub-regions. The IRRP currently in development pertains to the Toronto Region. The IESO is the lead, working with Hydro One (the transmitter and Toronto Hydro (the sole LDC).

The purpose of the IRRP is to ensure that the electricity service requirements of the central Toronto community are served by an appropriate combination of demand and supply options that reflect the priorities of the community. Planning activities include forecasting the expected growth in electricity demand for 25 years, investigating the costs and benefits of conservation, distributed generation, and transmission and distribution options in meeting the future electricity needs of customers in the central Toronto area. The result of the planning process is an integrated plan, with a long-term perspective, which recommends a balance of options that account for costs, reliable electricity service, and mitigation of environmental impacts. The plan was completed in April 2015, and an

Addendum to the IRRP was completed in February 2017. The impact of the regional plan on the DSP is discussed in Section E2.2.3.3. An IESO link to the IRRP is provided below:

- http://www.ieso.ca/en/get-involved/regional-planning/gta-and-central-ontario/central-toronto-sub-region

The regional planning cycle is underway for the Toronto Region and an IRRP is expected to be posted in the fall of 2019.

B2.2 Metro Toronto Regional Infrastructure Plan

The Metro Toronto RIP was completed in January 2016. The plan is provided as Appendix C.[2]

The plan was the final phase of the regional planning process following the completion on the Central Toronto Sub-Region's IRRP by the IESO in April 2015 and the Metro Toronto Northern Sub-Region Needs Assessment Study by Hydro One in June 2014.

The Metro Toronto RIP provides a consolidated summary of needs and recommendations for Toronto over the near- and mid-term (five to ten years). The impact of the Metro Toronto RIP on the DSP is discussed in Section E2.2.3.3.

In response to the IRRP process that restarted earlier that year, in June 2017, Hydro One began the process of updating with the Needs Assessment, which will support the next IRRP and RIP. The Needs Assessment Report was completed in October 2017 and can be seen at the following link:

- https://www.hydroone.com/abouthydroone/CorporateInformation/regionalplans/metrotoronto/Documents/Needs%20Assessment%20-%20Toronto%20Region%20-%20Final.pdf

B2.3 GTA North Regional Infrastructure Plan

The GTA North Regional Infrastructure Plan (RIP) was completed in February 2016. The plan is attached as Appendix D.[3]

[2] https://www.hydroone.com/abouthydroone/CorporateInformation/regionalplans/metrotoronto/Documents/RIP%20Report%20Metro%20Toronto.pdf
[3] https://www.hydroone.com/abouthydroone/CorporateInformation/regionalplans/gtanorth/Documents/Needs%20Assessment%20Report%20-%20GTA%20North%20Region.pdf

http://www.ieso.ca/en/get-involved/regional-planning/gta-and-central-ontario/central4
toronto-sub-region

allow an evaluation of the multiple options available to meet needs, including conservation, generation, and "wires" solutions. Regional plans also provide greater transparency through engagement in the planning process, and by making plans available to the public.

3.2 The IESO's Approach to Integrated Regional Resource Planning

IRRPs assess electricity system needs for a region over a 20-year period, except in cases where the Working Group participants agree on a different planning horizon.[2] The outlook anticipates long-term trends so that near-term actions are developed within the context of a longer-term view. This enables coordination and consistency with the long-term plan, rather than simply reacting to immediate needs.

In developing an IRRP, a different approach is taken to developing the plan for the first 10 years of the plan—the near- and medium-term—than for the longer-term period, 10 to 20+ years. The plan for the first 10 years is developed based on best available information on demand, conservation, and other local developments. Given the long lead-time to develop electricity infrastructure, near-term electricity needs require prompt action to enable the specified solutions in a timely manner. By contrast, the long-term plan is characterized by greater forecast uncertainty and longer development lead-times; as such solutions do not need to be committed to immediately. Given the potential for changing conditions and technological development, the IRRP for the long term is more directional, focusing on developing and maintaining the viability of options for the future, and continuing to monitor demand forecast scenarios.

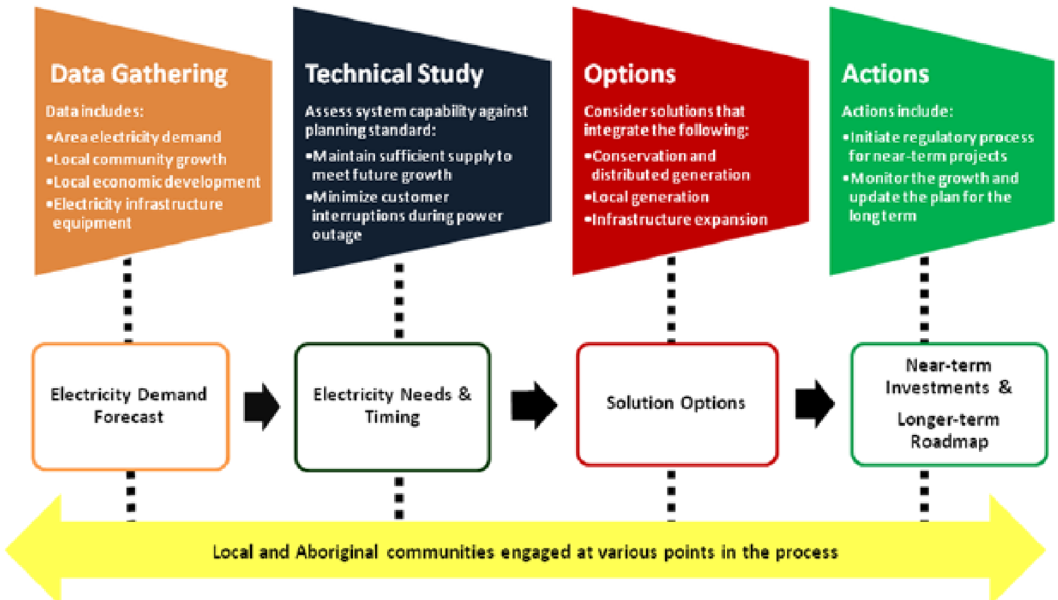
In developing an IRRP, the IESO and regional Working Group (see Section 3.3 below) carry out a number of steps. These steps include electricity demand forecasts; technical studies to determine electricity needs and the timing of these needs; the development of potential options; and, a recommended plan including actions for the near and long term. Throughout this process, engagement is carried out with stakeholders and First Nation and Métis communities, who may have an interest in the area. The steps of an IRRP are illustrated in Figure 3-2 below.

The IRRP report documents the inputs, findings and recommendations developed through the process described above, and provides recommended actions for the various entities that are

[2] In some cases, such as in this IRRP, the planning assessment was based on a 25-year forecast to account for longer-term growth potential and/or municipal plans. As planning for Central Toronto was initiated in 2011, the forecast period extends to 2036.

responsible for plan implementation. Where "wires" solutions are included in the plan recommendations, the completion of the IRRP report is the trigger for the transmitter to initiate an RIP process to develop those options. Other actions may involve development of conservation, local generation, or other solutions, community engagement, or information gathering to support future iterations of the regional planning process in the Region.

Figure 3-2: Steps in the IRRP Process



3.3 Central Toronto Working Group and IRRP Development

The Central Toronto IRRP process was commenced in 2011 by the Ontario Power Authority ("OPA"), in response to the significant rate of growth of new buildings and urban intensification in the downtown core and other areas within the central part of the city. It had been almost five years since the previous planning study for the area was done for the 2007 Integrated Power System Plan. The OPA proposed that a joint integrated planning study be undertaken which led to the establishment of the Working Group which as noted above included representatives of the former OPA, IESO, Toronto Hydro, and Hydro One.

The OPA developed a Terms of Reference that were signed by each of the participating organizations.[3] The Working Group gathered data, identified near term and potential long-term needs in the area, and recommended the near-term plan included in this IRRP. Implementation of elements of the near-term plan began in 2014 with the OPA issuing letters supporting near-term projects so that they could commence immediately in order to be in-service in time to address imminent needs.

This Central Toronto IRRP is therefore a "transitional" IRRP in that it began prior to the development of the OEB's regional planning process and much of the work was completed before the new process and its requirements were known. When the Regional Planning process was formalized by the OEB in 2013, the planning approach was adjusted to comply with the elements of the new process. This included the incorporation of formal input from electricity consumer groups in the city, municipal planners, other governments groups interested in electricity planning, industry stakeholders and interested community participants. This IRRP reflects this revised and updated information.

[3] The IRRP Terms of Reference can be found on the IESO website: http://www.ieso.ca/Documents/Regional-Planning/Metro_Toronto/Central-Toronto-IRRP-Terms-of-Reference.pdf

4. Background and Study Scope

The City of Toronto ("City"), the largest city in Canada by population and employment, has a very high land-use density of commercial and residential buildings, especially in the central parts of the city. Toronto is the largest electricity demand centre in Canada, at about 5,000 MW of peak summertime electricity demand, 40% of which (about 2,000 MW) is in the central area.[4] Extensive high density residential and commercial urban redevelopment has contributed to steady electricity demand growth in localized pockets, although the overall City of Toronto demand has been steady at around 5,000 MW for the last 10 years. This pace of growth in localized areas is expected to continue for the next several years. In recent years, more tall buildings have been under construction in Toronto than in any other major city in North America.[5]

To set the context for this IRRP, the scope of the IRRP and the existing electricity system serving the area are described in Section 4.1, and a summary of recent investments in the local electricity system is presented in Section 4.2.

4.1 Study Scope

The IRRP study area is shown in green shading in Figure 4-1. The study area is roughly bounded by Highway 401 to the north, Highway 427 and Etobicoke Creek to the west, Victoria Park Avenue to the east and Lake Ontario to the south. Most of this area operates at the 115 kV transmission level, whereas the surrounding Metro Toronto area is served at the 230 kV level. At the distribution level, most of the area operates at 13.8 kV, while the surrounding area is served by distribution at the 27.6 kV level.[6]

The 230 kV corridors supplying the two main 230kV/115kV transformer stations ("TS") in the east and the west are included within the scope of this IRRP. The individual supply stations along the 230 kV corridor in the east were included in the Metro Toronto Northern sub-region Needs Screening assessment completed by Hydro One in 2014.

[4] The central area includes the downtown central business area.

[5] There are starting to be some signs of a slow-down in the construction of condominium buildings in Toronto, however, at least 55 tall buildings remain under construction, with many more approved by the City of Toronto for construction. Therefore, despite the possibility of a slower pace of growth in the future, electricity system infrastructure will still be required in the near term to supply the growth that is known with more certainty.

[6] Exceptions in the Central Toronto Area include four transformer stations in the study area that supply distribution system voltages at 27.6 kV. These stations include Manby, Leaside, Runnymede, Fairbank, and Horner transformer stations. These stations are shown in Appendix B.

RESPONSES TO ND HANN INTERROGATORIES

INTERROGATORY 119:

Reference(s): **Exhibit 4B, Tab 2, Schedule 3 – 2016 Tax Return REDACTED, UPDATED, p. 47 of the PDF file, lines 41-55, section 244**

How many pole mounted wireless gatekeeper have been physically or electronically damage during storm events?

RESPONSE:

Toronto Hydro does not have records of any gatekeepers damaged due to storm events.

RESPONSES TO ND HANN INTERROGATORIES

INTERROGATORY 120:

Reference(s): **Exhibit 4B, Tab 2, Schedule 3 – 2016 Tax Return REDACTED, UPDATED, p. 47 of the PDF file, lines 41-55, section 244**

What was the time to restore the gatekeeper?

RESPONSE:

Please refer to Toronto Hydro's response to interrogatory 4B-Hann-119.

for that?

MR. KEIZER: So your question is who repairs the wireless gatekeeper? And what impact the damage has on customer bills; is that correct?

MR. HANN: Right.

MR. KEIZER: Yeah, I think that is fine --

MR. MILLAR: JTC2.28 --

MR. KEIZER: We don't really have records, apparently, but anyway, to the extent we can provide it we will.

MR. MILLAR: 2.28.

UNDERTAKING NO. JTC2.28: TO ADVISE WHO REPAIRS THE WIRELESS GATEKEEPER AND WHAT IMPACT THESE DAMAGES HAVE ON THE CUSTOMER BILLS; TO ADVISE HOW TORONTO HYDRO KNOWS THE GATEKEEPER HAS BEEN REPAIRED.

MR. HANN: And also 120, how does Toronto Hydro know the gatekeeper has been repaired, if you don't have any records?

MR. MILLAR: Can that be part of the undertaking, to the extent it can't be answered at this moment?

MR. HANN: Sure.

MR. MILLAR: Okay.

MR. HANN: And two more questions. 130 -- or, sorry, 8-134. So Toronto Hydro reviews the information sent by the other utilities like Rogers or Bell, correct? And what happens? Does Toronto Hydro change the poles if the loading exceeds the design loads? When is this done, and how many poles are changed due to the review/analysis?

[Witness panel confers]

TECHNICAL CONFERENCE UNDERTAKING RESPONSES TO ND HANN

UNDERTAKING NO. JTC2.28:

Reference(s): 4B-Hann-119

To advise who repairs the wireless gatekeeper and what impact these damages have on the customer bills; to advise how Toronto Hydro knows the gatekeeper has been repaired.

RESPONSE:

Wireless gatekeeper maintenance is performed by Toronto Hydro crews. Toronto Hydro knows that a gatekeeper has been successfully repaired when communication with the gatekeeper is re-established. If a gatekeeper is damaged, there is a possibility that the meters being read through that gatekeeper will be billed on estimated reads, which would be reflected in Toronto Hydro's billing accuracy measure reported to the OEB. Toronto Hydro currently meets, and slightly exceeds, the OEB's billing accuracy targets. Please see Exhibit 1B, Tab 2, Schedule 2 at pages 6-7 for more information about the utility's performance on this measure.

RESPONSES TO ND HANN INTERROGATORIES

INTERROGATORY 121:

Reference(s): **Exhibit 4B, Tab 2, Schedule 3 – 2016 Tax Return REDACTED, UPDATED, p. 47 of the PDF file, lines 41-55, section 244**

What was the cost to restore the gatekeeper?

RESPONSE:

Please refer to Toronto Hydro's response to interrogatory 4B-Hann-119.

RESPONSES TO ND HANN INTERROGATORIES

INTERROGATORY 123:

Reference(s): **Exhibit 4B, Tab 2, Schedule 3 – 2016 Tax Return REDACTED, UPDATED, p. 38 of the PDF file, lines 1-10, section 242**

The evidence states "THESL's network distribution system, used in the downtown core, is the most 2. reliable distribution system in use in the city of Toronto. Most feeder and 3. equipment failures do not result in any interruption to customers." [sic]

a) Is this because the downtown core is an underground system?

b) Is the system not exposed to tree damage to the infrastructure or

c) Are there other reasons?

RESPONSE:

a) The network distribution system experiences certain reliability benefits from being situated underground. However, the main contributor to the network distribution system's superior reliability is its unique ability to tolerate the loss of one or more primary feeders, network units, or secondary distribution cables without any interruption to customers. The network system has also been designed with the ability to self-isolate most faults without requiring human intervention. The attributes and benefits of Toronto Hydro's network distribution system are described in Exhibit 2B, Sections D2.2.3 and E6.4.

b) The network distribution system is largely isolated from damage caused by trees.

c) See response to part (a).

RESPONSES TO ND HANN INTERROGATORIES

INTERROGATORY 128:

Reference(s): Exhibit 4B, Tab 2, Schedule 3 – 2016 Tax Return REDACTED, UPDATED, p. 45 of the PDF file, lines 23-27, section 246

What are the failure causes for the studied equipment, by equipment type?

RESPONSE:

Please see Tables 1 and 2 below.

Table 1: Failure Causes by Equipment Type

Equipment Type	Root Causes
Transformer, CSP	Unknown, End of Life, Known Issue, Process, External
Transformer, Network	Unknown, Secondary Failure, End of Life, Process, Supplier Quality, External
Transformer, Padmount	Process, End of Life, External, Unknown, Lightning Strike, Supplier Quality, Secondary Failure, Overload, Overvoltage
Transformer, Polemount	End of Life, External, Process, Unknown, Supplier Quality, Secondary Failure, Lightning Strike, Overload, Overvoltage, Known Issue, Shipping & Handling, Compliance
Transformer, Station	End of Life
Transformer, Submersible	Supplier Quality, Process, End of Life, Overload, External, Secondary Failure, Unknown, Lightning Strike, Known Issue, Shipping & Handling, Overvoltage
Transformer, Vault	End of Life, Supplier Quality, External, Unknown, Overload, Secondary Failure, Known Issue, Process, Overvoltage, Shipping & Handling
Transformer, Other	External, Supplier Quality, Process, Overload, End of Life, Unknown, Lightning Strike
Circuit Breaker	End of Life, Process, Unknown, External

Equipment Type	Root Causes
Switchgear	Supplier Quality, Process, External, Unknown, End of Life, Secondary Failure, Known Issue
Switch, Manual	Unknown, External, Process, Supplier Quality, End of Life, Lightning Strike
Switch, SCADA	Unknown, Supplier Quality, Process, Known Issue, External, End of Life, Shipping & Handling
Switch, Other	Unknown, Supplier Quality, End of Life, Process, External, Known Issue
Network Protector	Process, Supplier Quality, External, Unknown
Pole, Guy Wire, Anchor	Process, End of Life, External, Unknown, Supplier Quality, Secondary Failure, Lightning Strike, Overload, Overvoltage, Known Issue, Shipping & Handling, Compliance
O/H Conductor Hardware	Supplier Quality, Process
Surge/Lightning Arrester	Unknown, External, Supplier Quality, Known Issue, End of Life
Insulator	Unknown, External, End of Life, Supplier Quality, Known Issue, Process
Cable	Unknown, End of Life, Process, External, Supplier Quality, Secondary Failure, Known Issue, Overload, Compliance
Splice/Termination	Process, Unknown, Supplier Quality, Secondary Failure, End of Life, External, Overload, Compliance
Fuse	Supplier Quality, Process, Known Issue, Unknown, External,
Crew Equipment/Tools	Supplier Quality, Process, End of Life, Unknown, Known Issue, External
Metering	Supplier Quality, Process, End of Life, Unknown, External
Misc. Vault Equipment	External, Supplier Quality, End of Life, Known Issue, Process
Communication	Supplier Quality, End of Life, Process, Secondary Failure, Known Issue, External, Unknown
Other	External, Unknown, Process, Supplier Quality, End of Life

Table 2: Failure Cause Definitions

Root Cause	Definition
Process	Caused by an internal process; may be further subcategorized as an issue with the design, installation, maintenance, operation, or standards/specifications.
Supplier Quality	Caused by the supplier/manufacturer; includes manufacturing issues, insufficient or lack of manufacturing procedures, product design, inadequate packaging, or damage from supplier, final inspection failure, failed/incorrect test reports.
End of Life	Unit has met or exceeded its useful life.
Unknown	Not enough information to root cause the failure.
External	Caused by events/conditions outside of the failed asset; includes animal contact, corrosion, contamination, extreme weather (for major event days), hit by vehicle, triggered by another failure, tampering (stealing, vandalism), and tree contact.
Overload	The unit was overloaded.
Secondary Failure	Failure on the secondary triggered a failure of the asset.
Known Issue	This is a known issue that has been investigated before and programs are already in place to correct this issue from future occurrence.
Lightning Strike	Lightning strike caused damage to the asset through means of overvoltage.
Overvoltage	Lightning/Switching/Other – failed due to transients or surges.
Shipping & Handling	Damage caused by shipping and handling within our own facilities or from our suppliers.
Compliance	Failed due to lack of adherence to standards.

RESPONSES TO ND HANN INTERROGATORIES

INTERROGATORY 129:

Reference(s): **Exhibit 4B, Tab 2, Schedule 3 – 2016 Tax Return REDACTED, UPDATED, p. 45 of the PDF file, lines 23-27, section 246**

What are the "new methodologies and strategies in improving 27. reliability and repeatability of distribution system assets"? [sic]

RESPONSE:

To drive improvements to standards and equipment, and thus improve the reliability of distribution system assets, Toronto Hydro develops strategies by investigating distribution equipment failures and identifying and analyzing the root cause (using the Root Cause Analysis (RCO) methodology). Depending on the nature of the root cause identified, various preventative actions can be used to mitigate reoccurrences of the same failure mode.

For example, if the root cause stems from a manufacturing defect, Toronto Hydro coordinates with the manufacturer to implement preventative measures at the facility and to perform manufacturing audits to verify the effectiveness of the measure(s). Where the root cause is attributed to an internal process issue, Toronto Hydro may release a bulletin, engage the relevant personnel in a safety meeting, or consider updating its Construction Standards and/or purchasing specifications.

For more details on Toronto Hydro's standards and practice review process, please refer to Exhibit 2B, Section D1.2.5.

RESPONSES TO ND HANN INTERROGATORIES

INTERROGATORY 131:

Reference(s): **Exhibit 4B, Tab 2, Schedule 3 – 2016 Tax Return REDACTED, UPDATED, p. 34 of the PDF file, lines 22-27, section 242**

What does "Reduction of momentary outages." refer to?

RESPONSE:

Reduction of momentary outages refers to decreasing the frequency of interruptions that last less than one minute.

RESPONSES TO ND HANN INTERROGATORIES

INTERROGATORY 134:

Reference(s): **Exhibit 8, Tab 2, Schedule 1, UPDATED: Sep 14, 2018, p. 3 of 5, line 1-10**

What processes are in place to ensure that the Wireline Attachements do not exceed the capacity of the pole to withstand wind and ice loading including the overload factor? [sic]

RESPONSE:

Toronto Hydro has a permitting process which requires third party licensees to submit a plan (drawings, instructions) and pole loading analysis for locations with proposed wireline attachments. The plan and pole loading analysis is reviewed by Toronto Hydro to ensure it complies with the requirements of Section 4 of Ontario Regulation 22/04 – Electrical Distribution Safety. This includes a review of pole loading with wireline attachments to ensure it withstands wind and ice loading, as per CSA C22.3 No.1-15 requirements.

every year our assets age, and more assets move into that red quadrant on that pie chart of assets past their useful life.

Renewal of assets is, for Toronto Hydro, a large problem. It requires billions of dollars, sustained effort, and many years. Improving demographics is important because for Toronto Hydro deteriorated equipment is the single largest cause for unreliability; that is shown on the chart to the right.

Our plan is to continue to focus in on deteriorating equipment and defective equipment outages. As shown on the chart to the bottom right, you will see that in recent years, and as Toronto Hydro has invested consistently in its system improved demographics, what we have actually been able to achieve is an improvement in reliability. That chart is of SAIFI, and demonstrates the average customer experience when it comes to the number of outages that customers experience in a given year. You will notice considerable improvement over the last decade and a half.

The plan that we have before the Board is aimed at maintaining the gains that we have achieved. What we want to do is we do not want to fall back, and our plan is designed to do that. However, there are significant pressures that continue to exist. Our equipment inspections continue to find high levels of deficiencies. We have neighbourhoods and pockets on our system that continue to experience poor reliability, and the need for reactive and unplanned replacements continues to be high.

As a result, our engineers and planners recommended a higher level of renewal investments. However, based on customer engagement and what we heard from our customers, we had to make some difficult decisions.

What I'd like to speak to you now is about some of those difficult decisions and the details of our underlying system renewal category.

In total, the category is made up of seven programs; one of the programs is station renewal. It addresses assets at our transformer stations. In fact, the picture of our top left is of our Windsor transformer station in downtown Toronto, and at our municipal stations, which is shown in the picture on the bottom left there.

Inside these stations, equipment has in many cases been operating for decades. Station assets are some of the oldest assets on Toronto Hydro's system, and they contribute to the roughly one-quarter of assets that are past useful life that I spoke to you about a few minutes ago.

Age, of course, is a high level indicator and in and of itself, it's not what drives our investment. What is most instructive for us is asset condition. Insights from our new asset condition methodology, as shown on this slide, are something that we relied on heavily when developing this plan.

The methodology itself categorizes assets in five health index bands, also called HI bands. The bands of most concern are HI4 and HI5, as they represent assets with at a least material deterioration. The methodology that we have adopted is an industry leading one. We are always looking for ways to improve our engineering analytics, and we devoted considerable effort over the last couple of years to move from a former ACA methodology to this new one.

This new one is used by Ofgem in the United Kingdom. For station assets, our circuit breakers and power transformers, the analysis shows that the number of assets in HI4 and HI5 are expected to significantly increase if we do not invest from 200 assets to 900. Given that stations are the backbone of a reliable system and given that station assets and renewal in the station environment can be challenging, challenging because often station assets are customized to a very particular location, they require significant design work before they can be replaced, and they often require coordination with other entities such as Hydro One. There is a strong need for us to increase expenditures in station renewal in the coming rate period.

Moving now from stations to the needs for our distribution lines, the next program I will speak to you about is area conversions. Area conversions funds the renewal of legacy installations. It is a continuation of efforts from recent rate periods.

One type of legacy installation is box construction. The picture on the bottom left is of Gerrard Street near Hastings Avenue in Toronto. That picture is from 1919. You will see on the right of that picture the very distinct

Questions by the Board:

MR. FRANK: I just have one question. Throughout this presentation, you talked about areas where you have improved, and there seem to be many, many areas where you made improvements. And you also talk about not backsliding. I heard that from several people, that that was a priority.

Yet, when I look at what you've spent over the last period, your last investment period and the performance, you were getting improvement at that level of spend. So one would think if it's just maintaining that you are interested in, you could actually reduce spend, and I know the link between outcomes or performance and investment is a bit tenuous.

But I was wondering have you done any scenarios, have you done any looking at how do we -- because your customers seem to be concerned about reducing cost. So how could you reduce cost and still try to maintain, or only have minor areas of deterioration if the focus is on reducing cost. I am just uncertain how much your focus was on reducing cost.

MS. KLEIN: Thank you for that question. That is very much the sort of question that we were working through ourselves as we were developing the plan. And we have ended up with a plan that I think goes to one of the points that you just mentioned, which is really about --fundamentally about maintaining service and with some very modest improvements, not looking at large improvements.

The types of improvements that we are looking at are things like improving reliability in certain pockets throughout the city that have reliability that's lower than the system average, for example. And what very much guided us in coming up with this particular plan was what we heard from customers.

We heard from customers that they don't want to see deterioration of service. We heard from them that they want to see maintaining service, safety, reliability with some modest improvements. And we were also guided by the customer acceptance, the two-thirds customer acceptance that we received for actually a price impact that was slightly higher than this plan.

So from that perspective we were guided by those inputs as well as the needs of the system, which is why we landed where we did, so we feel that we are consistent with what we heard from customers.

MR. FRANK: If I look at page 15 of your presentation, which showed capital spend and number of outages, there's actually incredible improvement in the outages, you know, very significant improvement over this period. And the spend except for the one-year blip looks to be higher. So I would have thought the outages would continue to improve, unnecessarily I'd say, from a customer's perspective. More concerned about my bill than my performance.

MS. KLEIN: Mm-hmm. I will give some opening comments and I will pass it over to Mr. Lyberogiannis to speak specifically about the reliability.

Our experience has been that it has taken us over a decade of concerted investment in order to see these types of improvements, that we have finally started to turn a corner, and our fundamental concern is not having the future look like the past and backsliding, and based on our engineering assessments and based on the customer input we -- and the needs of the grid we certainly believe that this level of spend is what is required in order to maintain. We are not looking to make significant improvements in our reliability, and we are not expecting to have improvements in -- big improvements in reliability in the future, so let me pass to Mr. Lyberogiannis to speak about some of those specifics.

MR. LYBEROGIANNIS: Thank you, Ms. Klein.

Yes, so in the process of developing the plan we actually asked exactly the same question that you asked, which is, you know, are there areas that we can pull back on and what would that mean for reliability, for example.

So what you will notice when you look through the programs in system renewal, which is, like I mentioned, the biggest program that we have, we seek considerable needs when it comes to deteriorating assets, and we are in fact looking to move into areas of the system that have very high consequence, so if a station asset fails and we potentially have, you know, a couple of failures, what will end up happening is you have a large number of customers out but lower probability. So what's going on is we are moving into stations, we are looking to invest in our network system, we are looking to invest in the downtown core, where we are starting to see higher consequence events that may not necessarily be shown in this particular reliability chart.

In other areas where we've achieved improvements -- and I mentioned to you in the horseshoe, for example, our underground horseshoe program, we are looking to maintain. In other areas in system service -- I had mentioned system expansion program, for example -- where we are able to leverage the investments that we have made in the past, we are looking to bring those programs to lower levels.

So you will see that balance throughout the plan, and each of the categories and each of the programs really have their own nuances, but ultimately the way the plan is designed, it is designed to maintain that level and to address obviously reliability risks but also broad risks that may not be necessarily evident when it comes to this particular chart, whether they are environmental, whether they are other customer-service type elements to them.

MR. FRANK: Okay, thank you for that.

MR. JANIGAN: Thank you. Mr. Nahyaan, I believe you indicated that over the last rate period extreme weather caused about $10 million in unanticipated expenses. Has that experience caused Toronto Hydro to change any forecasts with respect to both operations or potentially capital expenditures on the basis that potentially extreme weather is something that will be more recurrent as we go forward?

MR. NAHYAAN: Thank you for that question. The that we are looking to do.

MR. JANIGAN: Thanks very much.

MS. ANDERSON: Mr. Lyberogiannis, I was looking at your slide 7, and -- which has the outage stuff -- and it twigged a memory. I will just probe it since I am here. There's a large other category, and I seem to recall in your Exhibit U that there was large unknown category. Am I remembering that correctly? Is it an unknown category or is there an "other" bucket when it comes to reliability? And I know -- I didn't lug my binders down to double-check on this, and I know you didn't bring all your evidence, but...

MR. LYBEROGIANNIS: Yes, that's correct, Madam Chair. So the "other" bucket that you see there does have an unknown component to it. It also has a couple of other elements as well, tree contacts, human elements, so, yes, there are a group of outage causes that are within that specific green band in the chart.

MS. ANDERSON: Okay. So unknown is included in "other" in this slide 7 chart?

MR. LYBEROGIANNIS: Yes, that's correct.

MS. ANDERSON: Okay, thank you.

I would like to explore just the bill impacts a little bit. Ms. Klein, you said that it's a net 1.1 percent over the five years, but I think in your opening remarks it sounded like an inflation-adjusted number; is that correct?

MS. KLEIN: So the base rate impacts are 3 percent, and once we add the clearances of the deferral and variance

I take it from a lot of the evidence, it's on a system-wide basis that Hydro One looks at its system reliability as essentially average. Would that be a fair comment?

MR. LYBEROGIANNIS: Mr. Rubenstein, can I ask you to clarify the last part of your question? In terms of with respect to looking at it from a system-wide basis of being average? What do you mean by average?

MR. RUBENSTEIN: Well, when I look at the SAIDI and SAIFI metrics on a system-wide basis -- and we can walk through some of this -- as I understood from your response to Energy Probe 64 -- and I apologize it is not in the compendium -- you noted, as compared to Ontario utilities, you are in second-quartile SAIDI and third-quartile SAIFI, you reference the PSE study, where you are better than the benchmark in SAIDI and worse in SAIFI.

I take it that you seem to look at that as averaging things out, that you have average reliability compared to the benchmark on a system-wide basis. Is that a fair comment?

MR. LYBEROGIANNIS: Well, SAIFI and SAIDI are two measures of reliability, and, yes, on SAIFI we are typically in the third quartile, and, yes, on SAIDI we are typically in the second quartile. So on those two separate measure basis, yes, that is the fact.

MR. RUBENSTEIN: And am I correct as well you compare yourself against not just Ontario utilities and the benchmark that looks at U.S. utilities but also Canadian utilities as a whole?

MR. LYBEROGIANNIS: We do participate in sort of various groups where we do receive information around Canadian utilities, so, yes, we do look at them as indicators.

MR. RUBENSTEIN: Yes. So if we turn to page 21 of the compendium, this is your annual information form, so this is the document you provide to the public. On page 23, the only measure of reliability that I saw in the document as a benchmark was against the CEA, the Canadian Electricity Association, aggregate. Correct?

MR. LYBEROGIANNIS: In the annual information form we do have three measures of reliability, SAIDI, SAIFI, and CAIDI. And in this particular document the comparison is to the CEA composite.

MR. RUBENSTEIN: And you are much better? On all three of those metrics.

MR. LYBEROGIANNIS: With respect to the CEA composite we are. That doesn't necessarily -- yes, we are with respect to that composite measure.

MR. RUBENSTEIN: Well, there is no other benchmarking. I didn't see the Ontario benchmark or the U.S. benchmark in your annual information form.

MR. LYBEROGIANNIS: In the annual information form to the best of my knowledge there isn't any other reliability comparison, no.

MR. RUBENSTEIN: So obviously you value the CEA benchmark.

MR. LYBEROGIANNIS: Yes.

MR. RUBENSTEIN: You'd agree -- so we don't have to go through the numbers, but you agree with me that you are beating the targets?

MR. LYBEROGIANNIS: Yes, I do.

MR. RUBENSTEIN: And my understanding was the targets were based on the plan as filed, correct, in the last case?

MR. LYBEROGIANNIS: That's correct.

MR. RUBENSTEIN: And so you got benefits based on the plan that was filed, and the Board actually didn't even give you everything you needed, or you said you needed, more accurately.

MR. LYBEROGIANNIS: Let me take a step back, Mr. Rubenstein. Earlier during our dialogue this morning you drew my attention to the system renewal expenditures.

MR. RUBENSTEIN: Hmm-hmm.

MR. LYBEROGIANNIS: And you made reference to the fact that in system renewal, which is the category of spending which contributes the most to this particular set of reliability metrics that you have drawn my attention to, you will notice, actually, that in system renewal we have actually slightly spent more than what was the proposed plan in 2015 to 2019.

So it is not a surprise to me that with that magnitude of expenditure and the implementation execution of our plans within system renewal that we achieved the results that we did.

MR. RUBENSTEIN: So the Board made a reduction. You more. Within system access, we spent less. And again within system service, we spent less.

MR. RUBENSTEIN: Now, if we go back to page 18, this is the forecast, on SAIFI, as I understand, for the upcoming term, no improvements. Correct?

MR. LYBEROGIANNIS: We are forecasting to maintain SAIFI performance.

MR. RUBENSTEIN: And if we just flip over to the next page on SAIDI, similar. No improvements.

MR. LYBEROGIANNIS: We are also forecasting to maintain reliability on SAIDI, yes.

MR. RUBENSTEIN: So it goes back to what we discussed at the beginning. You are seeking 24 percent more in system renewal spending, but no improvements.

MR. LYBEROGIANNIS: Yes, that's correct.

MR. RUBENSTEIN: And is that value for money for customers?

MR. LYBEROGIANNIS: Yes, it certainly is. If you can bear with me for a second, I will find an interrogatory response which speaks to specifically that question that you are asking.

[Witness panel confers]

MR. LYBEROGIANNIS: Yes. Mr. Rubenstein, if I could draw your attention to U-EP 64, it is actually the interrogatory that you drew my attention to earlier with some of the benchmarking information.

And so if I can begin with the bottom of page 5, what I will do is paraphrase, as it is a bit of a longer

THESL_2020-2024 Distribution Rates Application Overview_20190503 Pg 9

Toronto Hydro's improvement in this reliability measure can be attributed to the utility's distribution system investments, grid operations performance, and various external factors that affect average outage duration.

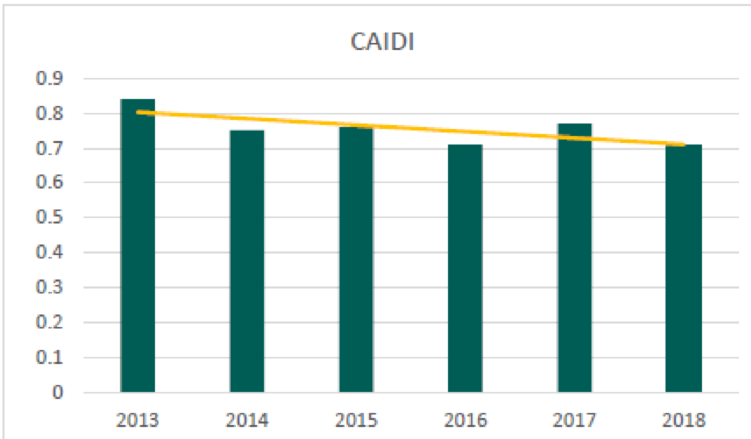


Figure 12: CAIDI Performance from 2013 – 2018

4.1.2 Momentary Average Interruption Frequency Index ("MAIFI")

MAIFI measures the average frequency of momentary interruptions (i.e. less than one minute) that affect Toronto Hydro's customers. Figure 13, below, shows the utility's performance for this measure over the 2013-2018 period. The five-year annual frequency value for the period 2014 to 2018 is 2.64 compared to the corresponding value of 2.74 reported in the utility's last Rate Application (for the period 2009 to 2013). For 2018, MAIFI was 2.78. This result represents an increase from the prior years, which is due to a number of drivers including weather.

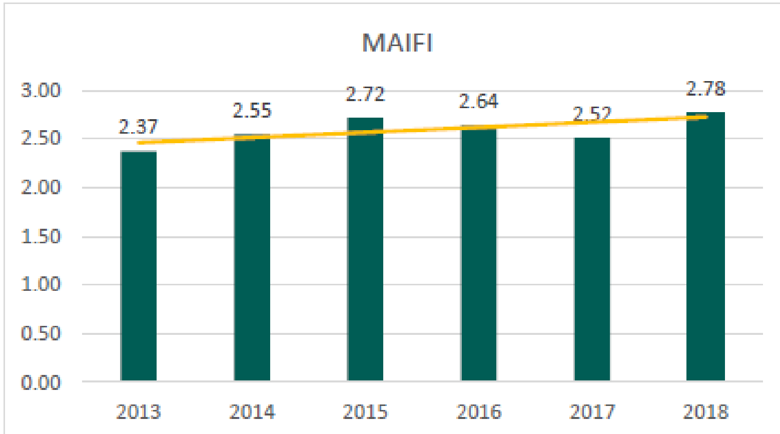


Figure 13: MAIFI Performance from 2013 – 2018

4.1.3 Outages caused by Defective Equipment

Figure 14, below, shows the utility's performance in this measure over the 2013-2018 period. In 2018, Toronto Hydro recorded 441 outages caused by defective equipment. The overall declining trend is indicative of Toronto Hydro's achievements in directing capital expenditures toward the renewal and modernization of its core distribution system assets.

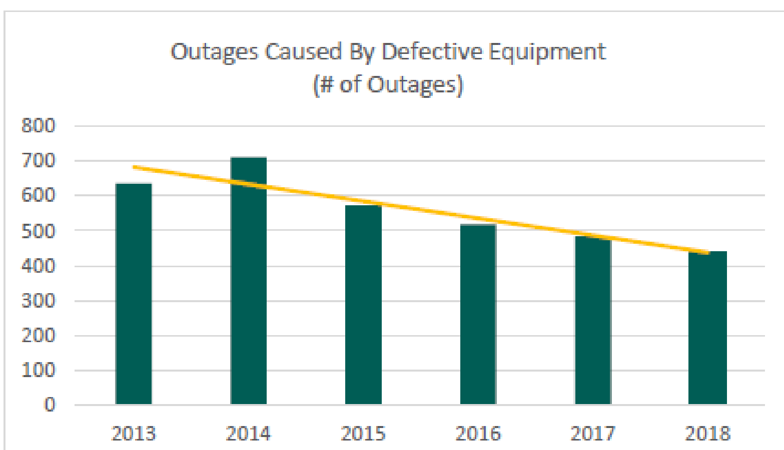


Figure 14: Outages by Defective Equipment Performance from 2013 – 2018

5.11 Emergency Response

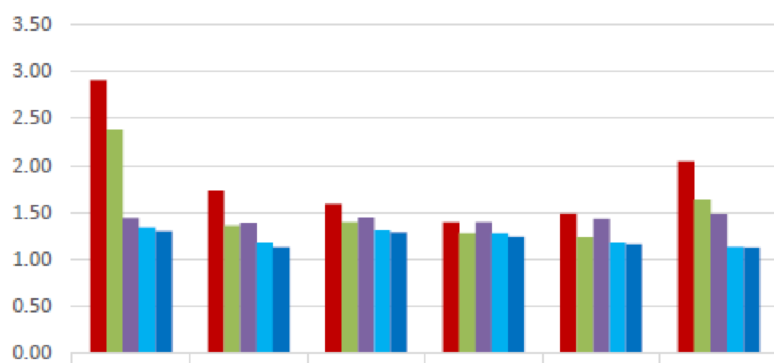
Toronto Hydro's Emergency Response performance decreased in 2018 when compared to the prior year. The 86.63 percent performance in 2018 compares to 93.6 percent in 2017. Over the course of 2018, Toronto Hydro experienced 11 significant weather events as compared to five in 2017. The total number of calls during a number of these events surpassed the number of field resources available for the company to respond within sixty minutes.

5.12 Reconnection Performance Standard

In 2018, Toronto Hydro's reconnection performance standard result was 99.65 percent, which is a slight increase from the 99.38 percent in 2017.

6. RELIABILITY PERFORMANCE

6.1 System Overview



	2013	2014	2015	2016	2017	2018
Total SAIFI	2.91	1.73	1.59	1.40	1.49	2.04
SAIFI Excluding LoS	2.38	1.36	1.40	1.28	1.24	1.64
SAIFI Excluding MED's	1.44	1.39	1.45	1.40	1.43	1.48
SAIFI Excluding MED's and LoS	1.34	1.18	1.31	1.28	1.18	1.14
SAIFI Excluding MED's, LoS and Scheduled Outages	1.30	1.13	1.29	1.24	1.16	1.13

Figure 16: System Level SAIFI

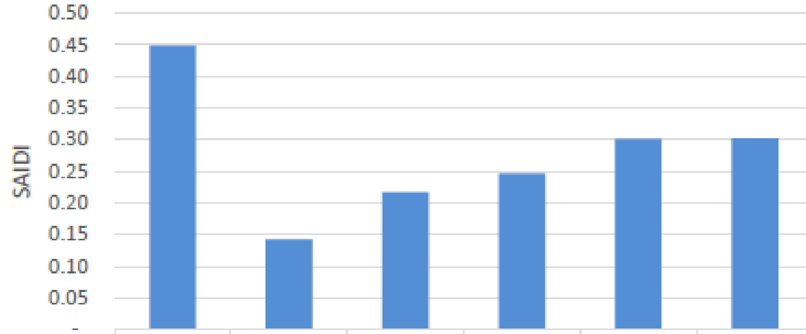
Figure 19 above shows an increase from 2017 to 2018 in the Loss of Supply impact on SAIDI.

6.3 Major Event Days

Major Event Days ("MEDs") experienced by Toronto Hydro since 2013 are shown in Table 4, below, including those in 2018.

Table 4: Major Event Days (including 2018)

Dates	Description	Number of Outages	Total Customers Interrupted	Total Customer Hours Interrupted
July 8, 2013	Major Storm (Thunderstorm)	56	324,672	2,377,913
July 9, 2013	Major Storm (Thunderstorm)	44	41,502	91,646
December 21, 2013	Freezing Rain Ice Storm	42	175,928	3,204,481
December 22, 2013	Freezing Rain Ice Storm	208	441,547	8,295,093
December 23, 2013	Freezing Rain Ice Storm	25	29,530	196,633
December 24, 2013	Freezing Rain Ice Storm	23	13,983	149,337
December 25, 2013	Freezing Rain Ice Storm	18	20,225	92,924
December 26, 2013	Freezing Rain Ice Storm	20	19,147	91,458
April 15, 2014	Loss of Supply to Manby TS	27	113,035	129,479
June 17, 2014	Major Thunderstorm	38	55,442	88,496
November 24, 2014	Wind Storm	46	82,053	99,027
March 3, 2015	Freezing Rain	49	107,242	291,672
October 15, 2017	Wind Storm	31	43,175	107,846
April 4, 2018	Wind Storm	68	97,378	112,230
April 15, 2018	Freezing Rain	47	85,281	164,214
May 4, 2018	Wind Storm	98	164,261	800,390
June 13, 2018	Wind Storm	31	35,366	96,504
July 28, 2018	Loss of Supply Finch TS (Tx Fire)	22	45,475	192,195



	2013	2014	2015	2016	2017	2018
SAIDI	0.45	0.14	0.22	0.25	0.30	0.30

Figure 29: Weather Impacts to SAIDI

6.8 Foreign Interference Impacts

Figures 30 and 31 below illustrate the impact of animal contact, dig-ins, vehicles, and other foreign objects on SAIDI and SAIFI. The 2018 cause analysis is consistent with prior year's results.

	ANIMALS	THIRD PARTY INTERFERENCE	MEMBER OF PUBLIC	VEHICLE
2013	0.04	0.05	0.00	0.04
2014	0.06	0.05	0.00	0.03
2015	0.05	0.04	0.00	0.02
2016	0.07	0.03	0.00	0.02
2017	0.04	0.05	0.00	0.05
2018	0.06	0.04	0.00	0.04

Figure 30: Foreign Interference – Root Cause SAIFI

not feasible. Restoration methods that utilities, specialized companies, and manufacturers have developed in this field were reviewed in order to restore the network as quickly and efficiently as possible. Evaluations and trials of the proposed methods will be investigated and tested prior to being implemented as a standard practice.

The following 2020-2024 program activities will contribute to Toronto Hydro's ongoing efforts to renew and enhance its system to increase resiliency to changes in the weather and climate, thereby supporting the continued delivery of outcomes expected by existing and future customers:

- As assets are replaced in the Overhead System Renewal program (Exhibit 2B, Section E6.5), Toronto Hydro will install taller poles with armless construction and tree-proof wire to reduce vegetation contact risks.
- Stainless steel submersible transformers will replace existing units as the utility carries out its Underground System Renewal – Horseshoe program (Exhibit 2B, Section E6.2).
- Underground System Renewal – Horseshoe program will also replace air-vented padmounted switches with SF_6 sealed-type padmounted switches to mitigate risk of failure due to ingress of dirt and road contaminants on the live surface.
- The Network System Renewal program (Exhibit 2B, Section E6.4) will replace non-submersible automatic transfer switches and remote power breakers with submersible equipment to tolerate flooding.
- The Network System Renewal program will also replace other end-of-life and deteriorated non-submersible protectors with submersible protectors to protect against flooding.
- The Network Condition Monitoring & Control program (Exhibit 2B, Section E7.3) will help the utility detect flooding in network vaults before it damages equipment.
- The Network Circuit Reconfiguration segment under the Network System Renewal program (Exhibit 2B, Section E6.4) will help the utility improve system restoration capabilities in the event of outages.
- Installation of flood mitigation systems at stations identified as being vulnerable to flooding will occur under the Stations Renewal program (Exhibit 2B, Section E6.6).
- New switchgear installed in the Stations Renewal or Station Expansion (Exhibit 2B, Section E6.6 and E7.4) programs will be specified to mitigate flood risk where appropriate (e.g. installing air-tight SF_6 switchgear or other engineered solutions).

- The Control Operations Reinforcement program (Exhibit 2B, Section E8.1) will improve Toronto Hydro's operational resiliency by developing a dual control centre at an existing work location.

Toronto Hydro is a partner of the City of Toronto in planning and preparing for the effects of climate change. The City's *ResilientTO* initiative includes a Resilient City Working Group that facilities collaboration between City divisions, agencies and corporations and external stakeholders on the topic of climate change resilience. Members share knowledge and technical information to facilitate the implementation of resilience actions within their operations.

D2.1.3 Economic Profile

The City of Toronto is Canada's economic and financial hub. It is home to the Toronto Stock Exchange, as well as the headquarters of five of the nation's largest banks. Toronto accounts for 10 percent of Canada's Gross Domestic Product ("GDP").[4] Its GDP growth has outperformed not only the national average, but also many of the most developed countries in the world in the past year, which is a trend that is expected to continue over the next year.[5]

Toronto also has a diverse industrial and commercial base comprised of 13 key sectors including aerospace, financial services, education, life sciences, technology, food, entertainment, and tourism.[6] The critical and growing importance of Toronto's economy underscores the necessity of continuing to invest sufficiently to ensure the delivery of value for current and future distribution customers and to prepare for technology driven change in this highly urbanized area.

D2.1.4 Toronto Hydro's Evolving Role in the City of Toronto

The role that Toronto Hydro plays in its service territory is evolving as new technologies emerge. In many cases, local and provincial policy imperatives aim to accelerate the uptake of new energy related technologies such as distributed generation and energy resources, and power quality, reliability and resiliency solutions.

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[4] City of Toronto, Business and Economic Development facts, (2013), online: <http://www.toronto.ca/toronto_facts/business_econdev.html>. ["Toronto Business and Economic Development Facts"]
[5] City of Toronto, Toronto Economic Bulletin, Conference Board (December 2016 & September 2017) and OECD Economic Outlook – Interim Release, September 2017
[6] City of Toronto, Business & Economy, online: <https://www.toronto.ca/business-economy/industry-sector-support/>. ["Industry Sector Support"].

around the rear lot program, and I talked about the reliability issues and the safety issues associated with those neighbourhoods. And it is described in detail in the evidence as well.

MR. LADANYI: You can correct me again. I believe that Etobicoke Hydro had specialized equipment, i.e. smaller equipment to access the backyards to get at those poles. And you don't have that, do you?

MR. TAKI: I can't confirm what Etobicoke Hydro had in terms of equipment.

MR. LADANYI: But is the rear lot really a very pressing problem? It seems to me it has been there for a long time, and your conversions are going at a slow pace and they're relatively expensive.

So is this a very urgent need? Or is this a nice-to-be-able-to-do-if-we-have-the-money need?

MR. TAKI: The rear lot program is a program where there is a need for us to address the issues associated with those areas, to convert those and to bring them up to the current standard, again as we discussed in detail yesterday.

MR. LADANYI: Now, in the same map, there is a legend about overhead. What does overhead mean?

MR. KEIZER: Just to be clear, Madam Chair, this is not a Toronto Hydro map. So the witness has identified and agreed that the legends read these things, and those legends correspond to something on the map. But just so we're not confusing this as being a Toronto Hydro map.

Madam Chair. I mean, we don't know the basis of the information, where it came from.

I know my friend is indicating it is coming from Environment Canada. The most that this reveals is that this is a trend. Whether or not that is the basis of its calculation or whatever else, I don't know if we can agree or disagree with respect to that. I don't think it is something within the purview of these witnesses.

MS. ANDERSON: Mr. Ladanyi, I think Mr. Keizer has a point.

MR. LADANYI: Yes. I heard his point. I will put it another way.

Does Toronto Hydro have any information that would be contrary to this? For example, let's turn to page 14, which is specific to Toronto. Do you have any information that is different that would say -- that would, let's say, prove your statement that there is increased frequency of severe weather?

MR. TAKI: Mr. Ladanyi, I would like to take you to -- there is a section in our evidence where we talk about extreme weather, and it provides a number of examples that hopefully will help address the question.

So if you go to Exhibit 2B, section A-4, and you go to page 12. You will see that we have provided a figure there -- actually, two charts. One of them is for cumulative rainfall and the other one is cumulative high-wind days. And what we've indicated there is that the days with the highest -- the ten days with the highest cumulative rainfall have occurred, as you can tell in the red, in the more recent years, and similarly as it relates to cumulative high-wind days.

And if you move to the next page, Table 4, we've described a number of extreme weather events that we have experienced over the last few years that demonstrate the statement that we started off with in this dialogue, that Toronto Hydro is experiencing more events around extreme weather.

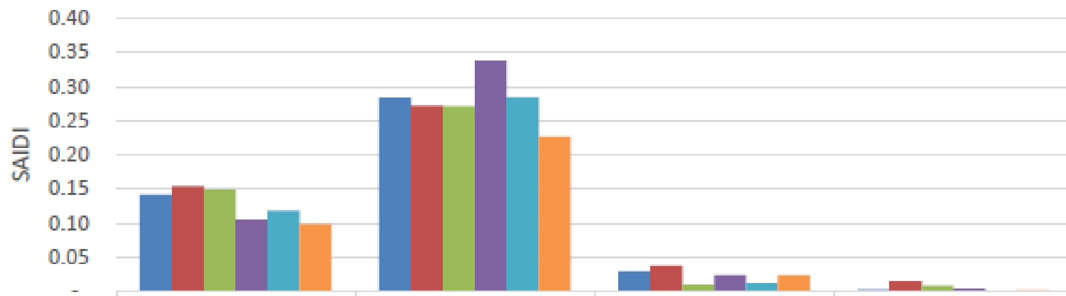
MR. LADANYI: I see that. If I could draw your attention to the letter from the Minister of Environment, Honourable Catherine McKenna, and what exhibit is that, please?

MR. MILLAR: 2.5.

MR. LADANYI: 2.5? Okay. In the middle of that letter, there is a sentence. It says:

> "Extreme precipitation is also projected to increase in the future, although the observation on the record has not shown evidence of consistent changes in short-duration precipitation extremes across the country."

So although there is a lot of other things in the letter -- and you can certainly refer to it -- here the Minister McKenna says that in fact the Ministry -- or the Department of Environment and Climate Change Canada does not have any evidence that there is a persistent or consistent change in short-duration precipitation. There'

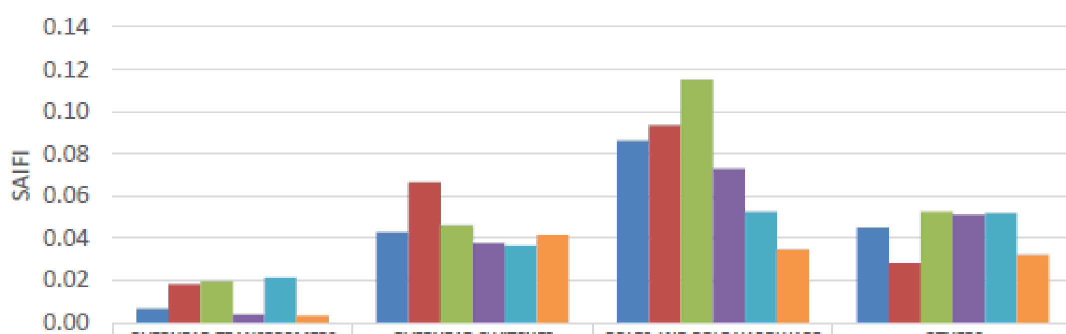


	OVERHEAD EQUIPMENT	UNDERGROUND EQUIPMENT	STATION EQUIPMENT	OTHERS
2013	0.14	0.28	0.03	0.00
2014	0.15	0.27	0.04	0.02
2015	0.15	0.27	0.01	0.01
2016	0.11	0.34	0.02	0.00
2017	0.12	0.28	0.01	0.00
2018	0.10	0.23	0.02	0.00

Figure 35: Defective Equipment SAIDI

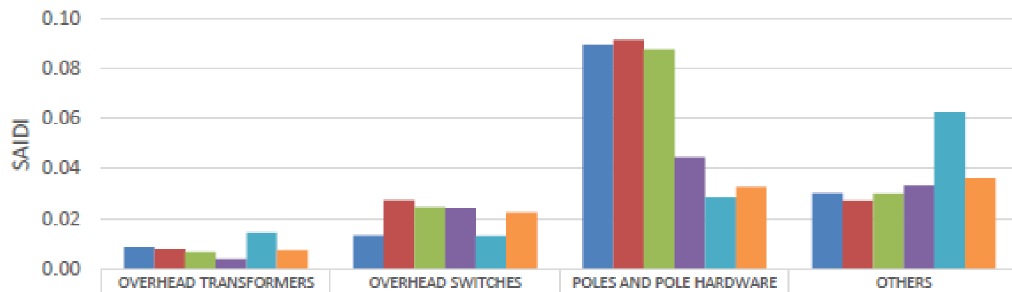
6.10.1 Overhead Defective Equipment

Figures 36 and 37 illustrate the trend of stable or improving outcomes continuing under most of the categories of Overhead Defective Equipment.



	OVERHEAD TRANSFORMERS	OVERHEAD SWITCHES	POLES AND POLE HARDWARE	OTHERS
2013	0.01	0.04	0.09	0.05
2014	0.02	0.07	0.09	0.03
2015	0.02	0.05	0.12	0.05
2016	0.00	0.04	0.07	0.05
2017	0.02	0.04	0.05	0.05
2018	0.00	0.04	0.03	0.03

Figure 36: Defective Equipment SAIFI – Overhead

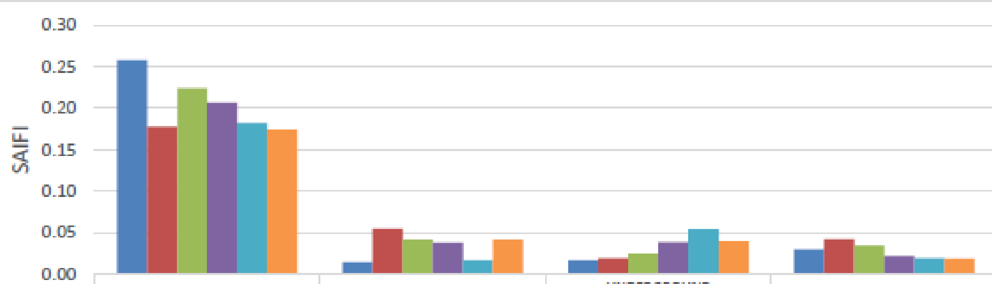


	OVERHEAD TRANSFORMERS	OVERHEAD SWITCHES	POLES AND POLE HARDWARE	OTHERS
2013	0.01	0.01	0.09	0.03
2014	0.01	0.03	0.09	0.03
2015	0.01	0.02	0.09	0.03
2016	0.00	0.02	0.04	0.03
2017	0.01	0.01	0.03	0.06
2018	0.01	0.02	0.03	0.04

Figure 37: Defective Equipment SAIDI – Overhead

6.10.2 Underground Defective Equipment

Figures 38 and 39, the cause codes for Underground Defective Equipment, illustrate the continuing stable or improving outcomes across all categories, with the exception of underground transformers, which have demonstrated a slight worsening trend in SAIFI.



	UNDERGROUND CABLES	UNDERGROUND SWITCHES	UNDERGROUND TRANSFORMERS	OTHERS
2013	0.26	0.01	0.02	0.03
2014	0.18	0.05	0.02	0.04
2015	0.22	0.04	0.02	0.03
2016	0.21	0.04	0.04	0.02
2017	0.18	0.02	0.05	0.02
2018	0.17	0.04	0.04	0.02

Figure 38: Defective Equipment SAIFI – Underground

Toronto Hydro's 2020 forecast program expenditure of $17.2 million is based on historical spending levels and work request volumes, after accounting for the higher 2017 costs to address a backlog of work.

4.2 Cost Control and Productivity Measures

Corrective maintenance expenditures are driven largely by work request volumes and the types of repairs required. With work request volumes rising and the budget remaining relatively stable, Toronto Hydro is getting more work done for fewer dollars. Toronto Hydro has taken steps to manage costs and improve work processes in this Program.

- In 2016, Toronto Hydro introduced new inspection forms to capture more objectively quantifiable and measureable facts from field inspections. The revised inspection forms presented engineers with greater visibility into asset health and allowed for more effective condition assessment and risk mitigation.
- Toronto Hydro also continues to emphasize "find it and fix it" practices in the Preventative and Predictive Maintenance programs, which promote the on-site repair of minor deficiencies as they are identified. Examples of minor deficiencies and associated corrective actions include lubricating components, replacing nomenclature, replacing faulted circuit indicators, replacing sump pumps, clearing drains, caulking ducts and roof slabs, installing missing guy guards, and repairing or replacing locks, hinges, and handles. Addressing these deficiencies while on site during Preventative and Predictive Maintenance reduces the likelihood of having to dispatch another crew in the near future.
- The work request process has been improved in several ways in recent years. In particular, the time required for processing deficiencies into work request for execution has decreased. Updated records have helped to clarify asset

ownership and to more appropriately allocate spending (i.e. Toronto Hydro issues Customer Action Forms to non-Toronto Hydro owned assets).

- Lastly, through the "find it fix it" approach, Toronto Hydro strives to have cable chamber nomenclature deficiencies corrected on the spot as the contractor performing cable chamber infrared inspection identifies the need for such corrections. This eliminates the need to create a separate work request and additional travel time for repair, resulting in savings of approximately $400,000 per year. Furthermore, deficiency and work request reviews are now done digitally. This leads to a savings of approximately $50,000 per year.

4.3 Corrective Maintenance Program Year-over-Year Variance Analysis

2015 – 2016 Variance Explanation

The costs from 2015 to 2016 increased by $0.7 million due to an increase in the volume of corrective maintenance work requests.

2016 – 2017 Variance Explanation

The costs from 2016 to 2017 increased by $3.5 million as work volume increased to address backlog of issues across distribution system, especially for station assets.

2017 – 2018 Variance Explanation

The costs from 2017 to 2018 are forecast to decrease by $3.3 million as the backlog of work in 2017 has been addressed and work volumes are expected to return to steady increase consistent with 2015 and 2016 expenditures.

2018 – 2019 Variance Explanation

There is no material variance in this period.

2019 – 2020 Variance Explanation

The costs from 2019 to 2020 are forecast to increase slightly due to a higher budget for vegetation management, which is necessary to mitigate interruptions caused by worst performing feeders.

savings of planned initiatives".

Then you say:

> "As part of continuous improvement throughout the planned period, Toronto Hydro intends to evaluate the operational efficiencies gained, as well as the reduced and avoided costs."

And that -- so my question is, there -- is why is it that you cannot or you have not estimated the approximate dollar value of these various initiatives? Is it because you haven't yet defined the initiatives sufficiently? Or you -- is it because you simply think that the -- it's impossible at this stage to identify the -- or estimate the dollar savings? Or is there some other reason why you can't specify what the -- not specify. I mean, you're not going to -- I understand -- I get that you are not going to be able to give us this to the dollar. But sort of an estimate, even a range, so one can get an idea of what the overall magnitude of these potential savings are. Are they really, you know, the reality of them, the magnitude of them? Do they seem proportional to the effort? Do they sort of generally, in a general sense, make sense?

And I have another -- you know, that's -- I would like that -- that is my first question. Why can't you do this, really?

MR. LYBEROGIANNIS: Perhaps the best way to answer that question is through an example and an illustration of how Toronto Hydro has communicated within all of the evidence that's on record, the efforts that we make when it comes to productivity.

So if I can draw your attention to Exhibit 4A, tab 2, Schedule 4. If we can go to page 11.

MR. BRETT: Now, this is in the OM&A, eh? Could you put that up, please? This is the paragraph --

MR. LYBEROGIANNIS: Yes.

MR. BRETT: All right.

MR. LYBEROGIANNIS: So this is an example, and this is pervasive throughout our evidence. You will see headings such as cost control and productivity measures. This is from our corrective maintenance program. And what you will notice is a series of bullets that outline cost control and productivity measures that we have undertaken.

This particular example has four bullets. The first one, for example, speaks to introduction of new inspection forms and how the data that we are receiving from those new inspection forms allows our engineers to make more comprehensive decisions and richer -- sort of a richer basis for the decisions we're making. And improvements such as that is very difficult to quantify on a dollar perspective.

The next bullet there speaks about what we refer to as "find it, fix it". It is a productivity initiative that we have introduced over recent years in our inspection programs, and what we're doing is we are arming our inspectors with equipment to make very -- to make relatively small fixes on-site; for example, replacing guy guards, replacing light bulbs, changing some hinges.

And AMPCO actually asked an interrogatory about this specific item, this specific productivity improvement, and I can actually read that reference into the record. We don't necessarily need to pull it up, but I believe, if I am not mistaken, it is 4A-AMPCO-79.

So there we actually quantified the number of work requests that we're saving through this type of productivity initiative. So with that initiative, we can quantify the dollars savings.

What our position is, is that throughout this evidence, you will see this type of heading; productivity is pervasive in everything that we do. Productivity is not about a list for us. It is really about how we operate our business.

So throughout the evidence, you will see those types of examples of productivity initiatives and the tangible benefits that we're receiving from them.

MR. BRETT: Well, thank you. There are some specific instances, particularly in respect to OM&A that you have pointed out.

At this stage, I am more interested in the way in which the capital budget incents or allows for productivity, and I asked the question in light of the passage I read you Hydro One decision that basically said: we want to see specific proposals and we want to see efforts to measure those proposals.

Now, they did leave open the idea that you could do this on a year-by-year basis, and report on a year-by-year

Thank you for your letter of comment. Toronto Hydro is sorry that you were disappointed with the community meeting presentations and responses to questions by OEB and Toronto Hydro staff. Recognizing the value of your time, if you have any specific feedback on how we in particular can do better, we would appreciate receiving that.

Regarding the gentleman who provided the presentation and asked questions, we believe you are speaking about Mr. Hann. We did not have the information readily available to answer those questions at the community meeting, and even if we had, providing the answers would have taken a number of hours and eliminated the time for other customers to provide their feedback and ask questions at the meeting. As you may recall, during the community meeting, we committed to providing written answers to Mr. Hann's questions on the public record as part of our application process before the Ontario Energy Board. As the OEB has since granted Mr. Hann intervenor status in this proceeding, he has now filed those and other questions in writing and Toronto Hydro is responding to them as part of the public record at the same time as filing this reply to your letter of comment.

Regarding rate increases and our plan to invest in the grid, you may also be interested in our reply to Mr. Lancaster's letter of October 4, 2018.

EB-2018-0165 Presented to the Meeting at North York Central Library November 22,2018

Members of the OEB and Toronto Hydro, thank you for the opportunity to speak today.

I have a number of comments and questions based on the Toronto Hydro submission EB-2018-0165, that I suspect you will not be able to answer immediately. It is my hope that your answers will be provided to me and the Ontario Energy Board (OEB) and that the answers will become part of the evidence considered by the OEB.

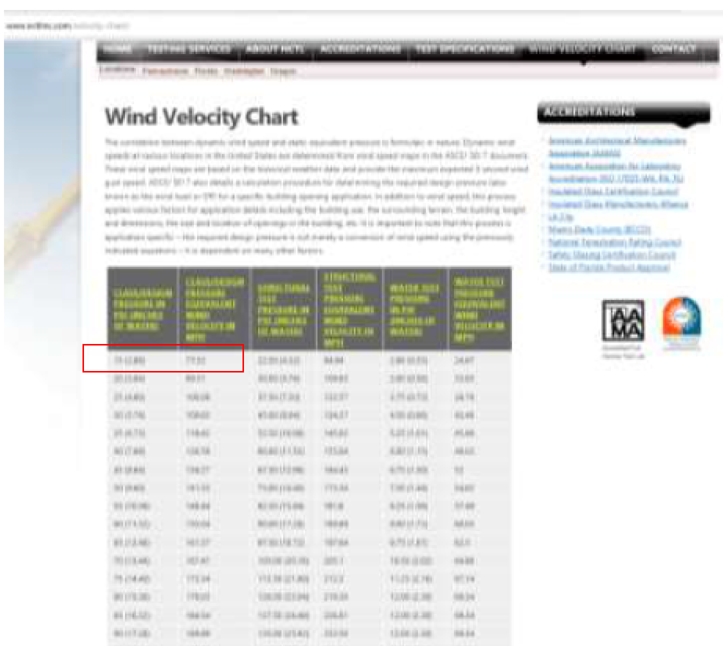
The evidence refers extensively to extreme weather conditions, high winds and ice and implies that capital spending will improve the reliability of the overhead distribution system.

Lets look at Weather Loads briefly

The evidence refers to CSA design requirements (CSA 2010) for overhead systems. (C.3.1.3 Case Specific Findings December '13 Ice Storm: Toronto, Hydro_CIR_Appl_Exhibit 2B_20180815 page 775 of the PDF file)

What are the design loads according to this standard? Are they 12.7mm of radial ice = ½ inch ice and 0.38 KPa = 8 PSF wind that translates to 124 KPH (77.5 MPH).

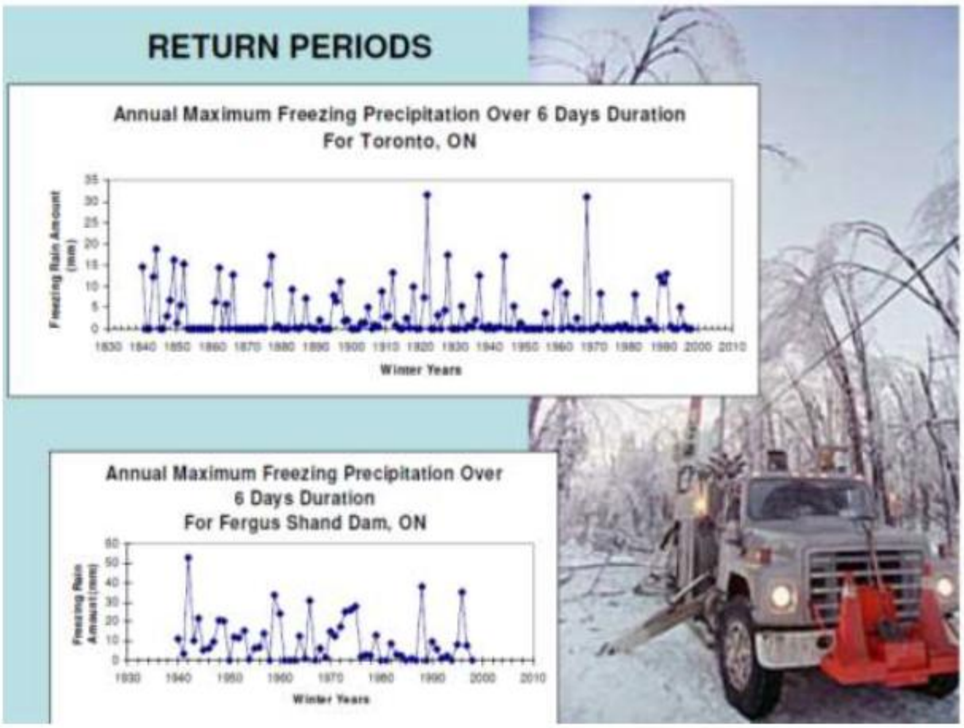
http://www.nctlinc.com/velocity-chart/



These values are calculated from the Ensewiler Formula, P = 0.00256 V^2, where V = Wind Velocity in MPH and P = the Differential Pressure across the window in Pounds per Square Foot (PSF).The equation assumes the direction of wind is perpendicular to the window and there are no effects from surrounding terrain or the shape of the building in which it is installed. Positive (+) pressures act inward and Negative (-) pressures act outward on the window.
An easier way to perform this calculation would be as follows:
Square Root of PSF X 20.016 (e.g. 15 Sq.Rt. = 3.87 X 20.016 = 77.52)

Would you please provide the actual data and dates (ice/wind from a recognized weather service) for the Toronto service ares showing that there is an increasing **frequency** of major weather events **that**

exceed the design loading (including the overload factor) of the assets of the Toronto Hydro system and the number times (including the overload factor) the CSA Standard for Pole Line Hardware and Wood pole design has been exceeded since 1840 as was done in the 2013 Ice storm report. (see http://www.iclr.org/images/2004_Nov_ICLR_Final_ICE_STORMS.pdf Page 17 for reference)?
Severe Ice Storm Risks in Ontario - Heather Auld Joan Klaassen M Geast, S Cheng, E Ros, R Lee
Meteorological Service of Canada Environment Canada-Ontario Region



Major Event Days

The evidence refers to Major Event Days or "MED" as defined by IEEE specification 1366.

a) Please provide the actual “Major Event Day (MED) Thresholds for exclusion”, dates and descriptions of the events from 2005 to 2018.
b) Please provide the expected “Major Event Day Thresholds” from 2014 to 2018(year to date - ytd) using just the 2008 to 2012 data which will provide expected performance in the future years and then compare it to the actual performance for 2014-2018 (ytd)
c) Please recalculate SAIDI and SAIFI based on “reduced days in the year” due to MED exclusions. Eg. If there were 10 MED than the “customer hours/customers served” should be factored so that it is based on 355 days and then normalized to 365 days to give a true year of year comparison.

Please show evidence as to why the events in Table 4 below are extreme events since they did not exceed the design loads with overload factor applied?

Table 4: Extreme Weather Events since the Beginning of 2017

Event	Description
Freezing Rain (February 2017)	• Approximately 2-6 mm of freezing rain followed by additional heavy rain. • Estimated 9,200 customers out at peak; all customers restored within 24 hours of the start of the freezing rain event.
High-water/flooding (May - June 2017)	• Heavy rainfall in southern Ontario exceeded the yearly average for an entire summer. • Numerous incidents of high-water/flooding reported across Toronto. • No customers were directly impacted during this 55-day incident due to the utility's proactive damage assessment and DPM mitigation measures, including flood mitigation efforts.
Wind Storm (October 2017)	• Strong wind gusts approaching 100 km/h in some areas and lasting approximately 3 hours. • Estimated 43,000 customers out at peak. • 90 percent of customers restored within 11 hours of event; all customers restored within 48 hours of the end of the event.
Wind storm (April 2018)	• Sustained 65km/h winds, with gusts approaching 90km/h. • Estimated 24,000 customers out at peak; all customers restored within 48 hours of the end of the event.
Ice Storm (April 2018)	• Approximately 10-20 mm of freezing rain, 20-25 mm rain, sustained winds of 70 km/h with gusts up to 110 km/h. • Estimated 51,000 customers out at peak. • 99 percent of customers restored within first two days of response; all impacted customers restored within 5 days of the start of the event.
Wind Storm (May 2018)	• High winds reported throughout service territory with gusts reaching approximately 120 km/h. • Estimated 68,000 customers out at peak. • 96 percent of customers restored within 48 hours of the start of the event.
Flash Storm (June 2018)	• High winds reported throughout service territory with gusts reaching approximately 90-100/h. • Estimated 16,500 customers out at peak. • 86 percent of customers restored within the first 12 hours and 97 percent of customers restored within the first 24 hours of the event.

Changing Urban Environment

Please note the change in the urban environment from some simple photos.

Blue spruce – photo taken in 1969 Blue Spruce photo taken Nov 2018

Please note that these 2 trees are on the same property separated by 49 years. This is one small example of how the urban vegetation environment has changed.

Another example is root system support failure. This tree's root system is contained on 3 of 4 sides. The lack of horizontal room for growth of the root system makes the tree vulnerable to wind and ice load above the ground so 40 years ago, this tree would have not caused an interruption or damage to the system. Today it would even though the house may have experience the same ice or wind storm 50 years apart.

The Norway Maple is another problem in the City of Toronto, it is an invasive species. According to the Toronto Star "The Norway maple is very resilient ... It gets into problems when it gets older because they have a weak structure, but they're good for the first 20 to 40 years, they grow really rapidly."

"They kind of give you that instant curb appeal, but then they kind of get more dangerous and more prone to falling down as they grow, whereas some of the native trees are a little bit slower off the get-go but then they mature into beautiful, functional trees."

https://www.thestar.com/news/gta/2018/11/07/how-torontos-ravines-have-become-critically-ill-and-how-they-can-be-saved.html

Native trees are meant to live in a forest – to support each other, with limbs and roots – they are not meant to be on their own in a confined root space – they need adequate root space horizontally in all directions to support horizontal and vertical loads on the tree.

Was the tree failure above due to high wind or the fact that the roots are contained on 3 of 4 sides?

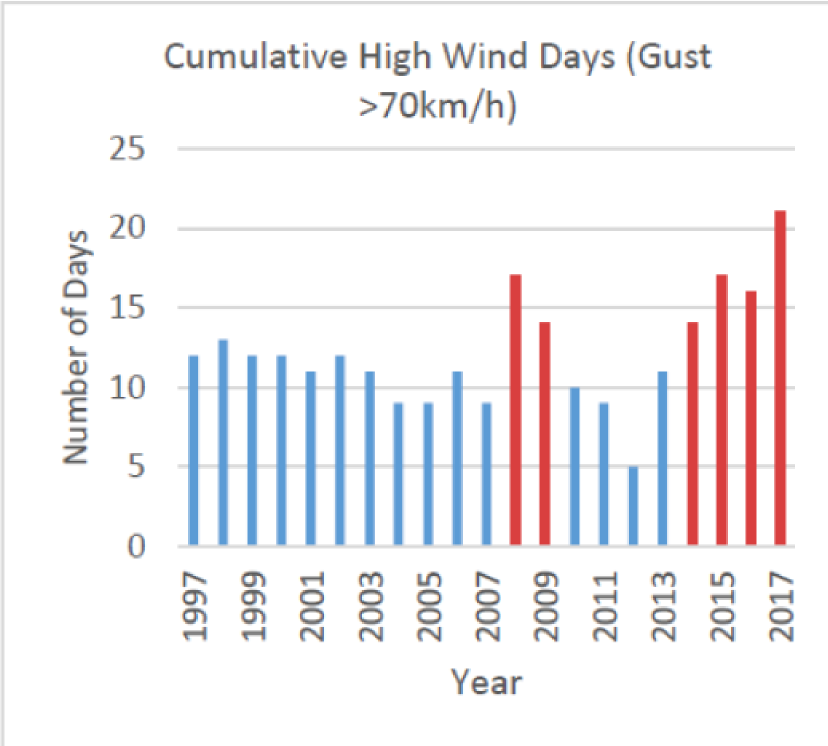
What is the restoration process? Is the feeder completely restored or are the largest interruptions restored first leaving individual transformers and customers to the end? This will impact the values of SAIDI and also MED's. Do you utilize "smart meter" data to assist in this process?

Why did Toronto Hydro choose 70 KM/hr as a wind speed threshold? The charts in the evidence imply that the poles are falling down at this speed, when in fact it is tree branches that are causing the problem. The trees have grown for 30 to 60 years since most of the system was build – does it not make sense that a tree that didn't exist in the 80's is now going to cause problems, especially the Norway Maples?

Background for 70 and 90 km/h and 15 mm ice

- The 70 km/h threshold for wind gusts, originally provided by Toronto Hydro staff during Phase I, appears to be correlated with tree damage, particularly during the warm portions of the year when deciduous trees are in full leaf, resulting in secondary impacts to the distribution system; further research is needed to confirm this relationship
- The 90 km/h threshold appears to be both related to the baseline climatic loading used in design of civil infrastructure components (see CSA 2010) as well as tree damage after deciduous trees have shed their leaves
- The lower bound of 15 mm for freezing rain totals resulting in tree contacts with overhead systems agree well with the findings from Klaassen et al. (2003)
- Freezing rain totals of less than 15 mm, however, may cause impacts when combined with high humidity environments near the 0°C boundary. This can specifically result in flashovers and other related impacts. While not as severe as direct damage to overhead lines and other equipment, these types of impacts can be numerous, widespread, and localized, presenting particular challenges for restoration efforts

According to the Beaufort Scale developed in 1805, 70 KM/hr is a "Fresh Gale" (Twigs broken from trees. Cars veer on road.) and 90 Km/hr is Whole Gale or storm (Trees are broken off or uprooted, saplings bent and deformed, poorly attached asphalt shingles and shingles in poor condition peel off roofs.). Does this mean that Fortis in Newfoundland and Nova Scotia Power lose their whole system every time an Atlantic storm blows through? Does Toronto Hydro design to CSA standards or just "blue sky days"?



Number of High Wind Days (right) in Toronto

EB-2018-0165 Presented to the Meeting at North York Central Library November 22,2018

Beaufort Wind Scale in Miles per hour (Mph), knots and Kilometers per hour (Km/h)				
Beaufort Scale Force	Wind in MPH	Wind in Knots	Wind in Km/h	Description - Wave Heights—Visible Condition
Force 0	0-1	0-1	0-1	Calm; Ht 0.0m ~ At sea no waves - glassy like appearance of sea.
Force 1	1 - 4	1 - 3	2 – 6	Light Airs Ht 0m ~ At Sea wind makes glassy ripples on water.
Force 2	4 - 7	4 - 6	7 – 11	Light breeze Ht 0.1m ~ At Sea smooth wavelets
Force 3	8 - 12	7-10	13 - 19	Gentle breeze Ht 0.4m Slight ~ At sea slight waves no white horses.
Force 4	13 - 18	11-16	20 – 30	Moderate breeze Ht 1m - Slight to moderate ~ At Sea waves described as with occasional white horses. On land raises dust and loose paper; small branches are moved
Force 5	19 - 24	17 - 21	31- 39	Fresh breeze Ht 2m Moderate ~ At sea consistent white horses
Force 6	25 - 31	22 - 27	40 – 50	Strong breeze Ht 3m Rough At Sea large waves start to form, more extensive white foam crests, some blown spray.
Force 7	32 - 38	28 - 33	51 – 61	Moderate (near) gale Ht 4m Rough to very rough. At Sea waves begin to heap up and streaks begin to appear down the waves. On land whole trees in motion; inconvenience in walking against wind
Force 8	39 - 46	34 - 40	62 – 74	Fresh gale Ht 5.5m Very rough to high At Sea waves get longer - crests break into spindrift and the streaks become more pronounced.
Force 9	47 - 54	41 - 47	75 – 88	Strong or severe gale Ht 7m High At Sea high waves and dense streaks of foam may begin to affect visibility. On land slight structural damage occurs; chimney pots and slates removed
Force 10	55 - 63	48 - 55	89 - 102	Whole gale or Storm - Ht 9m Very High At Sea very high waves with overhanging crests, lots of spray makes the sea almost white, visibility seriously affected.
Force 11	64 - 72	56 - 63	103 – 117	Violent Storm Ht 11m Very High At Sea exceptionally high waves and a complete coverage of long white foam patches. All crests blown into froth.
12	73+	64 +	118 +	Hurricane Ht 14m plus Phenomenal At sea the air is completely filled with driving spray, visibility extremely difficult. On land devastation occurs.

Date Printed: 2018-11-22 3:09 PM File: EB-2018-0165 N Hann Submission 2018-11-22 r1 Page: 7

Vegetation

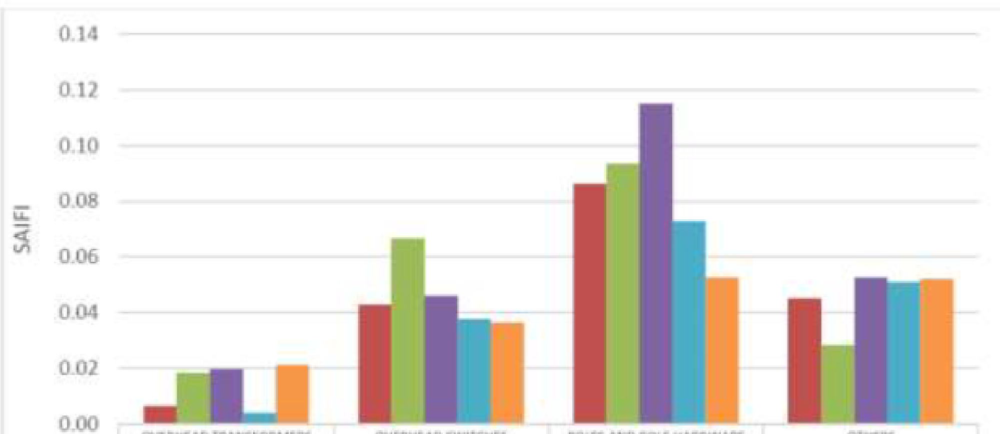
How up to date is the vegetation clearing in Toronto? The interruption problems appear to have been with trees. Trees that are mature and not growing upward as in a forest, but outward across lawns and roads as in an urban environment or with contained root balls between sidewalks, curbs and driveways which fail without proper vegetation management. How is Toronto Hydro planning to manage the vegetation assets in an effective manner given that the money that was awarded in 2014 does not appear to have dramatically improved the performance of the distribution system as illustrated by this rate application.

What is Toronto Hydro doing to get the City of Toronto to not plant trees on city property so they will grow into the wires?

Defective equipment

Does defective equipment mean the switch did not operate as it should have, or does it mean that the switch operated due to a root cause of say tree a branch falling on the conductor?

Does defective Pole and Pole hardware mean that the pole broke due to a structural load causing failure, or does it mean it broke because say a tree fell on the conductor and broke the pole?



	OVERHEAD TRANSFORMERS	OVERHEAD SWITCHES	POLES AND POLE HARDWARE	OTHERS
2013	0.01	0.04	0.09	0.05
2014	0.02	0.07	0.09	0.03
2015	0.02	0.05	0.12	0.05
2016	0.00	0.04	0.07	0.05
2017	0.02	0.04	0.05	0.05

Figure 21: Defective Equipment SAIFI – Overhead

What is the relationship with failed components and their age? In terms of forced interruptions what are the failure rates by age category?

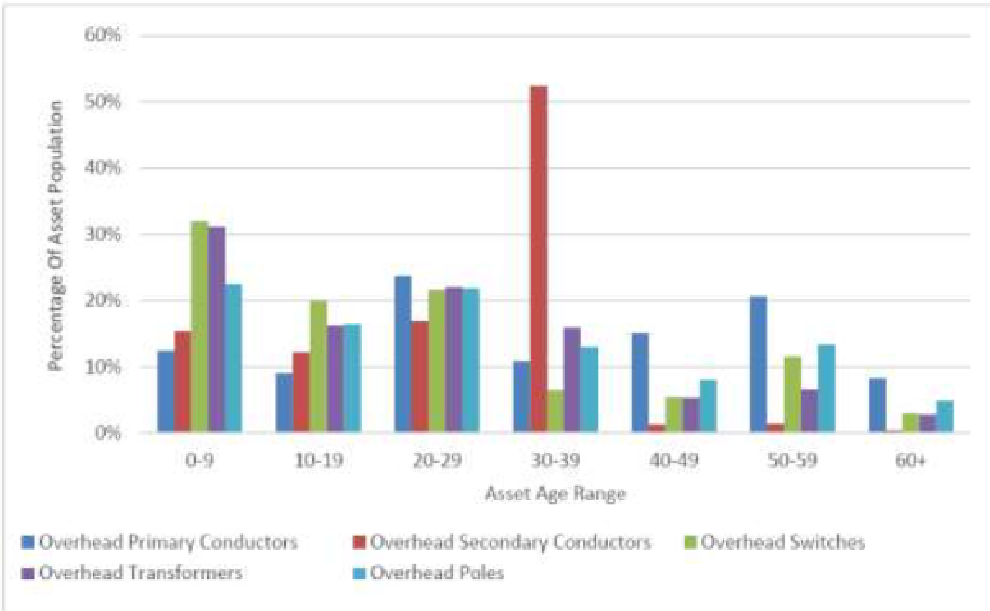


Figure 9: Overhead Assets Age Demographics as of 2017

Why is MAIFI not increasing given that Toronto Hydro should have more SCADA coverage since the previous rate filing?

See EB-2014-0116 Exhibit 1A Tab 2 Schedule 1 Page 13 line 23 footnote 4

These plans and programs include emergency response, enhanced emergency
22 preparedness, vegetation management, climate change adaptation studies, and key
infrastructural renewal and system service programs.4

4 These programs include Overhead Infrastructure Relocation, Rear Lot Conversation, Box Construction Conversion, Feeder Automation, Contingency Enhancement, Downtown Contingency and Design Enhancement.

How has feeder automation prevented large scale interruptions of the feeders where a branch falls on the line and the interruption is captured by the protective device at the station, not near the location of the falling tree or branch?

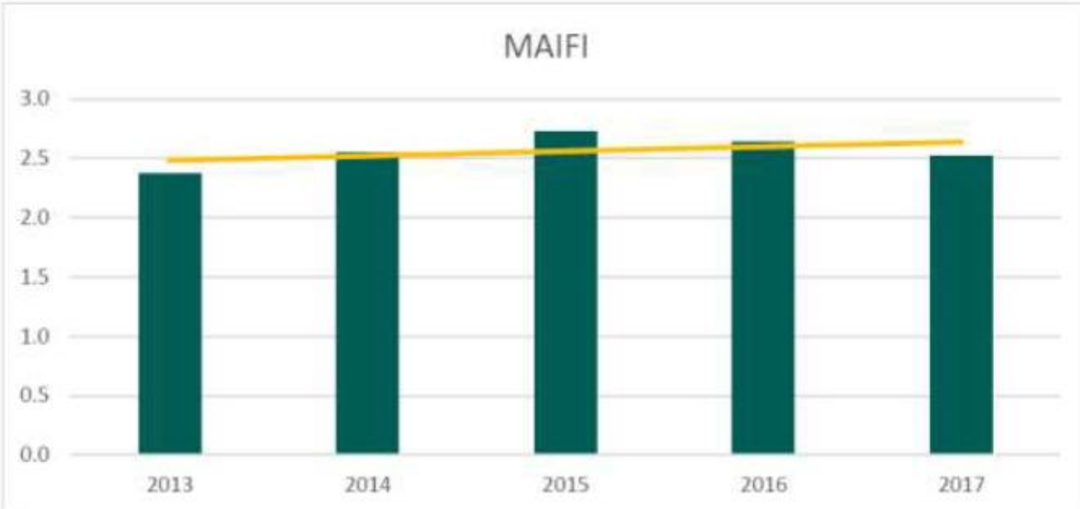


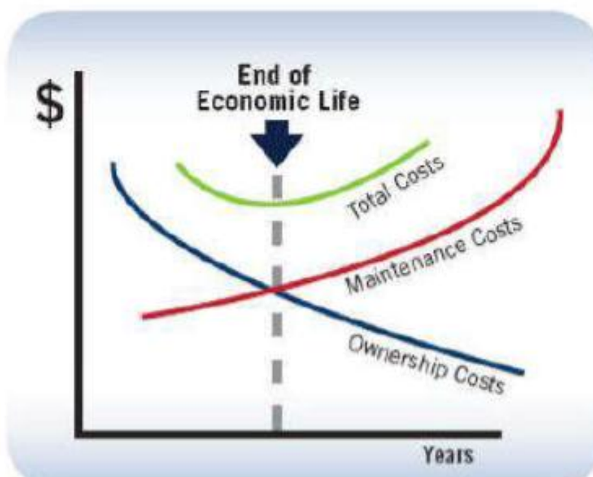
Figure 2: MAIFI Performance from 2013-2017

<u>Asset Condition and Replacement</u>

What are the criteria for Asset Condition Assessment ("ACA")?

What is the definition of "useful life"? Economic or physical, eg. Are you replacing assets because the book value is zero?

This is a very interesting graph that is in most asset management books. What are the **actual dollar curves for wood poles and conductor on the Toronto Hydro System,** since as stated in the evidence the maintenance that is done is mostly vegetation management which is not dependent on the age of the asset?



Why is Toronto Hydro not replacing assets "like for like"? In my subdivision the assets were replaced in the fall of 2013 with 10 foot higher poles and larger conductor even though there was no visible deterioration. The proof being that both assets withstood the 2013 ice storm with out damage and the interrupted switches were at the station feeder switch.

TECHNICAL CONFERENCE UNDERTAKING RESPONSES TO ND HANN

UNDERTAKING NO. JTC2.29:

Reference(s): **1B-Staff-17, Page 8**
Exhibit 2B, Section D4, Page 5 of 5

To provide a graph, say, of poles that shows the actual ownership costs, the maintenance costs, and thus the total costs for wood poles.

RESPONSE:

Please see Figure 1 for a graphical representation of the total annualized life cycle cost of a sample wood pole.

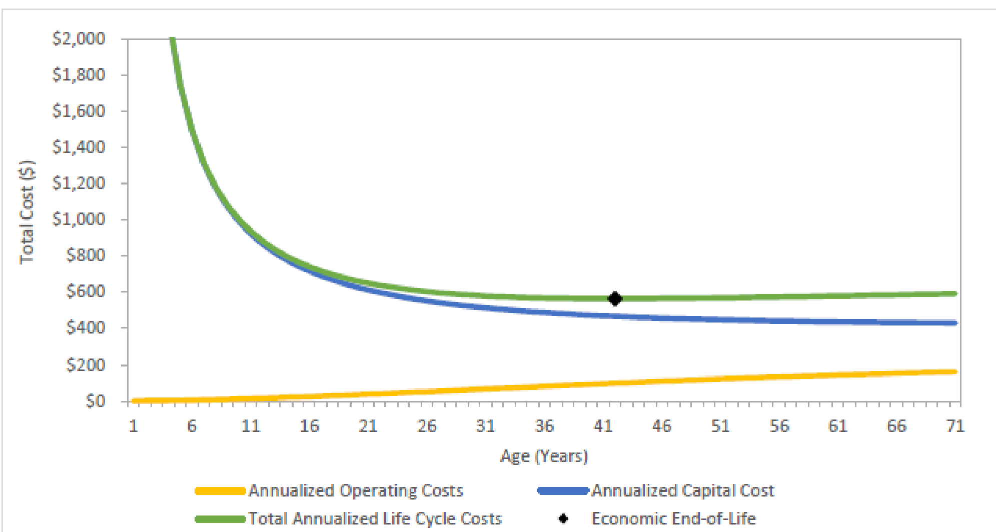


Figure 1: Total Annualized Life Cycle Cost of a Sample Wood Pole

Panel: Distribution Capital & Maintenance

Fuse coordination

How many interruptions occur at the station feeder switches? On average how many customers were impacted by interruptions at the station feeder switch? Where did the actual faults occur on the feeder? Were the fuses coordinated properly, so the interruption did not go back to the station feeder switch?

Does this information imply failure of the fused switches to capture the interruptions further downstream of the stations?

Please provide a list of feeders showing the names and dates when the last fuse co-ordination studies were performed and implemented to ensure the interruptions are captured at the switch directly upstream of the fault?

Meters

What was the replacement interval for mechanical meters used before the Smart Meter program? What is being done to ensure that Smart Meters have the same life span?

E5.4.3.2 Failure Risk

Toronto Hydro was among one of the first utilities to implement Smart Meters in support of provincial policy objectives, installing the bulk of its residential and small commercial meters between 2006 and 2008. Given Toronto Hydro's status as an early adopter provincially and globally, there is an absence of empirical data from other utilities and jurisdictions of meter failure rates in relation to asset lifespan. However, in an Asset Depreciation Study undertaken by Kinetrics for the OEB (the "Kinetrics Report"), the expected lifespan of a typical smart meter was determined to be 5-15 years, which is consistent with Toronto Hydro's internal observed lifespans of other electronic based operational technology assets.5 Beginning in 2021, Toronto Hydro's meters will surpass this 15 year lifespan, thereby increasing the probability of failure beyond standard operating levels.

By 2025,

approximately 90 percent of Toronto Hydro's residential and small commercial meters will surpass their useful life. This will negatively affect Toronto Hydro's ability to accurately bill its customers (which is tied to the OEB's billing accuracy performance standards) as failed meters result in estimated billing.

Residential Service Charge

What was the Residential Service Charge from 2005 to 2018? This was shown as a separate line item and is now buried in the bill so customers do not see it. Why should an additional "fixed rate" be imposed on the rate payers of Toronto because they have conserved energy?

Summary

- Design loads have not been exceeded
- Aging/Weakening urban vegetation is a major problem
- Are interruptions being captured in the correct locations by the protective devices?
- Large capital replacement programs are not the solution.

Would the OEB and Toronto Hydro agree that the Ice Storm of 2013 was one of the worst storms to hit the city in recent years?

Would also you agree that any similar storms from say 1960 would not have the same impact of the city then as now because the main reason for the interruptions is not equipment failure, but the failure of the urban forest in Toronto?

So maybe Toronto Hydro should be exploring ways to minimize tree damage due to the aging/weakening urban vegetation instead of replacing poles and conductor that do not need to be replaced.

> While ice accretion values likely approached or even slightly exceeded minimum CSA design requirements (CSA 2010) for overhead systems for small portions of the city of Toronto, Durham Region, and other areas, it appears that the vast majority of damage inflicted on overhead distribution lines during the ice storm was due to the impacts from falling tree limbs. Immediately following the ice storm, tree damage was indicated as "worse than originally anticipated" (TH Press Release, Dec 23, 2014, 3 PM)

> There are a large number of photos of large trees on the conductor/ground in the submission. Toronto Hydro's solution appears to be "replace" capital. This will not prevent these types of interruptions. The urban vegetation is 50 years older than what it was in the 1960's, trees have grown and trees are going to fail. The storms are still not exceeding the design criteria of 124 km/hr or 13 mm of radial ice.

What is Toronto Hydro going to do to address the root cause of failures other than communication and after the fact restoration? Is Toronto Hydro going to do fuse coordinations to isolate the interruptions where the trees fall? The philosophical question is answered; if a tree falls in the city does it make a sound? The answer, no but it causes a large interruption at the supply station feeder switch instead of being captured at the location of the fall.

Additional questions during the Q and A session

On the slide showing the customer bill, how much of the customer bill is dividend from Toronto Hydro to the share holder? (percent and actual dollars)

How is the dividend calculated? Or to put another way, what is it based on?

Figure 12: Deterioration at the base of a pole

Toronto Hydro examined the current and projected health scores of its wood pole population to ensure the proposed pacing of wood pole replacement could prevent failure risk across this asset class from worsening over the forecast period. As shown in Figure 13 below, about a third of Toronto Hydro's are showing at least material deterioration, with approximately 11,000 poles in each of the HI4 ("material deterioration") and HI5 ("end-of-serviceable life") condition bands. The utility projects this number could nearly triple to an estimated 34,000 by 2024 without intervention, including an increase in HI5 poles from approximately 1,000 to 17,000. The Overhead System Renewal program budgets for approximately 13,000 pole replacements between 2018 and 2024. Combined with pole replacements in the Area Conversions program and the Reactive Capital program, and prioritizing poles within or nearing the HI5 category, Toronto Hydro anticipates that its 2020-2024 expenditure plan as proposed is sufficient to manage wood pole failure risk.

Wood pole replacement is the highest-volume renewal activity out of the subset of assets that are analyzed through Toronto Hydro's ACA methodology. Given the importance of managing the overall condition-informed failure risk for this asset class over the planning period, the utility is proposing to track and report on wood pole condition demographics as a Custom Performance Measure over the 2020-2024 period (see Section C for more details).

Pg 26 01REDACTED_EX 4B_Tab 02_Sch 03 - 2016 Tax Return_THESL_UPDATED_201801113

Page 26 of the PDF file lines 5-15 section 244
r-4b-hann-11 Was the methodology developed by a subcontractor tested against the 25 years 1993 to 2017, using data from 1968 to 1992 or any period of time (eg 10 year periods) that would be reasonable to test the methodology? If yes, how did the predicted data correlate with the actual results?
Complete Dec 2017

5. A subcontractor **completed a long-term/25 year spatial peak demand**
6. forecast, including sensitivity analysis and a peak demand forecast process
7. design, based on City forecasts of population & employment and IESO weather
8. correction and extremes calculation, with the flexibility to handle multiple
9. CDM and DG scenarios. Different CDM and DG scenarios were analyzed using the
10. newly developed method. The Spatial Peak Demand Forecast from this study was
11. contributed to the Central Toronto IRRP. THESL also continued to work with
12. the OPA on developing contingencies for reliability and security analysis to
13. identify mid- to long-term needs of the transmission system supplying downtown
14. Toronto. Needs were examined on a probabilistic in addition to a
15. deterministic approach traditionally used.

Part 2 – Project information (continued)

Project number **4**

CRA internal form identifier 060
Code 1501

Complete a separate Part 2 for each project claimed this year.

Section A – Project identification

200 Project title (and identification code if applicable)

P3: Electric Power System Capacity Planning & Improvement

202 Project start date: 2007-03 (Year Month)

204 Completion or expected completion date: 2017-12 (Year Month)

206 Field of science or technology code (See guide for list of codes): 2.02.01 Electrical and electronic engineering

Project claim history

208 1 [X] Continuation of a previously claimed project

210 1 [ ] First claim for the project

218 Was any of the work done jointly or in collaboration with other businesses? . . . . 1 [ ] Yes 2 [X] No

If you answered **yes** to line 218, complete lines 220 and 221.

220 Names of the businesses	**221** BN
1	

Section B – Project descriptions

242 What scientific or technological uncertainties did you attempt to overcome? *(Maximum 50 lines)*

1.
2. The technological objective of the project is to develop more accurate and
3. flexible tools for peak demand forecasting and option development. The
4. primary tool for input into subsequent tools is the load forecasting tool.
5.
6. Challenges with current methods are: 1) they deal poorly with abrupt changes
7. in underlying drivers of peak demand, 2) they are not flexible to include new
8. factors (without previous history) that will increase electricity demand such
9. as the electrification of transportation as proposed in the Ontario Climate
10. Change Action Plan and 3 they do not provide understanding in the seasonality
11. of peaks (as compared with a yearly peak) and further they are not designed
12. to provide an hourly profile for peak conditions (which would be necessary in
13. order to understand the feasibility of non-wires solution to deal with peak
14. constraints).
15.

244 What work did you perform **in the tax year** to overcome the scientific or technological uncertainties described in line 242? (Summarize the systematic investigation or search) *(Maximum 100 lines)*

1.
2. Investigation into two key studies continued from the previous tax year.
3.
4. In the first, new methods/techniques, beyond current practices, were
5. developed. A subcontractor completed a long-term/25 year spatial peak demand
6. forecast, including sensitivity analysis and a peak demand forecast process
7. design, based on City forecasts of population & employment and IESO weather
8. correction and extremes calculation, with the flexibility to handle multiple
9. CDM and DG scenarios. Different CDM and DG scenarios were analyzed using the
10. newly developed method. The Spatial Peak Demand Forecast from this study was
11. contributed to the Central Toronto IRRP. THESL also continued to work with
12. the OPA on developing contingencies for reliability and security analysis to
13. identify mid- to long-term needs of the transmission system supplying downtown
14. Toronto. Needs were examined on a probabilistic in addition to a
15. deterministic approach traditionally used. A broader Metro Toronto Regional
16. Infrastructure Report Plan (MTRI) extrapolating from the central IRRP was made
17. and incorporated GO Line electrification and other potential future system
18. additions. Through FY2016, a method to reduce work load in forecasting was
19. pursued, and a new load forecasting approach conceived as a result of the

Appendix A – Supporting Material

UMS Group used the following THESL provided information and data to support the study:

- Unit Cost Survey – THESL September 5, 2017 (THESL Response to Unit Cost and Accounting Tabs on the Survey Form)
- 2-AMPCO-3 Table of Costs
- 2015-2019 Programs to Asset Category Mapping_V2_20170801 (Capital Program Tracker)
- Capital UC Methodology (Capital Unit Cost Methodology-Power Point Presentation)
- Interrogatory Response-AMPCO (1-AMPCO-3 filed May 27, 2016)
- Maintenance Practice
- SAIFI SAIDI 2012-2016 (2012-2016 SAIFI SAIDI by Cause Code with and without MED for Lines and Stations)
- SAP Asset Class Mapping Extract 08082017)Master Spreadsheet of Distribution Assets)
- THESL-Reply Argument (EB-2014-0116 pages 66 through 68 13398-2009 19208026.4)
- THESL LTR Affidavit of A. Rouse 20150116 (THESL Custom Incentive Rate Application (EB-2014-0116 dated January 16, 2015)
- THESL Response AMPCO Motion Settlement 20170121 (THESL Custom Incentive Rate Application (EB-2014-0116 dated January 21, 2015)
- THESL SUB AMPCO Affidavit of M. Walker dated January 13, 2015 (THESL Responses to motions filed by Energy Probe and AMPCO on December 22nd and 31st, 2014)
- UMS Info Request Response 2017-09-15 (Estimated Labor % per Unit by Asset Class – Capital / Regulated Safety Training, and Employee Fringes)
- Unit Cost Local Factors (THESL Response to Local Factors Tab on the Survey Form)
- Unit Costs for Benchmarking Study – Maintenance (VM, Pole Testing, OH Line Patrol and IR Screening, OH Switch Maintenance, and UG Vault Inspection 2014 through 2019)
- Whitepaper Adoption of IAS16 PPE Engineering and Admin Reclassification 2010-04-03 (“EAR” Version V5.7-Final dated July 30, 2010)

Appendix B – Peer Group

The Peer Group Panel used for this study consisted of 17 electric utilities; namely:

- AES-IPL (Indianapolis, IN)
- AES-DPL (Dayton, OH)
- Ameren UE (St. Louis, MO)
- Baltimore Gas and Electric (Baltimore, MD)
- Detroit Edison (Detroit, MI)
- Dominion – VP (Richmond, VA)
- ENMAX (Edmonton, AB)
- FirstEnergy CEI (Cleveland, OH)
- Lansing Board of Water and Light (Lansing, MI)
- Pacific Gas and Electric (San Francisco, CA)
- Portland General Electric (Portland, OR)
- Philadelphia Electric Company (Philadelphia, PA)
- SMUD (Sacramento, CA)
- SaskPower (Regina, Saskatchewan)
- Seattle City Light (Seattle, WA)
- Southern California Edison (Southern California including Los Angeles suburbs)
- Xcel Energy – MN (Minneapolis, MN)

In selecting the utilities that comprise this group, we strove to provide results based on comparisons that would be relevant to an electric utility of THESL's size and complexity (and where there are inconsistencies, apply industry-accepted normalization processes – ***see*** Appendix C). Table B-1 illustrates THESL's relative position across the myriad factors that need to be considered in conducting like-for-like unit cost comparisons of Electric Distribution Companies; and though no two Electric Distribution Systems / Organizations are identical, THESL is among the highest percentages within this peer group for four of five factors that can influence comparisons to unit costs.

There are 83 U.S. utilities in the sample for the cost model, plus seven Ontario distributors (including Toronto Hydro). The observations for the U.S. sample span the years 2002 to 2016. The observations for the Ontario distributors span the years 2005 to 2016.[13] Eight data points fall outside that range: Toronto Hydro's projected data from 2017-2024. The total number of observations in the dataset is 1,318.[14] Observations were excluded if key data (cost or outputs) were missing or implausible. Additional exclusions were made due to mergers, or where there was missing or implausible explanatory variable data. The large number of observations is more than sufficient for the creation of a statistically robust econometric model.

Ontario distributors were added if a portion of their service territory was classified as "congested urban" (see Section 2.3.4). This added six Ontario distributors to the sample. No other Ontario distributors have been identified as containing "congested urban" service territory.

2.2 Summary of Variables

In general, there are two types of variables used in econometric cost benchmarking: output variables and business condition variables. Output variables measure the output of the utility in question (i.e. what the utility "produces"). Business condition variables quantify the factors that drive costs in a particular service territory, such as regional input prices, highly congested urban areas, forestation, etc.

The output variables used in the total cost econometric benchmarking research are:

- Retail customers, and
- Maximum peak demand.

The business condition variables used in the total cost econometric benchmarking research are:

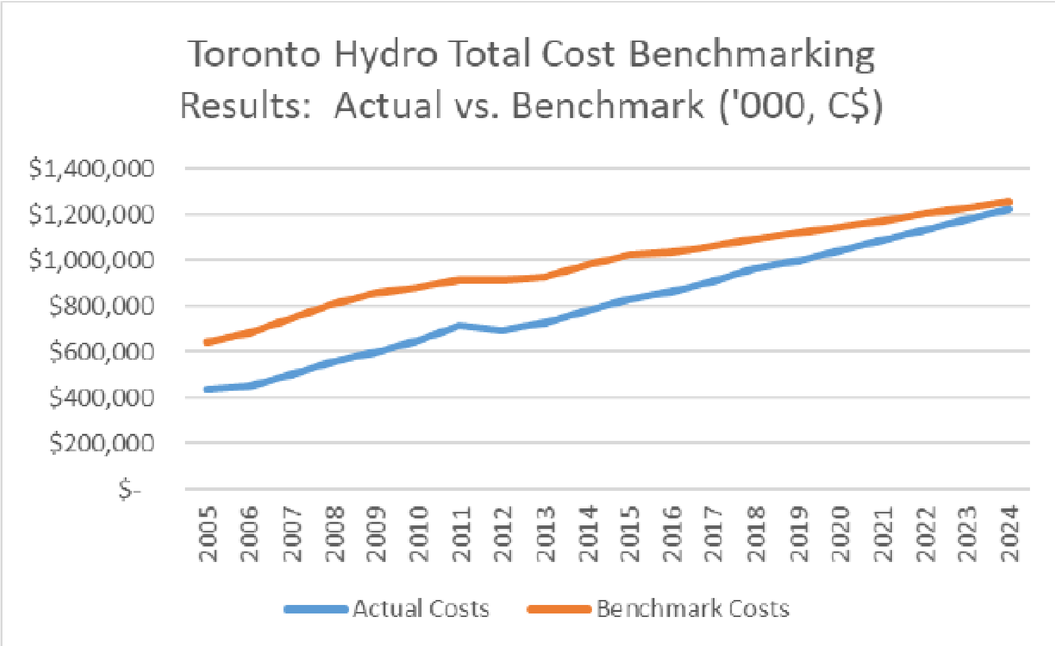
- Regional input prices;
- Percent electric customers (out of total gas and electric customers);
- Standard deviation of the elevation within the territory;
- Forestation of the service territory;
- Percent service territory classified as congested urban;
- Percent smart meters deployed on system;
- Percent distribution plant that is underground;
- Percent distribution plant that is underground multiplied by the congested urban variable;
- An Ontario binary variable indicating whether the distributor operates in Ontario or the

---

[13] 2005 is the first available year of Uniform System of Account data for the Ontario distributors.

[14] These total observations and the reported total cost model include Toronto Hydro's observations. However, when constructing the Toronto Hydro benchmarks, the company's observations are excluded from the modeling dataset to assure the benchmark is external to Toronto Hydro.

Figure 1 Toronto Hydro's Cost Performance 2005-2024



1.4 Reliability Benchmark Findings

In addition to total cost benchmarking, PSE conducted econometric reliability benchmarking of Toronto Hydro's system average interruption frequency index ("SAIFI") and the customer average interruption duration index ("CAIDI"). When presented with cost benchmarking, reliability benchmarking presents a more complete picture of a company's performance, since in general, lower total costs can come at the expense of reliability. Both indexes exclude major event days ("MEDs") from the calculation of the metrics, which permits them to gauge reliability performance during normal operating conditions.[8] SAIFI measures how many outages an average customer experiences, whereas CAIDI measures the average duration of those outages. This separates the evaluation into examining how often the system fails (SAIFI) and the length of the company's restoration time when the system fails (CAIDI).[9]

[8] This differed from the 2015 CIR reliability benchmarking research, where we included MEDs. The reason for including MEDs in the prior research was that MED exclusion information was not yet available for the Ontario distributors and we included Ontario distributors in the combined dataset. For the 2020 research, we decided to focus on the U.S.-only sample for the current reliability research, because of the limited MED excluded data for Ontario. This allowed us to exclude MEDs and provide a benchmark analysis that excludes the large variations that result from severe weather events.

[9] Our 2015 CIR research examined SAIFI and SAIDI. However, since SAIDI is the product of SAIFI and CAIDI, the SAIDI index includes both the system failure and the restoration time in the index. Separating the two evaluations

PSE gathered U.S. data for the reliability indexes from annual regulatory filings and the EIA-861 form.[10]

PSE's reliability benchmarking analysis resulted in the following findings.

1. Historical SAIFI metrics for Toronto Hydro are considerably higher than the benchmark values.
2. Projected SAIFI metrics remain higher than the benchmarks.
3. Historical CAIDI metrics for Toronto Hydro are considerably lower than the benchmark values.
4. Projected CAIDI metrics for Toronto Hydro continue to be lower than the benchmark values.

The following table and graph illustrate the historical and projected SAIFI values for Toronto Hydro as compared to benchmark values, using a dataset consisting of of 73 U.S. distributors.[11]

provides a cleaner look at how often the grid fails and how long it takes to restore electricity when it does fail.

[10] Beginning in 2013, US utilities were required to file reliability data to the Energy Information Administration (EIA). This data is compiled in the EIA-861 form.

[11] The reliability sample is smaller than the total cost sample for two reasons: (1) Ontario distributors were not included (because data was not available in some cases and MED exclusion information was not available in other cases), and (2) Some of the U.S. utilities had missing or implausible reliability data, and so were left out of the dataset.

Independent Statistics & Analysis U.S. Energy Information Administration	FORM EIA-861 ANNUAL ELECTRIC POWER INDUSTRY REPORT INSTRUCTIONS	Approval: OMB No. 1905-0129 Approval Expires: 3/31/2020 Burden Hours: 12.75

SCHEDULE 3, PART B: DISTRIBUTION SYSTEM RELIABILITY INFORMATION - IEEE

If your entity calculates system average interruption duration index (SAIDI) and/or system average interruption frequency index (SAIFI) answer yes to question 1. If you determine Major Event Days in accordance with the IEEE standard, answer 'yes' to question 2 and complete Part B, otherwise answer 'no' to question 2 and complete Part C. If your entity does not calculate SAIDI and SAIFI answer 'no' to question 1 and go to Schedule 4A.

For lines 3 through 6 complete all that you calculate.

Example 1, if you include all outage data in your SAIDI/SAIFI calculations, fill out the fields under the subtitle 'Including Major Events'.

Example 2, if you do the calculations to find out which outages are major events or Major Event Days, exclude major events or Major Event Days from the data and use the limited remaining data to calculate SAIDI and SAIFI, complete the area under the subtitle 'Excluding Major Events'.

1. The **system average interruption frequency index, or SAIFI**, indicates how often the average customer experiences a sustained interruption (of over 5 minutes) over a predefined period of time. In this schedule report annual SAIFI, or the SAIFI resulting from all interruptions in the reporting year. SAIFI is calculated as the sum over the year of total number of customers that experienced an interruption of more than 5 minutes, divided by the total number of customers.
2. SAIFI = [Sum of total number of customers interrupted over the year] / [Total number of customers served]
3. The **system average interruption duration index, or SAIDI**, indicates the total duration of interruption for the average customer over a predefined period of time. In this schedule report annual SAIDI, or the SAIDI resulting from all interruptions in the reporting year. SAIDI is calculated as the sum over the year of all customers interrupted for more than 5 minutes times the number of minutes they experienced an interruption, divided by total number of customers.
4. SAIDI = [Sum of customer minutes interrupted over the year] / [Total number of customers served]
5. On lines 3 through 6 report the values that you calculate.
   a. Report the Annual Distribution SAIDI Including Major Event Days on line 3,
   b. Report the Annual Distribution SAIDI Excluding Major Event Days on line 3,
   c. Report both the Annual Distribution SAIDI Including Major Event Days excluding events where the reliability event was initiated from loss of supply (e.g. resulted from an event on the distribution system, not from the high-voltage system) the Annual Distribution SAIDI Excluding Major Event Days excluding events where the reliability event was initiated from loss of supply on line 4.
   d. Report the Annual Distribution SAIFI Including Major Event Days on line 5,
   e. Report the Annual Distribution SAIFI Excluding t Major Event Days on line 5,
   f. Report both the Annual Distribution SAIFI Including and Excluding Major Event Days excluding events where the reliability event was initiated from loss of supply on line 6.

Table 2 Toronto Hydro's SAIFI Performance 2005-2024

Year	Toronto Hydro Actual SAIFI	Toronto Hydro Benchmark SAIFI	% Difference (Logarithmic)
2005	0.93	0.60	43.7%
2006	1.11	0.60	61.2%
2007	1.14	0.60	63.9%
2008	1.08	0.60	58.8%
2009	0.95	0.60	46.4%
2010	0.98	0.60	48.9%
2011	1.05	0.60	56.7%
2012	0.88	0.59	39.8%
2013	0.95	0.59	47.5%
2014	0.92	0.59	44.5%
2015	0.97	0.59	49.7%
2016	0.93	0.59	45.7%
2017	0.94	0.59	46.3%
2018 (projected)	0.94	0.59	46.7%
2019 (projected)	0.92	0.59	44.3%
2020 (projected)	0.92	0.59	44.0%
2021 (projected)	0.91	0.59	43.8%
2022 (projected)	0.91	0.59	43.6%
2023 (projected)	0.91	0.59	43.5%
2024 (projected)	0.91	0.59	43.5%
Average % Difference			
2015-2017			**47.2%**
2020-2024			**43.7%**

RESPONSES TO ENERGY PROBE RESEARCH FOUNDATION INTERROGATORIES

INTERROGATORY 64:

Reference(s): **Exhibit U, Tab 1B, Schedule 1, p. 4, 2.10 System Reliability: SAIDI/SAIFI**

Preamble:

"Toronto Hydro achieved improvements in both SAIDI and SAIFI in 2018. SAIDI was measured at 0.81, which is a reduction from the 0.91 in 2017 and 2016. SAIFI in 2018 reduced to 1.14 versus the 1.18 in 2017 and 1.28 in 2016."

a) At a high level please provide a short narrative with the reasons that SAIDI and SAIFI (CAIDI) have improved over 2015-2018 period, including system renewal investment.

b) Please comment if TH is an average performer relative to its Ontario peer group, and if system reliability will continue to improve, given continuing investment over the 2020-2024 CIR Plan Period?

c) Please confirm that TH provided 2020-2024 reliability projections/outlook to PSE and PEG for their Econometric models.

d) Please provide a copy of this projection/outlook.

e) Please comment if the reliability improvement in 2018 is material relative to the projection/outlook provided to PSE and PEG.

RESPONSE:

a) As illustrated in Exhibit U, Tab 1B, Schedule 1, pages 23 and 24 (in Figures 16 and 17), reliability performance has improved over the 2015-2018 period. For example, after excluding major event days (i.e. MEDs) and loss of supply (i.e. LOS), SAIFI and SAIDI have improved by an average of approximately 4 percent and 6 percent respectively each year. Although some of the improvement can be attributed to reductions in contributions from cause codes such as Adverse Environment, Human Element, and Scheduled Outages, the majority of the improvement is attributed to reductions in interruptions caused by Defective Equipment.

The reductions in Defective Equipment interruptions have been achieved predominantly through investment in System Renewal. Between 2015 and 2018, Toronto Hydro invested $1,066 million in this category of capital expenditures. Although $204 million of this was for Reactive Capital, the remainder was directed to planned investments that addressed aging, deteriorated, and obsolete assets that posed elevated reliability (and other) risks. (Please see Exhibit U, Tab 2, Schedule 2, at pages 9 and 16 for Tables 9 and 15 for expenditure details between 2015 and 2018.)

With respect to 2018, please note that although SAIFI and SAIDI results bettered 2015-2017 results, they benefited from performances in some areas that are considered to be anomalies. For example, SAIFI benefited from its best performance in the past 15 years for the cause codes of Lightning and Scheduled Outages. Within the Defective Equipment cause code, contributions from assets such as non-direct buried cables, overhead insulators, and poles were lower than expected and are also considered to be anomalies.

b) The following two graphs compare the SAIFI and SAIDI performance (excluding Loss of Supply and Major Event Days) of Toronto Hydro to the other Ontario utilities using OEB RRR data for the most recently availably year, 2017. The charts highlight Toronto Hydro's performance in orange, other utilities that serve the Greater Toronto Area (GTA) in green, and the remaining utilities in grey. Toronto Hydro's reliability performance is worse than average for SAIFI (i.e. third quartile) and better than average for SAIDI (i.e. second quartile) when compared to all other Ontario utilities.

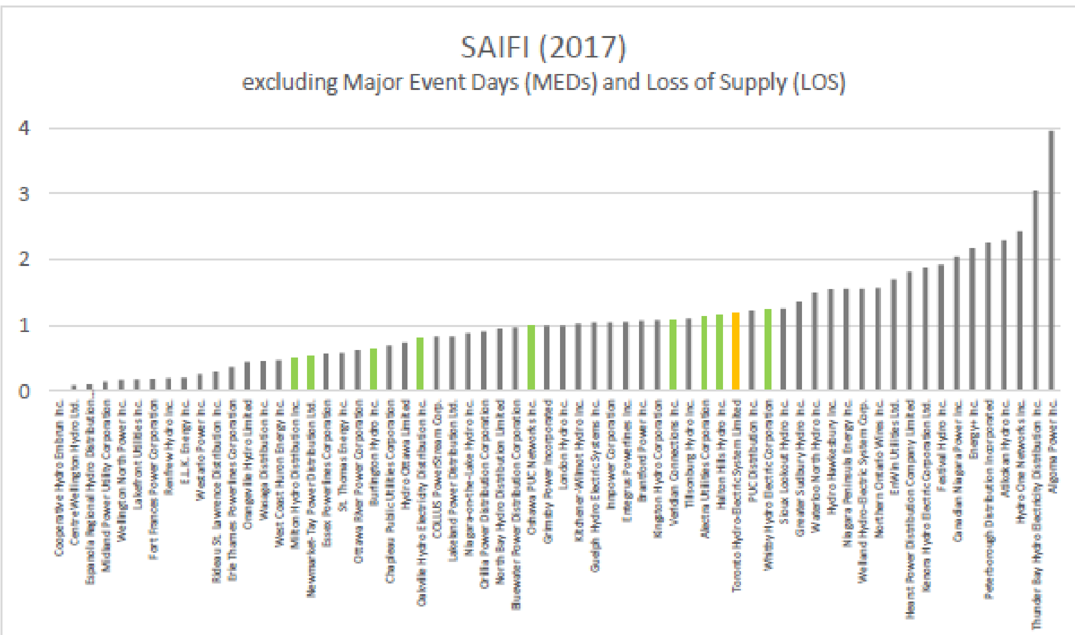


Figure 1: 2017 SAIFI (excluding MEDs and LoS)

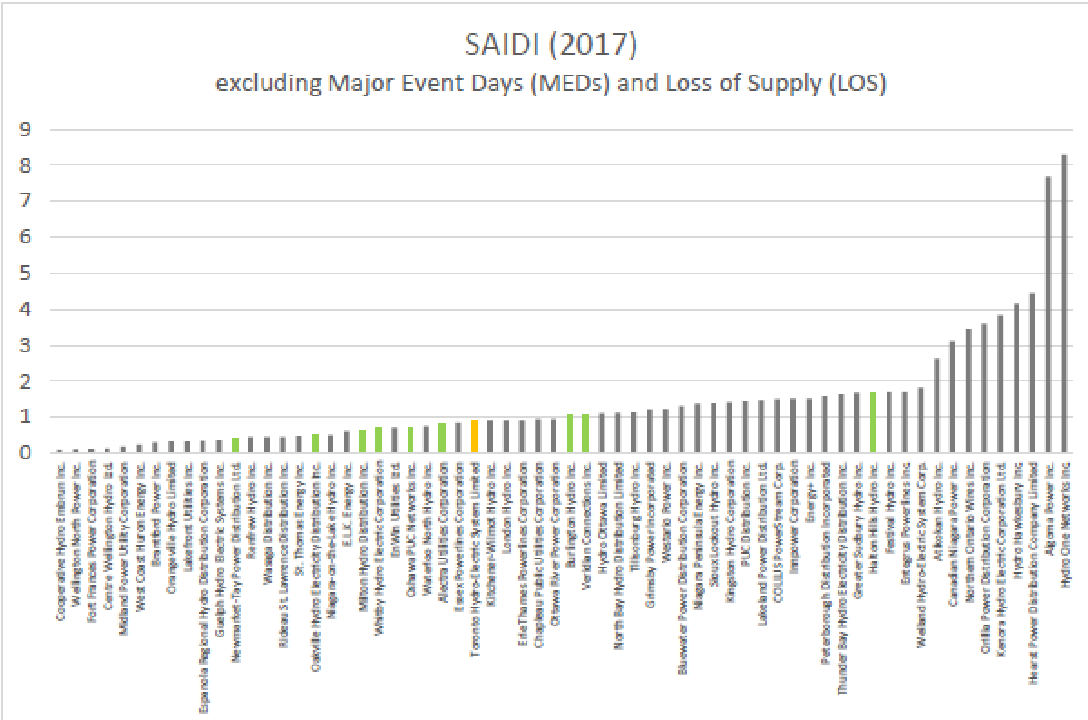


Figure 2: 2017 SAIDI (excluding MEDs and LoS)

These findings are directionally similar to the findings in PSE's reliability benchmarking study, which used an econometric approach to compare Toronto Hydro to a broader set of U.S. utilities. That study found that Toronto Hydro is worse than its predicted benchmark on SAIFI performance and better than its benchmark on SAIDI performance.

The results above do not speak to the customer's perspective on Toronto Hydro's reliability performance and whether that performance aligns with customer priorities. As explained in Exhibit 2B, Section E2.3.1, feedback received during the first phase of customer engagement indicated that the average customer was satisfied with current reliability performance. Customer priorities were to keep distribution price increases to what is necessary to maintain long-term performance for customers experiencing average or better reliability service, and improve service levels for customers experiencing below average service. In response to this feedback, Toronto Hydro designed a plan that would achieve these objectives.

As illustrated in Toronto Hydro's response to U-SEC-105, Toronto Hydro does not expect continued improvement in SAIDI and SAIFI results through the 2020-2024 period. As detailed throughout the DSP, the utility has relied on various indicators of future asset performance (e.g. asset health) and other indicators of system need (e.g. weather and climate analyses) to develop an expenditure plan that is paced to prevent asset failure risk from increasing over the period (e.g. by seeking to maintain the number of assets in HI4 and HI5 condition). Toronto Hydro is generally not planning to invest at a pace that will reduce asset failure risk from current levels, with a few exceptions for areas where risk accumulation has reached unacceptably high levels (e.g. Stations Renewal). In addition, the utility used its Reliability Projection methodology – which compiles asset demographics data, historical reliability performance, and planned program investments – to guide the development of the proposed plan and ultimately ensure that the proposed investment program would be of the right pace and mix to sustain system reliability. The results of this analysis are shown at Exhibit 2B, Section E2, Figures 8 and 9.

Toronto Hydro's proposed increase in total capital expenditures relative to the 2015-2019 period is necessary to deliver not only on its proposed reliability outcomes, but also to manage a number of other critical needs and objectives that drive material investment requirements. Some examples are provided below.

System Renewal

Although System Renewal as a proportion of the overall Distribution System Plan is remaining consistent at approximately 57 percent in 2020-2024 (relative to 2015-2019), the mixture of planned work is shifting to address significant needs on parts of the distribution system that contribute less to system average reliability, and more to critical drivers such as safety, resiliency and environmental impacts. For example:

- Toronto Hydro is planning to invest $122 million in the new Underground System Renewal – Downtown program, which replaces obsolete lead and asbestos cables that pose environmental risks. The program also manages a growing population of deteriorating civil assets such as cable chambers, which present safety risks. (Please see Exhibit 2B, Section E6.3, Table 1.)

- Toronto Hydro is planning an increase of $56 million from 2015-2019 in Stations Renewal to address deteriorating assets that generally have a lower probability of causing an outage, but that can lead to significant consequences (e.g. widespread customer outages; extended weakening of system contingency capabilities) if a failure is to occur. (Please see Exhibit 2B, Section E6.6, Table 1.)

- Based in part on historical trends, the plan includes projected increases in Reactive Capital, which often replaces equipment after it has failed and has contributed to unreliability, instead of prior to failure. (Please see Exhibit 2B, Section E6.7, Table 1.)

- The plan includes an increased proportion of spot replacements, particularly for transformers containing, or at-risk of containing PCBs, in both the Overhead System Renewal and Underground System Renewal (Horseshoe)

Program. Spot replacements of transformers mitigate less reliability risk than area rebuilds, which target clusters of deteriorated assets in an area. (Please see Exhibit 2B, Section 6.5, page 20, lines 1 to 3 and Section 6.2, page 32, lines 26 to 30.)

System Service

System Service investments that have the potential to contribute to improvements in reliability have either been reduced in 2020-2024 (e.g. System Enhancements, discussed in Exhibit 2B, Section E7.1, Table 1) or in the case of Network Condition Monitoring and Control (i.e. Exhibit 2B, Section 7.3), are being directed to the Network System, which on a day-to-day basis is highly reliable (given its inherent design), to address safety and resiliency needs. (Please see Exhibit 2B, Section C2, page 11, for details related to Toronto Hydro's Network Units Modernization objectives.)

System Access

Toronto Hydro is forecasting an increase in System Access investments in 2020-2024 to address demand and compliance-based projects that are largely unrelated to system average reliability. For example, the utility anticipates greater investments in Customer Connections, Externally Initiated Plant Relocations, and Metering.

c) Toronto Hydro confirms that it provided 2020-2024 reliability projections for SAIFI and SAIDI to PSE. These same projections were provided to PEG via the request for PSE's working papers. These projections used a momentary interruption definition of five minutes or less (as opposed to Ontario's one minute or less) for comparison with U.S. utilities.

d) Please refer to Toronto Hydro's response to Technical Conference undertaking JTC2.10 for projections of SAIFI and SAIDI provided to PSE.

RESPONSE (PREPARED BY PSE):

e) Toronto Hydro's 2018 reliability results would improve the model result for SAIFI by an estimated 3 percent and would worsen the CAIDI results by about 2 percent. PSE does not consider this to be a material change within the context of our findings.

central-southwest area of Toronto. During 2018, the testing on high voltage cable, the protection and control equipment, and the supervisory control and data acquisition system were all completed. The Corporation received approval from HONI, the electricity transmission provider, and the IESO for energization of the project and successfully energized one of two Copeland Station power transformers with associated cables and switchgear. The second power transformer and associated switchgear is anticipated to be energized in the first half of 2019 following the HONI's completion of additional servicing to some of their equipment. As at December 31, 2018, the cumulative capital expenditures on the Copeland Station project amounted to $202.6 million, plus capitalized borrowing costs. All capital expenditures related to Copeland Station are recorded to PP&E. The total capital expenditures required to complete the project has increased from $200.0 million to approximately $204.0 million, plus capitalized borrowing costs. There may be additional unforeseen delays and expenditures prior to completion of the project. See Part 8 under the heading "Risk Factors" below for further information on the Copeland Station project.

(iv) *Distribution Transformers and Municipal Substations*

Electricity at distribution voltages is distributed from the terminal stations to distribution transformers that are typically located in buildings or vaults or mounted on poles or surface pads that are used to reduce or step down voltages to utilization levels for supply to customers. The electricity distribution system includes approximately 60,560 distribution transformers. The electricity distribution system also includes 146 in-service municipal substations that are located in various parts of the City and are used to reduce or step down electricity voltage prior to delivery to distribution transformers. LDC also delivers electricity at distribution voltages directly to certain commercial and industrial customers that own their own substations.

(v) *Wires*

LDC distributes electricity through a network comprised of an overhead circuit of approximately 15,515 kilometres supported by approximately 179,400 poles and an underground circuit of approximately 13,207 kilometres.

(vi) *Metering*

LDC provides its customers with meters through which electricity passes before reaching a distribution board or service panel that directs the electricity to end use circuits on the customer's premises. The meters are used to measure electricity consumption. LDC owns the meters and is responsible for their maintenance and accuracy.

As part of its metering services, LDC also installs Unit Smart Meters in multi-unit complexes that fall within the Competitive Sector Multi-Unit Residential rate class. As at December 31, 2018, LDC had installed approximately 77,000 Unit Smart Meters in these types of multi-unit complexes.

(vii) *Reliability of Distribution System*

The table below sets forth certain industry recognized measurements of system reliability with respect to LDC's electricity distribution system and the composite measures reported by LDC and the CEA for the twelve month periods ending December 31 in the years indicated below.

	LDC 2018	LDC 2017	CEA 2017[(1)]
SAIDI	0.98	0.99	7.15
SAIFI	1.48	1.43	2.53
CAIDI	0.66	0.69	2.82

Note:

(1) Data was extracted from the CEA's 2017 Service Continuity Report on Distribution System Performance in Electrical Utilities, excluding significant events. At the date of this AIF, such report for the year 2018 has not been published by the CEA.