Enhancing Resilience to Climate Change

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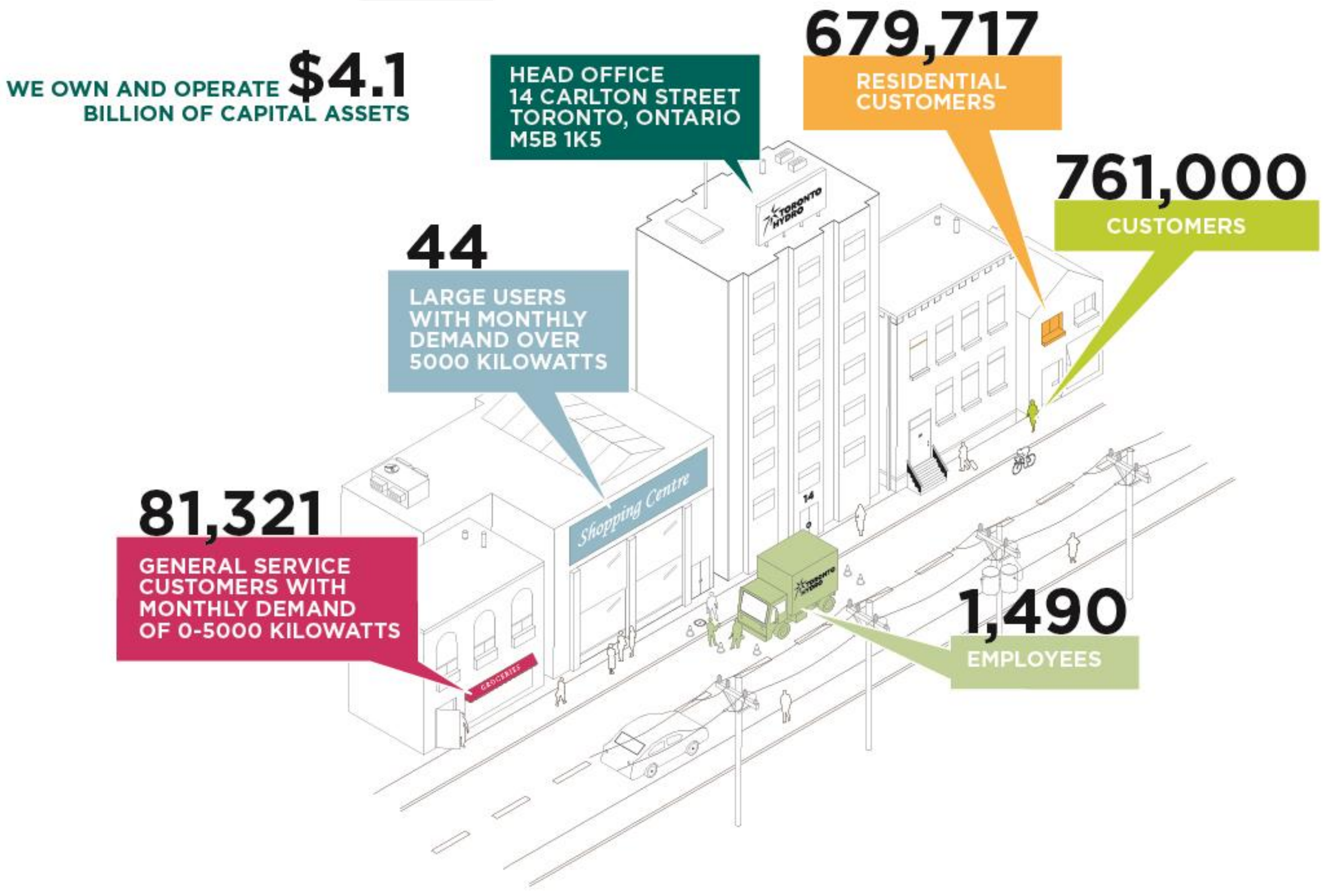
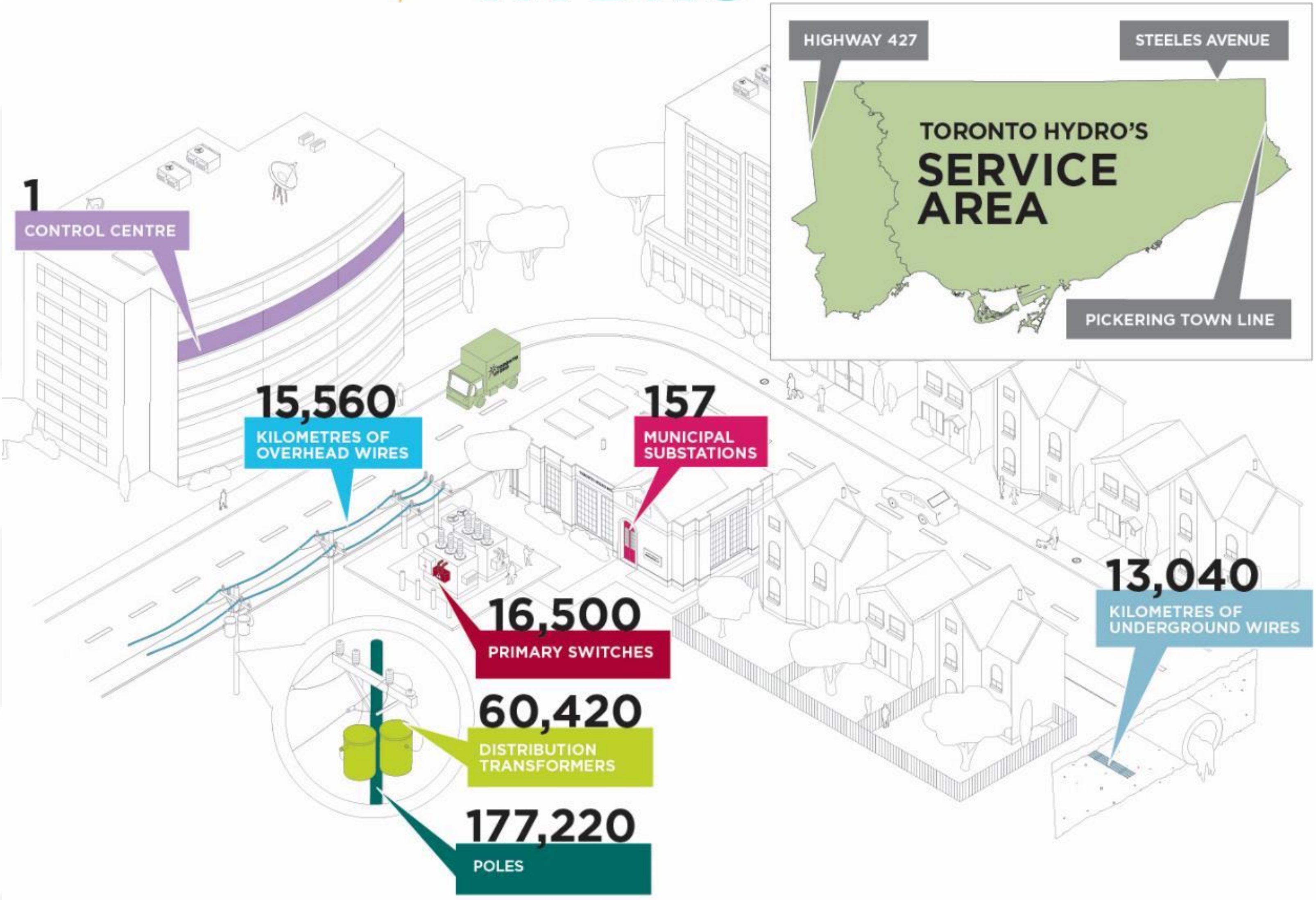
Engineering & Construction Division

Ontario Climate Consortium
April 26th, 2017
Ontario Science Centre


WE OWN AND OPERATE $4.1 BILLION OF CAPITAL ASSETS
HEAD OFFICE 14 CARLTON STREET TORONTO, ONTARIO M5B 1K5
679,717 RESIDENTIAL CUSTOMERS
761,000 CUSTOMERS
44 LARGE USERS WITH MONTHLY DEMAND OVER 5000 KILOWATTS
81,321 GENERAL SERVICE CUSTOMERS WITH MONTHLY DEMAND OF 0-5000 KILOWATTS
1,490 EMPLOYEES
Shopping Centre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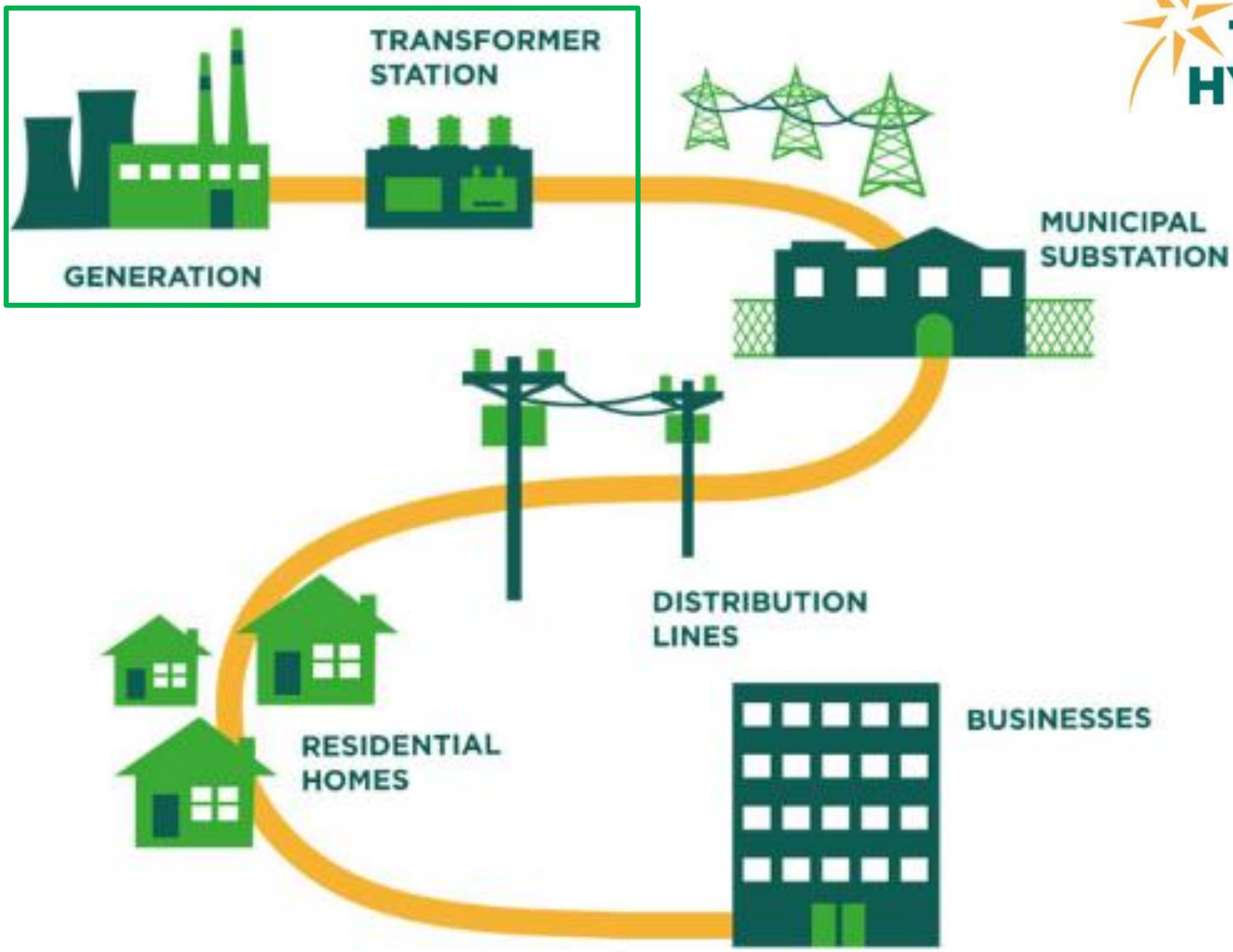
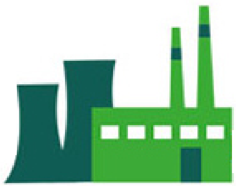
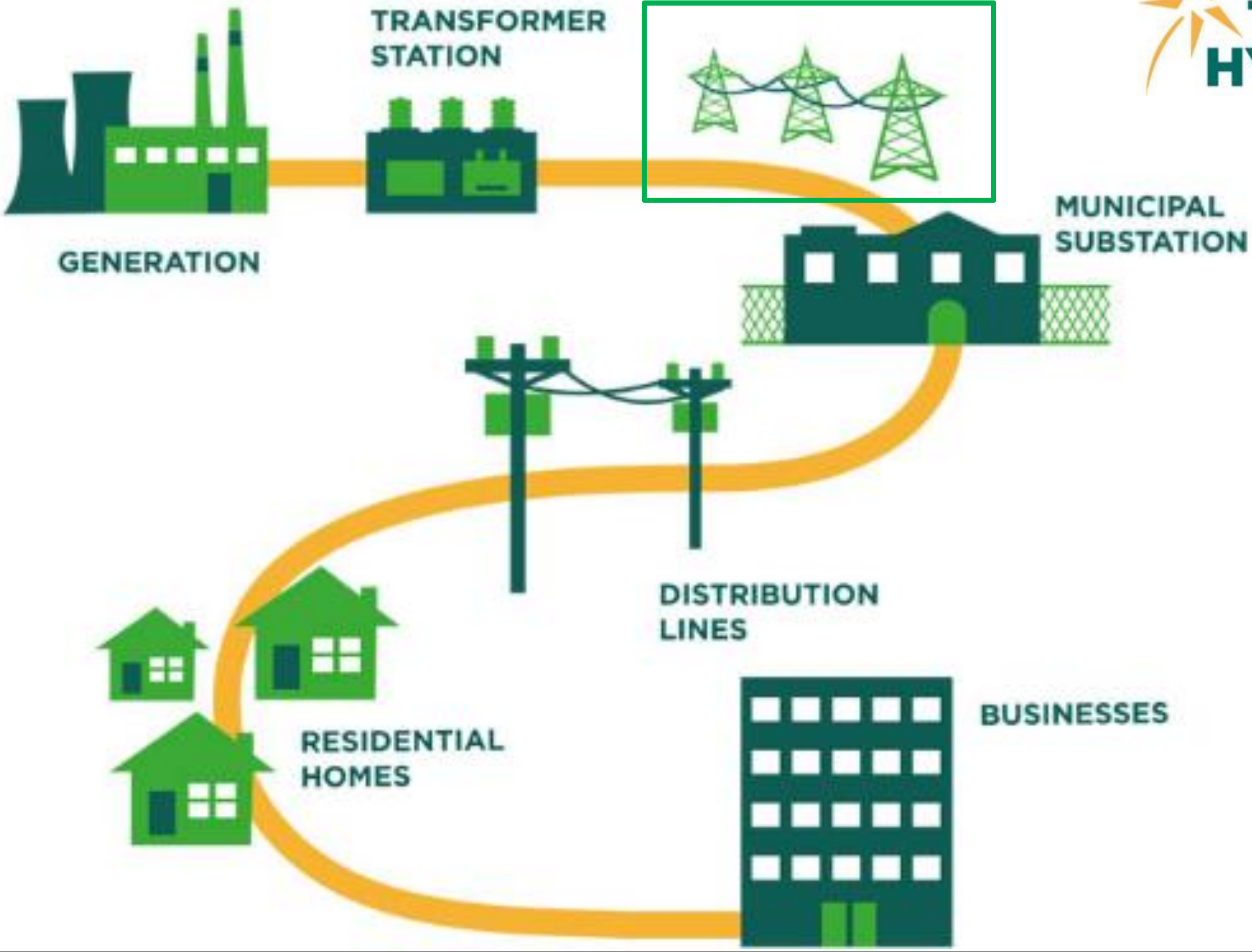
CONTROL CENTRE
15,560
KILOMETRES OF OVERHEAD WIRES
157
MUNICIPAL SUBSTATIONS
16,500
PRIMARY SWITCHES
60,420
DISTRIBUTION TRANSFORMERS
177,220
POLES
13,040
KILOMETRES OF UNDERGROUND WIRES
HIGHWAY 427
STEELES AVENUE
TORONTO HYDRO'S
SERVICE AREA
PICKERING TOWN LINE



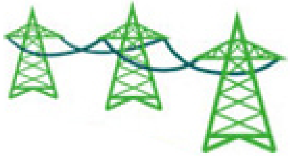
Generation

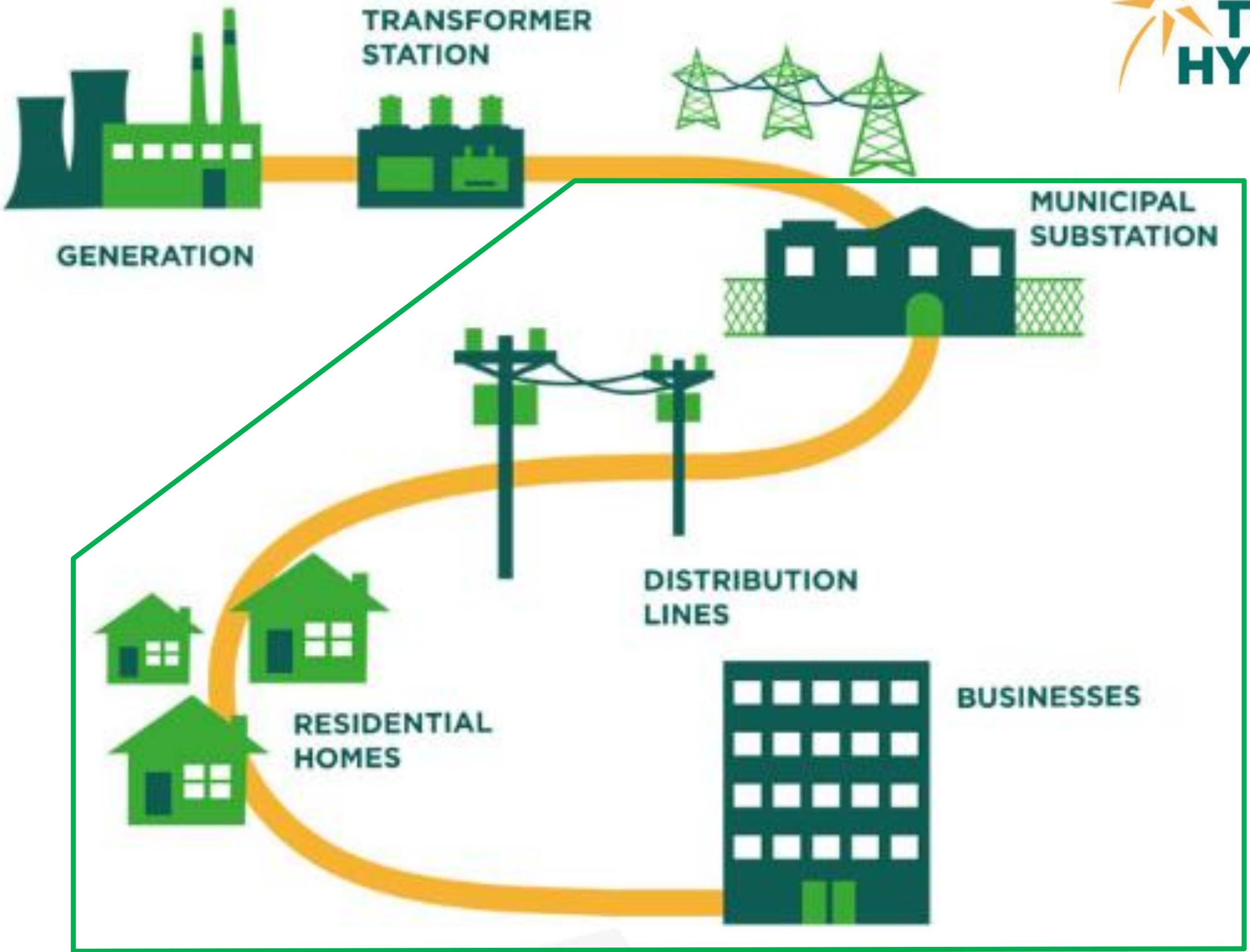
In Ontario, 70% of electricity is generated by Ontario Power Generation. This provincially-owned organization has generating stations across the province that produce electricity from hydroelectric, nuclear and fossil fuel sources



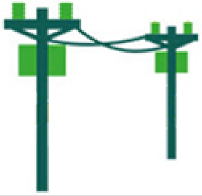


Transmission
Once electricity is generated, it must be delivered to urban and rural areas in need of power. This happens through high voltage transmission lines that serve as highways for electricity. There are approximately 30,000 km of transmission lines in Ontario and the majority are owned by Hydro One.

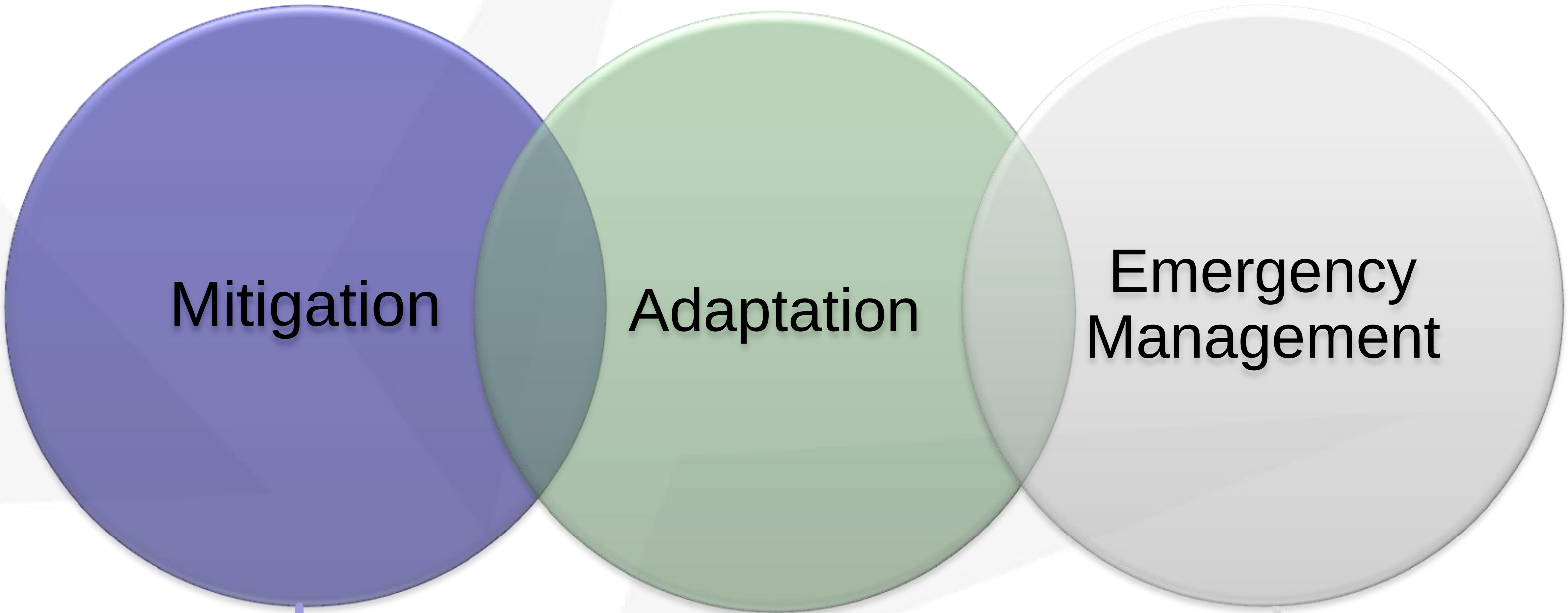




Distribution
Toronto Hydro is responsible for the last step of the journey: distributing electricity to customers in Toronto.



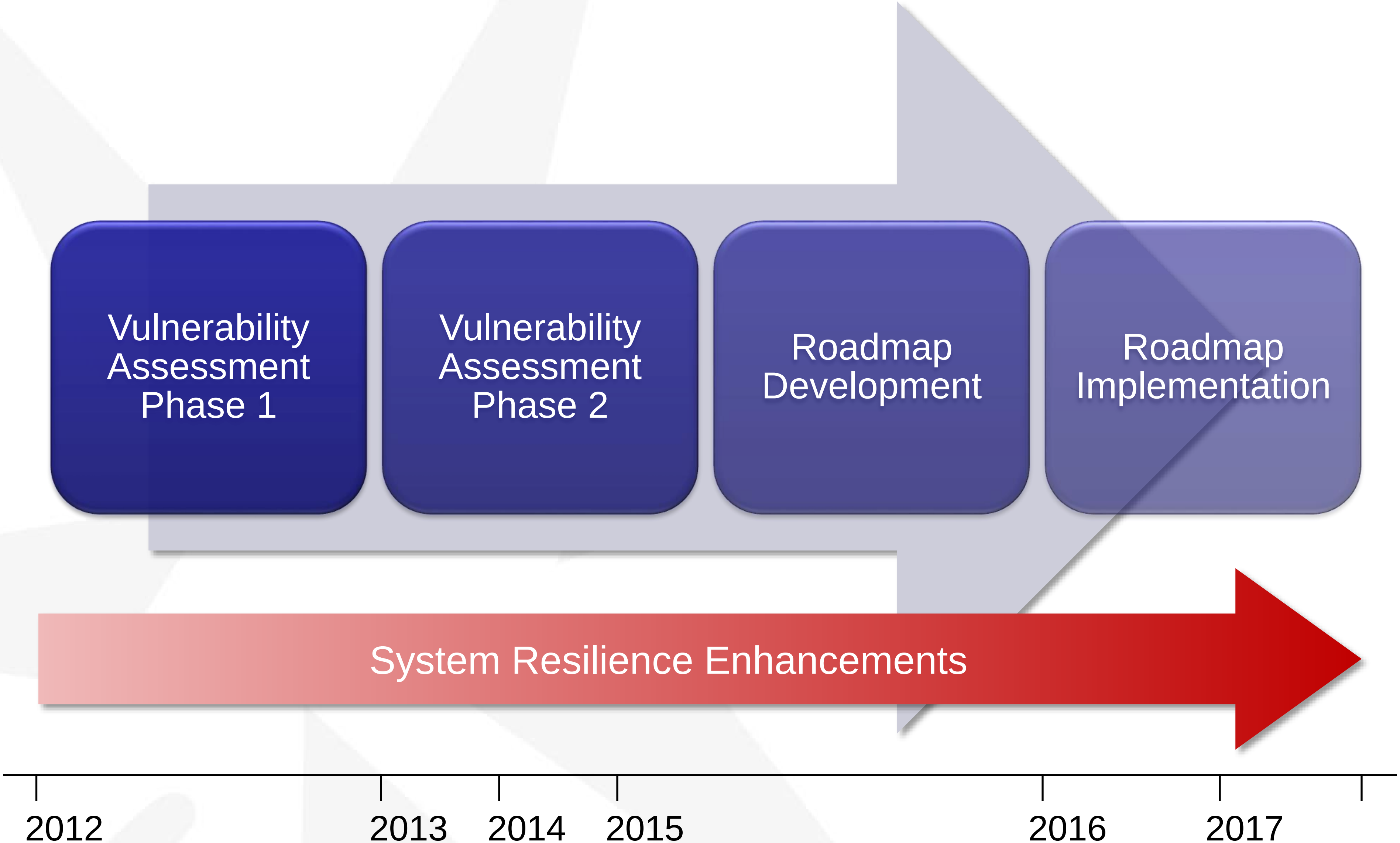
Climate Change Adaptation



Source: thestar.com

Source: news.nationalpost.com

Climate Change Adaptation



Climate Change Adaptation

July 2013 – Extreme rainfall (126mm in 2 hrs)

325,000 customers impacted
Flooding of station control equipment

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2012 2013 2014 2015 2016 2017

Climate Change Adaptation

December 2013 – Ice storm

300,000 customers impacted
Tree limbs falling on power lines

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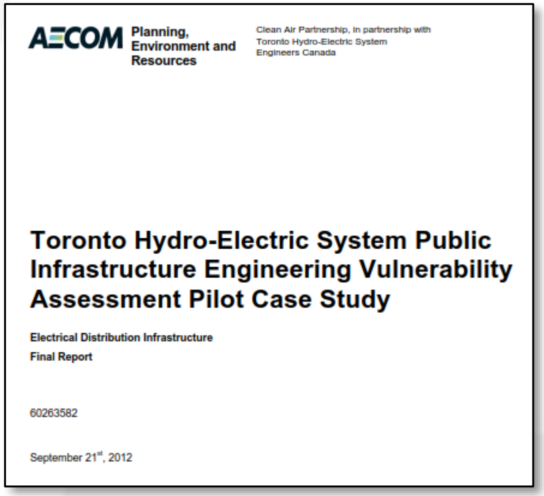
2012 2013 2014 2015 2016 2017

Climate Change Vulnerability Assessment

- Engineers Canada's *Public Infrastructure Engineering Vulnerability Committee* (PIEVC) Engineering Protocol
- Consortium: AECOM, City of Toronto, Clean Air Partnership, Engineers Canada, Risk Sciences International…
- NRCan funding
- Available at: www.pievc.ca


AECOM Planning, Environment and Resources

Clean Air Partnership, in partnership with Toronto Hydro-Electric System Engineers Canada

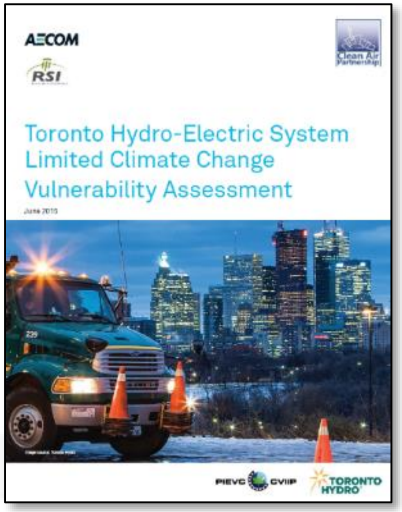
Toronto Hydro-Electric System Public Infrastructure Engineering Vulnerability Assessment Pilot Case Study

Electrical Distribution Infrastructure

Final Report

60263582

September 21st, 2012



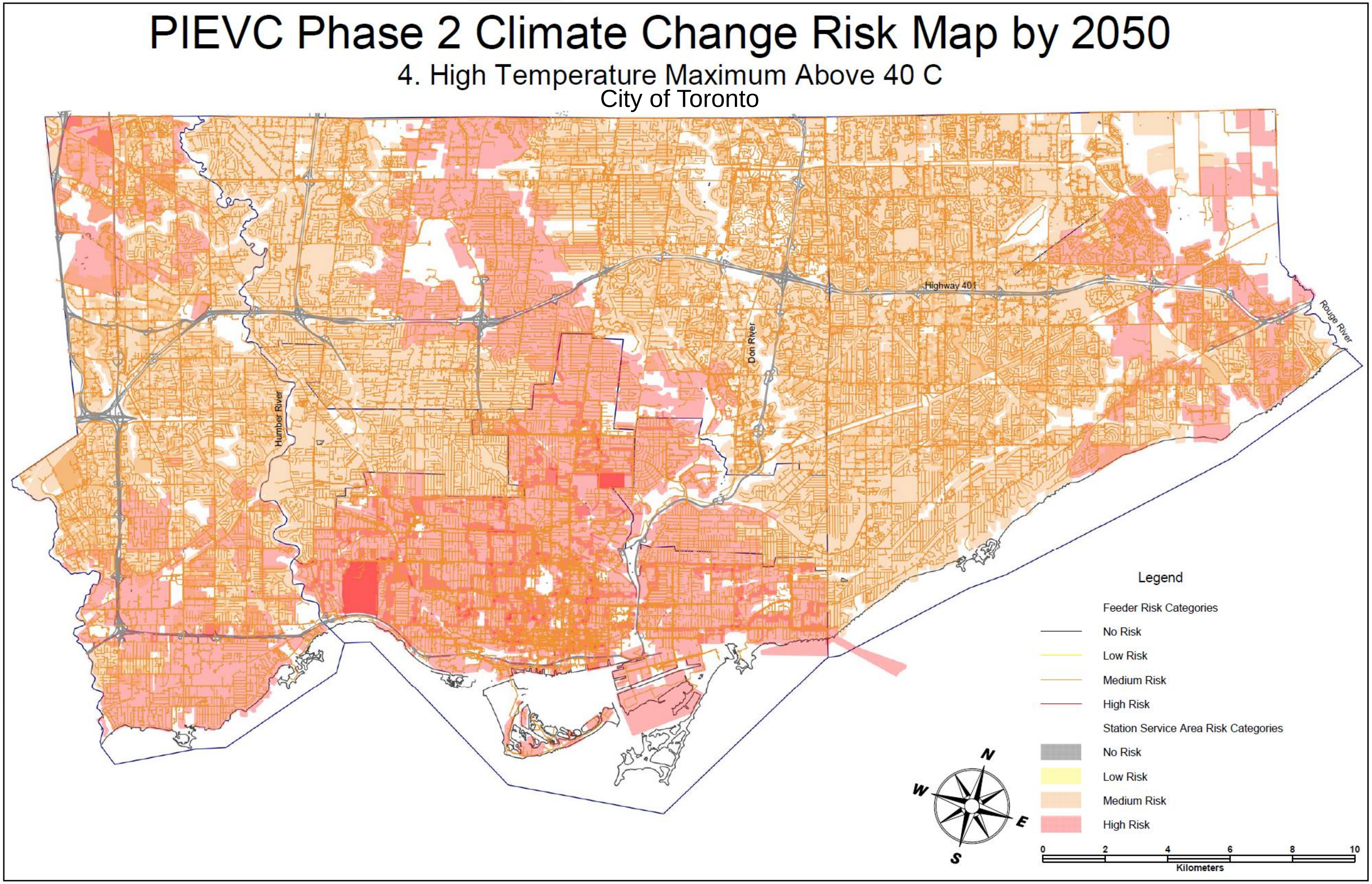
Phase 1	Phase 2
• Pilot case study • Current climate only • Small portion of distribution system • Completed Sept 2012	• 2010-2050, 20 climate parameters • Entire distribution system • Completed June 2015

PIEVC Phase 2

Table ES-1 Climate Parameters and Probability of Occurrence

Climate Parameter		Annual Probability (Historical; **Projected 2030's and *2050's***)	Probability of Occurrence Study Period (2015-2050)
Daily Maximum	25°C	66 per year; **84 per year**, ***106 per year***	100%
	30°C	16 per year; **26 per year**, ***47 per year***	100%
40°C		~0.01 per year; **0.3 to 2 days per year**, ***1-7 days per year***	
High Daily Avg. Temperature	30°C	0.07 per year; **N/A**, ***1.2 days per year***	~100%
Heat Wave	3 days max temp over 30°C	0.88 per year; **>1 for both**	100%
High Nighttime	Nighttime low ≥23°C	0.70 per year; **7 per year**, ***16 per year***	~100%
100 mm in <1 day + antecedent		0.04 per year; ***extreme precipitation expected ↑, percentage unknown***	
	15 mm (tree branches)	0.11 per year; **>0.13 per year**, ***>0.16 per year***	
	25 mm ≈ 12.5 mm radial	0.06 days per year; **>0.07 per year**, ***>0.09 per year***	
		Upper bound of estimate: 0.007 events per year; **>0.008 per year**; ***>0.01 per year***	
70 km/h+ (tree branches)		21 days per year; **N/A**, ***24 to 26 per year***	
90 km/h		2 days per year; **N/A**, ***>2.5 per year***	
120 km/h		~0.05 days per year; ***likely ↑, but % unknown***	
Lightning	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)
Snowfall	Days w/ >10 cm	1.5 days per year; ***Trend decreasing but highly variable***	100%
	Days w/ > 5cm	5 days per year; ***Trend decreasing but highly variable***	100%
Frost		229 frost free days; **249 frost free days**, ***273 frost free days***	100%

PIEVC Phase 2

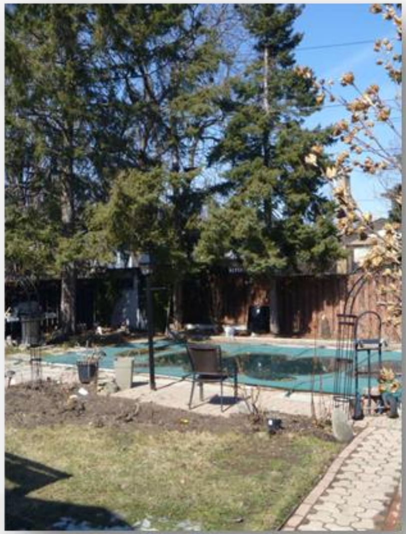


Vulnerability Assessment Adaptation Opportunities

- Infrastructure strengthening
- Capacity planning
- Inspection and maintenance programs
- Data collection and quality

Ongoing System Resilience Enhancements
Capital & Maintenance Programs

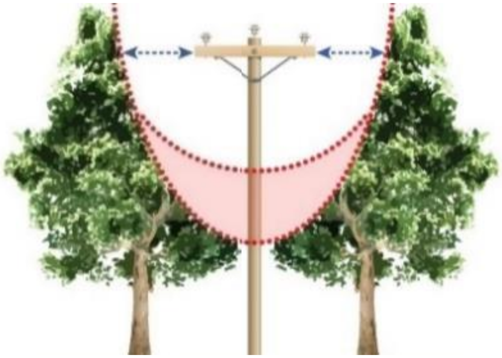
Rear Lot Conversion



Overhead Infrastructure Relocation

Tree Trimming Standards

City of Toronto Strategic Forest Management Plan 2012-2020



Ongoing System Resilience Enhancements

New Technologies

Breakaway Connectors

Stainless Steel Submersible Transformers

Solid Dielectric Submersible Transformers

www.cheryongusa.com

Roadmap Development

- Multi-disciplinary team
- Looking at data, analysis tools, investment programs, standards,…
- Develop initiatives to help make system more resilient

Roadmap Development

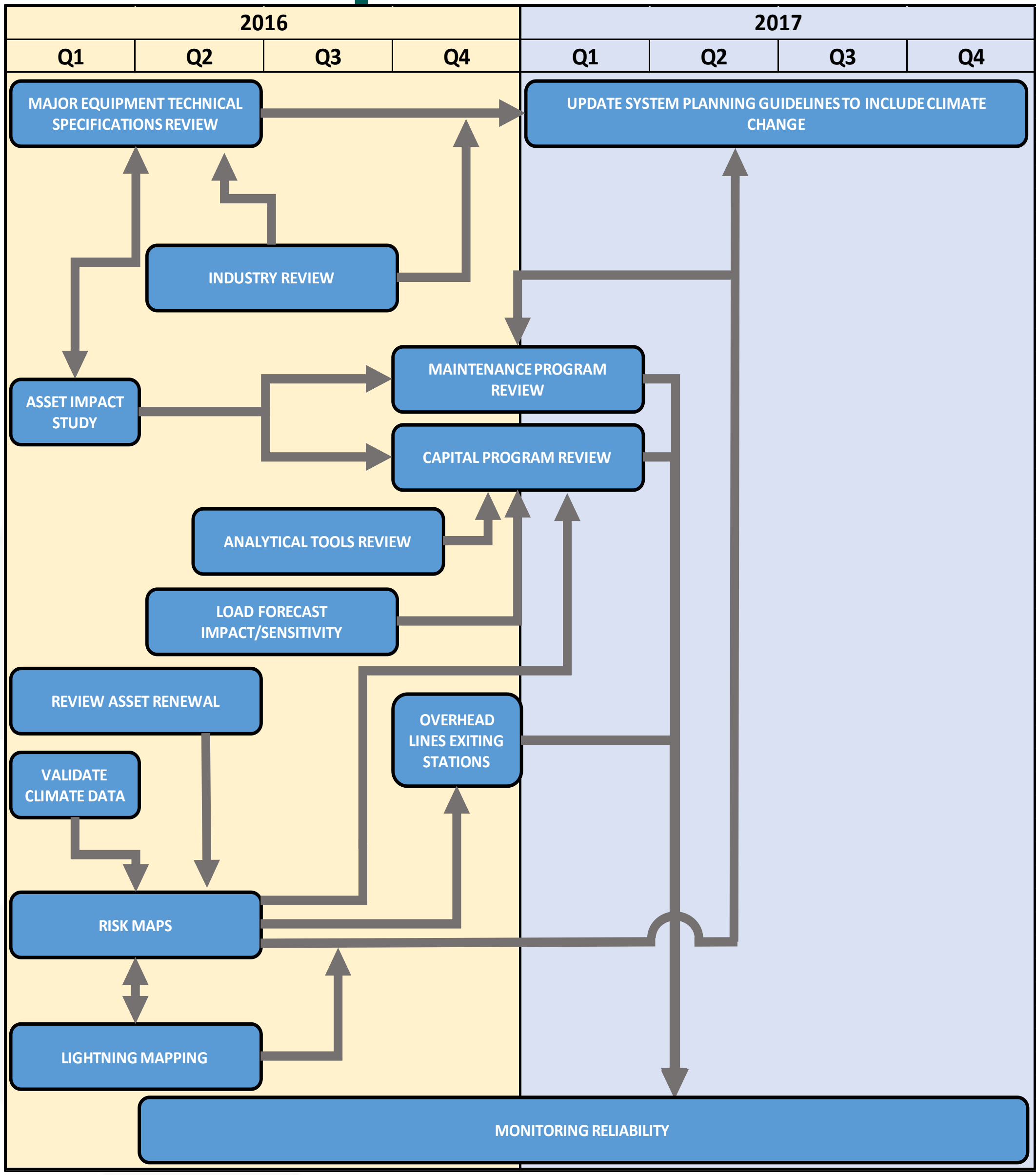
4 SECTOR PERSPECTIVES AND PRACTICES ON ADAPTATION

B. BRIDGING THE GAP: TOOLS TO INTEGRATE ADAPTATION INTO INVESTMENT PLANNING

1. CEA'S CLIMATE CHANGE ADAPTATION MANAGEMENT PLANNING GUIDE
2. ENGINEERS CANADA'S PUBLIC INFRASTRUCTURE ENGINEERING VULNERABILITY COMMITTEE'S PROTOCOL

Roadmap Development

- Climate data validation
- Asset lifecycle
- Equipment specifications
- Capital and maintenance programs
- Planning data, tools, guidelines
- Design practices
- Construction standards



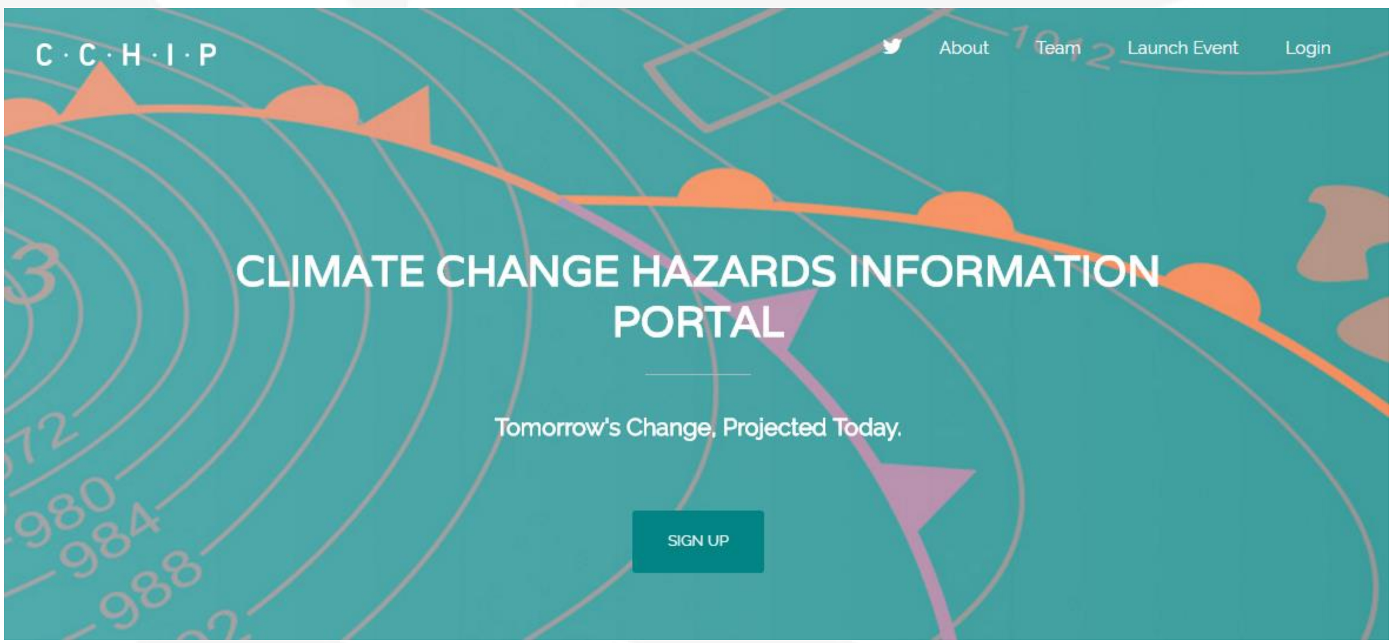
Validate Climate Data

Canadian Electricity Association | Association canadienne de l'électricité

CEA'S CLIMATE CHANGE ADAPTATION MANAGEMENT PLANNING GUIDE

2.2 Determine Future Projections:

To adapt to climate change impacts the expected changes must first be understood. Much of the existing infrastructure that is climate sensitive was designed using statistics on past climate and risk that may not be representative of future climate risks. Climate conditions are projected to change on an ongoing basis for the foreseeable future. To plan for future conditions they must be understood.



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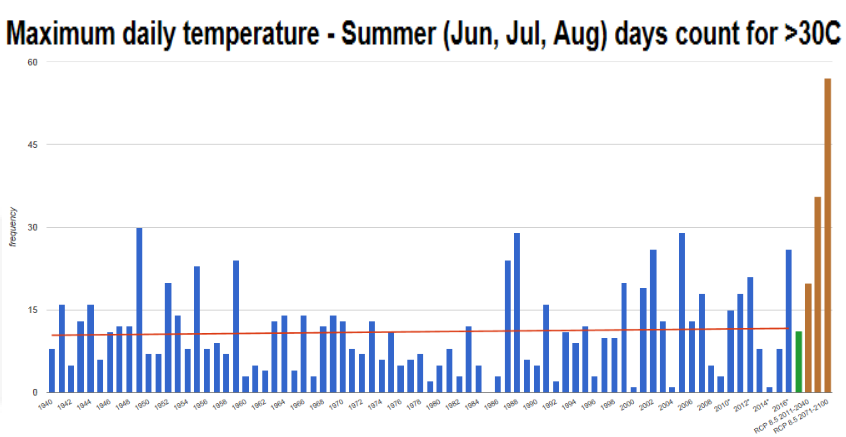
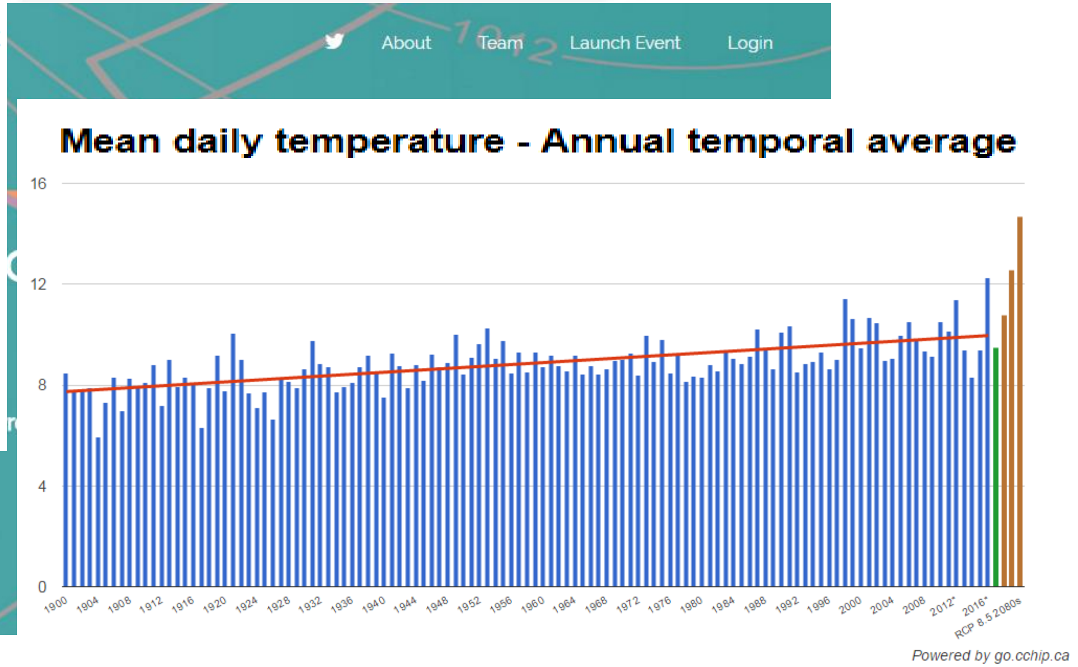




Validate Climate Data

Historical Climate Data

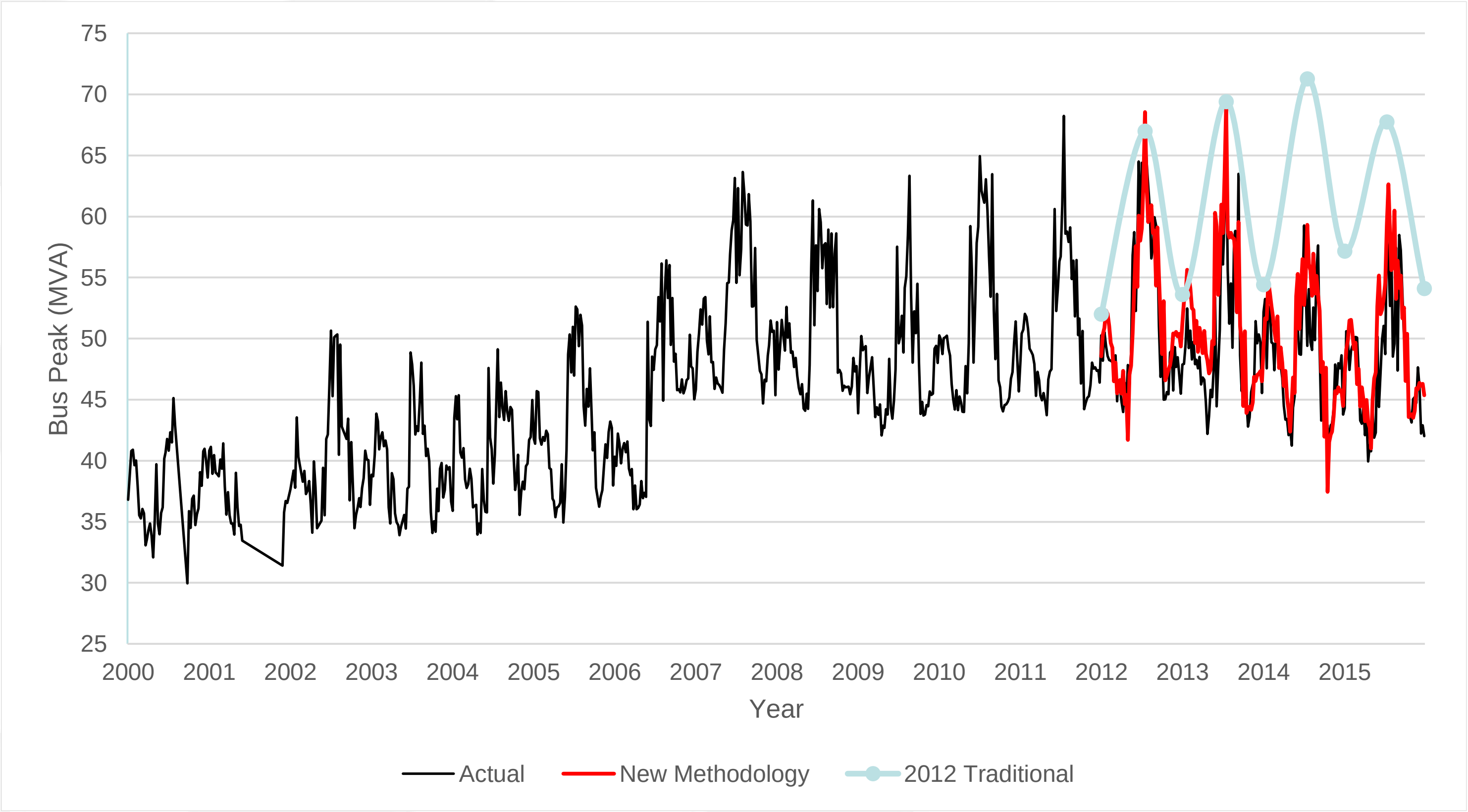
- Environment and Climate Change Canada (ECCC)
- Natural Resources Canada

Climate Projection Data within CCHIP

- Suite of models used
- Fifth Coupled Model Intercomparison Project (CMIP5), coordinated by the World Climate Research Program.
- List of models available on the website

Load Forecast Impact/Sensitivity

- Station Load Forecast report is prepared annually
- Used for the purpose of evaluating station bus capacity adequacy



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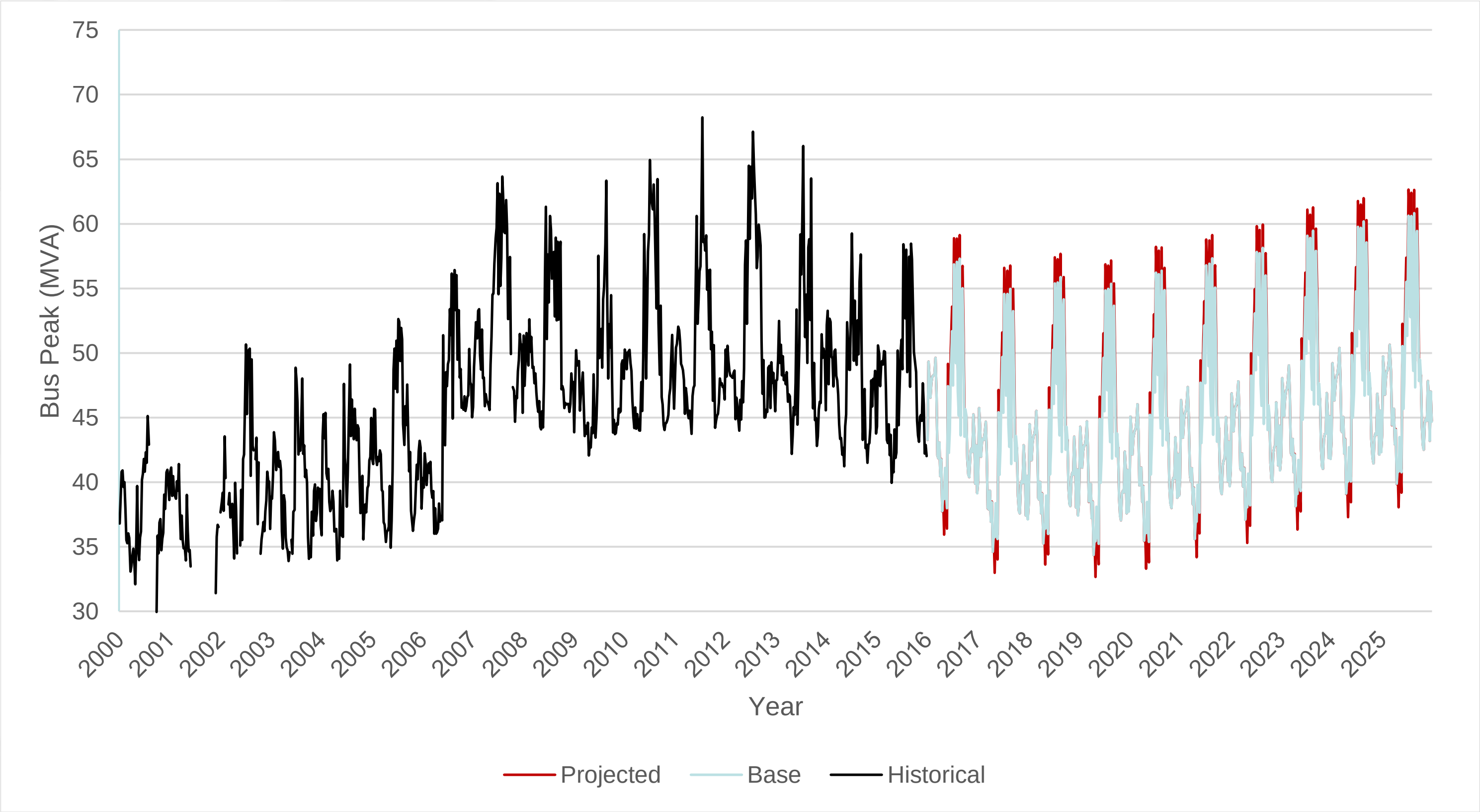


Major Equipment Specifications

- Technical Specifications for Major Equipment
- Codes, Standards and Regulations typically use historical values.
- Review specifications, investigate impacts of climate projections and revise as necessary.

TORONTO HYDRO

TORONTO HYDRO
TECHNICAL SPECIFICATION FOR
SINGLE PHASE SUBMERSIBLE DISTRIBUTION TRANSFORMERS
13,860Y/8000 - 240/120 OR 8000/13860Y - 347
KNAN TYPE
NO. DT-108-7R2

2.2 Codes, Standards and Regulations

CSA Standards

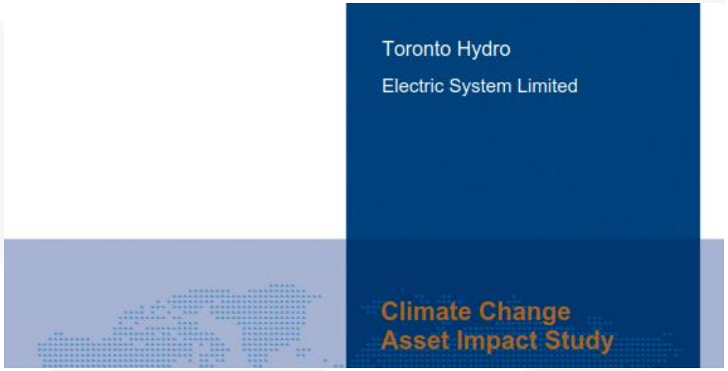
C301.1	Single-phase submersible distribution transformers
C2.1	Single Phase and three-phase liquid-filled distribution transformers
C50	Mineral insulating oil, electrical, for transformers and switches
C802.1	Minimum Efficiency Values for Liquid-Filled Distribution Transformers
CAN3-108.3.1-1987	Limits and measurements methods of electromagnetic noise from AC power system 0.15-30 MHz - Third Edition

IEEE Standard

C57.12.90	Test Code for Liquid-Immersed Distribution, Power, and Regulating Transformers and Guide for Short-Circuit Testing of Distribution and Power Transformers
C57.12.23	IEEE Standard for Submersible Single-Phase Transformers: 167 kVA and Smaller; High Voltage 25 000 V and Below; Low Voltage 600 V and Below
ANSI\IEEE 386	Separable Insulated Connectors for Power Distribution Systems Above 600 V.

4.1.3 As the transformer enclosure may be subjected to flooding or to high water tables, the transformer including its terminations shall be capable of continuous unattended operation while continuously submerged under a head of 3 m (10 ft) of water. Manual operation of certain accessories may require that the water level be lowered below the top of the transformer prior to operation.

Asset Impact Study



- Transformers vs temperature
- Poles vs climatic loads
- Overhead conductors vs climatic loads
- Underground cables vs extreme rainfall
- Overhead conductors vs temperature

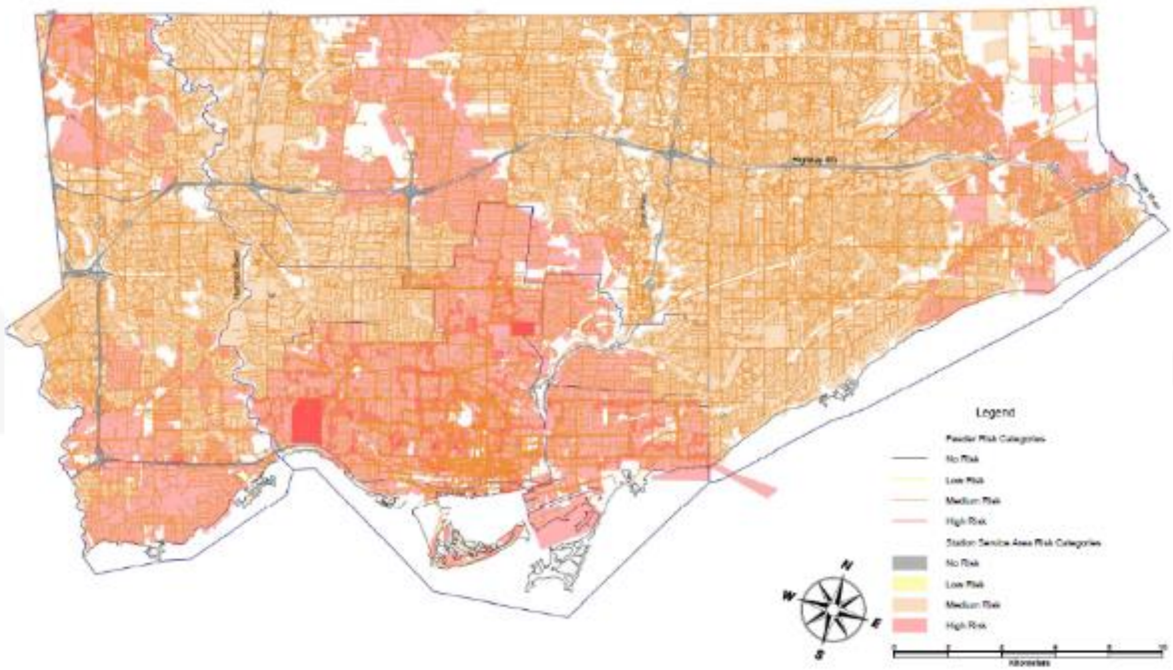
Loads	2 ACSR (installed @1000N)	3/0 ACSR	336.4 ASC	556.5 ASC
C22.3 heavy weather loading 12.5 mm ice radial, 400 Pa, -20 °C	46 %	30 %	34 %	32 %
100 kg (large branch) 15 mm ice total, 0 °C	67 %	38 %	41 %	33 %
300 kg (limb) 15 mm ice total, 0 °C	128 %	67 %	79 %	60 %
600 kg (small tree) 15 mm ice total, 0 °C	199 %	113 %	122 %	92 %
	TREEPROOF 3/0 ACSR 15 kV	TREEPROOF 3/0 ACSR 25 kV	TREEPROOF 336.4 ASC 15 kV	TREEPROOF 556.5 ASC 25 kV
C22.3 heavy weather loading 12.5 mm ice radial, 400 Pa, -20 °C	29 %	29 %	35 %	32 %
100 kg (large branch) 15 mm ice total, 0 °C	37 %	35 %	41 %	34 %
300 kg (limb) 15 mm ice total, 0 °C	70 %	67 %	79 %	60 %
600 kg (small tree) 15 mm ice total, 0 °C	108 %	106 %	124 %	93 %

Table 16 : Cable % RTS according falling vegetation loading

Risk Maps

PIEVC Phase 2 Climate Change Risk Map by 2050

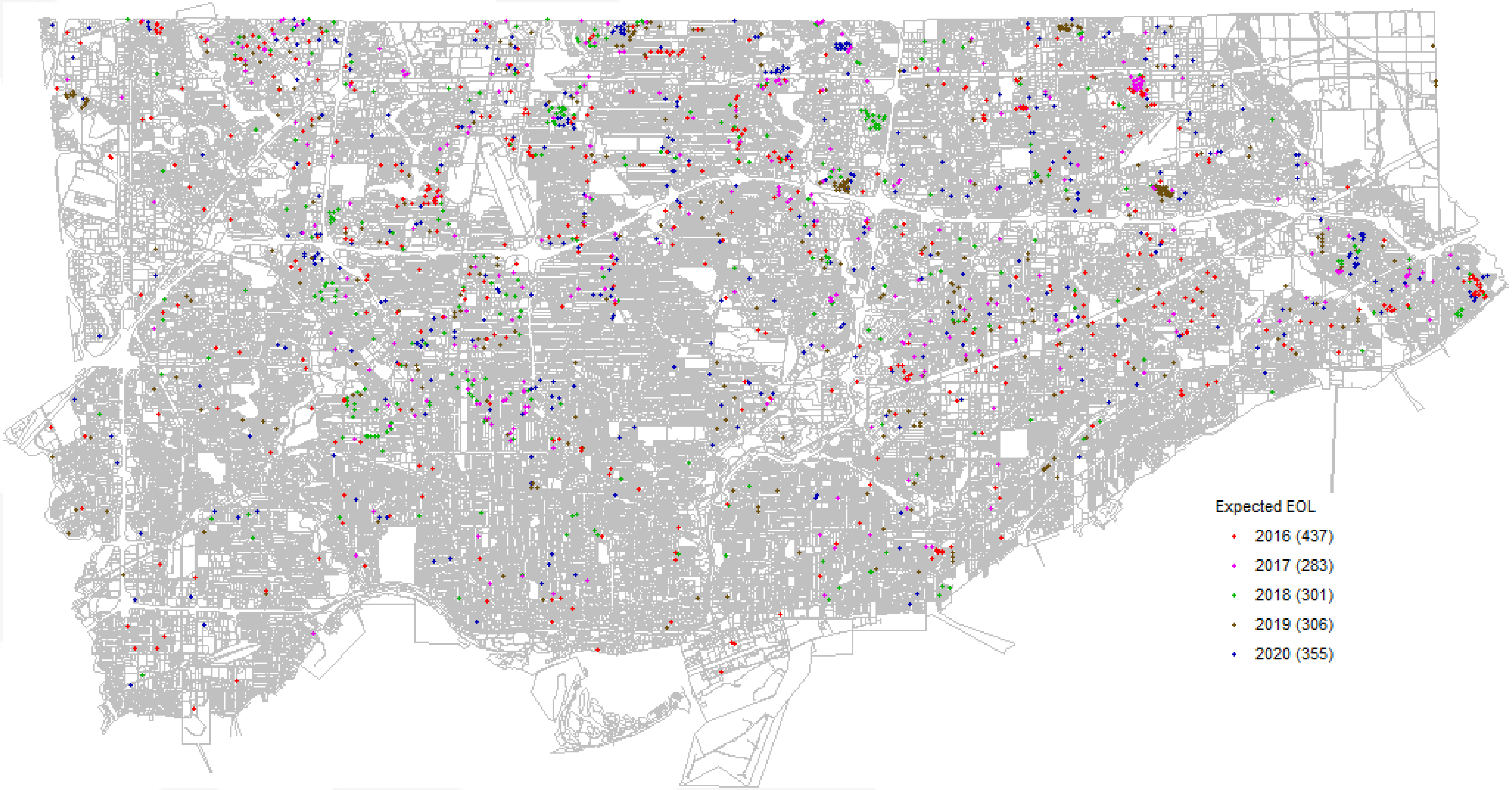
4. High Temperature Maximum Above 40 C



- Risks maps were completed at a high level
- Narrow down to asset level to be more useful to planning teams

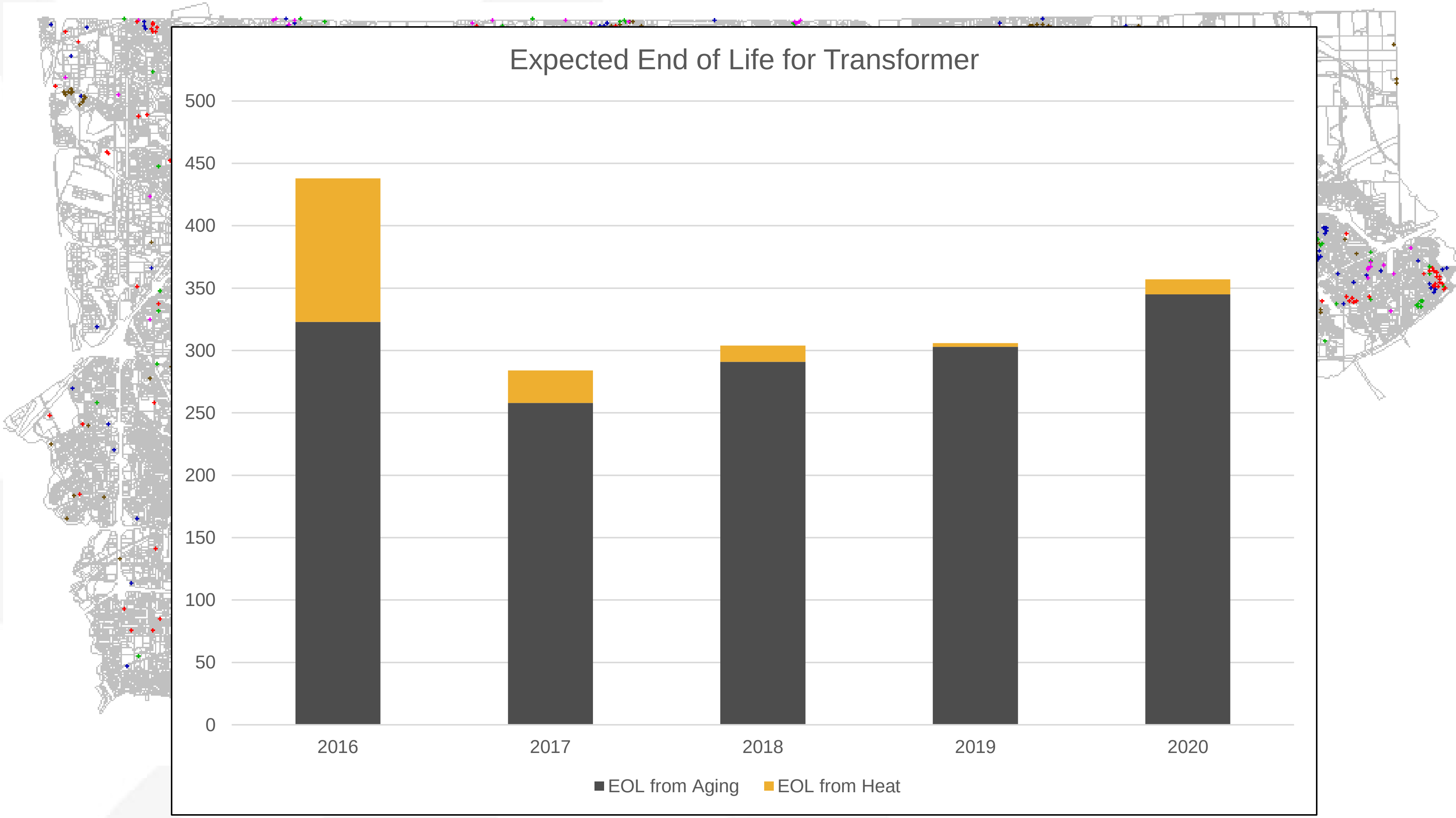
Risk Maps

Transformers at End of Life for 2016 - 2020



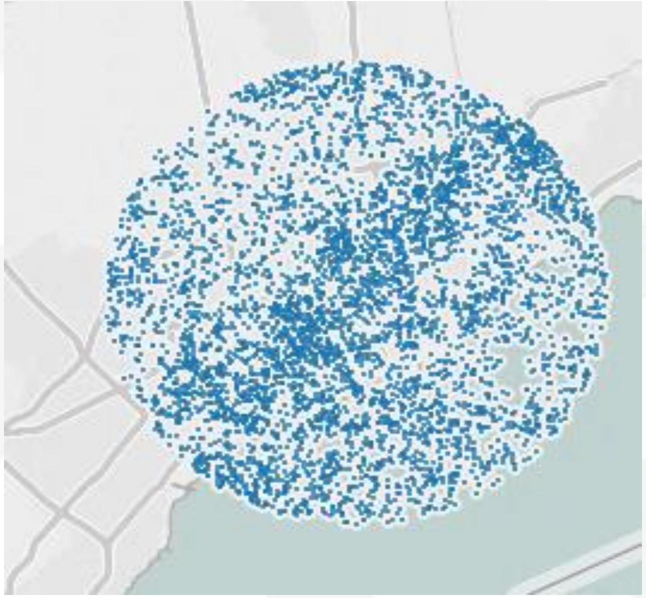
Risk Maps

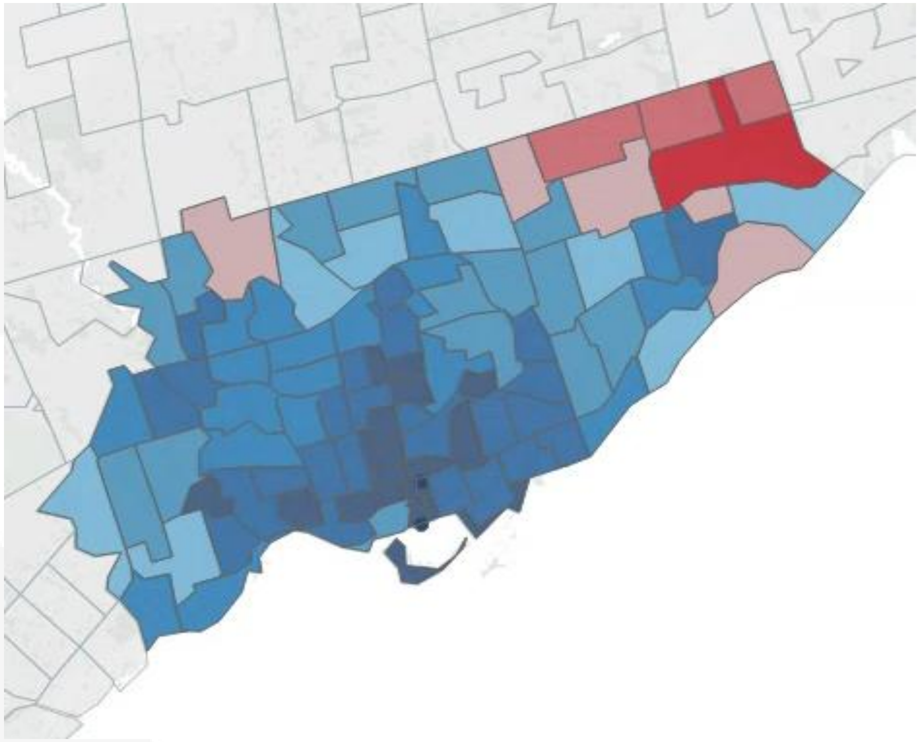
Transformers at End of Life for 2016 - 2020



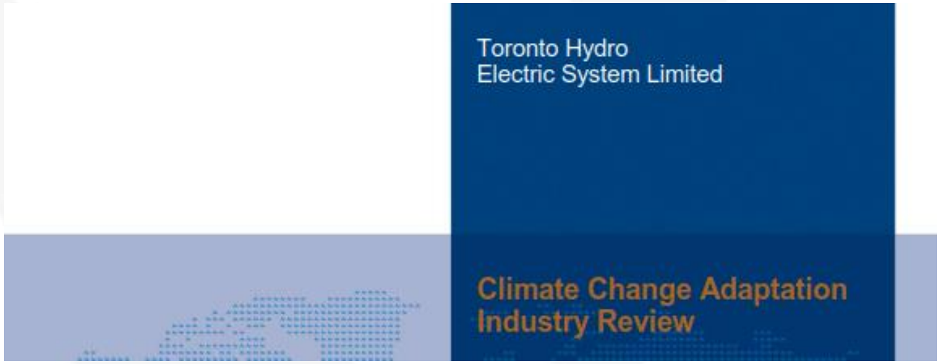
Lightning Mapping

- Lightning strike data over the last 20 years has been mapped across the city
- Correlation with system outage information will continue in 2017





Industry Review



- Review practices of major utilities in Canada and USA
- Paper review on industry best practices

Roadmap Development

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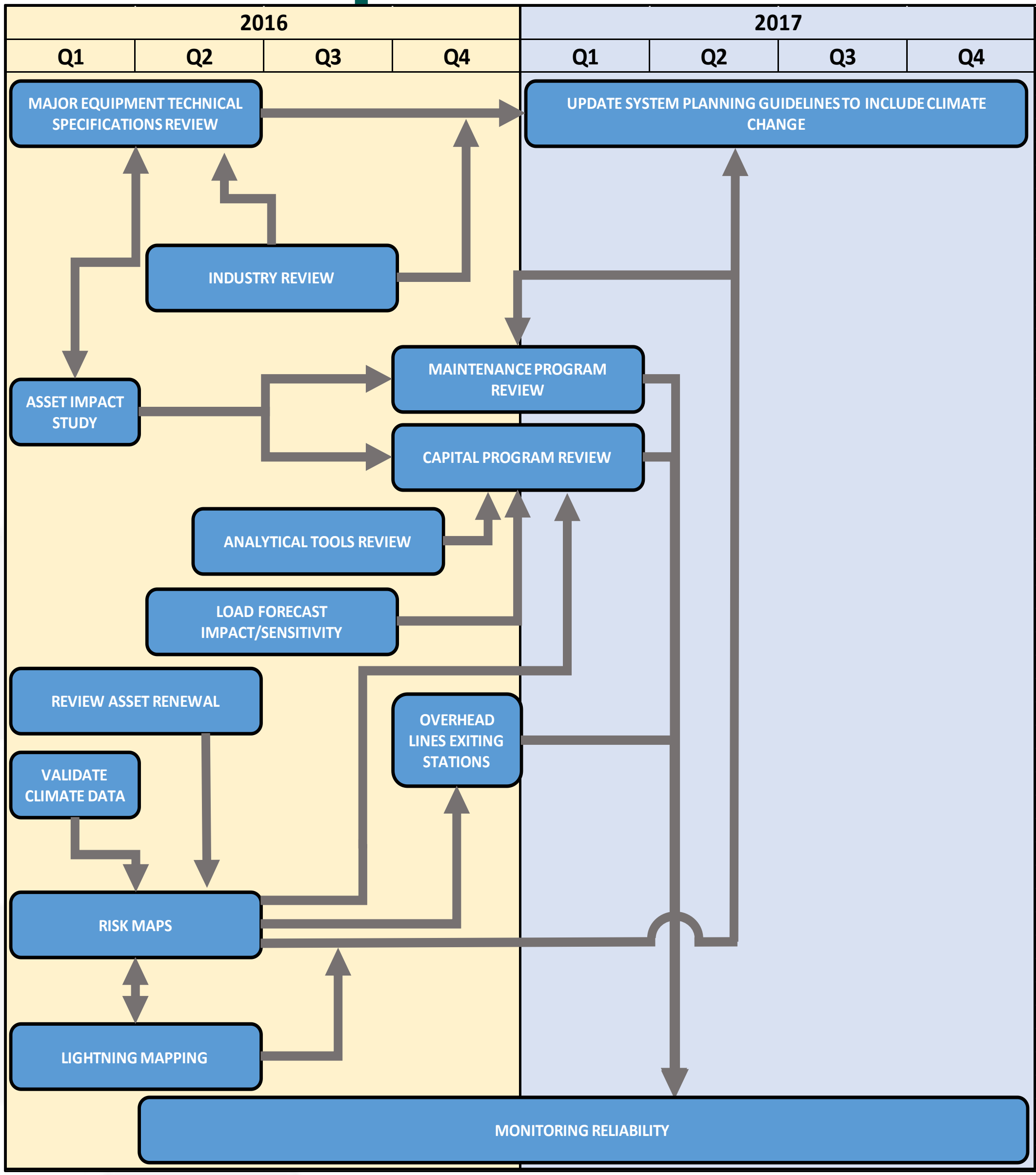


THANK
YOU!

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Questions

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