Climate Change Adaptation
System Resilience

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Engineering & Construction

6th Forum on the Climate-Energy Security Nexus
June 7, 2016
Ottawa, Canada
- Population of 2.8 million
- Largest city in Canada
- Fourth largest city in North America
- Consistently ranked one of the world's most livable cities

Toronto has North America's largest continuous underground pedestrian system and shopping complex
WE OWN AND OPERATE $3.0 BILLION OF CAPITAL ASSETS

HEAD OFFICE
14 CARLTON STREET
TORONTO, ONTARIO
M5B 1K5

674,201 RESIDENTIAL CUSTOMERS

757,000 CUSTOMERS

81,492 GENERAL SERVICE CUSTOMERS WITH MONTHLY DEMAND OF 0-5000 KILOWATTS

44 LARGE USERS WITH MONTHLY DEMAND OVER 5000 KILOWATTS

1,480 EMPLOYEES
Toronto Hydro

Climate Change Adaptation – June 7, 2016

1 CONTROL CENTRE

15,560 KILOMETRES OF OVERHEAD WIRES

161 MUNICIPAL SUBSTATIONS

16,900 PRIMARY SWITCHES

60,440 DISTRIBUTION TRANSFORMERS

176,500 POLES

12,920 KILOMETRES OF UNDERGROUND WIRES

TORONTO HYDRO'S SERVICE AREA
Climate Change Adaptation

Vulnerability Assessment Phase 1
Vulnerability Assessment Phase 2
Roadmap Development
Roadmap Implementation

System Resilience Enhancements

2012 2013 2014 2015 2016 2017
Climate Change Adaptation

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

325,000 customers impacted
Flooding of station control equipment

Vulnerability Assessment
Roadmap Development
Implementation

System Resilience Enhancements

July 2013

Extreme rainfall (126mm in 2 hrs)
325,000 customers impacted
Flooding of station control equipment

news.nationalpost.com
Climate Change Adaptation

December 2013 – Ice storm
300,000 customers impacted
Tree limbs falling on power lines
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

<table>
<thead>
<tr>
<th>Phase 1</th>
<th>Phase 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Pilot case study</td>
<td>• 2010-2050, 20 climate parameters</td>
</tr>
<tr>
<td>• Current climate only</td>
<td>• Entire distribution system</td>
</tr>
<tr>
<td>• Small portion of distribution system</td>
<td>• Completed June 2015</td>
</tr>
<tr>
<td>• Completed Sept 2012</td>
<td></td>
</tr>
</tbody>
</table>
### Climate Parameters and Probability of Occurrence

<table>
<thead>
<tr>
<th>Climate Parameter</th>
<th>Annual Probability (Historical, Projected 2030’s and 2050’s)</th>
<th>Probability of Occurrence Study Period (2015-2050)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daily Maximum</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>25°C</td>
<td>66 per year; 84 per year, 106 per year</td>
<td>100%</td>
</tr>
<tr>
<td>30°C</td>
<td>16 per year, 26 per year, 47 per year</td>
<td>100%</td>
</tr>
<tr>
<td>High Daily Avg. Temperature</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>30°C</td>
<td>0.07 per year; N/A, 1.2 days per year</td>
<td>~100%</td>
</tr>
<tr>
<td>Heat Wave</td>
<td>0.88 per year; &gt;1 for both</td>
<td>100%</td>
</tr>
<tr>
<td>High Nighttime</td>
<td>Nighttime low &gt;23°C</td>
<td>0.70 per year, 7 per year, 16 per year</td>
</tr>
<tr>
<td>100 mm in &lt;1 day + antecedent</td>
<td>0.04 per year; extreme precipitation expected ↑, percentage unknown</td>
<td></td>
</tr>
<tr>
<td>15 mm (tree branches)</td>
<td>0.11 per year; &gt;0.13 per year, &gt;0.16 per year</td>
<td></td>
</tr>
<tr>
<td>25 mm ≈ 12.5 mm radial</td>
<td>0.06 days per year; &gt;0.07 per year, &gt;0.09 per year</td>
<td></td>
</tr>
<tr>
<td>70 km/h+ (tree branches)</td>
<td>21 days per year; N/A, 24 to 26 days</td>
<td></td>
</tr>
<tr>
<td>90 km/h</td>
<td>2 days per year; N/A, &gt;2.5 per year</td>
<td></td>
</tr>
<tr>
<td>120 km/h</td>
<td>~0.05 days per year; likely ↑, but % unknown</td>
<td></td>
</tr>
<tr>
<td>Lightning</td>
<td>Flash density per km km²</td>
<td></td>
</tr>
<tr>
<td>1.12 to 2.24 per year per km², Expected increase, % change unknown</td>
<td>~50-70%(Lg); ~10-20% (Sm)</td>
<td></td>
</tr>
<tr>
<td>Snowfall</td>
<td>Days w/ &gt;10 cm</td>
<td></td>
</tr>
<tr>
<td>1.5 days per year; Trend decreasing but highly variable</td>
<td>100%</td>
<td></td>
</tr>
<tr>
<td>Days w/ &gt; 5cm</td>
<td>5 days per year, Trend decreasing but highly variable</td>
<td>100%</td>
</tr>
<tr>
<td>Frost</td>
<td>229 frost free days, 249 frost free days, 273 frost free days</td>
<td>100%</td>
</tr>
</tbody>
</table>
Vulnerability Assessment Phase 2

PIEVC Phase 2 Climate Change Risk Map by 2050

4. High Temperature Maximum Above 40 C

Legend
- Feeder Risk Categories
  - No Risk
  - Low Risk
  - Medium Risk
  - High Risk
- Station Service Area Risk Categories
  - No Risk
  - Low Risk
  - Medium Risk
  - High Risk
Vulnerability Assessment Phase 2

PIEVC Phase 2 Climate Change Risk Map by 2050

8. Extreme Rainfall 100mm in Less than 24 Hours

Legend
- No Risk
- Low Risk
- Medium Risk
- High Risk

Station Service Area Risk Categories
- No Risk
- Low Risk
- Medium Risk
- High Risk
PIEVC Phase 2 Climate Change Risk Map by 2050
13. High Winds Greater Than 90km/h
Vulnerability Assessment Adaptation Opportunities

- Infrastructure strengthening
- Capacity planning
- Inspection and maintenance programs
- Data collection and quality
Climate Change Adaptation Roadmap

- Climate data validation
- Asset lifecycle
- Equipment specifications
- Capital and maintenance programs
- Planning data, tools, guidelines
- Design practices
- Construction standards
Ongoing System Resilience Enhancements
Capital & Maintenance Programs

Rear Lot Conversion

Overhead Infrastructure Relocation

Tree Trimming Standards

<table>
<thead>
<tr>
<th>Organization</th>
<th>Clearance from Bare Conductor (ft.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>City of Toronto (0.9 m = 3')</td>
<td>1 2 3 4 5 6 7 8</td>
</tr>
<tr>
<td>Toronto Hydro (1.3 m = 4'2&quot;)</td>
<td></td>
</tr>
<tr>
<td>Other Utilities (2.4 m - 3.7 m = 8' - 12')</td>
<td></td>
</tr>
</tbody>
</table>
Ongoing System Resilience Enhancements
New Technologies

Breakaway Connectors

Stainless Steel Submersible Transformers
Opportunities

- Common climate data source
- Accelerated industry standards adaptation
- Vulnerability interdependencies
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