# APPENDIX 3.0-C

## *Climate Analysis Report*

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# 1.0 Climate Analysis Report

## 1.1 Introduction

Hydro One Networks Inc. (Hydro One) is completing a comprehensive environmental assessment (EA) for the Waasigan Transmission Line (the Project), a proposed new double-circuit 230 kilovolt (kV) transmission line between the Lakehead Transformer Station (TS), in the Municipality of Shuniah and the Mackenzie TS, in the Town of Atikokan, and a new single-circuit 230 kV transmission line between the Mackenzie TS, in the Town of Atikokan and the Dryden TS, in the City of Dryden. The length of the transmission line will be approximately 360 kilometres (km). The Project also includes the separation of approximately 1 km of the double-circuit section of the existing 230 kV transmission line outside of Mackenzie TS in Atikokan (circuits F25A and D26A) into separate single-circuit transmission lines as well as modifications at the TSs.

This Climate Analysis and Resilience Report supports the EA by providing an assessment of the Project's resilience to climate change. This assessment has been completed in accordance with the "Considering climate change in the EA process" guidance (MECP 2017).

This assessment integrates aspects from an enterprise-wide initiative to develop a Climate Adaptation Plan at Hydro One. This initiative commenced in mid-2022 and, to date, has included a series of tasks to meet Hydro One's needs for climate change adaptation, including conducting exposure analysis for existing infrastructure and integrating sensitivity analysis to understand Hydro One's vulnerabilities to projected climate change. While the initiative is still under development, the projection data available was used to inform this analysis.

### 1.1.1 Future Climate Projections and Infrastructure Interactions

Climate change could impact a range of hazards throughout Hydro One's service territory, including increasing the frequency and intensity of extreme heat, heavy precipitation and flooding, and frozen precipitation. To support Hydro One's understanding of these hazards and how they are projected to change, this report describes preliminary exposure from projected climate-related changes that may occur in Hydro One's northern service territory on transmission assets. This climate science exposure analysis was completed by Hydro One's corporate climate change consultant, ICF (ICF 2022).

The exposure analysis was conducted on five distinct categories of climate-related hazards:

1) Temperature (extreme heat and average temperature);
2) Flood and heavy precipitation;
3) Winter precipitation;

4) Wildfire; and

5) Extreme wind and wind gusts.

Projecting future climate conditions requires the consideration of future climate scenarios based on assumptions about future greenhouse gas (GHG) emissions and atmospheric concentrations. These future climate scenarios are termed as Representative Concentration Pathways (RCPs) by the Intergovernmental Panel on Climate Change (IPCC) and describe changing climatic conditions until 2100. The analysis focused on the range of plausible climate change futures, with an analytical focus on plausible upper and lower bounds of climate model projections. The upper and lower bounds represent the range of potential climate futures that Hydro One considers in planning, as described herein, with an emphasis on understanding risks in higher-end scenarios. The scenarios are based on risk tolerance levels that have been derived from (1) probabilistic modelling across an ensemble of Global Climate Models (e.g., 10$^{th}$ percentile of model distribution represents lower range of distribution, 90$^{th}$ percentile represents high range) and (2) RCPs; greenhouse gas (GHG) pathways that set emission levels during the remainder of the 21$^{st}$ century in climate models. For atmospheric projections in this summary, these scenarios are summarized in Table 1.1-1.

**Table 1.1-1: Characterization of Representative Concentration Pathways**

| Name | Characterization |
|---|---|
| RCP 8.5 90th percentile scenario (upper bound) | Increasing GHG emissions over time, with no stabilization, representative of scenarios leading to high GHG concentration levels.<br>Represents a failure of global emissions reduction efforts and high-end climate sensitivity. |
| RCP 4.5 50th percentile scenario (lower bound) | Total radiative forcing is stabilized shortly after 2100, without overshoot. This is achieved through a reduction in GHGs over time through climate policy.<br>Represents aggressive global emissions reductions and middle-of-the-road assumptions on earth system sensitivity. |

Source: Summarized from van Vuuren et al., 2011.

RCP = representative concentration pathway; GHG = greenhouse gas; W/m$^2$ = Watts per square metre.

Throughout the study, analysis focused primarily on the medium-term (2050) timeframe to capture potential change through mid-century.

The climate projections provided in this report are primarily drawn from an ensemble of Localized Constructed Analogs (LOCA) statistically downscaled Coupled Model Intercomparison Project Phase 5 (CMIP5) Global Climate Models. LOCA projections have a high resolution 6 km by 6 km grid spacing for a large portion of Ontario, spanning all of Hydro One’s transmission service territory, with a focus on the northern region where the Project is located.

Supplementary climate data are drawn from NASA Nex-GDDP (Thrasher, B. et al. 2022) CMIP6 Global Climate Models (wind projections), ECCC CMIP5 Global Climate Models (drought projections; ECCC 2022), Natural Resources Canada and Canadian National Fire Database (historical wildfire data; Natural Resources Canada n.d.), and additional projections from a literature review (winter precipitation and winds).

In addition to the data derived from Hydro One's exposure analysis, references from peer-reviewed publicly available research for the Project region were used to describe changing climate trends, including the Government of Canada's *Changing Climate Report* (Bush, E. and Lemmen, D.S. 2019) and the Government of Canada's most recent report, *Canada's Changing Climate Report, In Light of the Latest Global Science Assessment* (Bush, E., et al. 2022).

Collectively, the climate projections, sensitivities, and vulnerabilities relevant to the Project are described in Sections 2.1 – 2.6. Extreme events associated with each category are discussed within the relevant section rather than discussed as a separate category. Extreme events, also knowns as acute or high-impacts/low-likelihood events, are an important consideration for future climate risks. There is growing confidence that the frequency and intensity of storm events will increase (Palko, K.G. and Lemmen, D.S. 2017).

### 1.1.2 Temperature

In Ontario, the mean annual temperature has increased by 1.3ºC from 1948 to 2016 (Cohen, S. et al. 2019). More specifically to the Project, in northern Ontario, the mean annual temperatures are projected to increase by 2.0ºC to 2.5ºC under RCP 8.5 scenario by the 2050s (NOCCH 2021).

To assess exposure to temperature variables, the analysis investigated multiple climate metrics relevant to Hydro One transmission and distribution assets:

- **Annual average daily summer temperatures** – relevant for transformers, structure foundations, vegetation growth, pests and pathogens that directly impact vegetation.
- **Annual average days per year exceeding 35°C** – common ambient temperature assumption for station infrastructure.
- **Annual average maximum temperatures** – relevant for load forecasting.

The analysis projects temperature and extreme heat to increase across the province of Ontario and the Hydro One service territory in the coming decades (Figure 1.1-1). Summer temperatures are particularly relevant to Hydro One's transmission system – for example, warmer seasonal temperatures could promote accelerated vegetation growth resulting in vegetation contact with the infrastructure which can cause asset damage, outages, and safety hazards. Increased temperatures can also impact the functioning of the transmission lines and power transformers. and prolonged heat could degrade foundation structures when coupled with increases in moisture and precipitation. The inland and northern portion of the service territory between Lake Superior and Hudson Bay tends to experience warm average summer temperatures relative to the more moderate coastal regions proximal to Lake Superior and Hudson Bay. Average summer temperatures projected by RCP 4.5 50th percentile are approximately 1-2°C lower than average summer temperatures projected by RCP 8.5 90th percentile. The projected increases in summer temperatures by mid-century could expose the service territory to more optimal growing conditions for vegetation, posing risks to poles and lines if unmanaged.

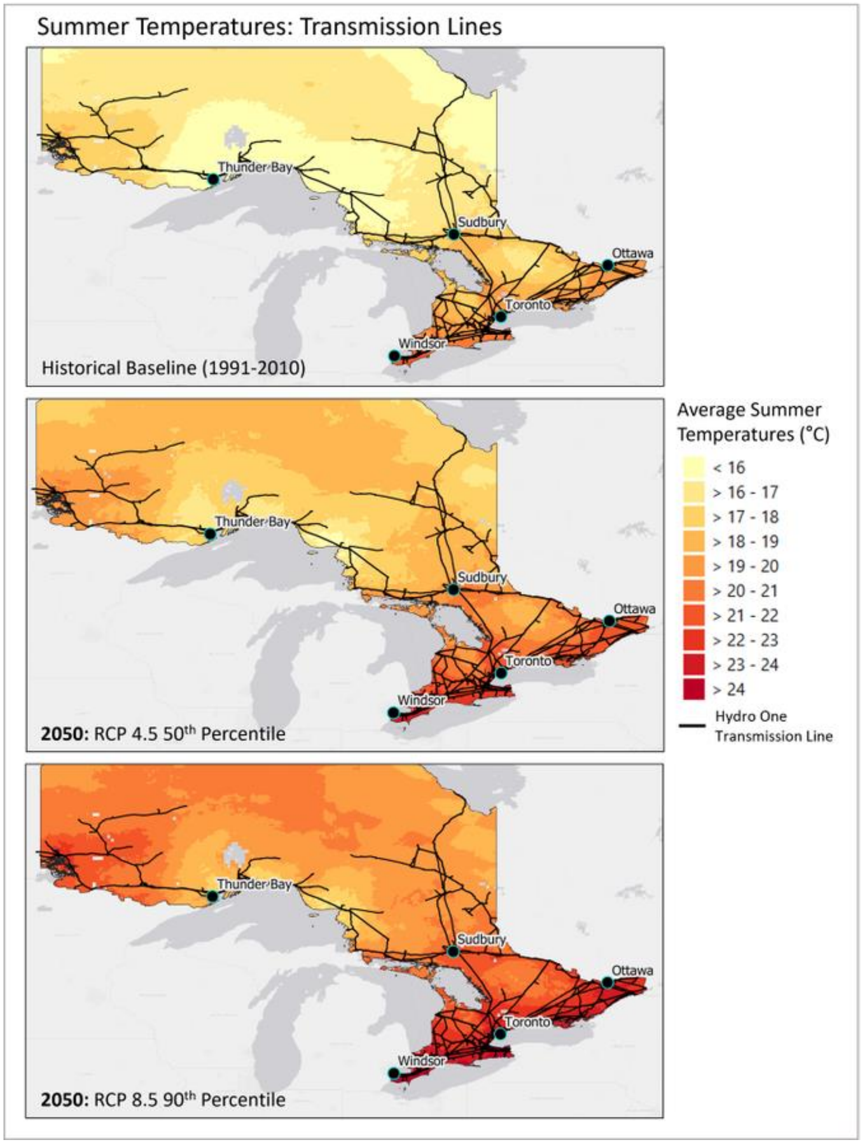


**Figure 1.1-1: Historical (top) and 2050 annual average summer (6/1 – 8/31) temperature for RCP 4.5 50th percentile (middle) and RCP 8.5 90th percentile (bottom) overlaid with overhead primary transmission conductors**

Extreme hot temperatures are projected to become more frequent and more intense (Bush, E. et al. 2022). For the region of northern Ontario, the average summer temperatures are projected to increase by 2.0ºC to 2.6ºC by the 2080s (NOCCH 2021).

Station equipment is sensitive to changes in ambient temperatures. Until recently, station equipment was selected based on historical averages of temperatures only, as opposed to also considering future temperature projections. By 2050, under RCP 4.5 50th percentile, transmission conductors could experience as little as one day above 35°C in the northern portion of Hydro One's service territory (Figure 1.1-2). Under RCP 8.5 90th percentile, there could be a more extreme increase in the number of days per year above 35°C – conductors in coastal areas along Lake Superior may experience several days above 35°C per year.

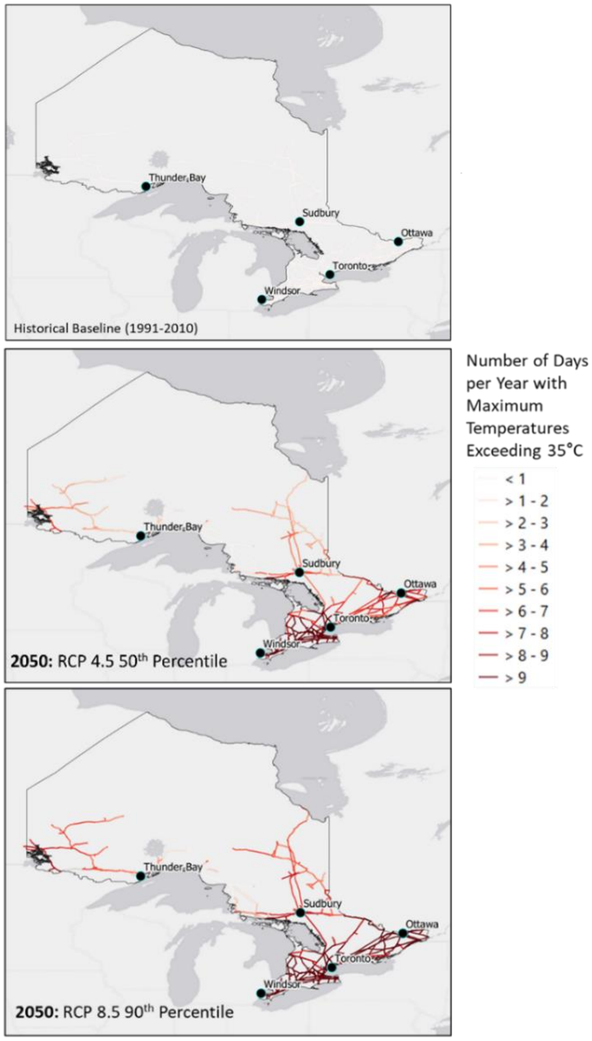


**Figure 1.1-2: Overhead primary transmission conductors colored by historical (top) and 2050 annual average number of days with maximum daily temperature exceeding 35°C for RCP 4.5 50th percentile (middle) and RCP 8.5 90th percentile (bottom)**

In most regions in Canada, there has been an observed decrease in intensity and frequency of cold extremes (Bush, E., et al. 2022). Extreme cold days are projected to decrease in the future, as the annual number of extreme warm days and nights continue to increase (Lemmen, D.S. et al. 2014). In northern Ontario, the greatest changes are projected to occur in the winter season with a projected increase of 4.0ºC in the season by the 2080s (NOCCH 2021).

### 1.1.3 Flood and Heavy Precipitation

In Ontario, the mean annual precipitation has increased by 9.7% from 1948 to 2012 (Cohen, S. et al. 2019). In Ontario, the mean annual precipitation is projected to increase by 6.6% from 2031-2050 and by 17.3% from 2081-2100 under the RCP 8.5 scenario, compared to the 1948-2012 baseline (Cohen, S. et al. 2019). The mean annual precipitation is projected to increase throughout northern Ontario with an anticipated shift projected in the spring and fall seasons, with warming temperatures resulting in wetter, inconsistent forms of precipitation (NOCCH 2021). Additionally, as climate warming has made more moisture available in the atmosphere, this additional moisture can lead to an increase in the intensity of extreme precipitation events that will vary between locations (Bush, E. and Lemmen, D.S. 2019).

To assess exposure to flood variables, Hydro One's analysis leverages multiple metrics and information:

- **Maximum annual 5-day and 1-day precipitation –** common variable for heavy precipitation relevant to inland flooding, and relevant for station transformer containment design assumptions, building design, station drainage.
- **Inland flood extent and inundation from 100-year flood event** – relevant to inland flooding.

The maximum amount of precipitation falling over a 5-day period represents a longer-duration event relevant to inland flooding. Historically, stations in coastal regions adjacent to the Great Lakes and in the southwestern portion of the service territory have experienced the largest maximum 5-day precipitation totals, with some stations approaching totals of approximately 80 millimetres (mm). Inland stations, including those north of Sudbury, have typically experienced lower maximum 5-day precipitation totals, with totals below 60 mm. Under RCP 4.5 50$^{th}$ percentile, average annual maximum 5-day precipitation totals are projected to increase minimally across Ontario, especially at inland and northern stations. However, under RCP 8.5 90$^{th}$ percentile, more dramatic increases in the average annual maximum 5-day precipitation totals are projected by 2050 (Figure 1.1-3).

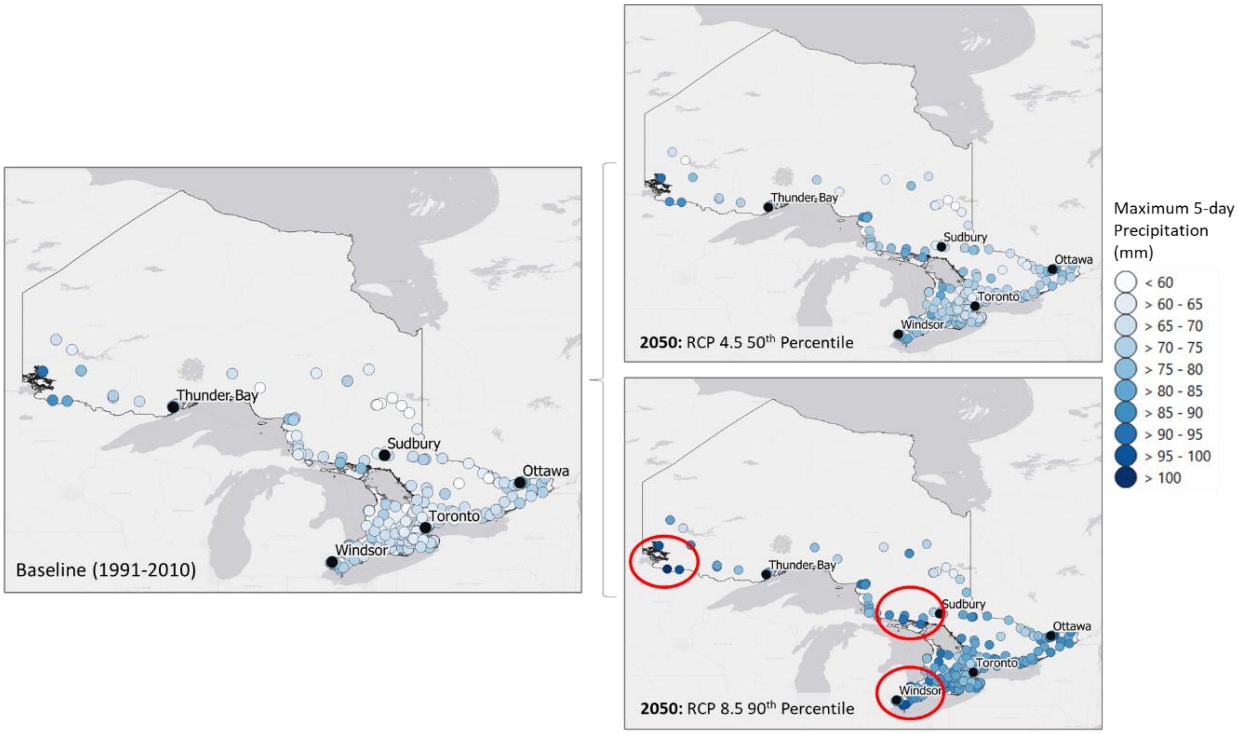


**Figure 1.1-3: Historical (top), 2050 RCP 4.5 50th percentile (middle), and 2050 RCP 8.5 90th percentile (bottom) average annual maximum 5-day precipitation at transmission stations. Circles highlight regions with highest exposure in RCP 8.5 90$^{th}$ percentile scenario**

On a global scale, observations indicate an increase in extreme precipitation events associated with increase in temperatures. In northern Ontario, heavy precipitation days have already increased (NOCCH 2021). In Canada, extreme precipitation events are projected to become twice as frequent by 2050. Extreme precipitation with a return period of 20 years is projected to become a 1-in-10-year event by the 2050s under the RCP 8.5 scenario, compared to the 1986-2005 baseline (Bush, E. and Lemmen, D.S. 2019). A warmer temperature is projected to intensify very wet and very dry weather and climate events, with implications for flooding (Bush, E. et al. 2022). For northern Ontario, projections indicate more frequent and intense incidences of heavy precipitation days that could include precipitation amounts greater than 10 mm in one day (NOCCH 2021).

Hydro One's exposure analysis evaluated the maximum amount of precipitation falling over a 1-day period represents a short-duration, high-intensity precipitation event more relevant to flash flooding and short-term extreme precipitation events. Inland stations, such as those to the north of Sudbury, have historically experienced less precipitation falling during the annual average maximum 1-day event (<28mm). In general, assets farther to the northwest could experience increased exposure to longer-duration 5-day precipitation events, but less exposure to shorter-duration 1-day events. Under RCP 4.5 50$^{th}$ percentile, totals for the annual average maximum 1-day event are projected to increase as little as 3% in northwestern Ontario. Under

RCP 8.5 90th percentile, the projected increase in the annual average maximum 1-day event ranges from a 9-12% in the northwestern portion of the service territory.

Changes in precipitation, notably extreme rain events, can have an impact on station drainage systems and the integrity of below-grade infrastructure such as structure foundations and basements. Coupled with increasing temperatures, there have been studies to suggest that accelerated degradation of some infrastructure may be expected, shortening the lifespan of assets such as wood poles (Wang and Wang 2012). Recent changes to design standards to accommodate projections related to changing precipitation have been made.

### 1.1.4 Winter Precipitation

In Canada, the seasonal snow accumulation has decreased by 5% to 10% per decade since 1981 (Bush, E. and Lemmen, D.S. 2019). In Canada, climate projections indicate that it is likely that seasonal snow accumulation will further decrease by the 2050s under all emission scenarios due to an increase in surface air temperatures (Bush, E. and Lemmen, D.S. 2019). Precipitation has increased in many parts of Canada, with a shift towards less snowfall and more rainfall (Bush, E. et al. 2022). In Canada, climate projections indicate general increases in rain-on-snow events from November to March for most of Canada by mid-century (2041–2070) for both medium (RCP4.5) and high (RCP8.5) emission scenarios (Bush, E. and Lemmen, D.S. 2019).

In northern Ontario, mixed precipitation, such as freezing rain and rain-on-snow events, are projected to increase along with projected increase in the frequency and intensity of winter storms (NOCCH 2021). In northern Ontario, the average number of winter season ice storms lasting at least six hours could increase upwards of 131% by 2050, and 216% by 2080, more than anywhere else in the province (Cheng et al. 2007). Shorter duration ice storms are projected to increase, as well, although increases are expected to be smaller relative to longer-duration events. Importantly, increases in the frequency of ice storms are likely to be proportionally greater in northern Ontario than in southern Ontario. The shift in frequencies of ice storms across Ontario could be attributed to poleward shifts in storm tracks under climate change, which would change pathways for major ice storms. Another study showed similar results, concluding that projected increases in ice storm frequency in northern Ontario may be relatively larger than increases in southern Ontario throughout the 21st century (2016–2035, 2046–2065, 2081–2100). Overall, projected increases in maximum frozen precipitation may be largest over northern Ontario relative to southern Ontario (Cheng et al. 2011).

To assess exposure to winter precipitation variables, which considers both snowfall and icing (freezing rain and sleet), Hydro One's analysis leverages multiple metrics and information:

- **Maximum annual frozen precipitation –** relevant for direct impacts of snow and ice, such as radial icing design limitations for stations and lines, vehicle access on roads, and personal health and safety.

- **Literature review of freezing rain frequencies through late-21st century –** relevant for likelihood of exposure to radial icing and personal health and safety.

Average annual maximum frozen precipitation indicates extreme winter weather may pose risks to overhead primary transmission conductors. Historically, the southern portion of the service territory and areas along the Great Lakes close to Thunder Bay have experienced the largest maximum frozen precipitation totals (>19 mm of liquid water equivalent), while the north and western portion of the service territory has seen smaller totals (typically <16 mm of liquid water equivalent and as little as <12 mm) (Figure 1.1-4).

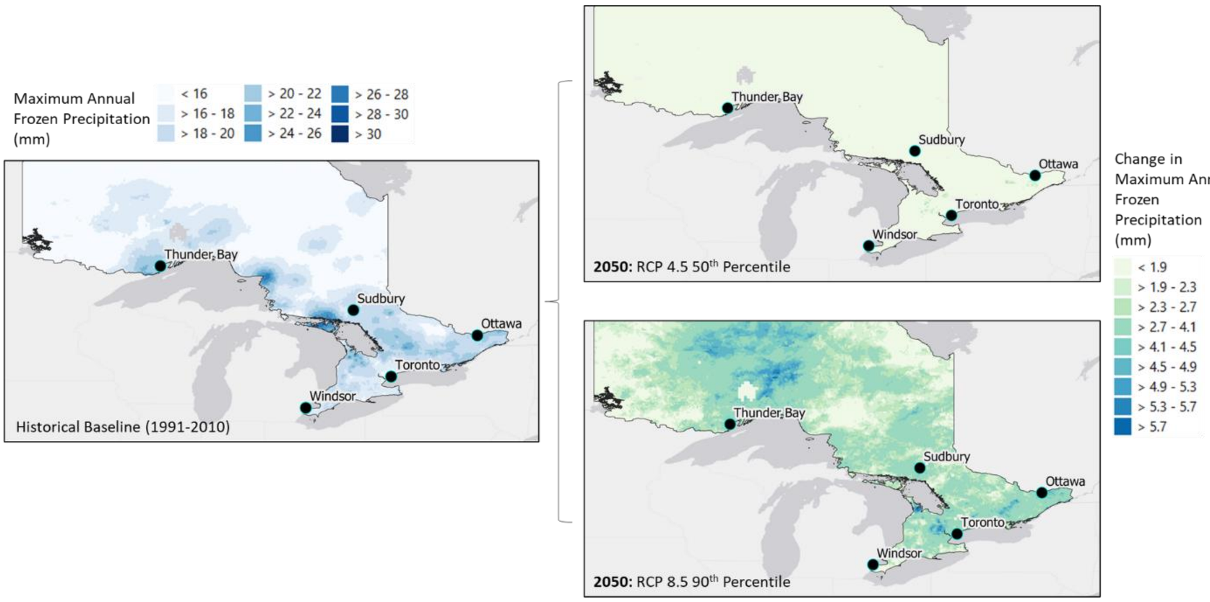


**Figure 1.1-4: LOCA CMIP5 projections of maximum annual frozen precipitation. Baseline scenario represents average annual magnitudes (1991-2010), and future scenarios (2050 RCP 4.5 50th percentile and RCP 8.5 90th percentile) represent change relative to baseline**

Across the province, transmission lines have historically seen an annual average maximum frozen precipitation between 15 mm and 20 mm. Under RCP 8.5 90th percentile, there is a significant shift such that the majority of transmission lines might experience between 20 mm and 25 mm.

While granular projections of frozen precipitation exposure can be quantified across the service territory, projected changes to ice storms, namely freezing rain, due to climate change remain highly uncertain due to the specific atmospheric conditions required for ice storms to occur relative to other high-impact hazards. A review of the scientific literature has shown that in Northern Ontario, the average number of winter season (December-February) ice storms lasting at least six hours could increase upwards of 131% by 2050, and 216% by 2080, more than anywhere else in the province (Cheng C.S., et al 2007). As discussed in Section 2.5, these freezing rain events can have a compounding impact on the infrastructure when exposed to wind.

### 1.1.5 Wildfire

An increase in the frequency and intensity of extreme hot temperatures and greater regional dryness has led to an increase in conditions that could increase wildfire risk (Bush, E. and Lemmen. S. 2019). In northern Ontario, incidences of wildfires are projected to increase by 25% by 2030 due to drier summers, increased lightning storms, and projected increase in dry, windy weather conditions (NOCCH 2021).

Hydro One's exposure analysis analyzed wildfire risk on a landscape scale, given that granular location-specific projections are not readily available to assess wildfire risk, and asset-level projections are less applicable for this hazard, as opposed to a generalized focus on projected trends. The analysis relies on drought projections as a proxy for wildfire exposure, supplemented by historical burned area data. To assess exposure to wildfire variables, this analysis leverages multiple metrics and information:

- **Maximum annual consecutive dry days –** common variable for short-term meteorological drought conditions, relevant for drying vegetation and increasing fire weather conditions.
- **Summer Standardized Precipitation-Evapotranspiration Index (SPEI) –** common variable for seasonal drought intensity, relevant for fuel dryness and increasing the likelihood of wildfire ignition and expansive.
- **Historical burned area composite from Natural Resources Canada and Canadian National Fire Database (Natural Resources Canada n.d.)** – provides historical context for how wildfires have historically impacted the service territory.

Future wildfire risk and exposure in Ontario may increase due to higher temperatures and greater regional dryness, although this is characterized by significant uncertainty. Moreover, wildfire risk has been most significant in northern Ontario, where boreal forest cover is greatest. Potential for asset exposure will be greatest where development encroaches into wooded landscapes, the Wildland-Urban Interface (WUI). This would represent area where wildfire ignition likelihood is greatest due to the presence of energy assets, residential structures, and vegetation. For transmission assets, longer lines that cover more expansive stretches of wooded areas could experience increased exposure to larger wildfires.

Evaluating historical burned area and projected changes in seasonal drought metrics, exposure could be greatest over the forested, fire-prone landscape of northwestern Ontario. Both projected drier summers and more intense dry spells could increase the frequency and intensity of fire weather conditions over northwestern Ontario by mid-century. However, future wildfire exposure is characterized by a high degree of uncertainty, given the complex interactions between climate-driven factors. Additionally, mitigating social factors and improved wildfire control measures may reduce the degree to which climate change increases wildfire risk.

### 1.1.6 Extreme Wind and Wind Gusts

For both average and extreme wind speeds, wind projections are subject to significant uncertainty due, in part, to the limited ability of global-scale climate models to resolve the small spatial and time scales over which strong winds occur. To assess exposure to wind variables, this analysis leverages multiple metrics and information:

- **Annual average daily mean wind speeds –** relevant for transmission line ratings, and structure strength.
- **Maximum historical wind gusts at weather stations –** provides historical context for how extreme winds have historically impacted the service territory.
- **Literature review of wind gust frequencies by intensity through late-21st century** – relevant for physical damage and design limitations of lines and stations.
- **Changes in icing frequencies which may create compounding impacts with high wind speeds** – relevant for diminishing design thresholds during ice storms.

The quantitative analysis initially focuses on understanding the exposure of overhead transmission conductors to average wind speed by 2050. Average wind speed changes are projected to be negligible – often increases of 2% to 3% at most are observed in the windier and lower-friction coastal areas of the Great Lakes and James Bay in the higher-end SSP5-8.5 90th percentile scenario (which represents a high-end scenario for CMIP6 Global Climate Models assuming greenhouse gas concentrations continue to rise throughout the 21st century). This leads to minimal changes in exposure of transmission assets to projected changes in daily wind speeds.

Across Ontario, high-intensity wind gusts are projected to increase in frequency through the end of the 21st century. In particular, the highest-intensity wind speeds will increase in frequency faster than lower intensity winds. The frequency of these events could increase 20% to 40% by late-21st century, exposing overhead transmission conductors to a higher frequency of extreme wind speeds. Less intense wind gust events (>28 km/h and >40 km/h) may also increase by the end of the century, but by a smaller margin (10% to 15% and 10% to 20%, respectively).

Compared to temperature and average daily wind data, extreme wind gusts are challenging to project in global climate models given the small space and time scales at which they occur and the limited availability of high-quality observed datasets. This introduces a high degree of uncertainty in projected trends at the local scale. In addition, the maximum wind gusts highlight the random nature of extreme wind across Ontario relative to average winds, likely an artifact of the strongest winds occurring in severe storms.

A Mesoscale Convective System (MCS) is an organized complex of thunderstorms often acting as a single system that spans approximately 100 km and can spawn multiple types of severe weather including, but not limited to, squall lines, gust fronts, and tornadoes (NOAA n.d.). Overall, thunderstorms and severe weather (which includes MCS and derechos) are projected to increase in frequency under climate change. In Ontario, the number of tornados has increased from the 1980-2009 period to the 1991-2020 period (Sills, D. et al. 2022). A derecho, which is a widespread, long-lived, and straight-line windstorm that is associated with a band of rapidly moving showers or thunderstorms, usually results from the violent outflow of an MCS. MCS and derechos activity has been limited to southern Ontario where the northern edge of warm moist air from hot summertime temperatures to the south in the United States meets cooler air to the north. In addition to impacts from the winds associated with these storms, lightening can also result in damage to the infrastructure.

Freezing rain / icing can amplify the impacts of winds on the Project's infrastructure. While the largest increases in frozen precipitation are projected over northern Ontario relative to southern Ontario, the highest historical icing has occurred in southern Ontario. Increases could bring the more extreme icing events exceeding 30 mm, which would expose transmission lines and stations to more severe icing totals. With the concurrent projected increase in the likelihood of ice storms and extreme winds, the likelihood of these large wind gust events occurring during extreme ice storms in Ontario may increase through the end of the 21st century, as well. Given Hydro One design standards, more frequent icing totals above 30 mm would lead to lower wind speed thresholds to produce physical damage to both stations and overhead lines (60% to 70% of the wind speed intensities designed to without significant icing).

These extreme events are also explored as part of the recent climate exposure analysis work. The focus was on historical analogues, future projections, and hypothetical future scenarios for (1) severe multi-day ice storms (freezing rain) coincident with high winds, and (2) mesoscale convective systems that produce severe thunderstorms with high winds and tornadoes. Global Climate Models are limited in their ability to resolve these extreme events due to the small spatial and time scales at which the events occur, as well as the shortness of the historical record relative to the rarity of the events. In addition, both mesoscale convective systems (thunderstorms) and ice storms are particularly difficult to resolve given the complex and rare environmental conditions that promote their formation. Regardless, this analysis is intended to provide a broader understanding of potential future climate hazards in Ontario in support of Hydro One's Climate Change Adaptation strategy.

Overall, exposure to extreme winds is projected to increase by late-21st century. Impacts to the infrastructure from these extreme winds could be highest during the winter months due to projected increases in freezing rain exposure across Ontario.

### 1.1.7 Climate Resilience Measures

Hydro One operates vital infrastructure that must be resilient to the impacts of climate change. Hydro One, as a licensed transmitter, complies with North American Electric Reliability Corporation (NERC) Reliability Standards to ensure the reliability and security of the transmission system. While having inherent resiliency built into current design standards, Hydro One continues to improve the resilience of its operations by focusing on the planning, designing, constructing, operating and maintaining of its infrastructure considering the future climate projections reviewed in Section 2, as well as the sensitivity and vulnerabilities presented in Section 3.

This section presents how these resilience and adaptation measures will be applied for this Project, specifically with respect to engineering and design and operations.

### 1.1.8 Engineering and Design

Integrating resilient design has been an effort at Hydro One for many decades (Hydro One, 2019). The Project will be designed and constructed according to standard industry design codes and guidelines applicable to transmission projects. These will include, but are not limited to, design requirements set forth by the Canadian Standards Association documents C22.3 No. 1-15 “Overhead Systems” and C22.3 No. 60826-10 (R2015) “Design criteria of overhead transmission lines (Adopted from Commission Electrotechnique Internationale/ International Electrotechnical Commission [CEI/IEC] 60826:2003, third edition, 2003-10, with Canadian deviations).”

Designing to the existing code is currently understood to offer the appropriate level of reliability to comply with NERC and Independent Electricity System Operator (IESO) reliability standards.

In addition to meeting design codes and guidelines, Hydro One has completed many actions to increase resiliency in infrastructure design including:

- Updating criteria for new transmission lines electrical current capability (thermal rating), now based on an ambient temperature of 35°C (previously 30°C).
- For station equipment, including power transformers, technical requirements specify ambient temperatures of -40°C to 40°C (maximum) with an average operating ambient of 35°C.
- Application of dual element spot network (DESN) for the majority of its transmission system, such that this system provides redundancy and reduces the impact of increasing temperatures.
- Applying new design standards to improve pole line resiliency for extreme weather events.
- Updating engineering design standards to mitigate the risks that are associated with wind and ice damage to stations and for large volumes of snow accumulation.

- Protection from lightning by (1) providing adequate shielding using overhead grounded shield wire or a mast in the vicinity of the objects being shielded, so that a lightning stroke descending from the cloud will terminate on the shielding conductor or mast, not elsewhere and/or (2) protecting the equipment against the travelling overvoltage waves which enter the station over the transmission lines. This is achieved by setting limits on the separation between the equipment and the surge arresters.
- Revising Station Buildings Basements Design Guidelines to mitigate flooding sensitivities which has effectively updated transformer and switching station drainage, effectively reducing the sensitivity of transformer stations to flooding.
- Establishing rigorous right-of-way (ROW) vegetation clearing widths for 230 kV transmission to manage various risks associated with vegetation and weather interactions including forest fire risk.

### 1.1.9 Operations

Ongoing operational processes contribute significantly to managing climate risks and ensuring grid resiliency. Table 1.1-2 summarizes existing and proposed operational practices that contribute to climate change adaptation.

**Table 1.1-2: Climate Related Operational Processes**

| Operational Category | Practices |
|---|---|
| Inspections | Hydro One will inspect the transmission line on a three-year basis. Typically, these inspections will be completed using a helicopter, but some inspection will be undertaken using the available access roads and trails. During these inspections, the effects of climatic events (e.g., sign of physical damage, general condition of the equipment) will be noted and repairs or equipment replacement will be conducted as necessary.<br><br>Power equipment at the stations will be inspected twice per year and environmental inspections will occur monthly. Thermography testing of the power equipment will occur annually. Breakers will be tested on a regular interval of approximately seven to eight years for diagnostic testing. The frequency of testing may vary depending on the practices of the transmitter or as regulatory requirements change. Switches will be maintained on a conditional basis. |

| Operational Category | Practices |
|---|---|
| Maintenance and Repairs | Typical transmission line maintenance activities include minor adjustments and replacements (e.g., replacement of insulators). However, more extensive repairs may be required that could involve the replacement of anchors or guy wires, necessitating the use of heavy equipment such as backhoes or cranes.<br><br>Equipment maintenance will be conducted in accordance with manufacturer's requirements and will be completed on site. All maintenance and repair activities will be undertaken in compliance with applicable environmental rules and regulations. |
| Vegetation Management | Vegetation management plays a critical role in minimizing the potential for vegetation contact with transmission assets. Vegetation contact can result in asset damage, outages, and safety hazards.<br><br>Ongoing investigations on changes to vegetation growth rates and the nature of such growth (including introduction of pathogens and invasive species) will be integrated into practices and may necessitate higher frequencies of trimming, more active monitoring, or other enhanced vegetation management approaches. |
| Emergency Management | Hydro One maintains a comprehensive Incident Management System for emergency management, encompassing personnel, facilities, equipment, procedures, and communications. This includes use of advanced forecasting techniques to more proactively predict weather impacts. Hydro One is a member of mutual assistance programs including North American Mutual Assistance Group and Ontario Mutual Assistance Group to provide collaborative emergency support focusing on expediting recovery, sharing resourcing, materials and information during emergencies.<br><br>The frequency and magnitude extreme events will likely increase in the future due to climate change. This may require future updates to the existing system.<br><br>Maintaining a large inventory of spare equipment to ensure backup is readily accessible and available for emergency replacement. |

Hydro One will continue to invest in understanding climate adaptation and ensure Hydro One's commitment to prepare for climate change is met. This will include continuous improvements to Hydro One's understanding of climate exposure, risk and investment priorities to achieve adequate grid resiliency in the face of a changing climate.

### 1.1.10 Construction

When assessing the resilience to climate change, construction is not considered to the same extent as operations due to its short-term nature. However, there will be contingency and management plans outlined in the Environmental Protection Plan (EPP) that will be prepared prior to construction. This EPP will include measures that will mitigate impacts to the environment from extreme weather events. For example, the Soil Management Plan, to be included within the EPP, will consider impacts from extreme rainfall, flooding, and high winds. The EPP will also include snow management measures that will mitigate not only potential safety hazards associated with snow, but also impacts to soil, vegetation and wildlife from snow clearing. Additionally, an Emergency Response Plan will be developed for construction that will incorporate the potential impacts of extreme events.

### 1.1.11 Environment's Ability to Adapt to Climate Change

The Project will have minimal additional impact on the ability of the surrounding environment to adapt to and cope with climate change. Project disturbances to wetlands, forests and wildlife and wildlife habitat may exacerbate changes already known to be occurring because of climate change (e.g., wetlands have the potential to become more susceptible to sedimentation, which can change their form and their function to regulate hydrological flow [flood attenuation]; and forest fragmentation has the potential to exacerbate drying conditions, which could heighten fire risk). However, Project design elements and mitigation measures (e.g., properly installed sediment and erosion controls; allowing edges of the right-of-way to grow back to shade the edges of newly fragmented forests) will serve to minimize the susceptibility of these disturbed natural features on the landscape to climate change risks.

The construction phase of the Project is anticipated to have minor impact as it is a temporary phase and short-term compared to the long-term nature of climate change. During the operational phase, the Project design incorporates measures to minimize additional impact on the ability for the environment to adapt to climate change. For example, water crossings will be designed to convey projected future flow events and regular maintenance will be conducted to evaluate crossing conditions so they can be modified as needed. Additionally, the route has been selected to minimize the impact to the environment, specifically sensitive features, to the extent possible.

# References

AECOM. 2015. Toronto Hydro-Electric System Limited Climate Change Vulnerability Assessment. [accessed November 2022]. Available at: https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/energy/energy-resources/Toronto_Hyrdo-Electric_System_Limited-Climate-Change-Vulnerability-Assessment.pdf

Auld, H., J. Klaassen, M. Geast, S. Cheng, E. Ros, and R. Lee. 2004. Severe ice storm risks in Ontario, presentation. Meteorological Service of Canada Environment Canada - Ontario Region. Available at: https://www.iclr.org/wp-content/uploads/PDFS/2004_Nov_ICLR_Final_ICE_STORMS.pdf

Bush, E. and D.S. Lemmen. 2019. Canada's Changing Climate Report. Government of Canada, Ottawa, ON. 444 p. [accessed November 2022]. Available at: https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/energy/Climate-change/pdf/CCCR_FULLREPORT-EN-FINAL.pdf

Bush, E., B. Bonsal, C. Derksen, G. Flato, J. Fyfe, J. Gillett, B.J.W. Greenan, T.S. James, M. Kirchmeier-Young, L. Mudryk, and X. Zhang. 2022. Canada's Changing Climate Report in Light of the Latest Global Science Assessment. Government of Canada. Ottawa, ON. 37p. [accessed November 2022]. Available at: https://changingclimate.ca/site/assets/uploads/sites/2/2022/03/CCCR-2022-Supplement-Final.pdf

Natural Resources Canada. n.d. Canadian National Fire Database. [accessed February 2023]. Available at: https://cwfis.cfs.nrcan.gc.ca/ha/nfdb?type=nbac&year=9999

Canadian Standards Association. 2022. C22.3 No. 1-15: Overhead Systems. [accessed November 2022]. Available at: https://www.csagroup.org/store/product/C22.3%20NO.%201-15/

Canadian Standards Association. 2022. C22.3 No. 60826-10 (R2015): Design criteria of overhead transmission lines (Adopted CEI/IEC 60826:2003, third edition, 2003-10, with Canadian deviations). [accessed November 2022]. Available at: https://www.csagroup.org/store/product/2420791/

Cheng, C.S., H. Auld, G. Li, J. Klaassen, and Q. Li. 2007. Possible impacts of climate change on freezing rain in south-central Canada using downscaled future climate scenarios, Natural Hazards and Earth System Science, 7(1), 71–87. Available at: https://doi.org/10.5194/nhess-7-71-2007

Cheng C., G. Li, and H. Auld. 2011. Possible impacts of climate change on freezing rain using downscaled future climate scenarios: updated for eastern Canada, Atmosphere-Ocean, 49(1), 8-21. Available at: https://doi.org/10.1080/07055900.2011.555728

Cheng, C.S., G. Li, Q. Li., H. Auld, and C. Fu. 2012. Possible impacts of climate change on wind gusts under downscaled future climate conditions over Ontario, Canada. Journal of Climate 25(9), 3390-3408. Available at: https://doi.org/10.1175/JCLI-D-11-00198.1

Cohen, S., E. Bush, X. Zhang, N. Gillett, B. Bonsal, C. Derksen, G. Flato, B. Greenan, and E. Watson. 2019. Synthesis of Findings for Canada's Regions; Chapter 8 in Canada's Changing Climate Report, (ed.) E. Bush and D.S. Lemmen; Government of Canada, Ottawa, Ontario. p. 424–443.

ECCC (Environment and Climate Change Canada). 2022. CMIP Standardized Precipitation Evapotranspiration Index Data. Average monthly SPEI data. Available at: https://climate-scenarios.canada.ca/?page=spei Hydro One. 2021. 2021 Sustainability Report: Task Force on Climate-related Financial Disclosures – 2021. [accessed November 2022]. Available at: https://www.hydroone.com/Sustainability/Documents/CSR_2021/HydroOne_CSR_2021_Task_Force.pdf

Hydro One. 2021. Grid Resilience Strategy – Natural Hazards.

ICF. 2022. Summary of exposure to climate hazards for the Hydro One Service Area. Prepared by ICF for Hydro One.

IPCC (Intergovernmental Panel on Climate Change). 2013. Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, Qin, Plattner, Tignor, Allen, Boschung, Nauels, Xia, Bex and Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1535 pp.

IPCC (Intergovernmental Panel on Climate Change). 2021. Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2391 pp.doi:10.1017/9781009157896

Klima, K. and M.G. Morgan. 2015. Ice storm frequencies in a warmer climate. Climatic Change, 133(2), 209–222. Available at: https://doi.org/10.1007/s10584-015-1460-9

Lemmen, D.S., M. Johnston, C. Ste-Marie, and T. Pearce. 2014. Natural Resources; in Canada in a Changing Climate: Sector Perspectives on Impacts and Adaptation, (ed.) FJ Warren and DS Lemmen; Government of Canada, Ottawa, ON. P 65-98. [accessed November 2022]. Available at: https://www.nrcan.gc.ca/impacts-adaptation-canada-changing-climate/10253

MECP (Ministry of the Environment, Conservation and Parks). 2017. Considering climate change in the environmental assessment process. [accessed November 2022]. Available at: https://www.ontario.ca/page/considering-climate-change-environmental-assessment-process#section-0

NOAA National Severe Storms Laboratory. nd. Severe Weather 101 – Thunderstorms. [accessed February 2023]. Available at: https://www.nssl.noaa.gov/education/svrwx101/thunderstorms/types/

Northern Ontario Climate Change and Health (NOCCH). 2021. Climate Change and Health in Northern Ontario.

O'Neil, B.C., E. Kriegler, K. Riahi, K.L. Ebi, S. Hallegatte, T.R. Carter, R. Mathur, and D.P. van Vuuren. 2014. A new scenario framework for climate change research: the concept of shared socioeconomic pathways. Clim. Change. 122: 387-400. doi: 10.1007/s10584-013-0905-2.

Palko, K.G. and D.S. Lemmen. 2017. Climate risks and adaptation practices for the Canadian transportation sector 2016. Ottawa, ON, Government of Canada. Accessed at: https://publications.gc.ca/site/eng/9.832658/publication.html

Prairie Climate Centre. 2019. Climate Atlas of Canada, version 2, using BCCAQv2 climate model data. [accessed November 2022]. Available at: https://climateatlas.ca

Sills, D., F. Lavigne-Thériault, and B. Rousseau. 2022. Updating Canada's National Tornado Database. Northern Tornadoes Project Poster.

Thrasher, B., W. Wang, A. Michaelis, F. Melton, T. Lee, and R. Nemani. 2022. NASA Global Daily Downscaled Projections, CMIP6. Scientific Data, 9 (1), 1-6. Available at: https://doi.org/10.7917/OFSG3345

Toronto Region Conservation Authority. 2015. Climate Change Vulnerability Assessment of Ontario's Electrical Transmission Sector. [accessed November 2022]. Available at: https://pievc.ca/wp-content/uploads/2021/01/electrical-tranmission_pievc_final-report_public.pdf van Vuuren, D.P., J. Edmonds, M. Kainuma, K. Riahi, A. Thomson, K. Hibbard, G.C. Hurtt, T. Kram, V. Krey, J-F. Lamarque, T. Masui, M. Meinshausen, N. Nakicenovic, S.J. Smith and S.K. Rose. 2011. The Representative Concentration Pathways: An Overview. Climate Change 109, 5 (2011). [accessed November 2022]. Available at: https://link.springer.com/article/10.1007/s10584-011-0148-z#citeas

Wang C.-h and X. Wang. 2012. Vulnerability of Timber in Ground Contact to Fungal Decay under Climate Change. Available at: https://link.springer.com/article/10.1007/s10584-012-0454-0