Development of Climate Change Adaptation Solutions Within the Framework of the CSA Group Canadian Electrical Code Parts I, II and III

Cross Country Stakeholder Workshops Phase II
Final Report

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A Note on Related Background and Workshop Reports:

A Phase I report, which included a literature review, scan of global best practices and results of initial interviews with sector experts, served as a background document for the cross-country workshops summarized in this report. Summary workshop reports were prepared following each of the regional workshops, detailing the specific findings coming out of each of those discussions. As the Phase I report and workshop summary reports may contain sensitive data, they are not currently available for further distribution.

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Executive Summary

Climate change and its associated impacts and opportunities will play a central role in Canada's electricity future. Events such as high winds, flooding, excessive ice build-up, hail and extreme heat and cold are already affecting the integrity and reliability of electricity grids and these climate risks are projected to increase. As electrical infrastructure is critical to modern society, climate change impacts to the electrical sector can have cascading economic, social and environmental consequences, ranging from contaminated water to business closures.

The Conference Board of Canada estimates that approximately $347.5 billion will need to be invested in electricity infrastructure to maintain the system reliability we have today.[1] Smart investments today can increase the resiliency of the system and help to avoid more severe costs in the future. Identifying and managing climate risk will be an integral part of this investment strategy to ensure money is being spent wisely in light of future climate challenges.

National codes and standards can support actors in integrating considerations of climate change impacts in decision making. It is increasingly being recognized that codes and standards that support climate-related considerations enhance resilience in our communities. This study aims to highlight high priority potential changes to Parts I, II and III of the Canadian Electrical Code (CE Code) to better incorporate climate change adaptation solutions.

This report summarizes extensive research and consultation conducted concerning climate-related risks, impacts and best practices relevant to the Canadian electricity sector and, in turn, the CE Code. The study process included a review of literature, interviews with subject-matter experts and cross-country regional workshops revealing:

- Top risks and impacts related to climate change relevant to the CE Code
- Gaps in current applicable codes and standards
- Best practices in adaptation in the electricity sector
- Potential actions for consideration, including changes to the CE Code

Key Findings

The following key findings emerged from this study, showing the most promising opportunities for climate change adaptation within the CE Code. These findings also emphasize the importance of complementary efforts—from good data to education to action beyond the four corners of the CE Code—to ensure resiliency in the Canadian electrical sector going forward.

- Updating codes and standards can help overcome barriers to adaptation in the electricity sector
- The nature of codes and standards may require non-traditional approaches to incorporate climate resilience
- The scope of the CE Code presents challenges to meaningfully incorporating climate adaptation solutions
- Regional differences should be considered if CE Code updates are to address localized climate impacts and minimize costs

[1] Shedding Light on the Economic Impact of Investing in Electricity Infrastructure. The Conference Board of Canada, 2012. <http://www.conferenceboard.ca/e-library/abstract.aspx?did=4673>

- Coordination with related codes and standards is required to maximize effectiveness of climate adaptation solutions
- Good data is a necessary precursor to climate action
- Climate resilience is also relevant to infrastructure construction, operation and maintenance (not just design)
- Changing baselines and risk profiles mean that being climate-ready today does not necessarily translate into being climate-ready for tomorrow
- Emergency response protocols for the electricity sector and related stakeholders are urgently needed
- Complementary actions and initiatives are needed in addition to updates to the CE Code

Top Risks and Impacts

Research revealed that ice, snow and wind loads are perceived as the highest, most prevalent climate risk to the electrical sector across Canada. All cross-country workshops discussed impacts related ice storms, high wind events and freezing rain, from loss of poles and downed lines, to transmission and distribution infrastructure damage and widespread power outages.

Flooding and extreme weather were also perceived as high risk to the sector in many parts of the country. Pluvial and riverine flooding appear to be more threatening in central Canada (e.g. Alberta, Manitoba, Ontario, Québec), while coastal flooding from sea-level rise and storm surge were more of a concern in coastal areas (e.g. British Columbia, the Maritimes). Although many Yukon communities are located in floodplains, stakeholders indicated that flood-related impacts to date have been limited. In terms of extreme weather, hurricanes have been experienced in Atlantic Canada; tornadoes are a risk in Ontario; and “combination events” such as heavy rain mixed with extremely low temperatures are becoming increasingly common. Lightning is also becoming more of an issue for the sector.

Wildfires are perceived as low-risk to the electrical sector for most of the country, but they have had devastating impacts in regions where they have been experienced.

Finally, permafrost and land movement are also perceived as low-risk in relation to the CE Code for most of Canada, except for Manitoba. Northern stakeholders reported that they have not experienced significant and relevant permafrost-related impacts yet. That said, permafrost thaw and its associated impacts could become more of an issue in the future as the discontinuous permafrost zone shifts north, and there are more links to other permafrost-related impacts in other sectors.

Each of these climate risks presents a host of potential impacts, from electrical infrastructure damage to threats to human health and safety.

Best Practices

Incorporating adaptation and resilient strategies into policies, planning and practices can help electrical systems and infrastructure be more prepared for the impacts of a changing climate.

Best practices in adapting to climate change in the electricity sector are starting to emerge but are still in the early stages. For instance, Northern Canadian jurisdictions use a range of best practices to build in permafrost regions. Manitoba Hydro uses a world-class ice visioning and melting technology for ice loads on overhead lines. Toronto Hydro has conducted a climate change vulnerability assessment of its distribution system using the Engineers Canada PIEVC (Public Infrastructure Engineering Vulnerability Committee) protocol. However, these best practices are not widely known or considered across the sector.

Many of the best practices discussed may not be easily incorporated into the CE Code due to the nature and limited scope of the CE Code. For instance, elevating buildings or electrical panels may be more likely dealt with in building codes. Better data and forecasting systems, although effective at preparing for extreme weather, would not likely be suitable as a standard or requirement of the Code. The use of shorter/slower growing or less fire-prone tree species in city planning to protect against wildfire and wind-related risk is also not likely captured by the CE Code. However, the study's findings point to the crucial importance of coordination across codes, standards and practices across economic and social sectors to ensure effective climate change adaptation within the electrical sector and more broadly.

Highest Priority Code-Related Actions for Consideration Across Workshops

Action Categories	Actions for Consideration as Identified in Workshops	Climate Impact	Workshop: Action Prioritized	Workshop: Action Discussed	CE Code
Standards for Shock Protection During Floods / Extreme Events	Require elevation of electrical panels above the ground or ensure the ability to disconnect power is above ground.	F	M, H, T	C, V, Wh, Wi	Part I and III
	Require or offer guidance on the use of water sensors in basements to shut off power and / or isolate connections.	F	M, H	T, Wi	Part I, III and CD
Updated Weather / Loading Maps and Requirements	Review and update ice, wind and snow loading maps and loading criteria, as well as associated equipment standards	EW / IS&WL	V, Wh, M, H, T	C, Wi	Part II and III
Updating Equipment Standards and Testing	Update product design standards and testing to account for new climate realities and incorporate climate projections (ambient and extreme temperatures, wind, rain, snow, peak loads, corrosion, water exposure).	F / EW / IS&WL / WF / PF	C, V, Wh, M, H, T	Wi	Part II and III
	Improve standards around mounting of electrical equipment on exteriors.	EW / IS&WL	H	V	Part I and III
Guidelines for Exposed Installations and Equipment	Guidance/standardization on treatment of impacted products, installations and equipment.	F / EW / WF	C, Wi	V	Part I, II, III and CD
Operation and Maintenance	Introduce more guidance on monitoring and maintenance of critical assets.	F / EW / IS&WL / WF / PF	M	T, Wh, Wi	Part III and CD
	Update vegetation management related standards.	EW / IS&WL / WF	T	C, H	Part III and CD
Climate Change Guidance Companion Document	Provide climate change guidance in a companion document.	F / EW / IS&WL / WF / PF	V, Wh, Wi, H	M	CD
Emergency Response Companion Document	Guidance on emergency response and resiliency (backup power and sump pumps).	F / EW / IS&WL / WF	V, M, H, T	C, Wh, Wi	Part I, II, III and CD
Regional Variability	Create regionally-specific compliance paths or flexibility to satisfy code requirements.	F / EW / IS&WL / WF / PF	V, Wh, Wi	C, H, M, T	Part I, II and III

Climate Impacts: F – Flooding, **EW** – Extreme Weather, **IS&WL** – Ice, Snow & Wind Loads, **WF** – Wildfires, **PF** – Permafrost
Workshops: C – Calgary, **V** – Vancouver, **Wh** – Whitehorse, **Wi** – Winnipeg, **M** – Montreal, **H** – Halifax, **T** – Toronto
CE Code: Part I, Part II, Part III and CD – Companion Document

Actions for Consideration

The table on page 6 summarizes the highest priority actions for consideration identified by stakeholders across the country, the climate impacts they seek to address and the regional workshops in which those actions were prioritized.

The results of this study will help to inform technical working group discussions and resulting recommendations for change, (with supporting impact analysis) to the CE Code Parts I, II, and III in their next respective cycle of revisions.

CSA Group would like to acknowledge the support of the National Research Council Canada towards the project. The project was made possible with funding from Infrastructure Canada, in support of the Pan Canadian Framework on Clean Growth and Climate Change.

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About This Study

The Canadian Standards Association, operating as CSA Group, is a leader in the development of standards and codes in North America. CSA Group develops and maintains the Canadian Electrical Code. To help meet the Canadian and global challenge related to climate change adaptation, the National Research Council of Canada (NRC) with funding from Infrastructure Canada (INFC) has collaborated with CSA Group to work towards the development of climate adaptation solutions within the framework of the CSA Group CE Code.

Mantle314 Inc. (formerly Zizzo Strategy) was engaged by CSA Group to conduct research, facilitate cross-country workshops with electricity sector stakeholders and report on findings and insights gleaned through the process.

Electrical infrastructure and the processes carried out to ensure safe installation, design and use of such infrastructure are impacted by flooding, permafrost, extreme weather, wildfires, and ice/snow loading—risks that are increasing in light of a changing climate. The purpose of this project is to assess the need for, and inform the subsequent development of, climate change adaptation solutions in the following Parts of the CE Code:

- **Part I –** a model code adopted across Canada as regulation for the safe installation of electrical equipment
- **Part II –** a series of equipment safety standards mandated by Part I and designed to protect people and property from shock and fire
- **Part III –** a series of standards used primarily by utilities and manufacturers to address electrical power distribution and transmission systems

While the main purpose of the CE Code is safety and the prevention of fire and shock, this study explores whether there may also be proposed changes to support some or all of the following:

- increased reliability
- increased safety during recovery efforts (i.e. following an extreme weather event)
- the safe return to service of select portions of the electricity systems during an extreme weather event to support emergency services
- the ability to enable sufficient return to service within a reasonable and appropriate amount of time

The research and analysis for this report involved:

- a review of Canadian and international literature
- a scan of global best practices
- a collection of interviews with electricity sector stakeholders across Canada
- an analysis of gaps in current Canadian codes and standards
- facilitated discussions in several cross-country workshops with Canadian electricity sector stakeholders in the following locations:
  - Calgary, Alberta
  - Vancouver, British Columbia
  - Whitehorse, Yukon Territories
  - Winnipeg, Manitoba
  - Montreal, Québec
  - Halifax, Nova Scotia
  - Toronto, Ontario

Following the literature review, scan of global best practices and initial interviews, a Phase I report was prepared to serve as a background document for the cross-country workshops. Summary workshop reports were also prepared following each of the regional workshops, detailing the specific findings coming out of each of those stakeholder discussions.

It should be noted that, although CSA Group and Mantle314 Inc. attempted to ensure representative participation from stakeholders across Parts I, II and III of the CE Code, the findings of this study reflect a greater level of participation by users of Part III (e.g. utility-sector stakeholders) than Parts I and II (e.g. electricians, electrical engineers, manufacturers, electrical designers and third-party certifiers).

This study aims to highlight high-priority potential changes to the CE Code based on the research and analysis conducted, with an emphasis on what was heard during the cross-country stakeholder workshops. It also showcases other high-potential best practices and suggests complementary approaches that may be outside the scope of the CE Code to guide further research and inform effective action going forwards.

Part I: Overview of Key Findings, Impacts, Best Practices and Actions for Consideration

Part I of this report identifies key themes, climate impacts and best practices related to climate adaptation and the electricity sector. It identifies the highest potential and most broadly supported actions for consideration identified during this research and consultation process.

Keeping Electricity Safe and Resilient in a Changing Climate

Canada's electrical sector is already being impacted by climate change, and impacts will likely increase significantly over time. The changing frequency, intensity and timing of climate events are causing infrastructure damage and widespread power outages, resulting in cascading effects on communities and local economies. Electricity supply regularly gets shut off to neighborhoods experiencing flood events to prevent shock or electrocution, often resulting in further property damage and equipment failure. Electrical equipment exposed to flood waters or other damaging climatic events are routinely destroyed after an event, with little guidance or standards related to refurbishment, replacement, recertification and/or reuse developed or applied. Overhead lines and poles are falling under the weight of increasing loads of ice and snow.

There is recognition that climate change considerations must be incorporated into the development and maintenance of codes and standards. Such considerations are particularly important in the context of critical infrastructure, such as electrical infrastructure. While the main purpose of the CE Code is safety and the prevention of fire and shock, proposed changes to the CE Code could also seek to increase reliability, enhance resiliency and ensure safety both during and in response to extreme weather events.

This project, supported by the National Research Council as part of its Climate-Resilient Buildings & Core Public Infrastructure Initiative, is a key first step in this ongoing process.

Key Study Findings

The following key findings emerged from this study, showing the most promising opportunities for climate change adaptation within the CE Code. These findings also emphasize the importance of complementary efforts—from good data to education to action beyond the four corners of the CE Code—to ensure resiliency in the Canadian electricity sector going forward.

- **Updating codes and standards can help to overcome barriers to adaptation in the electricity sector.** The electricity sector may have ingrained and significant capacity to adapt to climate change impacts. It has historically been required to respond to weather-related impacts, understands designing to extremes and has considerable financial and managerial resources. That said, there are significant obstacles to turning the sector's capacity to adapt into pragmatic action. These include high costs, the number and types of stakeholders involved (e.g. regulators, consumers, etc.), lack of supportive policies, short-term planning horizons and climate-projection uncertainty, among other things. Updating codes and standards will be particularly important to drive change in light of these barriers.

- **The nature of codes and standards may require non-traditional approaches to incorporate climate resilience.** Climate change risk management must consider the inherent uncertainty, challenges with predictions and uncertain projections related to climate change and its potential impact on the electricity system. Given these uncertainties, codes and standards will need to allow for flexibility based on regional variations, best available information and scientific advancements to incorporate climate adaptation solutions. Adaptive standards are likely to allow for an iterative approach and may be process-based on standardized outcomes, rather than

"Yes we are starting to see changes with respect to flooding, extreme weather, permafrost, ice and snow loading – however, I can't say we've seen a failure identified as being caused by one of these five issues."

prescriptive and static—an approach that may not easily apply to existing standard development, management and use.

- **The scope of the CE Code presents challenges to meaningfully incorporating climate adaptation solutions.** Research revealed much discussion surrounding the scope of the CE Code (i.e. what it covers or can address, and what is beyond its purview), the numerous stakeholders involved in amending the CE Code and the costs associated with implementing changes. Stakeholders in certain regions are already designing beyond Code requirements at times. As one Part III user in a particularly windy region explained: if they were to design to current standards, "poles would be on the ground." Part III allows for this flexibility; however, Parts I and II do not. Potential approaches for how to incorporate the many best practices available into the CE Code should be explored, recognizing that such integration poses significant challenges given the existing boundaries of the CE Code.

- **Regional differences should be considered if Code updates are to address localized climate impacts and minimize costs.** Canada is an extremely diverse place. Having the CE Code applicable across Canada is helpful in many instances, but it must allow for regional flexibility and reflect regional and local realities where possible. There is a need to avoid high unnecessary costs, while ensuring site-specific goals and standardized approaches are achieved.

- **Coordination with related codes and standards is required to maximize effectiveness of climate adaptation solutions.** Throughout this study, stakeholders emphasized that climate adaptation is not just an electricity code issue; it is also a building code issue, a land use planning issue, a fire code issue, etc. The imperative to align and strengthen the suite of applicable codes and standards was reiterated time and again. For instance, zoning plans could incorporate certain elevation requirements when building or rebuilding infrastructure and prevent the construction of electrical facilities in flood-prone areas. Building codes could require electric equipment to be elevated, electrical panels to be located above grade or critical facilities such as hospitals to install backup generators. There is a need to understand how the CE Code interacts with other relevant codes and standards (especially when these might be better placed to drive climate adaptation considerations) and work to support and facilitate those changes where possible.

- **Good data is a necessary precursor to climate action.** Forward-looking, downscaled, high-quality and trustworthy data is a necessary precursor to developing climate-resilient codes and standards. Research emphasized the need for data-driven decisions, including better climate change-adjusted projections that are scientifically sound, credible and impartial. It also emphasized the need for region-specific data and updated design criteria considering known and projected risks. Finally, data and projections related to combined events is needed. While there is more confidence around certain climate parameters such as temperature and precipitation in existing data sets and modeling, it is more difficult to tease out projections for mixed phase precipitation and wind events, for instance.

- **Climate resilience is not only relevant to design; operation and maintenance must be considered too.** The CE Code generally applies to new builds or significant renovations, meaning that updated standards may not apply to many assets that already exist. “Legacy equipment” that would not be built in the same location or manner if built today, will continue to pose problems if climate action is only focused on design. Monitoring, maintenance and operational approaches to adaptation, as they help to capture existing infrastructure, ensure all infrastructure continues to satisfy relevant standards throughout their useful life and offer lower-cost options when design options are economically infeasible.

- **Being climate-ready today does not mean we are climate-ready for tomorrow.** In some instances, electricity sector stakeholders felt they were adequately prepared for projected climate risks. Toronto stakeholders indicated that current design standards could likely withstand increasing temperatures; Québec stakeholders thought updated standards and practices were fairly flood-resilient; and Northern stakeholders were not as concerned with permafrost impacts as expected. That said, stakeholders agreed that adaptation is a continuous process and a sufficient level of preparedness today does not mean we should stop asking important questions and making improvements in the future. In other words, climate adaptation must consider future projections and be iterative over time to avoid merely “keeping up” and potentially falling behind.

- **Emergency response protocols are urgently needed.** As the likelihood of emergency situations and extreme events increases, the sector appears to need standardized approaches and training related to emergency response across the topics covered by the CE Code. Disagreements between utilities and government authorities and/or agencies during emergencies are common. Such disagreements not only threaten health and safety, they may also reduce the speed and efficiency of recovery efforts. Stakeholders identified a need to address the processes around responding to extreme weather and other climate-related emergency events, as well as recovery and ongoing resiliency.

- **Complementary actions / initiatives are needed in addition to updates to the CE Code.** Research stressed that the path towards implementation of climate change adaptation considerations in the CE Code is likely to be most effective if it begins with education campaigns around the impacts of climate change on the electricity sector, the adaptation options available and the costs and benefits of adaptation actions. Research indicated that CSA Group was well-positioned to drive these efforts and provide impartial education, guidance and support to help the sector become more literate on climate change-related information and best practices, within and supportive of the CE Code’s scope.

These findings point to a salient opportunity to develop and implement solutions in the Canadian context that have significant potential to assist in local, regional, national and international resiliency.

Climate Impacts in the Electricity Sector

A range of climate change risks threatening electrical infrastructure was identified and discussed.[2] For the purposes of this study, climate-related impacts have been mainly related to the following climate risks[3]:

- **Flooding:** includes heavy rain events and flooding, sea level rise and storm surges.

- **Extreme Weather:** includes severe storms, hurricanes, tornadoes, lightning, extreme heat and cold.

[2] Public Health Agency of Canada (2008). Fact Sheet - Methicillin-resistant Staphylococcus aureus. Available at: http://www.phac-aspc.gc.ca/id-mi/mrsa-eng.php

[3] Government of Canada (2014). Pathogen Safety Data Sheets: Infectious Substances – Clostridium difficile. Available at: https://www.canada.ca/en/public-health/services/laboratory-biosafety-biosecurity/pathogen-safety-data-sheets-risk-assessment/clostridium-difficile-pathogen-safety-data-sheet.html

- **Ice, Snow and Wind Loads:** includes ice, snow, high winds (note there may be some overlap between this category and the extreme weather category given that high winds and freezing rain are relevant to both).
- **Wildfires:** includes smaller fires such as grass fires, as well as large-scale fires such as those experienced in Fort McMurray in 2016.
- **Permafrost (and Land Movement):** includes risks related to permafrost thaw and associated land movement, as the existence of permafrost itself does not necessarily present any problems.

Research revealed that ice, snow and wind loads are perceived as the highest, most prevalent climate risk across Canada. All cross-country workshops discussed impacts related to ice storms, high wind events and freezing rain, from loss of poles and downed lines, to transmission and distribution infrastructure damage and widespread power outages. Risks related to increasing ice, snow and wind loads, as well as greater uncertainty and changing timing of such events, should be prioritized in updates to the CE Code.

Flooding and extreme weather were also perceived as high risk in many parts of the country. Pluvial and riverine flooding appear to be more threatening in central Canada (e.g. Alberta, Manitoba, Ontario, Québec), while coastal flooding from sea-level rise and storm surge were more of a concern in coastal areas (e.g. British Columbia, the Maritimes). In some parts of the country, flooding has become “the norm.” Although many Yukon communities are located in floodplains, stakeholders indicated that flood-related impacts to date have been limited. In terms of extreme weather, hurricanes have been experienced in Atlantic Canada; tornadoes are a risk in Ontario; and “combination events” such as heavy rain mixed with extremely low temperatures are becoming increasingly common. Lightning is also becoming more of an issue for the sector.

Wildfires are perceived as low-risk to the electrical sector for most of the country, but they have had devastating impacts in regions where they have been experienced. As discussed in more detail below, best practices in adapting to wildfire risks are also relatively limited, which is concerning.

Finally, permafrost and land movement are also perceived as low-risk for most of Canada, with the exception of Manitoba. Northern stakeholders reported that they have not experienced significant permafrost-related impacts as of yet. That said, permafrost thaw and its associated impacts could become more of an issue in the future as the discontinuous permafrost zone shifts north.

Each of these climate risks presents a host of potential impacts, from electrical infrastructure damage to threats to human health and safety. Table 1 provides a summary of electricity-sector impacts associated with each climate risk, many of which came out of workshop discussions and have already been experienced in Canada.

A number of other key findings around climate risks and impacts to the electricity sector were raised over the course of this study and are worth mentioning.

- **Changes in Timing of Events:** “Normal” weather events are now occurring at different times of the year, causing their own suite of risks and impacts for electricity sector stakeholders. For instance, Québec is experiencing rainfalls in November that are more characteristic of May and, because of the timing, hydro power reservoirs are already full. Similarly, Yukon is observing shifts in the form of precipitation such that it rains in January now.
- **Combined Events:** Stakeholders are also experiencing weather in combinations they are not used to. For instance, heavy rain and then extremely low temperatures (i.e. -20 degrees Celsius) can result in thick ice, damaging equipment and blocking access to equipment that was in need of response or repair.
- **Construction, Operation and Maintenance-Related Impacts:** Finally, stakeholders emphasized that climate-related impacts are not limited to infrastructure damage; rather, they also include construction, operation and maintenance-related impacts such as days during which winter roads and cranes had to be shut down or days during which scheduled maintenance could not be completed due to high humidity or wind levels.

Table 1: *Climate Risks and Impacts to Canadian Electricity Sector*

Climate Risk	Impacts To Electricity Sector
Flooding	▪ Flooded basements and risks of electrocution to those who enter basements to turn power back on. ▪ Flooded installations and damage to equipment and potential need for replacement, refurbishment or re-certification. ▪ Increased risks of landslides, coastal erosion and infrastructure damage. ▪ Oil leaks and contamination risks where heavy rains fill oil containment basins and cause spillover. ▪ Transformers made with regular steel are corroding. ▪ Leaves and sewage plus large volumes of water can clog and erode sump pumps, limiting their effectiveness. ▪ Sea level rise could pose issues for houseboat connections to shore power supply for these types of water-based facilities. ▪ Structures have washed out near river banks due to overland flooding.
Extreme Weather	▪ Extreme conditions can damage equipment and block access to equipment, in need of response or repair, delaying response times. ▪ Poor electrical installations and over-use of heaters in extremely cold temperatures can cause electrical fires. ▪ High winds combined with increased vegetation has led to power outages. ▪ Reduced capacity of transformers and dust on insulators during a heat wave can cause fires. ▪ Temperature changes are also impacting electricity demand, loads and associated pressures on the grid. ▪ Water can get into connectors, freeze and pop connectors open. ▪ Extreme freezing rain events can cause poles to break and weather monitoring instruments to fail, leading to gaps in data. ▪ Lightning contact with transmission lines can cause outages. ▪ Back-feed and other safety issues related to the installation and use of backup generation devices.
Wind, Snow and Ice Loads	▪ Unique and extreme high winds, varying in direction (can be both vertical and horizontal) can knock down entire forests. ▪ Wind and ice events causing trees to come down and interfere with electrical lines, leading to power failure. ▪ Ice accretion on towers, insulators, cable lines and tower arms, causing lines to drop or poles to break under the weight of ice. ▪ High winds and ice build-up can cause "galloping wires" and line failure. ▪ Icy conditions and increased salt use cause equipment to corrode. ▪ Ice storms can lead to loss of wood poles, destruction of steel towers, widespread damage to the electrical distribution network, with resulting severe service impacts to customers. ▪ During ice storms, electrical switches can freeze and stop working.
Wildfires	▪ Damage to transmission, storage, and distribution infrastructure. ▪ Can burn through both wood and metal poles. ▪ Widespread evacuation and threats to employee and community safety. ▪ Wind-related events can also increase the risk of grass fires.
Permafrost and Land Movement	▪ When permafrost starts to melt, wires can sink, tilt or both. ▪ Structure movement from unstable foundations. ▪ Ground shifting and lack of slack can cause damage to transmission tower footing (e.g. some parts may be frozen, while others are not, leading to different movement and steel buckling). ▪ Clearing vegetation from transmission right-of-ways can also reduce insulation and lead to permafrost degradation, lowering of land and ice build-up. Ice then lifts towers off their foundation. ▪ Can shift building sand foundations so ground electrode conductors need to be changed and installation of completely new conductor is required. ▪ Can lead to frost heave (vertical lifting of poles due to freezing of water in the active layer soils) lifting pole foundations and necessitating expensive repairs.

A more detailed discussion of climate risks and impacts can be found in the Phase I Report and workshop summary reports.

Best Practices are Emerging for Specific Climate Impacts

Incorporating adaptation and resilient strategies into policies, planning and practices can help electrical systems and infrastructure be more prepared for the impacts of a changing climate.

This study suggests that best practices in adapting to climate change in the electricity sector are starting to emerge but are still in the early stages. For instance, Northern Canadian jurisdictions use a range of best practices to build in permafrost regions. Manitoba Hydro uses a world-class ice visioning and melting technology for ice loads on overhead lines. Toronto Hydro has conducted a climate change vulnerability assessment of its distribution system using the Engineers Canada PIEVC (Public Infrastructure Engineering Vulnerability Committee) protocol. And yet, these best practices are not widely known or considered across the sector.

Moreover, and important to this study, many of the best practices discussed cannot be easily incorporated into the CE Code due to its nature and limited scope. For instance, elevating buildings or electrical panels may be more likely dealt with in building codes. Better data and forecasting systems, although effective at preparing for extreme weather, would not likely be suitable as a standard or requirement of the Code. The use of shorter/slower growing or less fire-prone tree species in city planning to protect against wildfire and wind-related risk is also not likely captured by the CE Code.

The following best practices summarized in Tables 2-6, are a combination of those: (i) identified in cross-country workshops as best practices stakeholders knew of or had implemented themselves; and (ii) identified in the literature review and confirmed by workshop participants to be best practices. Notably (and perhaps unfortunately) they are heavily geared towards users of users of Part III of the Code (e.g. the utility sector), as opposed to users of Parts I and II (e.g. electrical inspectors, manufacturers, etc.), given the greater representation of the utility sector in the literature review, interviews and cross-country workshops.

Note that some of the best practices originally proposed for discussion relating to Code updates were questioned or rejected by workshop participants. For instance, burying lines to address wind or wildfire concerns were thought to be too costly and presented flood risks. Similarly, using steel poles instead of wood poles to address risks in the North were perceived to actually accelerate permafrost thaw. Costs, benefits and trade-offs of each potential best practice should be considered for a given context.

Again, it is unlikely the CE Code can accommodate all of the adaptation solutions described above within its scope. In order to preserve and promote some of the best, most effective practices, complementary approaches such as guidance documents, educational programs and other information-sharing platforms should be explored. See section 7 below for more detail concerning these complementary approaches.

Climate Change Impacts to Electricity in the North

The stakeholder interviews revealed that there is some discrepancy around perceived climate change risks to the electricity sector in the north. That is, many who are not located in the north tend to believe that climate risks to the sector are more significant than those who are living, or working, in the north.

Interviews with northern experts and stakeholders provided the following insights:

1. **Permafrost risks may be over-exaggerated.** Interviewees indicated that permafrost changes have largely been mitigated against due to past and ongoing practices. For instance, in-ground services are limited and all supply is overhead, meaning that permafrost does not pose as many risks to installation. Interviewees did say, however, that they have seen buildings shift to the point where ground electrode conductors need to be changed.

2. **Wildfire risks are relatively low.** Many northern communities are above the tree line and are not exposed to land-based fires. They also experience few thunderstorms, meaning lower risk of lightning strikes. With many communities reliant on diesel, they have less expansive electrical infrastructure and less exposure to potential damage (e.g. one interviewee indicated that they have only one line to a hydro system north of them and one line to a hydro system south of them).

3. **Flood risks are relatively low.** While the north is seeing earlier freshet (i.e. spring melt) and more variable precipitation, interviewees stated that the changes they have experienced so far are still within equipment design tolerances.

4. **Increasing ice and snow is a risk.** Those in the north are seeing higher snowpack and increasing ice and snow. Ice and snow tends to get into openings and connectors, which can degrade neutral wires and lead to more serious impacts such as voltage shifts and electrical appliance fires. Interviewees stated that they are starting to see impacts on the durability of systems over time.

5. **Being remotely located presents its own set of risks.** A key factor to consider in the north is their inability to depend on proximity and connectivity with other utilities to support management of climate impacts. Back up equipment and emergency crews are not as accessible and easily deployable as in other parts of the country.

***Table 2:** Flooding – Best Practices*

	Best Practices
Flooding	▪ **Use of submersible and flood-proofed equipment.** Con Edison and Siemens worked together to install fully submersible equipment in lower Manhattan. The systems installed can also switch the direction that power is going in a matter of seconds. (Con Edison and Siemens, Toronto Workshop) ▪ **Elevate buildings.** Some buildings are built on stilts in the north to reduce flood risks and impacts (North Region, Whitehorse Workshop) ▪ **Technical bulletin providing guidance around flooded installations.** A technical bulletin dealing with flooded installations, including what needs to be done after a flood for inspection, recertification, etc., has been created for Manitoba, Minnesota and North Dakota (the three Red River Valley Jurisdictions). (Manitoba, Winnipeg Workshop) ▪ **NEMA standards for water-damaged equipment.** NEMA's guidance documents such as "Evaluating Water-Damaged Electrical Equipment" and "Replacing or Upgrading Water-Damaged Electrical Equipment". (NEMA, Calgary Workshop) ▪ **Government of Alberta, Electrical STANDATA bulletins on Disaster Recovery Program Flood Mitigation Measures.** (Alberta, Calgary Workshop) ▪ **Relocating critical assets outside of floodplains.** (National Grid, Phase I Report) ▪ **Placing critical plant and equipment in elevated positions.** (National Grid, Phase I Report) ▪ **Installing isolation switches on overhead network or breakaway connectors.** (Phase I Report) ▪ **Use of mobile flood defense system. These can be deployed on short notice.** (National Grid, Phase I Report) ▪ **Raising the standard of protection of substations** (e.g. from 1-in-100-yr to 1-in-1,000-yr). (National Grid, Phase I Report) ▪ **Raising flood standards.** These would reduce the vulnerability of federally-funded infrastructure, including safety margins (e.g. of 2 ft.) for critical infrastructure and a safety provision (e.g. of 1 ft.) for other infrastructure. (Obama Executive Order – now repealed, Phase I Report) ▪ **Revising substation design criteria.** New standards seek to avoid locating new substations in flood zones, ensuring elevations of > 24 inches above 100-year flood levels and relocating them out of flood zone areas during major upgrade projects. (National Grid, Phase I Report) ▪ **Install smart meters in flood-prone areas.** These would allow it to remotely control specific neighborhood and customer service connections and to ensure optimal use of utility resources.[4] (Enmax, Phase I Report) ▪ **Using more durable materials within 20 miles of coast and along evacuations routes.** (Entergy, Phase I Report) ▪ **Switch to stainless steel transformers.** These are to avoid/delay corrosion. (Toronto Workshop) ▪ **Use sump pumps with grinders.** These are to avoid build-up of debris, better address flooding and reduce the amount of time transformers are wet. (Toronto Workshop)

***Table 3:** Extreme Weather – Best Practices*

	Best Practices
Extreme Weather	▪ **Use of lightning arrestors.** PEI uses lightning arrestors to protect equipment. (PEI, Halifax Workshop) ▪ **Data and forecasting for extreme weather.** NB Power uses enhanced data and 6-day forecasting for extreme weather. (NB Power, Halifax Workshop) ▪ **Upgraded designs for insulators.** Newfoundland Power uses enhanced physical loading and design standards, increased pole classes and clamp top insulators for distribution lines. (Newfoundland Power, Halifax Workshop) ▪ **Creation of climate-related think tank.** Ouranos, collects updated and downscaled climate data and provides other services to help local organizations deal with the impacts of a changing climate. (Québec, Montreal Workshop) ▪ **Emergency agreements.** Utilities in the north have emergency agreements with each other. (Whitehorse Workshop)

[4] Resilient pipes and wires report - Adaptation awareness, actions and policies in the energy distribution sector. Quest, 2015.

Table 4: Ice, Wind & Snow – Best Practices

	Best Practices
Ice, Wind & Snow Loads	▪ **Updated design criteria and ice loading requirements.** Hydro One updated design criteria for equipment after a recent ice storm. (Hydro One, Toronto Workshop). Hydro Québec also uses more stringent ice loading standards than those required by the CE Code. (Hydro Québec, Montreal Workshop) ▪ **Switching to steel or fibreglass cross arms to address ice accretion.** Some utilities have switched to steel or fibreglass cross arms to address the ice accretion on towers with wood arms. (Calgary Workshop) ▪ **Updated return periods for wind/ice.** A number of utilities in Canada have taken steps in the past few years to develop return period loading maps for wind and ice (individually and in combination). (Calgary Workshop) ▪ **Use thicker overhead wires in areas prone to severe icing.** ATCO discussed using thicker wires, less heating, and shorter distance between poles in areas with icing. (Whitehorse Workshop) ▪ **Ice visioning systems.** Manitoba Hydro uses ice visioning systems that include a weather-hardened video camera integrated into the top of a pole. When ice forms, the systems can detect it. Manitoba Hydro also includes small compact weather stations on some poles, which are very low maintenance. (Manitoba Hydro, Winnipeg Workshop) ▪ **Ice melting technology.** Manitoba Hydro's ice melting technology works in coordination with its ice visioning systems. When ice build-up is detected, the company uses high and low voltage switching whereby the source station provides high current to melt ice. (Manitoba Hydro, Winnipeg Workshop) ▪ **Ice rolling technology.** If ice cannot be melted, Manitoba Hydro will utilize "ice rolling" instead, the physical removal of ice by placing rollers on lines and dragging the rollers across lines by ground vehicles. (Manitoba Hydro, Winnipeg Workshop) ▪ **Different pole and connector design strategies.** Manitoba Hydro uses different designs in "high ice areas." Some designs allow suspension insulators to move such that they can handle more movement and galloping. Stronger bolts are used for through-bolts, which are stronger than the standard bolt size. (Manitoba Hydro, Winnipeg Workshop) ▪ **Controlled failure of lines.** Hydro Québec uses "controlled failure" techniques where cable lines are designed to break upon ice buildup to stop poles from collapsing. (Hydro Québec, Montreal Workshop) ▪ **Smart connectors that release the system when ice loads become too heavy.** These are also used when the line makes contact with a tree, allowing the line to come to the ground de-energized. (Phase I Report) ▪ **Develop high resolution wind projections.** These improve wind forecast capabilities and management practices. (BC Hydro, Phase I Report) ▪ **Review design standards for high voltage lines and update construction standards** (Hydro-Québec, Phase I Report)

Table 5: Wildfires – Best Practices

	Best Practices
Wildfires	▪ **NRC "Code-ready" National Guide for Wildland Urban Interface Fire Design.** NRC is in the process of developing this guideline and indicated that the associated Fire Code change request has been received. At least three provinces have stated they will adopt the technical guide as law. (NRC, Toronto Workshop) ▪ **Install sprinkler systems.** Sprinkler systems are provided for all Yukon Energy facilities. (Yukon Energy, Whitehorse Workshop) ▪ **Radial feeder lines.** Manitoba Hydro has fire-guarded structures for ten miles by putting a culvert filled with rock around the base of the wood poles to act as a barrier to fire. (Manitoba Hydro, Winnipeg Workshop) ▪ **Improved / proactive vegetation management practices.** Reduces build-up of hazardous fuels near key power lines, as well as potential ignition points (e.g. tree trimming, forest thinning and prescribed burning). (Phase I Report) ▪ **Implementing greater minimum clearances for vegetation.** (Phase I Report) ▪ **Tree trimming standards.** (Phase I Report)

Table 5: Permafrost Thaw – Best Practices

	Best Practices
Permafrost Thaw (and Land Movement)	▪ **NRC "Code-ready" National Guide for Wildland Urban Interface Fire Design.** NRC is in the process of developing this guideline and indicated that the associated Fire Code change request has been received. At least three provinces have stated they will adopt the technical guide as law. (NRC, Toronto Workshop) ▪ **Install sprinkler systems.** Sprinkler systems are provided for all Yukon Energy facilities. (Yukon Energy, Whitehorse Workshop) ▪ **Radial feeder lines.** Manitoba Hydro has fire-guarded structures for ten miles by putting a culvert filled with rock around the base of the wood poles to act as a barrier to fire. (Manitoba Hydro, Winnipeg Workshop) ▪ **Improved / proactive vegetation management practices.** Reduces build-up of hazardous fuels near key power lines, as well as potential ignition points (e.g. tree trimming, forest thinning and prescribed burning). (Phase I Report) ▪ **Implementing greater minimum clearances for vegetation.** (Phase I Report) ▪ **Tree trimming standards.** (Phase I Report)

"Stakeholders agreed that we need to improve our understanding of climate change impacts specific to the electricity sector and approaches to address those impacts."

Overview of Code-Related Actions for Consideration

Table 7 summarizes the highest priority actions for consideration identified by stakeholders across the country, the climate impacts they seek to address and the regional workshops in which those actions were prioritized.

Overview of Actions for Consideration Complementary to the Code

Research revealed that complementary approaches that may not fit within the boundaries of the CE Code but would support electrical sector resiliency should be explored, such as:

- **Coordinated and continued data collection.** Changes in codes and standards must be accompanied by the development of sound, forward-looking climate change data, such as standardized projections and scenarios. The data required by users of the CE Code must be sufficiently granular and downscaled to account for regional differences. Research to date indicates that such data is not currently readily available, and the data sets that are available are not readily understood or considered.
- **Creation of a "one stop shop" for useable climate information.** Stakeholders indicated that the federal government or other public body would be the ideal custodian of reliable climate-related data and would create a "one stop shop" for consistent, trustworthy climate data and analysis. Environment and Climate Change Canada (ECCC) was suggested as a potential custodian, as was the "Canadian Centre for Climate Services", which is part of the ECCC, contemplated under the Pan-Canadian Framework on Clean Growth and Climate Change. (CCCS information and products will be made available through a new website, the Canadian Climate Information Portal, which is scheduled to launch in the fall of 2018).
- **Compendium of best practices / info-sharing platform.** Stakeholders indicated that a best practice guide or compendium around climate change adaptation would be helpful given data requirements and challenges (nature/scope of code, lengthy update process required) in making CE Code-specific updates. Many believe that best practices for climate change adaptation already exist and are being used by different stakeholders in the sector. An informative annex or guide could help promote these best practices, enhance information-sharing and ensure that all stakeholders are benefitting from the use of existing solutions.
- **Development of better tools to understand climate vulnerabilities and conduct cost-benefit analysis.** Stakeholders agreed that we need to improve our understanding of climate change impacts specific to the electricity sector and approaches to address those impacts. Much of the information available on climate change impacts and adaptation solutions is broad and not in a form that can be easily operationalized by electricity sector actors. Tools and knowledge relevant

Table 7: *Climate Risks and Impacts to Canadian Electricity Sector*

Action Categories	Actions For Consideration As Identified In Workshops	Description	Climate Impact	CE Code	Workshop: Action Prioritized
Standards for Shock Protection During Floods / Extreme Events	Require elevation of electrical panels above the ground or ensure the ability to disconnect power is above ground.	The requirement could apply to buildings in flood-prone areas or for all areas. Another option would be to allow first responders to safely turn off electrical equipment to a building in a flood (i.e. shut offs would have to be above flood levels in order for responders to have this ability).	F	Part I and III	M, H, T
	Require or offer guidance on the use of water sensors in basements to shut off power and / or isolate connections.	Ideas were raised around the use of water sensors in basements to shut trip loads, shut off power and / or isolate certain impacted connections. Another option discussed was using smart meters to shut off power remotely from a central utility location.	F	Part I, III and CD	M, H
Updated Weather / Loading Maps and Requirements	Review and update ice, wind and snow loading maps and loading criteria.	Participants discussed the need to review and update ice, wind and snow loading maps, as well as associated loading criteria, using forward-looking climate projections. This action would also improve the performance of overhead line standards to ensure that all components of overhead lines—poles, insulators, lines, and terminations—perform under extreme wind and ice conditions. Updates would need to be made continually.	EW / IS&WL	Part II and III	V, Wh, M, H, T
Updating Equipment Standards and Testing	Update product design standards and testing to account for new climate realities and incorporate climate projections (ambient and extreme temperatures, wind, rain, snow, peak loads, corrosion, water exposure)	Updated product designs and testing requirements could be integrated into Part II and could cover issues such as flood protection, what heat maximums are appropriate for a transformer, painting requirements and their relation to corrosion, etc. Enhanced waterproofing for submersible equipment (e.g. switchgear, transformers, better sump pump systems) could also be explored.	F / EW / IS&WL / WF / PF	Part II and III	C, V, Wh, M, H, T
	Improve standards around mounting of electrical equipment on exteriors.	Requirements or standards relating to how well electrical equipment is mounted on building exteriors or even potentially the height of the mounted equipment could help prevent damage and outages.	EW / IS&WL	Part I and III	H
Guidelines for Exposed Installations and Equipment	Guidance/standardization on treatment of impacted products, installations and equipment.	Accessible and easy-to-use guidance or standardization on treatment of electrical products, installations and equipment impacted by flooding or other climate impacts. This is important because specific classes of equipment can be rebuilt, while others can pose a hazard risk in the long term. More guidance is needed around whether and when replacement is needed (as opposed to restoration or refurbishment) as well as the steps to do a proper restoration. This guidance could be informative, not compulsory.	F / EW / WF	Part I, II, III and CD	C, Wi
Operation and Maintenance	Introduce more guidance on monitoring and maintenance of critical assets.	More guidance on monitoring assets and critical equipment, as well as subsequent and preventative maintenance to ensure equipment continues to meet design standards, is needed.	F / EW / IS&WL / WF / PF	Part III and CD	M
	Update vegetation management related standards	Updating vegetation management-related standards is also needed. Minimum clearance and vegetation requirements could be explored as an update to Part III of the CE Code. Participants suggested moving to a one-year vegetation management cycle and putting a lot of clearance in. Guidelines for new vegetation specifying the types (e.g. lower-growing species) and heights of trees could be explored.	EW / IS&WL / WF	Part III and CD	T
Climate Change Guidance Companion Document	Provide climate change guidance in a companion document.	A climate change guidance or companion document would include climate change-related risks, impacts, data, maps and best practices on how to manage risks.	F / EW / IS&WL / WF / PF	CD	V, Wh, Wi, H
Emergency Response Companion Document	Guidance on emergency response and resiliency (backup power and sump pumps)	Guidance around emergency planning and recovery could include: information to assist stakeholders recover from a climate-related event; system redundancy; backup supply; sump pumps; early warning systems; emergency response, contingency plans; prioritization of customers (i.e. who is most vulnerable and who should have power restored first); and communication with emergency responders.	F / EW / IS&WL / WF	Part I, II, III and CD	V, M, H, T
Regional Variability	Create regionally-specific compliance paths or flexibility to satisfy code requirements	Participants advocated for more regionally-specific compliance paths or flexibility in satisfying Code requirements on the basis of professional judgment or "good engineering principles."	F / EW / IS&WL / WF / PF	Part I, II and III	V, Wh, Wi

Climate Impacts: F – Flooding, **EW** – Extreme Weather, **IS&WL** – Ice, Snow & Wind Loads, **WF** – Wildfires, **PF** – Permafrost
Workshops: C – Calgary, **V** – Vancouver, **Wh** – Whitehorse, **Wi** – Winnipeg, **M** – Montreal, **H** – Halifax, **T** – Toronto
CE Code: Part I, Part II, Part III and CD – Companion Document

to vulnerability assessments, cost-benefit analyses and integrating climate change considerations into management and operations need to be shared more widely across the industry.

- **Education / guidance on climate change and how it interacts with various codes and standards (building code, fire code, insurance, etc.).** Given the interconnectedness of the CE Code, the Building Code, the Fire Code and emerging flood resilience standards, among other things, stakeholders indicated that more alignment with other codes and standards could help ensure changes to each are most effective. Education and guidance on how the CE Code interacts with other relevant codes and how various codes / standards committees can best work together to support and facilitate climate-related updates could be helpful. Stakeholders indicated that Part I of the CE Code already has a building code committee, which could be used to improve liaising and alignment with others working on building code updates.
- **Educating / engaging regulators and consumers.** In many Canadian provinces and territories, utilities operate in a heavily regulated environment. Utilities may face challenges in implementing adaptation solutions through regulated rates as regulators and consumers are keenly concerned with keeping rates low. For this reason, among others, effective solutions cannot be determined by the utility alone. Adaptive capacity will depend on regulator awareness, engagement and approval, as well as consumer support, which requires an understanding of the costs and impacts of climate change adaptation and inaction.

Areas for Further Research and Next Steps

To continue the significant interest and momentum on this topic, the following potential future research and actions were identified:

- Better data and projections for climate parameters other than temperature and precipitation (e.g. wind, mixed-phase precipitation) and combined events
- Models that project climate extremes versus averages
- More best practices related to wildfires and building in permafrost regions (or better sharing of such best practices where they are already available)
- The potential for outcome- or performance-based requirements in Parts I and II of the CE Code
- The benefits of adaptive action, including determinations related to return on investment for innovations in resilient and durable design
- The costs of climate inaction (specifically as compared to the costs of climate adaptation action)
- Accepted cost-benefit models and tools to make the business case for resilience investments
- Metrics for measuring progress and cost savings of resilience investments
- National risk profiles and updated, publicly-available and well-communicated flood maps
- How to best align updates to related complementary or related codes and standards

Coordination with other efforts through the NRC and other initiatives will be critical to both address some of these areas for further research and build additional support and momentum. This research has shown the clear progression occurring organically across economic sectors to encourage climate adaptation and further supports the need to facilitate rapid and smart developments to codes and standards while enabling helpful guidance and support.

Next steps include CSA technical working group discussions and resulting recommendations for change, (with supporting impact analysis) to the CE Code Parts I, II, and III in their next respective cycle of revisions.

Part II: Task Group Chapters

Part II of this report provides further detail into climate impacts experienced across the country and the actions for consideration discussed during the in-person workshops.

The findings contained in this report will help to inform technical working group discussions and resulting recommendations for change, (with supporting impact analysis) to the CE Code Parts I, II, and III in their next respective cycle of revisions. As part of those technical working groups, specific Task Groups have been created around the following themes: Flooding, Extreme Weather, Wildfires, Ice / Wind / Snow Loads and Permafrost.

Part II of this report has been organized according to Task Group theme to most effectively feed into future Task Group discussions. Each chapter in Part II corresponds to a Task Group theme. Each chapter provides:

- further detail on climate impacts, their geographic distribution and perceived levels of risk
- key actions for consideration discussed in the cross-country workshops that are relevant to that Task Group

For each action for consideration, links to select best practices and other particularly helpful resources have been provided to aid in the discussion of potential changes to the CE Code and drafting of specific proposals for change.

Each Part II chapter is intended to be able to stand alone. Therefore, readers will note that where an action for consideration is relevant to more than one climate impact (i.e. flooding, wildfire, etc.), it will be repeated in each instance it is relevant.

Flooding

This section provides a deep dive into flood-related impacts, best practices and actions for consideration in discussions related to potential CE Code updates.

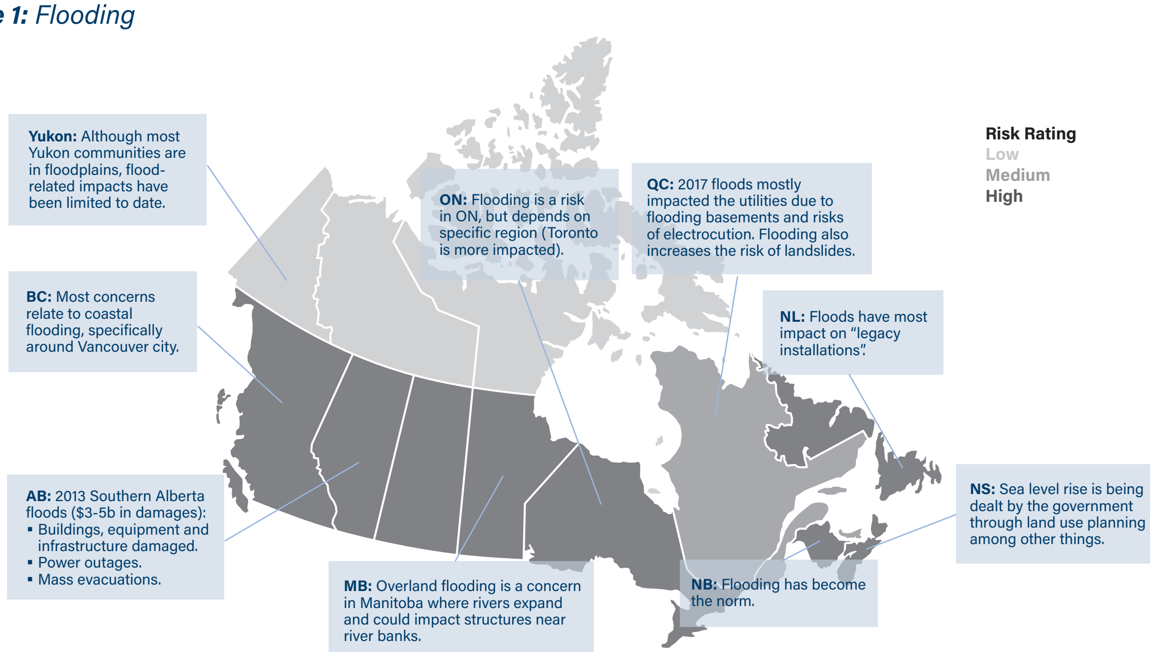
Impacts

Figure 1 summarizes the levels of perceived flood-related risks to the electricity sector by region based on the views of cross-country workshop participants. It also highlights some of the key impacts discussed associated with flooding. For the purposes of this study, flooding includes heavy rain events and flooding, sea level rise and storm surges.

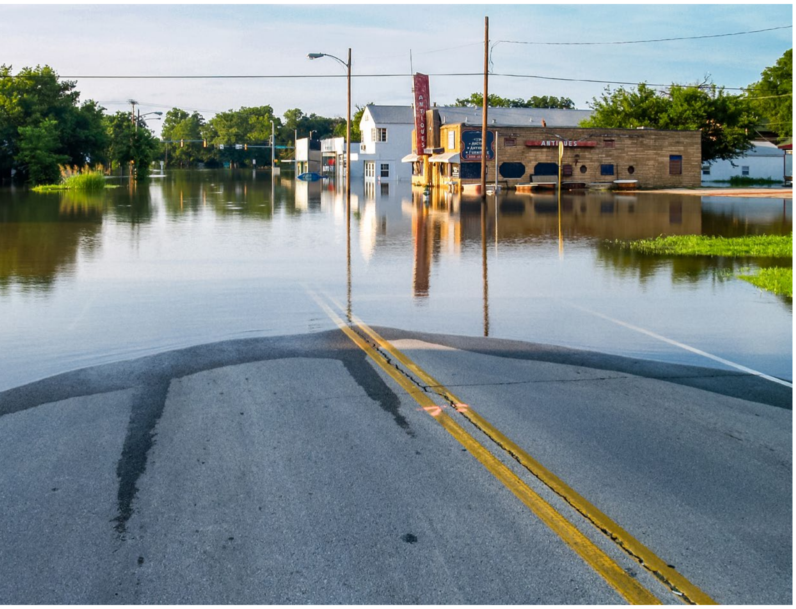
Actions for Consideration

The following are the highest priority actions for consideration, as identified by cross-country workshop participants that are relevant to flooding. While workshop participants did not necessarily link each action for consideration to a specific Part of the Code or climate impact, this report makes such links to maximize usability of the findings.

Figure 1: *Flooding*



* This map displays climate impacts specific to the electricity sector and is based on *perceived* levels of risk by workshop participants.



"It was widely acknowledged that there is a need to adapt to weather uncertainty and future climate projections in project design."

F1. Require elevation of electrical panels above ground or ensure ability to disconnect power is above ground. (Part I and III)

Elevating electrical panels above grade – or ensuring the ability to disconnect power is above grade – was broadly supported. Stakeholders suggested the CE Code should identify which types of risk areas would invoke this requirement (e.g. flood-prone, all areas, etc.) and could allow for multiple compliance paths depending on the context. Compliance paths could include:

(i) installing the panel above grade

(ii) ensuring the ability to disconnect is above grade

(iii) meet equipment standards under Part II (which might include requirements around water resistance)."

Another option discussed was using smart meters to shut off power remotely from a central utility location.

If a requirement to elevate panels above grade is explored further, the group raised the issue that this requirement would likely only apply to new builds. Therefore, complementary education relating to shutting off power during flood events for existing buildings was also recommended.

Highlighted Best Practices and Resources	Workshops
▪ Northern Canada practice of elevating buildings on stilts (Whitehorse workshop) ▪ CSA Basement Flood Protection Draft – December 2017 (Z800-18) (see section 7.1 specifically)[5] ▪ ICCA 20 best practices in building new flood-resilient communities.[6] ▪ Government of Alberta, Electrical STANDATA bulletins on Disaster Recovery Program Flood Mitigation Measures[7] ▪ THE WATER RESOURCES ADMINISTRATION ACT (C.C.S.M. c. W70), Designated Flood Area Regulation (Sets out flood-proofing criteria for building and construction in flood designated areas.)[8] ▪ Obama Executive Order – Establishing a Federal Flood Risk Management Standard[9]	***Action Prioritized:*** Montreal Halifax Toronto ***Action Discussed:*** Calgary Vancouver Whitehorse Winnipeg

[5] Adapting to Climate Change: A Risk Management Guide for Utilities, Canadian Electricity Association (CEA), 2017. <https://electricity.ca/wp-content/uploads/2017/11/Adapting_to_Climate_Change-A_Risk_Management_Guide_for_Utilities.pdf>

[6] Preventing Disaster Before It Strikes: Developing A Canadian Standard for New Flood-Resilient Residential Communities, Intact Centre on Climate Adaptation, 2017. <http://www.intactcentreclimateadaptation.ca/wp-content/uploads/2017/09/Preventing-Disaster-Before-It-Strikes.pdf>

[7] Disaster Recovery Program Flood Mitigation Measures for Homes Being Rebuilt / Disaster Recovery Program Flood Mitigation Measures, Standata, 2013. <http://www.municipalaffairs.alberta.ca/documents/ss/STANDATA/ building/bcb/06BCB010-DCP-FloodMitigationMeasuresForHomesBeingRebuilt.pdf>

[8] Designated Flood Area Recognition, The Water Resources Administration Act, 2002. <https://web2.gov.mb.ca/laws/regs/annual/2002/059.pdf>

[9] Executive Order – Establishing a Federal Flood Risk Management Standard and a Process for Further Soliciting and Considering Stakeholder Input, The White House of President Barack Obama, 2015. <https://obamawhitehouse. archives.gov/the-press-office/2015/01/30/executive-order-establishing-federal-flood-risk-management-standard-and->

F2. Require or offer guidance on the use of water sensors in basements to shut off power and / or isolate connections. (Part I, III or companion document)

Stakeholders supported guidance for the use of water sensors in basements to shut trip loads, shut off power and / or isolate certain impacted connections during times of flooding.

Highlighted Best Practices and Resources	Workshops
▪ Enmax's planned installation of smart meters in flood-prone areas with remote control of connections	***Action Prioritized:*** Montreal Halifax ***Action Discussed:*** Toronto Winnipeg

F3. Guidance / standardization on treatment of impacted products, installations and equipment. (Part I, II, III or companion document)

Accessible and easy-to-use guidance or standardization on the treatment of electrical products, installations and equipment impacted by flooding or other climate impacts is needed. This is important because specific classes of equipment can be rebuilt, while others can pose a hazard risk in the long-term. Some stakeholders indicated that the protocol was to automatically replace water-exposed equipment without consideration of refurbishment. Others indicated that exposed appliances and equipment were being re-sold without recertification or disclosure about the exposure. More guidance is needed around whether and when replacement is needed (as opposed to restoration or refurbishment), as well as the steps to do a proper restoration. This guidance could be informative, not compulsory.

Highlighted Best Practices and Resources	Workshops
▪ NEMA standards for Evaluating Water-Damaged Electrical Equipment[10] ▪ NEMA standards for Replacing or Upgrading Water-Damaged Electrical Equipment[11] ▪ Technical bulletin providing guidance around flooded installations (for Manitoba, Minnesota and North Dakota, the three Red River Valley Jurisdictions)[12] ▪ Manitoba Electrical Code, 2-024-2 SMOKE AND WATER DAMAGE TO CIRCUIT BREAKERS	***Action Prioritized:*** Calgary Winnipeg ***Action Discussed:*** Vancouver

F4. Update product design standards and testing to account for new climate realities and incorporate climate projections (rain, corrosion, water exposure) (Part II and III)

Updated product designs and testing requirements could be integrated into Part II to better prepare for changing climate realities. Such updates and requirements could cover issues such as flood protection, using sump pumps with grinders to avoid build-up of debris and painting requirements and their relation to corrosion, among other things. Enhanced waterproofing or submersible equipment standards (e.g. switchgear, transformers, and better sump pump systems) could also be explored.

Highlighted Best Practices and Resources	Workshops
▪ National Grid's new standards for substation protection (1-in-1,000-yr flood, > 24 inches above 100-year flood levels in flood prone areas, relocating out of flood zones during major upgrades) ▪ Entergy's use of more durable materials within 20 miles of coast and along evacuation routes ▪ Certain Ontario-based utilities' switch to stainless steel transformers ▪ Standards Council of Canada and National Research Council forthcoming standardization guidance for weather data, climate information and climate change projections	***Action Prioritized:*** Calgary Vancouver Whitehorse Montreal Halifax Toronto ***Action Discussed:*** Winnipeg

[10] Evaluating Water – Damaged Electrical Equipment, National Electrical Manufacturers Association (NEMA), 2004. <https://www.nema.org/Standards/Pages/Evaluating-Water-Damaged-Electrical-Equipment.aspx>

[11] Replacing or Upgrading Water-Damaged Electrical Equipment, National Electrical Manufacturers Association (NEMA), n.d..<https://www.nema.org/Storm-Disaster-Recovery/Replacing-and-Relocating-Equipment/Pages/Replacing-or-Upgrading-Water-Damaged-Electrical-Equipment.aspx>

[12] The Manitoba Electrical Code, 12th ed., Manitoba Hydro, 2015. <https://www.hydro.mb.ca/accounts_and_services/permits_and_inspections/pdfs/manitoba_electrical_code.pdf>

F5. Provide climate change guidance in a companion document. (companion document)

A climate change guidance or companion document would include climate change-related risks, impacts, data, maps and best practices on how to manage risks.

Relevant / Helpful Best Practices and Resources	Workshops
▪ CEA's Climate Change Adaptation Guide[13] ▪ Forthcoming Canadian Centre for Climate Services (CCCS) ▪ Creation of climate change-related research organization/think tank (Québec's Ouranos) ▪ Standards Council of Canada and National Research Council forthcoming standardization guidance for weather data, climate information and climate change projections ▪ CEN-CENELEC Guide 32 – Guide for addressing climate change adaptation in standards[14]	***Action Prioritized:*** Vancouver Whitehorse Winnipeg Halifax ***Action Discussed:*** Montreal

F6. Provide guidance on emergency response and resiliency. (Part I, II, III or companion document)

Guidance on emergency should provide information to assist stakeholders in recovering from a climate-related event, especially when we are seeing events that are increasing in scale. Such guidance could also cover issues such as system redundancy backup supply, emergency response, contingency plans and prioritization of customers (i.e. who is most vulnerable and who should have power restored first). Finally, emergency planning guidance could discuss federal government expectations of the electricity sector, including the number of hours/days after an event that utility companies should be back online.

Highlighted Best Practices and Resources	Workshops
▪ Government of Alberta, Electrical STANDATA bulletins on Disaster Recovery Program Flood Mitigation Measures[15] ▪ The Québec Ministry of Public Security / Ministère de la Sécurité publique provides general guidance on responding to disasters, including floods[16] ▪ CEA's Climate Change Adaptation Guide[17]	***Action Prioritized:*** Vancouver Montreal Halifax Toronto ***Action Discussed:*** Calgary Whitehorse Winnipeg

F7. Guidance on monitoring and maintenance of critical assets. (Part III or companion document)

Additional guidance on monitoring assets and critical equipment, as well as subsequent and preventative maintenance to ensure equipment continues to meet design standards, is needed.

Highlighted Best Practices and Resources	Workshops
No best practices identified.	***Action Prioritized:*** Montreal ***Action Discussed:*** Whitehorse Winnipeg Toronto

F8. Create regionally-specific compliance paths or flexibility to satisfy code requirements (Parts I, II and III)

Participants advocated for more regionally-specific compliance paths or flexibility in satisfying Code requirements on the basis of professional judgment or "good engineering principles" to account for local contexts.

[13] "Adapting to Climate Change: A Risk management Gide for Utilities". Canadian Electricity Association, 2018. <https://electricity.ca/adapting-climate-change/>

[14] CEN-CENELEC Guide 32 – Guide for addressing climate change adaptation in standards. <ftp://ftp.cencenelec.eu/EN/EuropeanStandardization/Guides/32_CENCLCGuide32.pdf>

[15] Disaster Recovery Program Flood Mitigation Measures for Homes Being Rebuilt / Disaster Recovery Program Flood Mitigation Measures, Standata, 2013. < http://www.municipalaffairs.alberta.ca/documents/ss/STANDATA/ building/bcb/06BCB010-DCP-FloodMitigationMeasuresForHomesBeingRebuilt.pdf>

[16] Floods, Sécuritê publique Québec, 2011. <https://www.securitepublique.gouv.qc.ca/en/civil-protection/floods-information-citizens.html>

[17] Adapting to Climate Change: A Risk management Gide for Utilities". Canadian Electricity Association, 2018. <https://electricity.ca/adapting-climate-change/>

Highlighted Best Practices and Resources	Workshops
▪ See how region-specific snow loads are communicated in building Codes	***Action Prioritized:*** Vancouver Whitehorse Winnipeg ***Action Discussed:*** Calgary Halifax Montreal Toronto

Extreme Weather

This section provides a deep dive into extreme weather-related impacts, best practices and actions for consideration in discussions related to potential CE Code updates. For the purposes of this study, extreme weather includes severe storms, hurricanes, tornadoes, lightning, extreme heat and cold.

Impacts

Figure 2 summarizes the levels of perceived extreme weather-related risks to the electricity sector by region based on the views of cross-country workshop participants. It also highlights some of the key impacts discussed associated with extreme weather.

Actions for Consideration

The following are the highest priority actions for consideration, as identified by cross-country workshop participants that are relevant to extreme weather. While workshop participants did not necessarily link each action for consideration to a specific Part of the Code or climate impact, this report makes such links to maximize usability of the findings.

E1. Review and update ice, wind and snow loading maps and loading criteria. (Parts II and III)

There is a need to review and update ice, wind and snow loading maps, as well as the loading criteria associated with them, in light of a changing climate. Radial ice and

Figure 2: *Extreme Weather*

* This map displays climate impacts specific to the electricity sector and is based on *perceived* levels of risk by workshop participants.

"A climate change guidance or companion document would include climate change-related risks, impacts, data, maps and best practices on how to manage risks."

wind speed standards could be reviewed. Quality climate data would be needed for this endeavor. (NRC is currently revisiting snow load design data and NBC snow load provisions as part of the climate resilience project).

Other options beyond updated loading criteria were also considered, such as smart connectors, controlled failures and pole distances. Indeed, improving overhead line standards to ensure that all components of overhead lines—poles, insulators, lines, and terminations—perform well under extreme wind and ice conditions was suggested.

Highlighted Best Practices and Resources	Workshops
▪ Province of Alberta has updated weather and loading maps to be more granular in scale ▪ CSA Standard C22.3 60826 – Design criteria of overhead transmission lines ▪ ASO Rule 502.2[18] ▪ Updated design criteria and ice loading requirements by utilities across Canada (Hydro One and Hydro Québec) ▪ Standards Council of Canada and National Research Council forthcoming standardization guidance for weather data, climate information and climate change projections ▪ Standards Council of Canada's Northern Infrastructure Standardization Initiative, phase II – Techniques for dealing with high winds pertaining to northern infrastructure[19]	***Action Prioritized:*** Vancouver Montreal Halifax Toronto Whitehorse ***Action Discussed:*** Calgary Winnipeg
▪ Updated return periods for wind/ice by utilities across Canada. ▪ Use of thicker overhead wires in areas prone to severe icing (ATCO) ▪ Controlled failure of lines techniques (Hydro Québec) ▪ Smart connectors that release the system when ice loads become too heavy. (Phase I Report) ▪ Review design standards for high voltage lines and update construction standards (Hydro-Québec, Phase I Report) ▪ Use of ice visioning, melting and rolling technologies (Manitoba Hydro) ▪ Standards Council of Canada's Northern Infrastructure Standardization Initiative, phase II[20] ▪ Manitoba Hydro uses different pole and connector design strategies in "high ice areas" ▪ Upgraded designs for insulators (Newfoundland Power)	

E2. Update product design standards and testing to account for new climate realities and incorporate climate projections (ambient and extreme temperatures, wind, rain, snow, peak loads, corrosion, water exposure). (Part II and III)

It was widely acknowledged that there is a need to adapt to weather uncertainty and future climate projections in project design.

[18] Alberta Electric System Operator, Section 502.2 - Bulk Transmission Line Technical Requirements. <https://www.aeso.ca/rules-standards-and-tariff/iso-rules/section-502-2-bulk-transmission-line-technical-requirements/>

[19] Standards Council of Canada's Northern Infrastructure Standardization Initiative, phase II. <https://www.scc.ca/en/nisi>

[20] Ibid.

This action for consideration encompasses a number of discussions and recommendations. One group talked about protecting high and medium voltage distribution equipment against wind by updating standards in accordance with more current climate data. Temperature variations, freezing rain and precipitation (rain and snow) were also raised as climate risks to consider when updating design criteria. One specific proposal put forward was potentially moving the extreme low temperature design standards from -35 degrees Celsius to -50 degrees Celsius; raising ambient temperature standards from 20-25 degrees Celsius to 30-35 degrees Celsius; and increasing the extreme high temperature standards from 60 degrees Celsius to 75 degrees Celsius. One group suggested that we should aim for 100 year lifespans for equipment.

Highlighted Best Practices and Resources	Workshops
▪ CSA Standard C22.3 60826 – Design criteria of overhead transmission lines ▪ ASO Rule 502.2[21] ▪ Upgraded designs for insulators (Newfoundland Power) ▪ Use of lightning arrestors (Province of PEI) ▪ Use of submersible and flood-proofed equipment (Con Edison) ▪ National Grid's new standards for substation protection (1-in-1,000-yr flood, > 24 inches above 100-year flood levels in flood prone areas, relocating out of flood zones during major upgrades) ▪ Entergy's use of more durable materials within 20 miles of coast and along evacuation routes ▪ Updated design criteria for ice loading. (Hydro One) ▪ Certain Ontario-based utilities' switch to stainless steel transformers ▪ Standards Council of Canada and National Research Council forthcoming standardization guidance for weather data, climate information and climate change projections ▪ Standards Council of Canada's Northern Infrastructure Standardization Initiative, phase II – Techniques for dealing with high winds pertaining to northern infrastructure[22]	***Action Prioritized:*** Calgary Vancouver Whitehorse Montreal Halifax Toronto ***Action Discussed:*** Winnipeg

E3. Guidance / standardization on treatment of impacted products, installations and equipment. (Part I, II and III or companion document)

Accessible and easy-to-use guidance or standardization on the treatment of electrical products, installations and equipment impacted by flooding or other climate impacts is needed. This is important because specific classes of equipment can be rebuilt, while others can pose a hazard risk in the long term. More guidance is needed around whether and when replacement is needed (as opposed to restoration or refurbishment) as well as the steps to do a proper restoration. This guidance could be informative, not compulsory.

Highlighted Best Practices and Resources	Workshops
▪ NEMA standards for water-damaged equipment. ▪ Government of Alberta, Electrical STANDATA bulletins on Disaster Recovery Program Flood Mitigation Measures[23] ▪ Technical bulletin providing guidance around flooded installations (for Manitoba, Minnesota and North Dakota, the three Red River Valley Jurisdictions) ▪ Manitoba Electrical Code, 2-024-2 SMOKE AND WATER DAMAGE TO CIRCUIT BREAKERS[24]	***Action Prioritized:*** Calgary Winnipeg ***Action Discussed:*** Vancouver

E4. Provide climate change guidance in a companion document. (companion document)

A climate change guidance or companion document would include climate change-related risks, impacts, data, maps and best practices on how to manage risks.

Relevant / Helpful Best Practices and Resources	Workshops
▪ CEA's Climate Change Adaptation Guide[25] ▪ Forthcoming Canadian Centre for Climate Services (CCCS) ▪ Creation of climate change-related research organization/think tank (Québec's Ouranos) ▪ Standards Council of Canada and National Research Council forthcoming standardization guidance for weather data, climate information and climate change projections ▪ CEN-CENELEC Guide 32 – Guide for addressing climate change adaptation in standards[26]	***Action Prioritized:*** Vancouver Whitehorse Winnipeg Halifax ***Action Discussed:*** Montreal

[21] Alberta Electric System Operator, Section 502.2 - Bulk Transmission Line Technical Requirements. <https://www.aeso.ca/rules-standards-and-tariff/iso-rules/section-502-2-bulk-transmission-line-technical-requirements/>

[22] Standards Council of Canada's Northern Infrastructure Standardization Initiative, phase II. <https://www.scc.ca/en/nisi>

[23] Disaster Recovery Program Flood Mitigation Measures for Homes Being Rebuilt / Disaster Recovery Program Flood Mitigation Measures, Standata, 2013. < http://www.municipalaffairs.alberta.ca/documents/ss/STANDATA/ building/bcb/06BCB010-DCP-FloodMitigationMeasuresForHomesBeingRebuilt.pdf>

[24] The Manitoba Electrical Code, 12th ed., Manitoba Hydro, 2015 <https://www.hydro.mb.ca/accounts_and_services/permits_and_inspections/pdfs/manitoba_electrical_code.pdf>

[25] "Adapting to Climate Change: A Risk management Gide for Utilities". Canadian Electricity Association, 2018. <https://electricity.ca/adapting-climate-change/>

[26] CEN-CENELEC Guide 32 – Guide for addressing climate change adaptation in standards. <ftp://ftp.cencenelec.eu/EN/EuropeanStandardization/Guides/32_CENCLCGuide32.pdf>

E5. Provide guidance on emergency response and resiliency. (Part I, II and III or companion document)

Guidance on emergency should provide information to assist stakeholders in recovering from a climate-related event, especially when we are seeing events that are increasing in scale. Such guidance could also cover issues such as system redundancy backup supply, emergency response, contingency plans and prioritization of customers (i.e. who is most vulnerable and who should have power restored first). Finally, emergency planning guidance could discuss federal government expectations of the electricity sector, including the number of hours/days after an event that utility companies should be back online.

Highlighted Best Practices and Resources	Workshops
▪ Government of Alberta, Electrical STANDATA bulletins on Disaster Recovery Program Flood Mitigation Measures. ▪ The Québec Ministry of Public Security / Ministère de la Sécurité publique provides general guidance on responding to disasters, including floods[27] ▪ CEA's Climate Change Adaptation Guide[28]	***Action Prioritized:*** Vancouver Montreal Halifax Toronto ***Action Discussed:*** Calgary Whitehorse Winnipeg

E6. Update vegetation management related standards. (Part III or companion document)

Stakeholders suggested that updated vegetation management-related standards are also needed. Minimum clearance and vegetation requirements could be explored as an update to Part III of the CE Code. Participants suggested moving to a one-year vegetation management cycle and increasing clearance distances. Guidelines for new vegetation specifying the types (e.g. lower-growing species) and heights of trees could also be explored. Participants suggested combining safety and climate resilience outcomes with climate change mitigation and carbon sequestration / storage goals.

Highlighted Best Practices and Resources	Workshops
No best practices identified.	***Action Prioritized:*** Toronto ***Action Discussed:*** Calgary Halifax

E7. Introduce more guidance on monitoring and maintenance of critical assets. (Part III or companion document)

More guidance on monitoring assets and critical equipment, as well as subsequent and preventative maintenance to ensure equipment continues to meet design standards, is needed.

Highlighted Best Practices and Resources	Workshops
No best practices identified.	***Action Prioritized:*** Montreal ***Action Discussed:*** Whitehorse Winnipeg Toronto

E8. Create regionally-specific compliance paths or flexibility to satisfy code requirements. (Part I, II and III)

Participants advocated for more regionally-specific compliance paths or flexibility in satisfying Code requirements on the basis of professional judgment or "good engineering principles" to account for local contexts.

Highlighted Best Practices and Resources	Workshops
▪ See how region-specific snow loads are communicated in building Codes.	***Action Prioritized:*** Whitehorse Winnipeg ***Action Discussed:*** Calgary Halifax Montreal Toronto

[27] Floods, Sécuritê publique Québec, 2011. <https://www.securitepublique.gouv.qc.ca/en/civil-protection/floods-information-citizens.html>
[28] "Adapting to Climate Change: A Risk management Gide for Utilities". Canadian Electricity Association, 2018. <https://electricity.ca/adapting-climate-change/>

E9. Improve standards around mounting of electrical equipment on exteriors. (Part I and III)

Requirements or standards relating to how well electrical equipment is mounted on building exteriors, or even potentially the height of the mounted equipment, could help prevent damage and outages from events such as wind storms.

Highlighted Best Practices and Resources	Workshops
No best practices identified.	***Action Prioritized:*** Halifax ***Action Discussed:*** Vancouver

Ice, Wind and Snow Loads

This section provides a deep dive into ice, wind and snow load-related impacts, best practices and actions for consideration in discussions related to potential CE Code updates. Note that, for the purposes of this study, there may be some overlap between this category and the extreme weather category given that high winds and freezing rain are relevant to both.

Impacts

Figure 3 summarizes the levels of perceived extreme ice, wind and snow load-related risks to the electricity sector by region based on the views of cross-country workshop participants. It also highlights some of the key impacts discussed associated with ice, wind and snow.

Actions for Consideration

The following are the highest priority actions for consideration, as identified by cross-country workshop participants, that are relevant to ice, wind and snow loads. While workshop participants did not necessarily link each action for consideration to a specific Part of the Code or climate impact, this report makes such links to maximize usability of the findings.

Figure 3: *Ice, Snow & Wind Loads*

* This map displays climate impacts specific to the electricity sector and is based on *perceived* levels of risk by workshop participants.

"Guidance on emergency should provide information to assist stakeholders in recovering from a climate-related event, especially when we are seeing events that are increasing in scale."

I1. Review and update ice, wind and snow loading maps and loading criteria. (Parts II and III)

There is a need to review and update ice, wind and snow loading maps, as well as the loading criteria associated with them, in light of a changing climate. Radial ice and wind speed standards could be reviewed. Quality climate data would be needed for this endeavor.

Other options beyond updated loading criteria were also considered, such as smart connectors, controlled failures and pole distances. Indeed, improving overhead line standards to ensure that all components of overhead lines—poles, insulators, lines, and terminations—perform well under extreme wind and ice conditions was suggested.

Highlighted Best Practices and Resources	Workshops
▪ Province of Alberta has updated weather and loading maps to be more granular in scale ▪ CSA Standard C22.3 60826 – Design criteria of overhead transmission lines ▪ ASO Rule 502.2[29] ▪ Updated design criteria and ice loading requirements by utilities across Canada (Hydro One and Hydro Québec)	***Action Prioritized:*** Vancouver Montreal Halifax Toronto Whitehorse ***Action Discussed:*** Calgary Winnipeg
▪ Standards Council of Canada and National Research Council forthcoming standardization guidance for weather data, climate information and climate change projections ▪ Standards Council of Canada's Northern Infrastructure Standardization Initiative, phase II – Techniques for dealing with high winds pertaining to northern infrastructure[30] ▪ Updated return periods for wind/ice by utilities across Canada. ▪ Use of thicker overhead wires in areas prone to severe icing (ATCO) ▪ Controlled failure of lines techniques (Hydro Québec) ▪ Smart connectors that release the system when ice loads become too heavy. (Phase I Report) ▪ Review design standards for high voltage lines and update construction standards (Hydro-Québec, Phase I Report) ▪ Use of ice visioning, melting and rolling technologies (Manitoba Hydro) ▪ Standards Council of Canada's Northern Infrastructure Standardization Initiative, phase II[31] ▪ Manitoba Hydro uses different pole and connector design strategies in "high ice areas". ▪ Upgraded designs for insulators (Newfoundland Power)	

[29] Alberta Electric System Operator, Section 502.2 - Bulk Transmission Line Technical Requirements. <https://www.aeso.ca/rules-standards-and-tariff/iso-rules/section-502-2-bulk-transmission-line-technical-requirements/>

[30] Standards Council of Canada's Northern Infrastructure Standardization Initiative, phase II. <https://www.scc.ca/en/nisi>

[31] Ibid.

I2. Update product design standards and testing to account for new climate realities and incorporate climate projections (wind, snow, ice). (Parts II and III)

It was widely acknowledged that there is a need to adapt to weather uncertainty and future climate projections in project design.

This action for consideration encompasses many discussions and recommendations. One group talked about protecting high and medium voltage distribution equipment against wind by updating standards in accordance with more current climate data. Temperature variations, freezing rain and precipitation (rain and snow) were also raised as climate risks to consider when updating design criteria. One specific proposal put forward was potentially moving the extreme low temperature design standards from -35 degrees Celsius to -50 degrees Celsius. One group suggested that we should aim for 100 year lifespans for equipment.

Furthermore, Part II of the Code covers ice and wind testing but not combination testing. Without combined testing, a piece of equipment could pass a test for rain alone, a test for wind alone and a test for ice alone, but may still fail in the instance of a combined event. Instead of absolute testing, participants suggested to start looking into combination testing (e.g. UV and rain; rain and ice; rain, wind and ice).

Highlighted Best Practices and Resources	Workshops
▪ Upgraded designs for insulators (Newfoundland Power) ▪ BC Hydro's high-resolution wind projections to improve wind forecast capabilities and management practices ▪ Updated design criteria for ice loading. (Hydro One) ▪ Standards Council of Canada and National Research Council forthcoming standardization guidance for weather data, climate information and climate change projections ▪ Updated design criteria and ice loading requirements by utilities across Canada (Hydro One and Hydro Québec) ▪ Updated return periods for wind/ice by utilities across Canada. ▪ Review design standards for high voltage lines and update construction standards (Hydro-Québec, Phase I Report) ▪ ATCO uses thicker overhead wires in areas prone to severe icing ▪ Manitoba Hydro uses different pole and connector design strategies in "high ice areas" ▪ Certain utilities across Canada have switched to steel or fibreglass cross arms to address ice accretion. ▪ Standards Council of Canada's Northern Infrastructure Standardization Initiative, phase II – Techniques for dealing with high winds pertaining to northern infrastructure[32]	***Action Prioritized:*** Calgary Vancouver Whitehorse Montreal Halifax Toronto ***Action Discussed:*** Winnipeg

I3. Provide climate change guidance in a companion document. (companion document)

A climate change guidance or companion document would include climate change-related risks, impacts, data, maps and best practices on how to manage risks.

Relevant / Helpful Best Practices and Resources	Workshops
▪ CEA's Climate Change Adaptation Guide[33] ▪ Forthcoming Canadian Centre for Climate Services (CCCS) ▪ Creation of climate change-related research organization/think tank (Québec's Ouranos) ▪ Standards Council of Canada and National Research Council forthcoming standardization guidance for weather data, climate information and climate change projections ▪ CEN-CENELEC Guide 32 – Guide for addressing climate change adaptation in standards[34]	***Action Prioritized:*** Vancouver Whitehorse Winnipeg Halifax ***Action Discussed:*** Montreal

[32] Ibid.

[33] "Adapting to Climate Change: A Risk management Gide for Utilities". Canadian Electricity Association, 2018. <https://electricity.ca/adapting-climate-change/>

[34] CEN-CENELEC Guide 32 – Guide for addressing climate change adaptation in standards. <ftp://ftp.cencenelec.eu/EN/EuropeanStandardization/Guides/32_CENCLCGuide32.pdf>

I4. Provide guidance on emergency response and resiliency. (Part I, II and III or companion document)

Guidance on emergency should provide information to assist stakeholders in recovering from a climate-related event, especially when we are seeing events that are increasing in scale. Such guidance could also cover issues such as system redundancy backup supply, emergency response, contingency plans and prioritization of customers (i.e. who is most vulnerable and who should have power restored first). Finally, emergency planning guidance could discuss federal government expectations of the electricity sector, including the number of hours/days after an event that utility companies should be back online.

Highlighted Best Practices and Resources	Workshops
▪ Government of Alberta, Electrical STANDATA bulletins on Disaster Recovery Program Flood Mitigation Measures[35] ▪ The Québec Ministry of Public Security / Ministère de la Sécurité publique provides general guidance on responding to disasters, including floods[36] ▪ CEA's Climate Change Adaptation Guide[37]	***Action Prioritized:*** Vancouver Montreal Halifax Toronto ***Action Discussed:*** Calgary Whitehorse Winnipeg

I5. Introduce more guidance on monitoring and maintenance of critical assets. (Part III or companion document)

More guidance on monitoring assets and critical equipment, as well as subsequent and preventative maintenance to ensure equipment continues to meet design standards, is needed.

Highlighted Best Practices and Resources	Workshops
No best practices identified.	***Action Prioritized:*** Montreal ***Action Discussed:*** Whitehorse Winnipeg Toronto

I6. Update vegetation management related standards. (Part III or companion document)

Stakeholders suggested that updated vegetation management- related standards are also needed. Minimum clearance and vegetation requirements could be explored as an update to Part III of the CE Code. Participants suggested moving to a one-year vegetation management cycle and increasing clearance distances. Guidelines for new vegetation specifying the types (e.g. lower-growing species) and heights of trees could also be explored. Participants suggested combining safety and climate resilience outcomes with climate change mitigation and carbon sequestration / storage goals.

Highlighted Best Practices and Resources	Workshops
No best practices identified.	***Action Prioritized:*** Toronto ***Action Discussed:*** Calgary Halifax

I7. Create regionally-specific compliance paths or flexibility to satisfy code requirements. (Parts I, II and III)

Participants advocated for more regionally-specific compliance paths or flexibility in satisfying Code requirements on the basis of professional judgment or "good engineering principles" to account for local contexts.

Highlighted Best Practices and Resources	Workshops
▪ See how region-specific snow loads are communicated in building Codes.	***Action Prioritized:*** Vancouver Whitehorse Winnipeg ***Action Discussed:*** Calgary Halifax Montreal Toronto

[35] Disaster Recovery Program Flood Mitigation Measures for Homes Being Rebuilt / Disaster Recovery Program Flood Mitigation Measures, Standata, 2013. < http://www.municipalaffairs.alberta.ca/documents/ss/STANDATA/ building/bcb/06BCB010-DCP-FloodMitigationMeasuresForHomesBeingRebuilt.pdf>

[36] Floods, Sécuritê publique Québec, 2011. <https://www.securitepublique.gouv.qc.ca/en/civil-protection/floods-information-citizens.html>

[37] "Adapting to Climate Change: A Risk management Gide for Utilities". Canadian Electricity Association, 2018. <https://electricity.ca/adapting-climate-change/>

I8. Improve standards around mounting of electrical equipment on exteriors. (Part I and III)

Requirements or standards relating to how well electrical equipment is mounted on building exteriors, or even potentially the height of the mounted equipment, could help prevent damage and outages from events such as wind storms.

Highlighted Best Practices and Resources	Workshops
No best practices identified.	***Action Prioritized:*** Halifax ***Action Discussed:*** Vancouver

Wildfires

This section provides a deep dive into wildfire-related impacts, best practices and actions for consideration in discussions related to potential CE Code updates. For the purposes of this report, wildfire includes smaller fires such as grass fires, as well as large-scale fires such as those experienced in Fort McMurray in 2016.

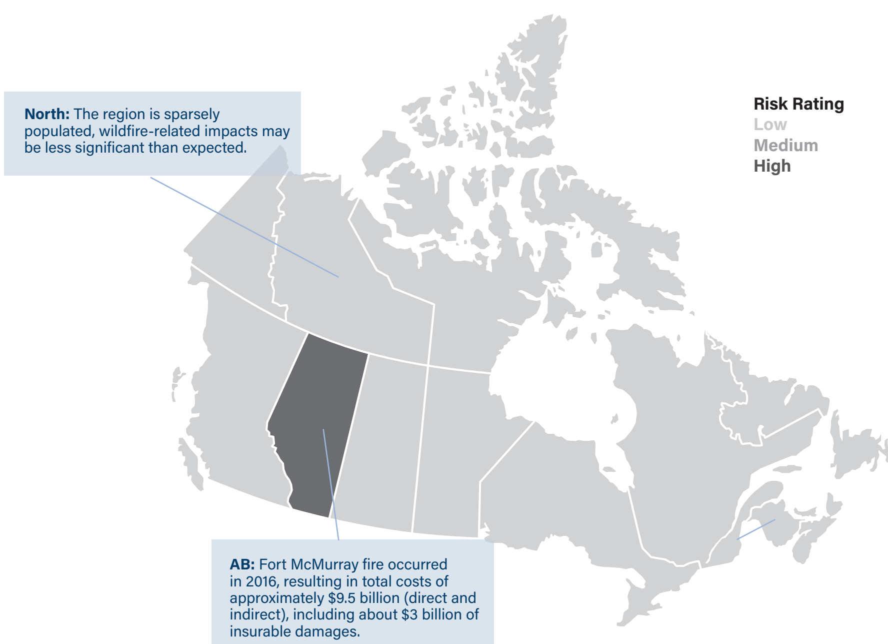
Impacts

Figure 4 summarizes the levels of perceived wildfire-related risks to the electricity sector by region based on the views of cross-country workshop participants. It also highlights some of the key impacts discussed associated with wildfires.

Actions for Consideration

The following are the highest priority actions for consideration, as identified by cross-country workshop participants that are relevant to wildfires. While workshop participants did not necessarily link each action for consideration to a specific Part of the Code or climate impact, this report makes such links to maximize usability of the findings.

Figure 4: *Wildfires*



* This map displays climate impacts specific to the electricity sector and is based on *perceived* levels of risk by workshop participants.

"The Fort McMurray fire occurred in 2016, resulting in total costs of approximately $9.5 billion (direct and indirect)."

W1. Update vegetation management related standards. (Part III or companion document)

Stakeholders suggested that updated vegetation management-related standards is also needed. Minimum clearance and vegetation requirements could be explored as an update to Part III of the CE Code. Participants suggested moving to a one-year vegetation management cycle and increasing clearance distances. Guidelines for new vegetation specifying the types (e.g. lower-growing species) and heights of trees could also be explored. Participants suggested combining safety and climate resilience outcomes with climate change mitigation and carbon sequestration / storage goals.

Highlighted Best Practices and Resources	Workshops
▪ National Research Council's forthcoming Code-ready National Guide for Wildland Urban Interface design ▪ Fire Smart Program[38]	***Action Prioritized:*** Toronto ***Action Discussed:*** Calgary Halifax

W2. Update product design standards and testing to account for new climate realities and incorporate climate projections (ambient and extreme temperatures, peak loads). (Parts II and III)

It was widely acknowledged that there is a need to adapt to weather uncertainty and future climate projections in project design. One specific proposal put forward was potentially raising ambient temperature standards from 20-25 degrees Celsius to 30-35 degrees Celsius; and increasing the extreme high temperature standards from 60 degrees Celsius to 75 degrees Celsius. One group suggested that we should aim for 100 year lifespans for equipment.

Updated product designs and testing requirements could be integrated into Part II and could cover what heat maximums are appropriate for transformers.

Highlighted Best Practices and Resources	Workshops
▪ Standards Council of Canada and National Research Council forthcoming standardization guidance for weather data, climate information and climate change projections ▪ National Research Council's forthcoming Code-ready National Guide for Wildland Urban Interface design ▪ Standards Council of Canada's Northern Infrastructure Standardization Initiative, phase II – Fire resilient building design and materials[39]	***Action Prioritized:*** Calgary Vancouver Whitehorse Montreal Halifax Toronto ***Action Discussed:*** Winnipeg

W3. Guidance / standardization on treatment of impacted products, installations and equipment. (Part I, II and II or companion document)

Many stakeholders agreed that more guidance is needed to determine whether and to what extent a product has

[38] Fire Smart Program. <https://www.firesmartcanada.ca/>

[39] Standards Council of Canada's Northern Infrastructure Standardization Initiative, phase II. <https://www.scc.ca/en/nisi>

been damaged, as well as what type of rejuvenation process should be followed to address exposed and potentially damaged equipment.

This is important because specific classes of equipment can be rebuilt, while others can pose a hazard risk in the long term. More guidance is needed around whether and when replacement is needed (as opposed to restoration or refurbishment) as well as the steps to do a proper restoration. This guidance could be informative, not compulsory.

Highlighted Best Practices and Resources	Workshops
▪ The new article 708, Critical Operations Power Systems added to the National Fire Protection Association 70 National Electrical Code[40] ▪ NEMA – Evaluating Fire and Heat Damaged Electrical Equipment Guide[41] ▪ Technical bulletin providing guidance around flooded installations (for Manitoba, Minnesota and North Dakota, the three Red River Valley Jurisdictions) ▪ Manitoba Electrical Code, 2-024-2 SMOKE AND WATER DAMAGE TO CIRCUIT BREAKERS[42]	***Action Prioritized:*** Calgary Winnipeg ***Action Discussed:*** Vancouver

W4. Provide climate change guidance in a companion document. (companion document)

A climate change guidance or companion document would include climate change-related risks, impacts, data, maps and best practices on how to manage risks.

Relevant / Helpful Best Practices and Resources	Workshops
▪ CEA's Climate Change Adaptation Guide[43] ▪ Forthcoming Canadian Centre for Climate Services (CCCS) ▪ Creation of climate change-related research organization/think tank (Québec's Ouranos) ▪ Standards Council of Canada and National Research Council forthcoming standardization guidance for weather data, climate information and climate change projections	***Action Prioritized:*** Vancouver Whitehorse Winnipeg Halifax ***Action Discussed:*** Montreal

W5. Provide guidance on emergency response and resiliency. (Part I, II and III or companion document)

Guidance on emergency should provide information to assist stakeholders in recovering from a climate-related event, especially when we are seeing events that are increasing in scale. Such guidance could also cover issues such as system redundancy backup supply, emergency response, contingency plans and prioritization of customers (i.e. who is most vulnerable and who should have power restored first). Finally, emergency planning guidance could discuss federal government expectations of the electricity sector, including the number of hours/days after an event utility companies should be back online.

Highlighted Best Practices and Resources	Workshops
▪ Government of Alberta, Electrical STANDATA bulletins on Disaster Recovery Program Flood Mitigation Measures[44] ▪ The Québec Ministry of Public Security / Ministère de la Sécurité publique provides general guidance on responding to disasters, including floods[45] ▪ CEA's Climate Change Adaptation Guide[46]	***Action Prioritized:*** Vancouver Montreal Halifax Toronto ***Action Discussed:*** Calgary Whitehorse Winnipeg

W6. Introduce more guidance on monitoring and maintenance of critical assets. (Part III or companion document)

More guidance on monitoring assets and critical equipment, as well as subsequent and preventative maintenance to ensure equipment continues to meet design standards, is needed.

[40] Replacing or Upgrading Water-Damaged Electrical Equipment, National Electrical Manufacturers Association (NEMA), n.d. <https://www.nema.org/Storm-Disaster-Recovery/Replacing-and-Relocating-Equipment/Pages/Replacing-or-Upgrading-Water-Damaged-Electrical-Equipment.aspx>

[41] Evaluating Fire- and Heat-Damaged Electrical Equipment, National Electrical Manufacturers Association (NEMA), 2016. <https://www.nema.org/Standards/SecureDocuments/NEMA%20GD%202-2016%20Evaluating-Fire-and-Heat-Damaged-Electrical-Equipment-Guide.pdf>

[42] The Manitoba Electrical Code, 12th ed., Manitoba Hydro, 2015.

[43] "Adapting to Climate Change: A Risk management Gide for Utilities". Canadian Electricity Association, 2018. <https://electricity.ca/adapting-climate-change/>

[44] Disaster Recovery Program Flood Mitigation Measures for Homes Being Rebuilt / Disaster Recovery Program Flood Mitigation Measures, Standata, 2013. <http://www.municipalaffairs.alberta.ca/documents/ss/STANDATA/ building/bcb/06BCB010-DCP-FloodMitigationMeasuresForHomesBeingRebuilt.pdf>

[45] Floods, Sécuritê publique Québec, 2011. <https://www.securitepublique.gouv.qc.ca/en/civil-protection/floods-information-citizens.html>

[46] "Adapting to Climate Change: A Risk management Gide for Utilities". Canadian Electricity Association, 2018 <https://electricity.ca/adapting-climate-change/>

Highlighted Best Practices and Resources	Workshops
▪ Install sprinkler systems (Yukon Energy, Whitehorse Workshop)	***Action Prioritized:*** Montreal ***Action Discussed:*** Whitehorse Winnipeg Toronto

W7. Create regionally-specific compliance paths or flexibility to satisfy code requirements. (Parts I, II and III)

Participants advocated for more regionally-specific compliance paths or flexibility in satisfying Code requirements on the basis of professional judgment or "good engineering principles" to account for local contexts.

Highlighted Best Practices and Resources	Workshops
▪ See how region-specific snow loads are communicated in building Codes.	***Action Prioritized:*** Vancouver Whitehorse Winnipeg ***Action Discussed:*** Calgary Halifax Montreal Toronto

Permafrost and Land Movement

This section provides a deep dive into permafrost and land movement-related impacts, best practices and actions for consideration in discussions related to potential CE Code updates. For the purposes of this report, permafrost includes risks related to permafrost thaw and associated land movement, as the existence of permafrost itself does not necessarily present any problems.

Impacts

Figure 5 summarizes the levels of perceived permafrost and land movement-related risks to the electricity sector by region based on the views of cross-country workshop participants. It also highlights some of the key impacts discussed associated with permafrost thaw and land movement.

Actions for Consideration

The following are the highest priority actions for consideration, as identified by cross-country workshop participants, that are relevant to permafrost and land movement. While workshop participants did not necessarily link each action for consideration to a specific Part of the Code or climate impact, this report makes such links to maximize usability of the findings.

P1. Update product design standards and testing to account for new climate realities and incorporate climate projections. (Parts II and III)

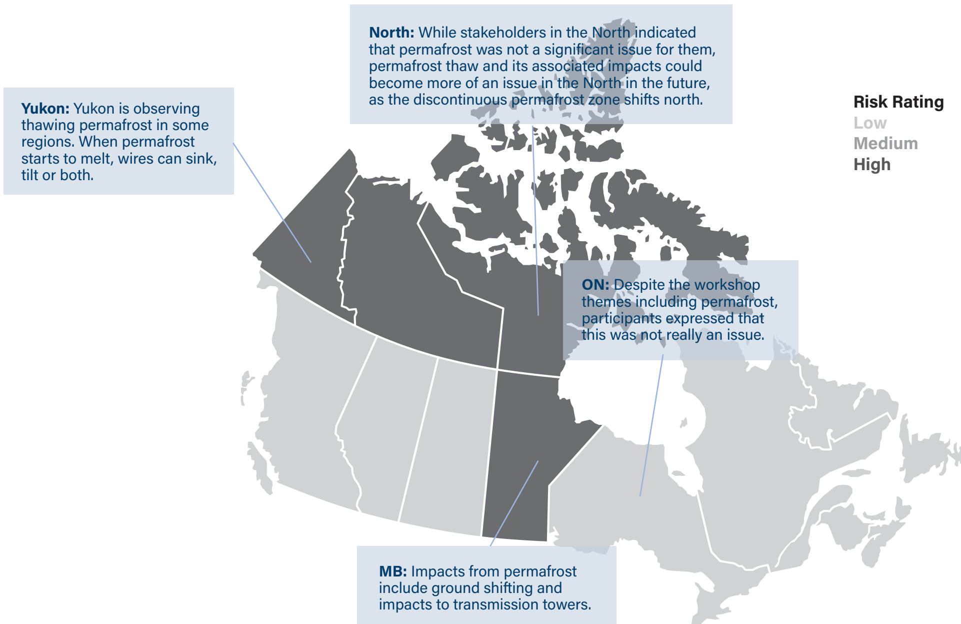
It was widely acknowledged that there is a need to adapt to weather uncertainty and future climate projections in project design.

This action for consideration encompasses a number of discussions and recommendations. One group talked about protecting high and medium voltage distribution equipment against wind by updating standards in accordance with more current climate data. Temperature variations, freezing rain and precipitation (rain and snow) were also raised as climate risks to consider when updating design criteria. One specific proposal put forward was potentially moving the extreme low temperature design standards from -35 degrees Celsius to -50 degrees Celsius. One group suggested that we should aim for 100 year lifespans for equipment.

Highlighted Best Practices and Resources	Workshops
▪ Standards Council of Canada and National Research Council forthcoming standardization guidance for weather data, climate information and climate change projections. ▪ Standards Council of Canada's Northern Infrastructure Standardization Initiative, phase II – Selection of foundation types for buildings in permafrost[47] ▪ Standards Council of Canada's Northern Infrastructure Standardization Initiative, phase II – Erosion protection in permafrost[48]	***Action Prioritized:*** Calgary Vancouver Whitehorse Montreal Halifax Toronto ***Action Discussed:*** Winnipeg

[47] Standards Council of Canada's Northern Infrastructure Standardization Initiative, phase II. <https://www.scc.ca/en/nisi>
[48] Ibid.

Figure 5: *Permafrost*



* This map displays climate impacts specific to the electricity sector and is based on *perceived* levels of risk by workshop participants.

Highlighted Best Practices and Resources Continued
▪ Standards Council of Canada's Northern Infrastructure Standardization Initiative, phase II – Techniques for dealing with high winds pertaining to northern infrastructure[49] ▪ Upgraded designs for insulators (Newfoundland Power) ▪ BC Hydro's high-resolution wind projections to improve wind forecast capabilities and management practices ▪ Updated design criteria for ice loading. (Hydro One) ▪ Updated design criteria and ice loading requirements by utilities across Canada (Hydro One and Hydro Québec) ▪ Updated return periods for wind/ice by utilities across Canada ▪ Review design standards for high voltage lines and update construction standards (Hydro-Québec, Phase I Report) ▪ ATCO uses thicker overhead wires in areas prone to severe icing ▪ Manitoba Hydro uses different pole and connector design strategies in "high ice areas" ▪ Certain utilities across Canada have switched to steel or fibreglass cross arms to address ice accretion. ▪ Use wood utility poles in areas of permafrost (Whitehorse Workshop) ▪ Increase building on-grade insulation, use different anchors and allow for innovative designs. (Whitehorse Workshop) ▪ Raising transmission towers in response to land shifting (Winnipeg Workshop) ▪ Limit vegetation clearing from right-of-ways (Winnipeg Workshop) ▪ The use of "frost boxes" (Manitoba Hydro, Winnipeg Workshop) ▪ The use of 200 Amp meter sockets for connectors. Manitoba Hydro chose to use 200 Amp meter sockets as the default size which have studs that require lug type connectors, to provide stronger mechanical connections to the conductors and to the meter socket. (Manitoba Hydro, Winnipeg Workshop) ▪ Use wedge-type compression connector (ATCO, Whitehorse Workshop)

[49] Ibid.

P2. Provide climate change guidance in a companion document. (companion document)

A climate change guidance or companion document would include climate change-related risks, impacts, data, maps and best practices on how to manage risks.

Highlighted Best Practices and Resources	Workshops
▪ CEA's Climate Change Adaptation Guide[50] ▪ Forthcoming Canadian Centre for Climate Services (CCCS) ▪ Creation of climate change-related research organization/think tank (Québec's Ouranos) ▪ Standards Council of Canada and National Research Council forthcoming standardization guidance for weather data, climate information and climate change projections ▪ Yukon Climate Change Indicators and Key Findings 2015[51]	***Action Prioritized:*** Vancouver Whitehorse Winnipeg Halifax ***Action Discussed:*** Montreal

P3. Introduce more guidance on monitoring and maintenance of critical assets. (Part III or companion document)

More guidance on monitoring assets and critical equipment, as well as subsequent and preventative maintenance to ensure equipment continues to meet design standards, is needed.

Highlighted Best Practices and Resources	Workshops
▪ Standards Council of Canada's Northern Infrastructure Standardization Initiative, phase II – Erosion protection in permafrost[52]	***Action Prioritized:*** Montreal ***Action Discussed:*** Whitehorse Winnipeg Toronto

P4. Create regionally-specific compliance paths or flexibility to satisfy code requirements. (Parts I, II and III)

Incorporate some level of regional specificity, or flexibility for local context or "good engineering principles."

Highlighted Best Practices and Resources	Workshops
▪ See how region-specific snow loads are communicated in building Codes.	***Action Prioritized:*** Vancouver Whitehorse Winnipeg ***Action Discussed:*** Calgary Halifax Montreal Toronto

[50] "Adapting to Climate Change: A Risk management Gide for Utilities". Canadian Electricity Association, 2018. <https://electricity.ca/adapting-climate-change/>

[51] Yukon Climate Change Indicators and Key Findings 2015, Northern Climate ExChange, 2015. <https://www.yukoncollege.yk.ca/sites/default/files/inline-files/Indicator_Report_Final_web.pdf>

[52] Standards Council of Canada's Northern Infrastructure Standardization Initiative, phase II. <https://www.scc.ca/en/nisi>

CSA Group Research

In order to encourage the use of consensus-based standards solutions to promote safety and encourage innovation, CSA Group supports and conducts research in areas that address new or emerging industries, as well as topics and issues that impact a broad base of current and potential stakeholders. The output of our research programs will support the development of future standards solutions, provide interim guidance to industries on the development and adoption of new technologies, and help to demonstrate our on-going commitment to building a better, safer, more sustainable world.

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