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Guide for Integrating Climate Change Adaptation Considerations into Canadian Standards

Manifest
Climate

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of Canada

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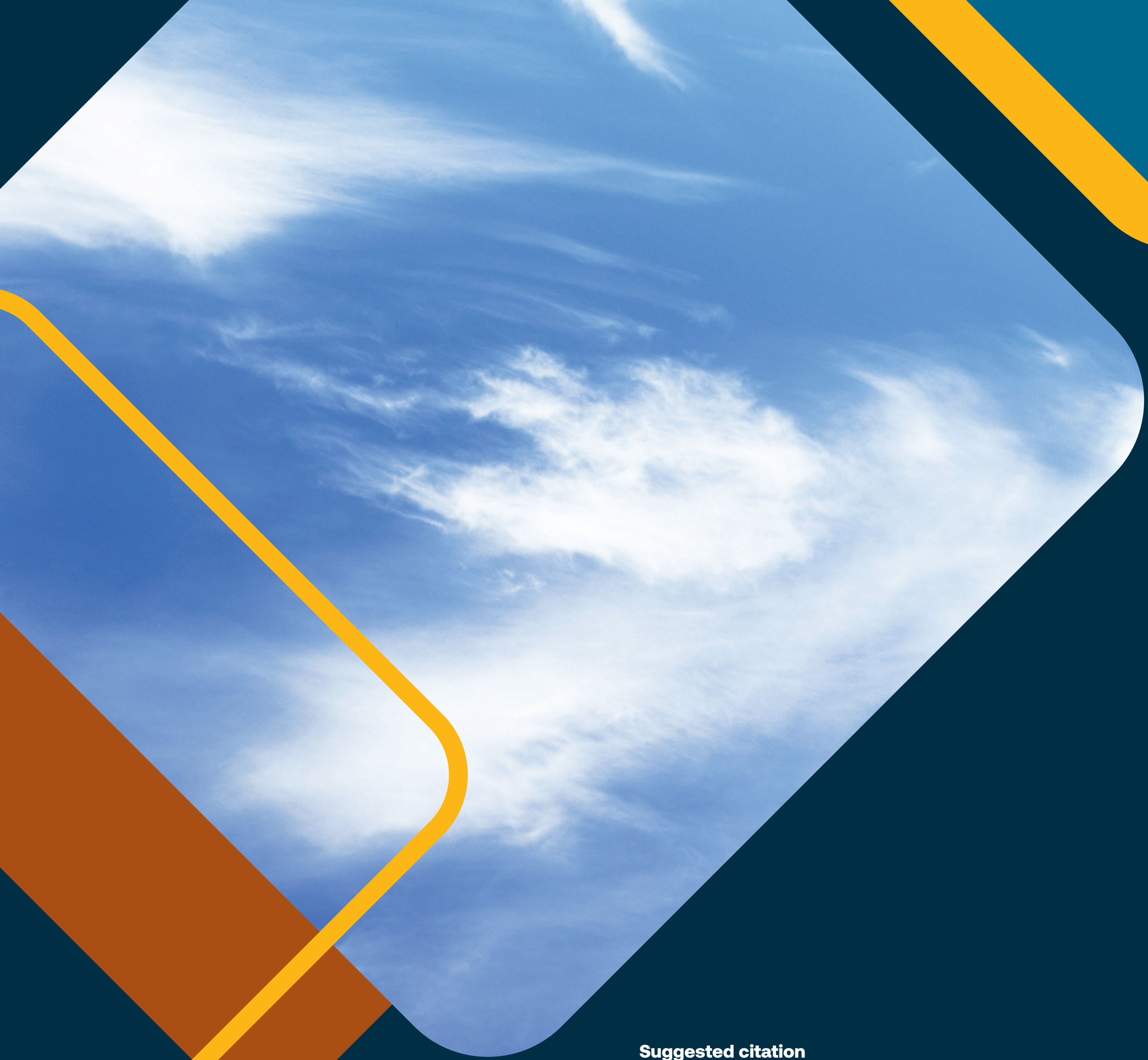

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The Guide reflects valuable input and feedback from members and associates of the Standards Development Organizations for Climate Resilient Infrastructure Working Group (SDO CRI WG) including:

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Executive summary

Climate change is altering the conditions under which we build infrastructure, perform work, maintain structures and buildings, transport goods, produce and deliver products and services, and source raw materials. Standards guide how goods are produced and used, how services are designed and delivered, how infrastructure is constructed and how testing is conducted. To ensure Canada is prepared for this changing reality, these standards must be developed and updated to be ready for (adapted for) the changing climate.

Over time, it is expected that many standards in Canada will need to be updated to reflect impacts of climate change. This *Guide for Integrating Climate Change Adaptation Considerations into Canadian Standards* (Guide) is intended to educate and support standards writers to incorporate climate change adaptation considerations into National Standards of Canada that are under development or revision. It provides a consistent methodology to help standards writers apply climate change considerations when updating existing or developing new standards through the introduction of principles, methods and techniques and provision of an example to facilitate its use, through a case study.

At the outset of the development process for a new standard, or a revision to an existing standard for product, services, infrastructure or test, standards writers are encouraged to utilize this Guide to incorporate consideration of climate-related risks, potential climate impacts and climate change adaptation into the standards development process, in much the same way that other risks are managed.

This Guide is meant to be read and applied in a holistic manner, with the only sequential considerations presented in chapters 4 and 6. Chapter 4 outlines a series of guiding questions to help determine the applicability of climate change adaptation to a given standard, and Chapter 6 provides a flow chart to help standards writers integrate climate change adaptation into standards, where appropriate.

Standards writers applying this Guide to their work on developing or updating standards are not expected to be experts in climate change and are encouraged to seek advice from qualified professionals and relevant subject matter experts.

1.

Introduction

1.1 Objective

This Guide is meant to educate and support standards writers to incorporate climate change adaptation considerations into National Standards of Canada that are under development or revision. It introduces principles, methods and techniques and provides examples to facilitate its use, through case studies.

A companion document to this Guide, which will provide more detailed information on the understanding and use of climate information, is currently under development by the Standards Council of Canada (SCC).

1.2 Audience

This Guide is meant to be used by any individual involved in the development of standards for use in Canada. This is broadly defined to include anyone directly involved in the drafting or revision of standards, such as:

- staff at standards development organizations who manage standards committees and/or projects
- subject matter experts who volunteer on a technical committee
- others who have input, such as consultants contributing to drafts, seed documents and other materials that will inform standards development

Throughout this Guide, the term “standards writers” is used to represent all of the above.

1.3 Intent

The Guide is intended to be used by standards writers and convey an understanding that:

- climate change is a complex and evolving issue
- climate change has affected, or will affect, nearly every type of standard, its design and life cycle, and its resultant product or process output
- it is important to consider integrating climate change adaptation principles in the development and revision of any standard, at all stages of its life cycle

1.4 Applicability

The Guide is universally applicable and should, at a minimum, **be considered** during the development and updating of standards that address:

- products
- services
- infrastructure
- tests

It is not expected that every standard will require revisions based on climate change. For example, some standards already contain “safety factors” within them that can accommodate climate-related disruptions. However, it is acknowledged that every product, service, infrastructure and test that is addressed by standards may be impacted by either short-term or long-term climate change impacts.

Standards writers applying this Guide to their work on developing or updating standards are **not expected** to be experts in climate change. This Guide provides considerations for inclusion and, where necessary or helpful, encourages writers to seek advice from qualified professionals and relevant subject matter experts.

1.5 How to use this Guide

This Guide is meant to be read and applied in a holistic manner, with the only sequential considerations presented in chapters 4 and 6. The Guide contains:

- background **information about climate change**, climate change adaptation and climate change impacts in Canada (Chapter 2)
- a set of **guiding principles** to establish the foundation for the guidance in subsequent chapters (Chapter 3)
- a series of **guiding questions** to help determine the applicability of climate change adaptation to a given standard (Chapter 4)
- a series of **considerations** to help standards writers think about and integrate climate change adaptation into standards (Chapter 5)
- a **flow chart** to help standards writers integrate climate change adaptation into standards, where appropriate (Chapter 6)
- a list of credible and relevant sources for **more information** (Appendix A)
- a **glossary** of key terms (Appendix B)
- **case studies** to help illustrate the integration of the principles, questions, considerations and guidance (Appendix C)

2.

About climate change

Climate change[1] refers to long-term changes in the weather conditions of a region, such as its typical temperature, rainfall, snow, ice, wind speed and frequency/duration/intensity of storms. Climate change means that the range of conditions expected in many regions will change over time and could be quite different from the historic climate experienced by that location, with increased likelihood of extreme weather conditions. Extreme weather refers to events such as floods, droughts, snow and thunderstorms that are rare for the season and region where they occur [2].

There is growing recognition that climate change considerations should be incorporated into the development and maintenance of many standards. This includes understanding of current weather patterns and how they are expected to change in the future. For example, Canada's electricity transmission and distribution assets are increasingly exposed to extreme weather events such as torrential rainstorms resulting in flooding. These extreme weather events may render electrical equipment unworkable, causing power outages and service disruptions. Therefore, as new transmission and distribution assets are designed and built, or existing assets are refurbished, it is critical to consider extreme weather and long-term climate change impacts.

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[1] Climate change in IPCC [31] usage refers to a change in the state of the climate that can be identified by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer.

Over time, it is expected that many standards and related documents in Canada will need to be updated to reflect impacts of climate change. This Guide provides a consistent methodology to help standards writers apply climate change considerations when developing or revising new and existing standards.

This chapter includes an overview of a series of climate change-related concepts to provide useful context for standards writers. It is organized in five sections:

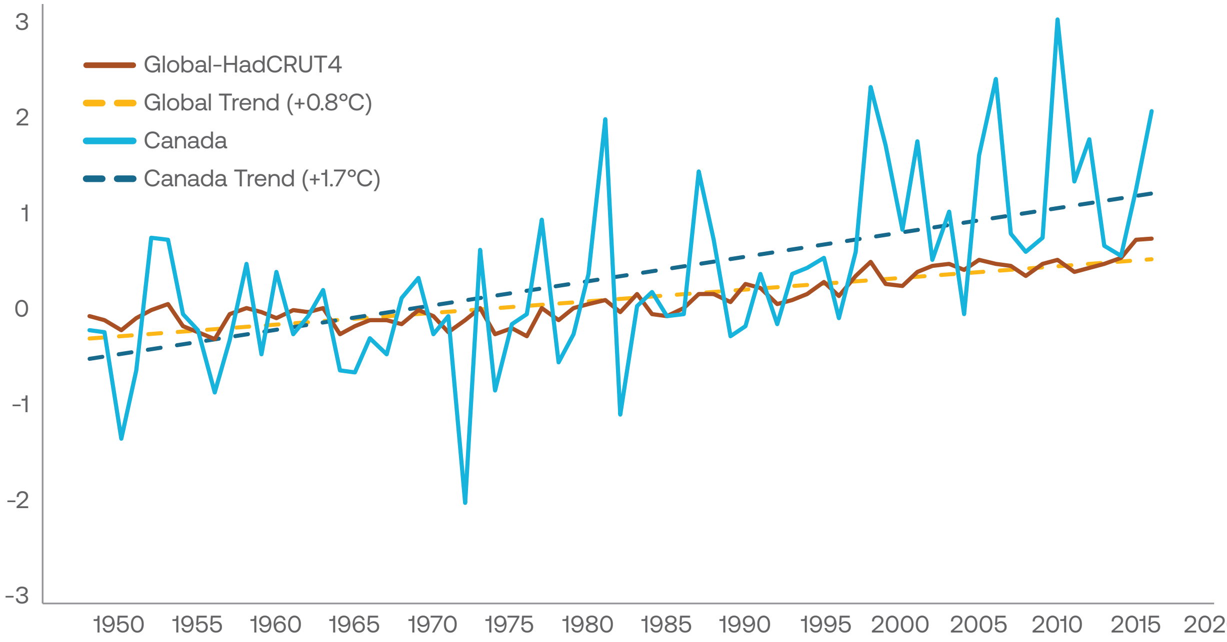
- 2.1 Climate change: A global imperative
- 2.2 Climate change: Understanding risk
- 2.3 Climate change: Understanding impacts
- 2.4 Climate change: Understanding adaptation
- 2.5 Current state of climate information and data

2.1 Climate change: A global imperative

Warming of the global climate system is unequivocal, and climate change impacts are only expected to intensify in the future [3, p. 38]. Human influences are changing the chemistry of the earth's atmosphere, which is causing increases in average global temperatures. Figure 1 shows changes in global and Canadian average temperature relative to the 1961–1990 reference period. On average, Canada is warming at **twice** the global rate, and northern Canada is warming even faster [3, p. 118].

Climate change is impacting humanity in numerous ways, and it is now a mainstream issue. Impacts of the warming global average temperature are wide ranging and include (but are not limited to) flooding, wildfires, damage to infrastructure, loss of land to rising seas, risk to water supplies and heat stress [5].

Figure 1: Change in global and Canadian average temperature relative to the 1961–1990 reference period[2] [4]



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[2] The change in global average temperature (in brown) is calculated from Hadley Centre's sea surface temperature records and the Climate Research Unit's land surface air temperature records version 4 (HadCRUTv4) dataset, while the change in Canadian average temperatures (in blue) is calculated from the Canadian Gridded Temperature and Precipitation Anomalies (CANGRD) dataset.

Weather versus climate:
Weather refers to the actual atmospheric conditions over a short period of time (i.e. days), while climate refers to weather patterns experienced across a region over longer time periods, typically 30 years.

Adapted from Environment and Climate Change Canada [4].

In the World Economic Forum's The *Global Risks Report 2019*, which assesses a wide range of risks ranging from asset bubbles to cyber-attacks to infectious diseases, the **top two risks** identified, in terms of likelihood, were "**extreme weather events**" at number one and "**failure of climate-change mitigation and adaptation**" at number two. Addressing climate change has become a global imperative, which is evident through the numerous declarations related to managing climate change risks and impacts, including:

- the Paris Agreement with its long-term goal to reduce the risks and effects of climate change by limiting the increase in global average temperature to well below 2°C above pre-industrial levels, and pursue efforts to limit the temperature increase even further to 1.5°C [6]
- the open letter on climate-related financial risks from Governor Villeroy de Galhau, Banque de France; Governor Mark Carney, Bank of England; and Frank Elderson, Chair of the Network for Greening the Financial System [7]
- the *Final Report of the Canadian Expert Panel on Sustainable Finance — Mobilizing Finance for Sustainable Growth* [8]
- the Global Commission on Adaptation's recommendation to mandate climate-resilient design and call for "Governments to develop and update national technical codes and standards to account for physical climate risks, adapting international best practices to local conditions" [9, p. 46]

Scientific overview

There is scientific consensus that the planet is warming at an accelerating pace, largely caused by human activities such as changes in land use and burning fossil fuels (e.g. coal, gas, oil), which increase the concentration of greenhouse gases (GHGs) in the atmosphere. GHGs trap energy from the sun in the atmosphere, raising the surface temperature. Climate change refers to this warming and the resulting long-term shifts in average weather conditions, such as typical temperature; rainfall patterns, duration and intensity; and storms across many geographical regions. While some of the changes in the earth's climate are caused by variations in heat output from the sun and other natural processes linking the atmosphere, ocean and land, the dominant forces affecting the changes currently under way are anthropogenic (human-made) in nature [4]. Furthermore, the rapid rate of change we are currently experiencing in the climate system far surpasses the much slower changes that come about from natural (non-human-made) causes.

The changing climate means that the range of conditions expected in many regions will change over the coming decades, and the thermal energy accumulating in the atmosphere means that extreme conditions will become more frequent and events more powerful.

Although the **average** temperature of the planet is increasing, there are many regional variations such as extreme cold in uncommon areas or long durations. It is not just heat waves, droughts and high temperatures that need to be considered but also changing winter storm and ice patterns. Research is actively investigating how climate change contributes to extreme precipitation events including rapidly intensifying storm systems [3, p. 294].

2.2 Climate change: Understanding risk

To consider climate risk as it relates to the development and revision of standards includes consideration of any potential physical risks associated with a changing climate, such as increased climatic loads (e.g. increased winds, hotter air, reduced humidity) as well as extreme weather events (e.g. torrential rain and thunderstorms, hurricanes and storm surges). Climate risks are dependent on many factors, such as the magnitude and rate of warming, levels of development and vulnerability in the geographic region relevant to the standard, the choices and implementation of adaptation and mitigation options, risk tolerance and geographic location. Climate-related risks are created by a range of hazards, including some that are slow in their onset (such as changes in temperature and precipitation leading to droughts or agricultural losses) and others that happen more suddenly (such as wildfires, thunderstorms and floods) [10]. The standards development and revision process should address climate risk in a similar manner to all other risks, using a systematic approach to determine the best course of action in the light of any uncertainty.

What is risk?
Risk is often expressed in terms of a combination of the **consequences** of an event (including changes in circumstances) and the associated **likelihood** of occurrence.

Adapted from ISO 31000:2018 Risk Management – Guidelines [11]

Climate risk refers to the risk that the changing climate will impose negative consequences on society, including natural ecosystems, the built environment, human health and well-being, business and the economy. Climate risks are caused by hazards such as sea-level rise, flooding, hurricanes.

Climate hazard refers to a potential source of harm associated with climate-related physical events or trends or their physical impacts.

Example climate hazards:
Sea level rise, storm surge, water availability, thawing permafrost, sea and lake water temperature change, flash flooding, wildfires, urban heat island, hurricanes, etc.

Adapted from the Intergovernmental Panel on Climate Change (IPCC) [31].

2.3 Climate change: Understanding impacts

The changing climate is impacting many aspects of life — from natural ecosystems to the built environment to human safety, health, security and well-being to business and the economy. While some impacts are beneficial, such as extended crop growing seasons in some regions, many more are adverse and need to be prepared and adapted for in order to manage the negative effects, such as urban flooding and damage to infrastructure. Climate change impacts vary regionally, with some areas experiencing significantly more negative consequences than others. Evidence has shown that the poles are warming faster than the equatorial regions. As Canada is a northern country, many regions will experience drastic changes associated with the changing climate, more than many other countries.

Impact refers to the effects of climate-related physical events or trends on natural and human systems.

Climate change impacts result from:

- changes in climatic loads such as wind-induced pressure differentials, humidity, air temperature, etc.
- extreme weather events such as torrential downpours, etc.

Adapted from IPCC [31].

Below are three summaries of expected climate change impacts and risks for several Canadian regions.

Central and western Canada

The changing frequency of temperature and precipitation extremes is expected to increase the likelihood of events such as wildfires and droughts. In western Canada, changes in climate causing drier conditions, warmer temperatures and increased wind and storms have led to an increase in droughts and potential for wildfires, as well as longer fire seasons. The extreme Alberta wildfire of 2016 that led to the Fort McMurray fires was preceded by below-average snowpack that melted early amid unusually warm temperatures, resulting in extremely dry vegetation (fuel) conditions. The Fort McMurray fires caused the evacuation of 80,000 people and cost approximately $10 billion, with $3.5 billion of insured losses — the costliest natural disaster in Canadian history [12]. These fires "...occurred in a world where earlier and longer fire seasons are more likely; where there is an increased risk of extreme fire potential; and a larger number of potential (fire) spread days that can result in the growth of a large fire" [13].

Canadian Arctic

The Canadian Arctic is experiencing a rapid decrease in sea ice and loss of permafrost. Over the last four decades, the amount of Canadian waters covered by sea ice in the summer decreased by approximately 7% per decade, and the loss is expected to accelerate. Canadian Arctic waters are projected to be nearly ice-free in summer by the 2050s. Decreasing sea ice and permafrost has a direct impact on the livelihoods and health of Indigenous peoples and northern communities across Canada. For example, it makes travel across sea ice less predictable and more dangerous, which can reduce access to traditional hunting and harvesting activities and isolate communities. Decreasing sea ice is also exposing shorelines to increased waves and storm surge activity, increasing erosion and flooding. Impacts of higher temperatures in the North also include infrastructure damage from permafrost thaw and increased freeze-thaw cycles, and a shortened and less predictable winter ice road season. For example, climate-related maintenance on the Dempster Highway, a year-round road linking central Yukon to the Arctic Ocean, has tripled in the past decade to $5.1 million in 2016, due to permafrost degradation [14].

Coastal Canada

Coastal flooding and storm surge are expected to worsen in many areas of Canada due to sea-level rise. Changes in local sea level are a result of both global sea-level rise and local land subsidence or uplift. Local sea level is projected to rise and increase flooding along most of the Atlantic and Pacific coasts of Canada and the Beaufort coast in the Arctic where the land is subsiding or slowly uplifting. Studies for the Fraser River Basin on the Pacific coast predict that damages associated with the next major coastal flood, combined with the failure of aging flood-prevention infrastructure, could cost upwards of $32 billion [15, p. 4] — this would be the costliest natural disaster in Canada.

Climate change is altering conditions under which we build infrastructure, perform work, maintain structures and buildings, transport goods, produce and deliver products and services, and source raw materials. To ensure Canadian society is prepared for this changing reality, the standards that guide how goods are produced and used, how services are designed and delivered, how infrastructure is constructed and maintained and how testing is conducted must be developed, reviewed and modified as appropriate for the changing climate.

Figure 2 below provides some examples of changes in the climate system, climate hazards and the resulting climate impacts.

Figure 2: Examples of climate system changes, climate hazards and climate impacts

Climate system changes

Examples include:

- changes in atmospheric (air) temperatures and humidity
- changes in ocean temperatures and chemistry (increased acidity and decreased oxygen levels)
- changes in wind speed
- changes in duration/severity of precipitation (ice, hail, etc.)

Climate hazards

Examples include increased frequency or strength of extreme weather such as:

- flooding
- drought
- storms
- heat waves
- sea-level rise
- permafrost thaw
- coastal erosion

Climate impacts

Examples include:

- damage to infrastructure, e.g. electricity systems, water and waste water systems, health care facilities, etc.
- more frequent and widespread disruption to transportation of goods and people
- economic disruptions and business continuity impacts (e.g. railway washouts, power outages, etc.)
- financial and mental health impacts to those impacted by extreme weather events
- destruction of natural resources and habitat
- homeland displacement (land lost to rising seas) resulting in climate refugees
- longer growing seasons in some regions

2.4 Climate change: Understanding adaptation

Climate change adaptation activities help to prepare and protect against current and future impacts of climate change by safeguarding assets and protecting populations in the face of increasing extreme weather events such as floods, droughts, high winds, fires and storm surges. It is important to incorporate climate change adaptation considerations into the standards development process to ensure that product, service, infrastructure and test standards guide or require the user to identify and prepare for the potential impacts associated with a changing climate. Some examples of this include:

- product — ensuring emergency generators can function in high humidity and heavy rains, and also endure winter freezing conditions and ice load
- services — ensuring drinking water and waste water services are not adversely compromised by localized flooding events
- infrastructure — ensuring a bridge is designed and constructed to withstand increased climatic loads (e.g. temperature range, ice accretion) and extreme weather events (e.g. floods)
- test — ensuring testing for surface burning characteristics of building materials incorporates higher heat loads and lower humidity for some areas

Incorporating adaptation considerations into standards encourages building resilience to the changing climate into products, services, infrastructure and tests and supports the proactive management of risks. Adaptation activities can help boost resilience to long- and short-term impacts of a changing climate. Ideally, adaptation activities will also incorporate mitigation activities aimed at reducing GHG emissions (e.g. energy efficiency retrofits, renewable energy projects, etc.). This Guide is intended to help standards writers incorporate climate change adaptation into the standards review and development process. Appendix C provides the reader with two case studies to demonstrate how adaptation can be incorporated into the standards development process through the integration of climate change adaptation considerations.

It is important to note that this Guide does not include considerations of mitigation. Adaptation actions can sometimes also reduce environmental impact and GHG emissions, but in some cases adaptation actions may result in increased emissions, and this should be considered and balanced.

2.5 Current state of climate information and data

Updating and developing Canadian standards requires a broad range of information and data. Standards writers should use authoritative sources of climate information, as presented in Appendix A, to inform the incorporation of climate change adaptation considerations.

Climate data is any information that quantitatively describes the past, present or future climate. This information may be directly measured over the historical period (e.g. precipitation and temperature from station observations), calculated from measurements (e.g. temporal and/or spatial interpolations of meteorological observations over a region) or modelled using regional or global physical climate models over the historical period (e.g. reconstructions of past climate over regions without a dense network of meteorological stations) as well as over the future period (called climate projections). Historical climate data derived from station measurements (e.g. intensity-duration-frequency [IDF] curves) can be represented at a point. Modelled climate data is provided as gridded data over geographic regions ranging in size from small grid cells to the entire globe. Climate data is also expressed in time steps ranging from sub-hourly to decades or longer, with different features of the climate only seen over certain timescales. For example, many intense precipitation events take place over minutes or hours and will not be accurately described in summaries of historical climate or projections of future climate using time steps of days, months or years. Similarly, trends or descriptions of the average state of the climate should be expressed over timescales of multiple decades to diminish the influence of natural variations such as weather events.

The Government of Canada's Canadian Centre for Climate Services (CCCS) website [16] and support desk, the ClimateData.ca portal and the Climate Atlas of Canada provide access to climate data and information. There are also several regional climate service organizations that specialize in providing tailored climate data and information. For guidance on use of climate information, standards writers are encouraged to refer to the *Guidebook on Climate Scenarios, Using Climate Information to Guide Adaptation Research and Decisions* [17] and, specifically for infrastructure standards, the *Standardization Guidance for Weather Data, Climate Information and Climate Change Projections* [18] both by Ouranos.

Standards writers are also encouraged to consider the recent report, *Climate-Resilient Buildings and Core Public Infrastructure: an assessment of the impact of climate change on climatic design data in Canada* [19]. This report provides an assessment of how climatic design data relevant to the users of the National Building Code of Canada and the Canadian Highway Bridge Design Code might change as the climate continues to warm.

Dealing with climate change requires both **mitigation** and **adaptation**. Climate change mitigation refers to reducing GHG emissions from human activities. Climate change adaptation refers to being prepared for the actual and expected impacts of climate change in a way that moderates harm or takes advantage of potential opportunities.

Adapted from IPCC [31].

2.6 Summary

At the outset of the development process for a new standardization document, or a revision to an existing standard for product, services, infrastructure or test, standards writers are encouraged to utilize this Guide to incorporate consideration of climate-related risks, potential climate impacts and climate change adaptation into the standards development process, in much the same way that other risks are managed.

WHY? **The Imperative**	**HOW?** **Guidance**	**WHAT?** **Outcome**
✓ Climate change is affecting communities, the natural environment and built environments across Canada and the world ✓ Climate change can affect the processes and products that are the subjects of Canadian standards for products, services, infrastructure and tests ✓ Standards writers need to integrate climate change adaptation considerations to ensure climate resiliency is built into products, services, infrastructure and tests	✓ Understand principles in Chapter 3 ✓ Determine relevance & applicability of climate change considerations using questions in Chapter 4 ✓ Apply the guidance in Chapter 5 ✓ Utilize the flow chart in Chapter 6 ✓ Review additional sources of information in Appendix A ✓ Integrate climate change considerations into new and updated standards	✓ Standards that are fit for purpose in Canada in light of the changing global climate

3.

Principles

Guiding principles of climate change adaptation for the standards development process

This chapter provides an introduction and overview of several guiding principles.[3] These principles provide a foundation that standards writers can use to consider climate change. The guiding principles should be used together throughout the application of this Guide.

Guiding principle #1: Determine relevance

Standards writers should determine if climate change impacts will be material (relevant) to the standard and if those impacts can be addressed by the standard.

Guiding principle #2: Apply professional judgment

Standards writers should apply a reasonable level of professional judgment, such as the precautionary principle, in the determination of the materiality of climate change impacts to ensure that climate change adaptation is considered in the standards development process, and in the absence of other adequate or appropriate data.

Guiding principle #3: Interpret climate information

Standards writers should consider consulting with climate scientists and specialists to ensure that interpretations of climatic and weather information to be used in the standards development process reasonably reflect the most current scientific consensus regarding the climate and/or weather information, and that said information is applied in an appropriate fashion. Section 5.2: Impact Considerations in this Guide addresses dealing with uncertainty.

Guiding principle #4: Assess risk

Past climatic conditions are no longer a reliable indicator of future climate. Standards writers should use a risk-based approach to assess climate change impacts and address uncertainties when incorporating climate change considerations into the standards development process.

Guiding principle #5: Integrate adaptation into standards

When relevant, standards writers should ensure that an understanding of the changing climate and the potential associated adverse effects, as well as adaptation considerations, are integrated into the standards development process.

Guiding principle #6: Ensure a systems-based approach

Addressing climate change adaptation means addressing cascading effects and/or interdependencies between the subject of the standard (products, services, infrastructure or tests) and its environment, use, community and surroundings.

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[3] Select principles adapted from the Engineers Canada's *Principles of Climate Change Adaptation and Mitigation for Engineers [32] and ISO 14090 Adaptation to climate change – Principles, requirements and guidelines* [28].

4.

Guidance — Determining applicability

Should standards development processes incorporate climate change adaptation considerations?

This chapter contains a series of questions for standards writers to consider when updating an existing standard or developing a new standard. The questions will help determine if the product, service, infrastructure or test within the scope of the standard might be **materially**[4] affected by climate change (i.e. whether climate change adaptation is **relevant** to the standard), in which case it should be considered and incorporated into the standards development process. Questions to assist in this determination include:

☐ Could life safety be affected by the impacts of climate change on the subject of the standard?

☐ Could the quality or performance of the product, service or infrastructure be materially affected by the changing climate?

☐ Could the results generated by the test methods be materially affected by the changing climate?

☐ Is another important aspect of the product, service, infrastructure or test likely to be materially affected by variations in the weather or climate?

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[4] For a discussion about materiality, refer to Section 5.3.

If the answer to any of the above listed questions is "yes," then climate change adaptation considerations are relevant to the development or update of the standard in question, and the guidance and considerations in chapters 5 and 6 should be utilized.

If the question as to whether climate change adaptation is relevant for the standard is still unclear, the following questions[5] may help:

☐ Is electrical energy required in the production/use of the product, service, infrastructure or test? Alternatively, can the product, service, infrastructure or test function without electricity from the grid?

☐ Are there any processes sensitive to weather, extreme weather, temperature or humidity, such as those reliant on cooling, water use or energy supply?

☐ Is the standard for a test method that is normally operated in an environment without temperature/humidity controls, and hence sensitive to temperature or humidity?

☐ Are disposal or reprocessing activities likely to be weather or temperature sensitive?

☐ Does the product, service, infrastructure or test rely on staff occupying premises where health, safety and comfort could be compromised by weather, extreme weather or temperature?

☐ Is the design lifetime of the product or infrastructure, including its reuse, greater than 10 years?

☐ Does the standard deal with transportation, or is transport involved in any stage of the life cycle for the product, service, infrastructure or test?

☐ Is there any part of the supply chain for the product, service, infrastructure or test that is exposed to climate change impacts? Some examples are any products heavily dependent on transportation logistics, agricultural products, forest products, any products that use water in either high volumes or of a specific quality.

If you answered "no" to all of the questions, then it is unlikely that climate change adaptation considerations need to be considered at this time. If further guidance is required related to the particular standard under development, consider referring to CEN-CENELEC Guide 32 [1] and applying professional judgment.

Note: Professional judgment is required to determine whether the guidance provided in chapters 4, 5 and 6 are applicable to the standard being developed or updated.

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[5] Questions adapted from CEN-CENELEC Guide 32 [1, p. 20].

5.

Guidance — Climate change adaptation considerations

How should standards writers incorporate climate change adaptation considerations?

This chapter describes important considerations for incorporating climate change adaptation into the standards development process when climate change has been determined to be materially relevant to a standard, based on the guiding questions in Chapter 4. The considerations included in this chapter are suggested good practices. Not all will be applicable to any given standard under development or revision. In addition, this list may be incomplete. Those involved in developing and updating standards are encouraged to share their thoughts with SCC for inclusion in future versions, via email to infrastructure-environment@scc.ca.[6]

Note that the considerations described here are not meant to be interpreted sequentially. The numbering provided is for presentation and ease of reference. Each consideration is equally important and should be considered independently. The considerations are organized by five key themes:

5.1 Data considerations
- Data availability
- Data interpretation

5.2 Impact considerations
- Data applicability and integration

5.3 Risk considerations
- Risk assessment
- Materiality
- Risk management and climate resilience

5.4 Life cycle considerations
- Life cycle stages
- Design life

5.5 Integration Considerations

Standards writers are encouraged to consult with relevant subject matter experts (such as climate and weather specialists), as they deem appropriate.

5.1 Data considerations

To adequately address climate change adaptation in new and updated standards, standards writers will need to include written statements, recommendations, requirements and/or informative annexes. This documentation will be based, whenever possible, on an understanding and application of reliable and relevant climatic data (as referenced in Appendix A).

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[6] Note: Outreach concept adapted from Engineers Canada.

Engineers Canada's *Principles of Climate Change Adaptation for Engineers* identifies an important data consideration: "Historical climatic design data is becoming less representative of the future climate. Many future climate risks may be significantly under-estimated. The engineer cannot assume that the future will be similar to the past. Historical climate trends cannot be simply projected into the future as a basis for engineering work." [20, p. 5]

When considering climate change adaptation during the update or development of a standard, standards developers should consider the following guidance regarding data:

Data availability

- If necessary, source and secure any available technical climatic and climate impact-related data required to support the new or updated standard (some helpful sources are listed in Appendix A).
- Clearly document the sources of climate data, including future climate scenarios for temperature, humidity, precipitation, wind and associated uncertainties.
- Use professional judgment and describe all assumptions made in the absence of other adequate or appropriate data.

Data interpretation

Climate models and projections can help standards writers to understand the future range of operating conditions for a product, service, infrastructure or test. Standards writers are strongly encouraged to engage subject matter experts to assist with data interpretation.

Climate change projections vary by region and are based on complex and multiple models. To help deal with uncertainty, scientists often use an ensemble approach (where more than one model is used) to understand the potential range of climate projections. It is good practice to use percentiles to help summarize the range of results from ensemble models.

Applying climate models [21]

There is not currently a single best climate model.[7] The most effective way of accounting for the range of results currently seen from climate models is by using an ensemble of results from several climate models to provide a range of possibilities. Use of ensemble results supports better assessment of uncertainty from model calculations in the use and application of results. This will increase the likelihood that the product, service, infrastructure or test within the scope of the standard will be fit for use under whatever future climate condition comes to pass.

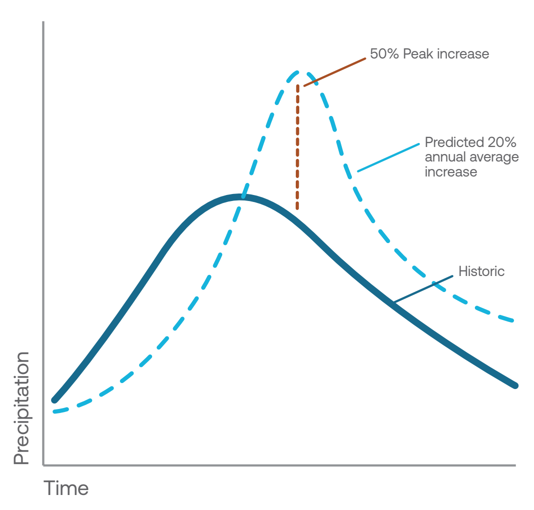
It is good practice to review projection results based on several different GHG emissions scenarios (e.g. a high emissions scenario in which little to no action is taken to curb global emissions, and a low emissions scenario in which the global economy rapidly decarbonizes). This will help standards writers account for uncertainty related to expected changes in global GHG emissions levels in the future.

Choosing the ensemble of models that is most appropriate for the context within which the standards writers are working will depend on several factors. For example, if the climate variable of interest for the standard under development is temperature, the Global Climate Models may provide the best basis for an ensemble. Alternatively, if the variable of interest is localized (e.g. wind or precipitation) or requires information at higher resolution, downscaled models may be better options, although downscaling may come with trade-offs.[8]

Another factor to consider when choosing an ensemble is what type of data is available from the climate models in the ensemble. For example, if extreme weather events are of concern, ensemble results that include information on extremes should be chosen.

Exercise caution in how results are applied, and in the timeframes involved. For example, if a model shows a given region is expected to receive 20% more annual precipitation, one might be tempted to increase all monthly rainfall values by 20%; however, this is likely not appropriate and would not capture any potential extreme highs and lows over the year. Some months may receive less rain while others receive significantly more, leading to the annual increase. It is also important to consider a range of variables associated with **precipitation**, including, but not limited to, type (snow/rain/ice), duration, intensity, preceding and subsequent weather conditions, seasonality and local effects.

A prediction of 20% average annual increase in precipitation could mask certain peaks where the increase could be significantly more than 20%, as illustrated in the graphic below.



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[7] Refer to Section 2.5 and Appendix A for more information.

[8] For a discussion about downscaling, refer to Section 1.9 of *A Guidebook on Climate Scenarios* by Ouranos [17].

5.2 Impact considerations

Standards writers, with input as required from relevant subject matter experts, will need to determine, to the best of their professional ability, how climate might interact with the product, service, infrastructure or test within the scope of the standard under development or revision. This involves looking at potential impacts and can be done by using the following types of climate information: historical climate data, and records of past impacts related to severe weather or climate conditions (if available).

By combining these two types of historic information, standards writers can develop an understanding about how past conditions could have impacted the product, service, infrastructure or test within the scope of the standard under development or revision. Once these interactions are understood, attention should be turned to considering possible future changes in climate using climate model projections that have been generated based on the following two elements:

- different GHG emission scenarios, e.g. IPCC Representative Concentration Pathway (RCP) scenarios including RCP2.6, RCP4.5, RCP 6.0 and RCP8.5 [22]
- simulations with different climate models, e.g. the Coupled Model Intercomparison Project, Phase 5 (CMIP5), incorporating 29 global climate models (GCMs) [22]

With an understanding of both the historic climate information and possible future changes in climate, standards writers can apply this information to the standard to identify potential impacts and adaptation approaches. If forecasted climate loads differ from historic values, this should drive the development of new performance values in the standard. Similarly, the known performance limits of a product, infrastructure, service or test should be used to identify and define climate loads where failure may occur. In addition, standards writers should consider future forecasted changes in climate that may introduce new loads or hazards that were not previously a consideration for the standard, such as permafrost thaw, frequency of severe weather, changes in growth rates or distribution patterns of pests and microbes.

Standards writers report that one hurdle to integrating climate considerations into the standards development process is that climate data has significant levels of uncertainty associated with it. **The existence of uncertainties should not prevent the use of this information in standards development.** Instead, standards writers are encouraged to assess the data through a risk-based lens (qualitatively or semi-quantitatively, as necessary), consult with a climate specialist, invoke professional judgment and document decisions made. This application is similar to how the concept of the precautionary principle is applied in the process of environmental assessment (i.e. lack of scientific certainty should not prevent protection from harm in the face of serious threats to the environment).

Data applicability and integration

- List the potential climate change impacts for the geographic area(s) associated with the standard under development or revision (refer to Figure 2 for examples).
- Identify which climate hazards are relevant to the climate-related impacts, including the time period over which they need to be assessed.
- Identify the projected change in relevant climate variables, including the range of uncertainty throughout the design lifetime and end of life.
- State any assumptions about climate change data or projections, and document the details about specific climate models and/or future emissions scenarios that were used as informative material published in the standard itself.
- Determine where the information gathered through this process should be stored (see Section 5.5).
- Document how climate change projections have been used in the standards development or revision process.

5.3 Risk considerations

A risk-based approach to climate change adaptation planning refers to making decisions in the face of uncertainty. Although it is unequivocal that the climate is changing, there are uncertainties about the rate of change, geographical distribution of changes in climate variables, future emissions scenarios and, as mentioned above, model data uncertainties. Climate is no longer considered stationary. Standards writers must now use a risk-based approach to understand and assess the significance of projections for wind, temperature and precipitation, because historic values for these variables are no longer valid to predict the future.

CEN-CENELEC Guide 32 states that "there are uncertainties relating to how climate change will translate into impacts on materials, processes and systems and what the consequences of these impacts will be for society. The use of a risk-based approach to adaptation allows for uncertainties to be acknowledged and incorporated in the decision-making process and for climate risks to be considered alongside and on an equal footing to other risks that are routinely managed" [1, p. 12].

Risk assessment

Standards writers across Canada have used a risk-based approach in the development of standards for many years; this is not new territory. To ensure the concept of climate risk is incorporated into the current risk assessment processes utilized by standards writers, the following considerations apply:

- Select the appropriate risk assessment tool and approach: Ideally, standards writers would conduct a quantitative risk assessment, but given the high uncertainty associated with future emissions scenarios and climate change projections, as well as the time and costs involved, users may have to use a qualitative or semi-quantitative risk assessment approach.
- Assess risk associated with each potential climate impact identified across each relevant geographic region in Canada and potentially in other regions of the world where acquisition and/or production stages may occur — this will be done by assessing historic and projected future climate information.
- Determine acceptable level of risk and what level of risk or what level of impact to which the product, service, infrastructure or test needs to be resilient.

Standards writers are encouraged to review and, where appropriate, utilize the risk management framework presented in Infrastructure Canada's Climate Lens guidance document [23]. While the guidance is specifically for infrastructure projects, the foundation of the risk assessment methodology presented is based on the ISO 31000 Risk Management standard. The climate risk assessment process described in Annex G of the Climate Lens guidance is applicable to the standards development process for product, services, infrastructure and test standards.

Materiality

It is important to determine which climate risks are most important for the purpose of the standard, meaning those that would have a significant, substantive, non-trivial or material effect. Conducting a materiality assessment guided by the Global Reporting Institute's materiality principle [24, p. 10] can help standards writers assess materiality.

- Focus on two or three material climatic impacts (as discussed in Section 2.3), and ensure that the efforts spent to assess climate impacts are proportionate to the risks and to the scope of the standard.
- Focus attention on relevant impacts of our changing climate: What is it about climate change that is most likely to be important for the specific standard or sector being considered?

Risk management and climate resilience

For climate risks that have been deemed to be material to the purpose of the standard, the following considerations apply:

- Ensure that risks are appropriately assessed in terms of significance, described or characterized, and documented.
  - Raise a flag, if warranted: Standards writers may have to communicate their concerns more broadly if recommendations being ignored would cause long-term implications to public safety and/or the environment [20, p. 9].
- Identify and describe possible climate adaptation measures that could be implemented to control or manage each of the risk(s) identified.
- Build requirements for resilience into standards when climate risk is found to be unacceptable.
- Consider no or low regrets options, i.e. those climate adaptation measures that yield benefits even in the absence of climate change and where the costs are relatively low.

Figure 3: Illustrative life cycle stages for consideration, by standard type [1]

Life cycle stages

Product	Acquisition	Production	Use	End of life
Services	Service design	Promotion	Provision	End of service provision
Testing	Sampling	Sample preparation	Testing	End of life
Infrastructure	Planning	Construction	Operating	Decommissioning

5.4 Life cycle considerations

In the development process for product, services, infrastructure and test standards, it is good practice to disaggregate the various life cycle stages associated with the subject of the standard to help in the identification of potential related climate risks and impacts at each stage. For example, the relevant stages to consider for a product standard might be 1) material input acquisition, 2) manufacturing of product, 3) use of product and 4) disposal of product. Disaggregating the standards development process into life stages of the product provides a logical framework to guide a writer's thought process and encourages consideration of potential climate change impacts during all phases of the product's life. Examining life cycle stages can help standards writers to understand how climate change impacts could affect or disrupt:

- selection and sourcing of the materials to build the product
- transportation of the materials to the production site
- manufacturing of the product (note: consider the physical infrastructure of the manufacturing facility and the working conditions for workers at the facility)
- transportation of the finished product
- the proper (as designed) functioning of the product (in its use phase of life)
- ongoing maintenance and/or servicing of the product
- disposal of the product after its end of life
- worker and/or user health and safety across all life cycle stages

Life cycle thinking allows for the thoughtful consideration of aspects and impacts related to climate change for all requirements in the standard as they apply to products, services, infrastructure or tests.

Life cycle stages will vary depending on the type of standard. Some representative life cycles are included in Figure 3.

Life cycle stages

During the development or update of a standard with material climate change considerations, standards writers will need to take the following actions:

- Identify potential climate risks and the associated potential climate impacts associated with each life cycle phase relevant to the type of standard under development — products, services, infrastructure or tests
- Assess the significance of the potential climate risks and impacts based on available data
  - Document if no reliable data is available for the assessment and document limitations
- Consider incorporating flexibility into the requirements for each phase of the life cycle of the product, service, infrastructure or test so that adjustments can be made as more information becomes available and/or climate scenarios change
- Consider whether the standard should require that adequate emergency planning and business continuity planning procedures are in place at all life cycle stages
- Consider costs: Achieving durable products and infrastructure that will last their entire envisioned service lives without major damage or disruption may lower life cycle costs; foregoing consideration of climate change impacts in the scope of a standard may not lead to life cycle cost avoidance [20, p. 13]

Design life

In the past, climate was considered stationary, and any design life requirements in standards (for products and infrastructure, in particular) were developed based on historical and stationary climate data. Standards writers did not typically examine interactions between changing climate loads and design life because the climate was not expected to change over time (i.e. stationary climate). This is no longer the case, and standards writers now need to consider the design life of an asset and how climate loads may change during that time period (i.e. non-stationary climate).

- Consider and document the expected design life of the product, service, infrastructure or test and how it will affect the identification of relevant climate hazards and climate risks over that period.
- Consider the intended lifetime of the product or infrastructure and consider inclusion of climate information from multiple time periods.
- Consider "designing for degraded performance": Check what happens if the product or component performs at below design capacity.
- Consider the trade-off between design life and operation and maintenance.
- Consider level of criticality and therefore required level of resilience to be achieved, recognizing consequences for cost.
- Consider the requirement for labelling that indicates thresholds relevant for use and end of life phase impacts.
- Consider maintenance activities on products and infrastructure, where appropriate; these can extend or modify its service life. Standards writers are encouraged to reference work by the National Building Code Part 5 Standing Committee.

5.5 Integration considerations

Upon the conclusion of the research and analysis phases associated with understanding climate change impacts, writers will need to document and integrate climate change considerations into standards. Climate change considerations may take the form of information about and/or descriptions of:

- climate change adaptation measures — current and/or future approaches to respond to impacts at various life cycle stages, including modular adaptive design
- adaptive designs for products, services, infrastructure and/or tests, if relevant
- information about impacts
- climate change assumptions

There are many ways to include and/or address climate change in Canadian standards. Responses to the considerations may be included in standards as any combination of:

- requirements
- recommendations
- statements
- assumptions
- supporting annexes (normative or informative)
- information notes or commentaries
- records held by the responsible technical committee

Some standards writers might find that the process leads them to stating the need for additional research, the need to develop normative documents such as technical specifications or the need for more specific technical guidance on climate change considerations. As with other aspects of standards writing, documenting the current state and future requirements, in as much detail as possible, will be necessary at this stage.

The timing for the recommended renewal cycle for the standard under development or revision will also need to be considered. Available data and climate models to help standards writers are constantly changing. The default cycle in Canada for updates and renewal is five years; however, some standards might need to be updated more frequently.

The case studies in Appendix C provide an example of how standards writers might incorporate climate change considerations into a standard.

6.

Guidance — Flow chart

This chapter provides standards writers with a high-level overview of a sample process to incorporate climate change adaptation considerations into the standards development process.

When should you consider climate?

STEP 1
ASSESS RELEVANCE

Determine if the purpose of the standard might be materially affected by climate change

Source: Questions in Chapter 4

No?

No further consideration of climate change adaptation required at this time
(Are you sure...?)

STEP 2
SEEK EXPERTISE

Include climate change and standards professionals/experts in Technical Working Group

STEP 3
GATHER INFORMATION

Gather relevant climate data

Need more?

Seek or commission additional research, as needed

Source: Section 5.1 and Appendix A

STEP 4
INTERPRET INFORMATION

Define climatic conditions affecting the product, service, infrastructure or test within the scope of the standard under development/revision

- Consider varying geographic region applicability
- Review historic climatic and extreme weather data
- Use the results of climate simulation model(s) for climate projection data

** Document uncertainties associated with climate simulations and future projections*

** Ensure QA/QC review of climate conditions assumptions and impact identification*

Source: Section 5.1

If appropriate climate information is unavailable

Invoke professional judgment and document any assumptions made

STEP 5
ASSESS SIGNIFICANCE

Assess impacts of climate change based on expected regional variations

Determine significance of impacts on standard under review or development

No significant impacts?

No further consideration of climate change adaptation required at this time
(Are you sure...?)

Source: Section 5.2

STEP 6	STEP 7	STEP 8	STEP 9	STEP 10
ASSESS RISKS	**UNDERSTAND LIFE CYCLE**	**EXAMINE CLIMATE**	**INTEGRATE ADAPTATION**	**DEVELOP TIMELINE**
Complete a climate risk assessment (quantitative or qualitative) Determine significance of risks on standard under review or development	Define applicable life cycle stages for the standard under development/revision	For each life cycle stage, identify climate change positive/ negative impacts and/or challenges/ opportunities (i.e. what could go right/wrong)	Identify and incorporate climate change adaptation measures (or adaptive designs for infrastructure, if relevant) into the standard under development/revision	Develop timeline for revision of the standard to acknowledge changing nature of climate change information, associated impacts and adaptation measures as well as the expected life cycle of the product, service, infrastructure and test
Source: Section 5.3	*Source: Section 5.4*	*Source: Section 5.4*	*Source: Section 5.5*	*Source: Section 5.5*
No significant risks? ▼ No further consideration of climate change adaptation required at this time (Are you sure...?)				

Appendix A — Reference sources

Standards writers are encouraged to utilize the library of climate resources at https://climate-change.canada.ca/climate-library and https://climatedata.ca supported by the Canadian Centre for Climate Services (CCCS).

These resources provide a collection of links to climate datasets, tools, guidance and related resources. The sources include the federal government, provincial and territorial governments, national professional organizations, climate consortia and established international organizations. They can be useful for impact, vulnerability and risk assessments, and for adaptation planning.

Standards writers are also encouraged to consider the recently published report, *Climate-Resilient Buildings and Core Public Infrastructure: an assessment of the impact of climate change on climatic design data in Canada*. The report provides an assessment of how climatic design data relevant to users of the National Building Code of Canada (NBCC 2015, Table C-2) and the Canadian Highway Bridge Design Code (CHBDC/CSA S6 2014, Annex A3.1) might change as the climate continues to warm. The report is available at: https://climate-scenarios.canada.ca/?page=buildings-report-overview

Other relevant resources include (presented alphabetically):

- CEN-CENELEC's Guide 32: Guide for addressing climate change adaptation in standards, available at : https://www.cencenelec.eu/standards/Guides/Pages/default.aspx
- Engineers Canada's *Principles of climate adaptation and mitigation for engineers*, available at : https://engineerscanada.ca/publications/public-guideline-principles-of-climate-change-adaptation-for-professional-engineers
  - The PIEVC Engineering Protocol, available at: https://pievc.ca/protocol
- Environment and Climate Change Canada's Canadian Centre for Climate Services, available at: https://www.canada.ca/en/environment-climate-change/services/climate-change/canadian-centre-climate-services
  - Display and download climate data webpage, available at: https://www.canada.ca/en/environment-climate-change/services/climate-change/canadian-centre-climate-services/display-download.html
  - Role of climate information in decision-making webpage, available at : https://www.canada.ca/en/environment-climate-change/services/climate-change/canadian-centre-climate-services/basics/role-decision-making.html
- Environment and Climate Change Canada's Engineering Climate Datasets, available at: http://climate.weather.gc.ca/prods_servs/engineering_e.html
- Environment and Climate Change Canada's Historical Climate Data, available at: http://climate.weather.gc.ca/
- Infrastructure Canada's *Climate Lens – General Guidance*, available at: https://www.infrastructure.gc.ca/pub/other-autre/cl-occ-eng.html
- Natural Resources Canada's Climate Change Adaptation Platform, available at: https://www.nrcan.gc.ca/climate-change/impacts-adaptations/adapting-our-changing-climate/10027
- Ouranos' *A Guidebook on Climate Scenarios*, available at : https://www.ouranos.ca/publication-scientifique/Guidebook-2016.pdf
- Ouranos' *Standardization guidance for weather data, climate information and climate change projections*, prepared for the Standards Council of Canada and available at: https://www.scc.ca/sites/default/files/file_attach/SCCReport_Standardization_guidance_for_Weather_data_Climate_Change_Infor_Final_English.pdf
- Summit Enterprises International Inc.'s *Canadian Climate Change Risk Assessment Guide*, available at: https://www.iclr.org/wp-content/uploads/PDFS/CC_Risk_Assessment_Guide_Interim2_Jun_8_14_.pdf

Appendix B — Glossary

Adaptation: The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects [3, p. 13].

Anthropogenic: Resulting from or produced by human activity [25].

Climate: The historical record and description of average daily and seasonal weather events that help describe a region. Statistics are generally drawn over several decades. Climatology, or the study of climate, includes climatic data, the analysis of the causes of the differences in climate and the application of climatic data to the solution of specific design or operational problems. It differs from weather, which is concerned with short-term or instantaneous variations in the state of the atmosphere at a specific time [26].

Climate change: Climate change refers to a change in the state of the climate that can be identified (e.g. by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcing factors, or to persistent anthropogenic changes in the composition of the atmosphere or in land use. Note that the United Nations Framework Convention on Climate Change (UNFCCC) defines climate change as “a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.” The UNFCCC thus makes a distinction between climate change attributable to human activities altering the atmospheric composition and climate variability attributable to natural causes [2].

Climate normal: Arithmetic calculations based on observed climate values for a given location over a specified time period and used to describe the climatic characteristics of that location. The World Meteorological Organization (WMO) considers 30 years long enough to eliminate year-to-year variations. Thus, the WMO climatological standard period for the calculation of climate normals is defined as consecutive periods of 30 years (e.g. January 1, 1901, to December 31, 1930) and should be updated every decade [25].

While 30 years of data is considered ideal, data gaps at many stations do not allow this and Environment and Climate Change Canada will calculate normals for some locations based on a minimum of 15 years of data [27]. Normals for some elements are derived from less than 30 years of record but can still be considered useful. The minimum number of years used are indicated by a "normal code" defined as:

- "A": WMO "3 and 5 rule" (i.e. no more than three consecutive and no more than five total missing for either temperature or precipitation)
- "B": At least 25 years of record
- "C": At least 20 years of record
- "D": At least 15 years of record

Climate projections: Portions of a climate model simulation that forecast the future [18].

Climate risk: The risk that the changing climate will impose negative consequences on society including natural ecosystems, the built environment, human health and well-being, business and the economy (refer to the definition of Risk).

Climate simulations: End-product of climate models; the results produced by solving a climate model's equations for a certain time period [18].

Climatic loads: The effects on an exposed product, service, infrastructure or test that result from local climate conditions. Examples include the intensity and spectral variation of sunlight; stationary and non-stationary forces resulting from wind; pressure differentials resulting from wind; surface temperatures, internal temperatures and temperature gradients; surface moisture density, internal moisture density and moisture density gradients (these two items are often considered together, as in "hygrothermal modelling"); wind-driven rain effects.

Degree days: Degree days for a given location represent the number of Celsius degrees that the mean temperature is above or below a given base temperature for an entire day. For example, heating degree days are the number of days and degrees below 18°C (when heating is required); if the temperature is equal to or greater than 18°C, then the number will be zero. If the temperature is two degrees below the baseline for six days, the heating degree days is 12 (six days times two degrees per day). Values above (cooling) or below (heating) the base of 18°C are used primarily to estimate the heating and cooling requirements of buildings [26].

Design life: The period of time during which the product, service or infrastructure is expected by its designers to function within its specified parameters. Also, design life is referred to as the life expectancy of the product, service or infrastructure.

Downscaling: A procedure in which information known at large scales is used to make predictions at local scales [18].

Ensemble (approach): A set of simulations encompassing multiple global or regional climate models, and/or simulations from the same model [18].

Extreme (weather) event: An event that is rare at a particular place and time of year [2]. An event during which loads are imposed on an exposed product or person, building or infrastructure that significantly exceed those applied during normal, annual and diurnal cyclic variations.

Greenhouse gas (GHG): Gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of infrared radiation emitted by the earth's surface, by the atmosphere itself and by clouds. Water vapour (H_2O), carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4) and ozone (O_3) are the primary GHGs in the earth's atmosphere. In addition, there are a number of entirely human-made GHGs in the atmosphere, such as the halocarbons and other chlorine- and bromine-containing substances [25].

Hazard: Potential source of harm referring to climate-related physical events or trends or their physical impacts. The potential for harm can be in terms of loss of life, injury or other health impacts, ecosystems and environmental resources.[9]

Impact: The effects of climate-related physical events or trends on natural and human systems [28].

Mitigation: In the context of climate change, defined as a human intervention to reduce the sources or enhance the sinks of GHGs, since GHGs have climate warming effects. A source is any process, activity or mechanism that releases GHGs to the atmosphere. Both natural processes and human activities release GHGs. A sink is any process, activity or mechanism that removes GHGs from the atmosphere. In addition to GHGs, mitigation also applies to reducing emissions of other substances that have a warming effect on the climate [3, p. 13].

Permafrost: Ground (soil or rock and included ice and organic material) that remains at or below 0°C for at least two consecutive years [25].

Resilience: The ability of a system and its component parts to anticipate, absorb, accommodate or recover from the effects of a hazardous event in a timely and efficient manner, including through ensuring the preservation, restoration or improvement of its essential basic structures and functions [25].

Risk: A combination of the consequences of an event (including changes in circumstances) and the associated likelihood of occurrence.[10]

Sea-level rise: An increase in the mean level of the ocean. Eustatic sea-level rise is a change in global average sea level brought about by an increase in the volume of the world ocean. Relative sea-level rise occurs where there is a local increase in the level of the ocean relative to the land, which might be due to ocean rise and/or land-level subsidence. In areas subject to rapid land-level uplift, relative sea level can fall [25].

Standard: A document, established by consensus and approved by a recognized body that provides, for common and repeated use, rules, guidelines or characteristics for activities or their results, seeking to achieve the optimum degree of order in a given context. Standards should be based on the consolidated results of science, technology and experience, and promote optimum community benefits [18].

Uncertainty: An expression of the degree to which a value is unknown. Uncertainty can result from lack of information or from disagreement about what is known or even knowable. It may have many types of sources, from quantifiable errors in the data to ambiguously defined concepts or terminology, or uncertain projections of human behaviour. Uncertainty can therefore be represented by quantitative measures (e.g. a range of values calculated by various models) or by qualitative statements (e.g. reflecting the judgment of a team of experts) [25].

Weather: State of the atmosphere at a given time and place with regard to temperature, air pressure, humidity, wind, cloudiness and precipitation. The term is mainly used to describe conditions over short periods of time [25].

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[9] Hazard comprises slow-onset developments (e.g. rising temperatures over the long term) as well as rapidly developing climatic extremes (e.g. heat wave or a landslide) or increased variability [28].

[10] Adapted from ISO 31000:2018 Risk Management – Guidelines [11]

Appendix C — Case studies

The SCC thanks John Wade (ULC Standards) and Mark Braiter (CSA Group) for their efforts in preparing the following case studies. Standards writers who are interested in providing additional case studies for applying this Guide are encouraged to reach out to the SCC by email at infrastructure-environment@scc.ca.

Case 1: A hypothetical case study for the integration of climate change adaptation considerations into the Standard for Factory-Built Type A Chimneys (CAN/ULC-S604:2016)

This case study guides the reader through the steps outlined in this Guide to undertake a hypothetical (high-level illustrative) revision of the Standard for Factory-Built Type A Chimneys [29]. It provides a brief, practical description for each step presented in the Guide.

This standard is for factory-built type A chimneys, which do not require field fabrication and are to be installed in accordance with the National Building Code of Canada. It applies across Canada for chimneys to be used with gas and liquid fuel-fired residential appliances and building heating equipment. It is an existing standard that requires updating. It is considered a product-related standard.

Step 1 – Determine if the purpose of the standard might be materially affected by climate change

This standard incorporates tests for resistance of the chimney design to the effects of wind loads and to the penetration of rainwater into the chimney assembly of the building in which it is installed, among other requirements related to accelerated corrosion and cemented joints. The product subject of this standard (chimneys) could be affected by variations in climate, particularly extreme weather. This standard might be materially affected by climate change.

Step 2 – Include climate change and standards professionals/experts in Technical Working Group

Climate change expertise, together with expertise in the manufacture and installation of the chimneys, will be required on the Technical Working Group.

Step 3 – Gather relevant climate data

The revision of the standard should consider relevant sources of climate data (historic, current and future projections) through reference to the following Government of Canada resources: https://climate.weather.gc.ca/, https://climatedata.ca/.

Step 4 – Define climatic conditions affecting the product within the scope of the standard under development/revision

- **Consider varying geographic region applicability**
- **Review historic climatic and extreme weather data**
- **Use the results of climate simulation model(s) for climate projection data**

Appendix C in the National Building Code (2015 edition referenced maximum and minimum measured values for various weather/climate parameters including humidity, wind gusts, temperatures, driving rain wind pressures, snow load, etc.) should be reviewed and determinations made as to whether the referenced max/mins applicable to this product standard might be expected to shift in the future — standards writers should consult climate change experts on these assumptions.

Step 5 – Assess impacts of climate change based on expected regional variations. Determine significance of impacts on standard under review or development.

During the update of this standard, writers will also need to factor in morphological and topological variations, as necessary. The Technical Working Group should review all of the tests outlined in the standard including those for strength, resistance to wind load, resistance to rain penetration, etc. and consider the worst-case values from Appendix C, and then modify test values for each test to account for future changing climate based on the climate change experts' input.

Step 6 – Complete a climate risk assessment (quantitative or qualitative). Determine significance of risks on standard under review or development.

After considering all of the individual variables and corresponding tests in the standard that might be impacted by a changing climate in steps 4 and 5, standards writers will also need to look at all of the parameters holistically to determine if and how the standard needs to be modified to address changes related to climate load.

Based on the findings in steps 4 and 5, there may not be a need to drastically modify the design of the product, but it may be necessary to require different manufacturing materials — this can be done by adjusting the test values in the standard.

It may be necessary to include a product service life assumption in the standard, stating that product life does not extend beyond a specific date or year. In more extreme instances (i.e. where a short product life would be required to ensure that the product will not fail under predicted future maximum loads), the standard may need to incorporate a stopgap measure indicating that the standard would require the product to be marked “REMOVE FROM SERVICE AFTER (a certain date).”

An alternative approach would be to outline specifications for a version of the product to be used in lower climate-stressed areas (these areas would have to be defined) and a version for higher climate-stressed areas. This approach would require manufacturers and distributors to attempt to control where (high climate stress vs low climate stress area) the product is to be used.

Step 7 – Define applicable life cycle stages for the standard under development/revision

For a product such as factory-built type A chimneys, typical life cycle stages to consider include acquisition of manufacturing materials and transportation to the production site, production (manufacturing) of the product and transportation of product to the user, installation of the product in a building, use of the product and end of life disposal of the product.

Step 8 – For each life cycle stage, identify climate change positive/negative impacts and/or opportunities

The Technical Working Group should consider the impact climate change may have in each life cycle stage and whether any identified impacts could be addressed within the scope of the standard.

Alternatively, the Technical Working Group could consider whether the scope of the standard should be expanded to address/incorporate climate-related impacts. For this product, where the supply chain is robust, transportation is robust and the product is manufactured inside a temperature-controlled facility, a requirement to build life cycle considerations into the standard may not be an issue, beyond the potential for power failure.

Note: It is recommended that each Technical Working Group record that it considered climate change impacts at each life cycle stage and decided whether it is something that the group felt needs to be addressed in a revision to the standard or the next edition of the standard. This record would be kept by the standards development organization (i.e. an indication that no action is needed on sourcing and transport or recycling of the product at the end of its life) so that it could be reviewed during the development work on future revisions or editions of the standard, and the validity of the decisions rechecked. This record could be incorporated into the standard, but not necessarily.

A question for standards writers to consider is whether the Technical Working Group wants to be silent on the reasoning for not building climate change impacts into the standard or explain a reason whether an action was needed in relation to material sourcing or transportation with respect to climate change.

Step 9 – Identify and incorporate climate change adaptation measures into the standard under development/revision

If the Technical Working Group concludes that climate loads are going to change — for example, if the force value of wind load is expected to increase — it may be necessary for standards writers to revise the parameters prescribed in the standard. Another possibility would be to introduce new tests or modify the proposed methods to address expected climate load changes. Another option, in this hypothetical case, might be to change requirements to ensure some components of a product are more robust to a certain limit and also require that the product be manufactured to be repairable instead of disposable.

Step 10 – Develop timeline for revision of the standard to acknowledge changing nature of climate change information, associated impacts and adaptation measures as well as the expected life cycle of the product

The result of the analysis may indicate that products meeting current requirements are robust to projected worst-case (for Canada) climate loads up to a certain date. If so, the Technical Working Group's work plan should include an item to ensure that the relevant requirements are revisited sufficiently in advance of that date to allow manufacturers and other stakeholders enough time to ensure that compliant products are available at that time. It may be necessary to state a shorter life cycle for the product standard.

Case 2: A case study for the integration of climate change adaptation considerations into the Canadian Highway Bridge Design Code (CSA S6)

This case study guides the reader through the steps outlined in this Guide to undertake an update to the Canadian Highway Bridge Design Code (CHBDC, Code) [30]. It provides a brief, practical description for each step presented in the Guide, regarding a project in progress at the time of the development of this Guide. Activities completed to date are therefore drafted in the past tense, whereas activities that are intended to be completed are written in the future tense.

The Code applies to the design, evaluation and structural rehabilitation design of fixed and movable highway bridges in Canada. It also covers the design of pedestrian bridges, bicycle bridges, retaining walls, barriers and highway accessory supports of a structural nature, (e.g. lighting poles and sign support structures). CSA Group initiated an extensive project in 2019 to update the Code to incorporate climate change adaptation considerations, with a new edition expected to publish in 2025.

Step 1 – Determine if the purpose of the standard might be materially affected by climate change

The current design of highway bridges is based on historical climatic data that assumes climate stationarity. Such an assumption is no longer valid, as historical climatic data is no longer a reliable predictor of future climatic conditions and associated loads. Due to changing climate and climate non-stationarity, highway bridges could be vulnerable to a range of climate hazards, which could result in increases in the intensity and frequency of extreme load effects from extreme temperature, precipitation and wind that, in turn, could reduce their safety, serviceability, post-event function or durability. Hence, to minimize the risk of failure of bridges due to climate change and extreme weather events, there is a need to develop enhanced and/or new provisions for the design of highway bridges that will increase their resilience. This Code will be materially affected by climate change.

The updated and new Code provisions will be developed to take into consideration the potential impacts of climate change on the intensity and frequency of climatic loads on bridge structures, and the potential impacts of climate change and extreme weather events on the safety, serviceability and durability of bridges.

Step 2 – Include climate change and standards professionals/experts in Technical Working Group

Climate change subject matter experts, including scientists, climatologists, consultants, academics and material experts, form the basis of a new CHBDC Climate Change Technical Working Group that is being established.

Step 3 – Gather relevant climate data

As part of the activity to develop updated and new climate change provisions for the CHBDC, the Climate Change Technical Working Group is reviewing and assessing new Environment and Climate Change Canada (ECCC) data and the implications of the data for bridge design and rehabilitation. The data reviewed includes environmental historical data up to and including 2017 (https://climate.weather.gc.ca) and the projected increases in mean global temperature derived by ECCC [19].

Step 4 – Define climatic conditions affecting the product within the scope of the standard under development/revision

- **Consider varying geographic region applicability**
- **Review historic climatic and extreme weather data**
- **Use the results of climate simulation model(s) for climate projection data**

The CHBDC Climate Change Technical Working Group recognized that datasets of historical, current and future-projected environmental variables, such as ice accretion, temperature or wind speeds, are necessary to allow the target reliability of the structural design of bridges to be achieved and maintained over the expected life span of a new bridge. Bridges designed in the present but in an environment of a changing climate will experience changing levels of safety over the coming decades. A challenge exists to provide an adequate level of initial reliability in the CHBDC such that future safety levels remain at acceptable levels as environmental demands (loads, deformations) evolve over time. Conversely, it is important to avoid undue conservatism in the initial design to avoid unnecessary cost, with little or no added value to infrastructure in terms of material risk reduction. Much of these considerations involve the statistically grounded understanding of climate change and application of changing environmental variables to engineering design.

Typically, climatic loads used in codes, standards and guides are based on the concepts of uniform climate hazard (i.e. defined using the same return period and independent of the site) and by assuming that the climatological elements can be modelled as stationary processes. The use of the uniform climate hazard approach can lead to inconsistent reliabilities (or safety levels) for structures across different regions within Canada, and the adoption of the stationarity is invalid for a changing climate, as the statistics of the occurrence rate of the load and its intensity will be time-dependent and random.

Step 5 – Assess impacts of climate change based on expected regional variations. Determine significance of impacts on standard under review or development.

During the update of the Code, the CHBDC Climate Change Technical Working Group will assess how climate change will affect various regions of Canada differently, and it will be necessary to investigate the impact of climate change (focusing on wind and precipitation) on the reliability of structures in different regions of Canada. There may be instances where the ratio of ultimate load design values to service load design values varies from region to region in Canada.

Specifically for Canada's North, the CHBDC Climate Change Technical Working Group will review bridge, culvert, wall and embankment planning and design that will also entail assessing current permafrost conditions and projected permafrost changes. Recommendations on design actions (qualitative descriptions) for bridge designers operating in Canada's North will be prepared that will focus on the resiliency of northern bridges to rapidly changing conditions, which will depart substantially from those present at time of design.

Step 6 – Complete a climate risk assessment (quantitative or qualitative). Determine significance of risks on standard under review or development.

The CHBDC Climate Change Technical Working Group will be examining the impact of the regional varying statistics of climatic load factors on the reliability of the designed bridges and identifying the physical reasons for such variations. Current design for extreme climatic hazards in the Code is based on the concept of "uniform hazard" or an event with geographically uniform probability of exceedance. Climate change, however, will affect various regions of Canada differently, and there may be instances where the ratio of ultimate load design values to service load design values varies from region to region in Canada. To achieve acceptable and uniform levels of reliability throughout the country for loading combinations where climatic loads dominate, it may be necessary to develop new formats for the presentation of the design values of climatic loads, such as wind pressure and ice accretion. For example, it may be necessary to specify wind pressures at current probabilities but with geographically varying load factors, or to specify wind pressures with reduced annual probabilities of exceedance. The change in design values of climatic loads may require a change in climatic load factors for use in different loading combinations for design. In addition, some climate-related effects on bridges may not be captured well using load factors or probabilities, owing to the evolving nature of the environmental data.

Step 7 – Define applicable life cycle stages for the standard under development/revision

As detailed in this Guide, the main life cycle stages of an infrastructure asset, such as a bridge, are planning, design, construction, operation, inspection and maintenance, rehabilitation and repair, and decommissioning. The scope of the Code focuses primarily on bridge design, and to a lesser extent on planning, construction practices, rehabilitation and repair, but does not address the other life cycle stages. While climate change may impact every stage of the life cycle of a bridge, the Code primarily focuses on addressing climate change as it relates to the design stage. It is noted that there is increased scrutiny on choosing an appropriate design life as concerns are shifting from durability to life safety. Climate change across a longer design life means bridges will see increased climatic loads. The year of commissioning is significant, since it impacts the starting point of what climate conditions the structure will experience.

Step 8 – For each life cycle stage, identify climate change positive/negative impacts and/or opportunities

The CHBDC Climate Change Technical Working Group identified top climate risks and impacts, as well as top strategies and approaches that should be considered in the design life cycle for the 2025 Code. They were as follows:

Climate impact	Description
Climate data uncertainty	Managing future climate data uncertainty is important when considering climate projections in bridge design. Environment and Climate Change Canada has presented considerations for dealing with this uncertainty that can inform how climate data could be used in the Code.
Design life	New bridges are currently designed with a design life of 75 years as stipulated in the Code. Discussion will need to take place on whether to increase or decrease the current design life, or to vary the design life based on the importance of the bridge, taking into consideration the associated implications.
Hydrology	Includes flooding, flows, debris loading, changes to land use or extreme weather events that may impact the surrounding watershed, and design flood level.
Permafrost	Permafrost was not covered prior to the 2019 Code. The 2019 Code included a new clause on Permafrost Design. How permafrost considerations and/or regions might change due to climate change and the impacts on bridge design, inspection and maintenance would be addressed in the 2025 CHBDC.
Rehabilitation	Beyond design provisions, the Code includes the rehabilitation of bridges taking into consideration future climate conditions. Considerations include the site-specific nature of the analysis that is required to assess criticality, and integration of climate considerations into bridge planning of existing bridges.
Scour	Scour is a leading cause of bridge failure. Climate change may increase river flows and speed, thawing of river ice and drainage conditions that may increase scour. The challenge is that geotechnical solutions for scour are typically site-specific.
Temperature change	This includes discussion on increased freeze-thaw cycles, maintenance and durability issues, sensitivity to temperature change of materials, thermal movement, corrosion and painting.
Wind	In the 2019 CHBDC, historical wind pressures were uniformly scaled upwards by a significant percentage across the country. However, local variations are more nuanced and were not captured in this update. This remains one area for improvement for the 2025 CHBDC.

Step 9 – Identify and incorporate climate change adaptation measures into the standard under development/revision

Steps 3 through 8 will feed into the task of developing updated and new climate change provisions in the Code. The potential impacts of climate change on the intensity and frequency of climatic loads on bridge structures and potential impacts of climate change and extreme weather events on the safety, serviceability and durability of bridges will be assessed. Possible climate change adaptation measures to reduce the risk of failure of bridge structures and ways to effectively integrate and stage climate-enhancing works into new and existing highway and bridge renewal plans will be recommended.

The 2019 edition of the Code will be reviewed clause-by-clause by the CHBDC Climate Change Technical Working Group, and a set of recommendations will be formulated that will then be assessed for possible inclusion in the 2025 edition of the Code.

Step 10 – Develop timeline for revision of the standard to acknowledge changing nature of climate change information, associated impacts and adaptation measures as well as the expected life cycle of the product

The foregoing research and assessment and the development of updated and new climate change provisions are intended to be completed within a period of 20 months. The CHBDC Technical Committee will then assess and confirm whether the final recommendations from the CHBDC Climate Change Technical Working Group meet the criteria for incorporation into the 2025 edition of the Code (CSA S6). In some cases, new practices will emerge as commentary material in the Commentary to the Code (CSA S6.1), then transition to CSA S6 in a later edition. The 75-year expected life cycle of a bridge is planned to remain unchanged in the Code.

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