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Using Climate Information in Standards Development

Technical Companion to the Guide for Integrating Climate Change Adaptation Considerations into Canadian Standards

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Suggested citation

Standards Council of Canada & WSP Canada (2022). Using Climate Information in Standard Development: Technical Companion to the Guide for Integrating Climate Change Adaptation Considerations into Canadian Standards, Version 1.0.

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Author: WSP Canada Inc.
Published: Ottawa: 2022

Aussi offert en français.

Table of Contents

Acknowledgements

This Guide was commissioned by the Standards Council of Canada and written by WSP Canada. ICLEI Canada delivered extensive engagement over the course of the project to gather input on the Guide. Guy Félio provided technical guidance and advice throughout the development of the Guide. The process to develop this Guide began in November 2020 and was completed in March 2022. This Guide reflects valuable input and feedback from members and associates of the Standards Development Organizations for Climate Resilient Infrastructure Working Group (SDO CRI WG). In addition, the authors are grateful for the industry experts and organizations that participated in engagement sessions that informed this Guide, including:

- BGC Engineering
- Bureau de normalisation du Québec
- Canadian Centre for Climate Services
- Canadian General Standards Board
- CSA Group
- Engineers and Geoscientists British Columbia
- Engineers and Geoscientists Manitoba
- Institute for Catastrophic Loss Reduction
- National Research Council Canada
- Natural Resources Canada
- Northwest Territories Association of Communities
- Ouranos
- Prairie Climate Centre
- Standards Council of Canada
- Standards Council of Canada's Northern Advisory Committee
- ULC Standards

Individual participants (participation not affiliated with a professional organization):

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Executive Summary

The effects of climate change are already evident across Canada and are expected to intensify in the future. The production, design and delivery of infrastructure, products, services and tests can no longer be based on historical assumptions about weather and climate. Standards and codes will need to be developed or adapted to account for the potential physical risks associated with climate change, such as increased climatic loads or effects on infrastructure (e.g., increased winds, increased air temperatures) and increasing extreme weather events. Due to the widespread and pervasive impacts of climate change, standards writers must be aware of risks and climate adaptation measures applicable to the scope of the standard. There is an urgent need for tools that enable the use of climate information in the standard development and update process.

This Guide is a technical companion to the Guide for Integrating Climate Change Adaptation Considerations into Canadian Standards. which was created to help users understand fundamental concepts in climate change and to determine potential climate impacts and risks to the scope of the standard. This technical companion is meant to be applied in cases where climate change has been determined relevant to the standard. It includes both informational sections (e.g., Section 3) and sequential guidance (e.g., Sections 4 and 5) on using climate information to inform standard development. Where possible, additional guidance and resources are recommended to further support standards writers in using climate information. Leveraging this Guide, standards writers will be better equipped to access and interpret relevant climate data, include climate-informed content in a standard, and identify ways that standards can reduce risks and support adaptation.

Note: 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 Objectives

This Guide is intended to help standards writers understand and incorporate climate change information into Canadian standards that are under development or revision. The Guide was developed through a review of best practices and direct engagement with climatologists, climate risk experts, engineers, standards writers, and standards users.

1.2 Audience

Standards writers applying this resource to the development or update of standards are not expected to be experts in climate change. This Guide provides considerations for inclusion and, when necessary or helpful, encourages writers to seek advice from qualified professionals and relevant subject matter experts. The Guide is intended for:

— Individuals or organizations involved in the National Standards System in Canada.

— Individuals or organization involved in drafting or revising standards, codes, and other related instruments, such as provincial and municipal standards.

— Standards users in Canada seeking information on how to apply climate change information.

1.3 How to Use this Document

This Guide is a technical companion to the Guide for Integrating Climate Change Adaptation Considerations into Canadian Standards, published by the Standards Council of Canada (SCC) in 2021. Both Guides are intended to help individuals and organizations involved in drafting, revising, or using standards. The Guides can be used in concert or separately, depending on the needs of the user.

The Guide for Integrating Climate Change Adaptation Considerations into Canadian Standards preceded this Guide and includes foundational information to help standards writers understand core concepts of climate change and general relevance to standards. If readers are unfamiliar with any of the following topics, it is recommended to start with the first Guide.

— Definitions of climate change, climate impacts and climate risks.

— How to identify climate risks and impacts relevant to a built asset, product, service, or test at various stages of its life cycle.

— How to determine relevance of climate change to the standard.

This technical companion should be used after it has been confirmed that the standard needs to consider climate change, and standards writers have identified the need to gather, understand and apply climate information to the content of the standard. Use Table 1 to determine which guide is appropriate for current needs.

Table 1: Comparison of this resource to the Guide for Integrating Climate Change Adaptation Considerations into Standards (2021)

	Guide for Integrating Climate Change Adaptation Considerations into Canadian Standards (2021)	Using Climate Information: Technical Companion to the Guide for Integrating Climate Change Adaptation Considerations into Canadian Standards (2022)
Explanations of climate change, climate risks and climate adaptation	Section 2	
Determining applicability of climate change to the product, service, infrastructure, or test within the scope of the standard	Section 4	
Understanding climate information (e.g., models, scenarios, climate variables, Traditional Knowledge)		Section 3
Seeking climate change expertise and engaging experts		Section 4
Availability of climate information and emerging data	Section 5.1	Section 3.7 and Annex A
Selecting and gathering climate data (including selecting time horizons, emissions scenarios, climate variables, etc.)		Section 5.3
Interpreting climate information	Section 5.2	Section 5.8
Assessing climate risks to the product, service, test or asset in the standard	Section 5.2 - 5.3	
Understanding climate impacts throughout different stages of the life cycle	Section 5.4	
Updating or incorporating climate change requirements into a standard		Section 5.11.1
Documenting climate information in a standard		Section 5.11.2
Establishing a timeline for revision		Section 5.11.3
Integrating climate change information into a supplemental report or informative annex		Section 5.11.6
Examples of standards including climate change		Annex B
Case studies and examples	Appendix C	Throughout

1.3.1 Icons and Document Features

The following icons and chapter features will repeat throughout this document.

Indicates the content of the section is **informational**.

Indicates the content of the section is **guidance**.

Section summary provides a list of the key takeaways from each section.

Yellow text box

Directs readers to other sections of this document with related information.

Red text box

Directs readers to other resources that could support standards writers.

2

Current Challenges Using Climate Information in Standards

This section provides an overview of challenges and barriers to using climate information in standard development and/or revision. The challenges were identified by standards writers and standard development organizations through surveys and workshops conducted during the development of this Guide.

Historical climate and weather conditions have long been applied to design and standardization of products, built assets, tests and services – as evidenced by age-old versions of codes and standards for bridges, roads, and buildings. However, the climate science is clear that historical data are not sufficient to protect our infrastructure and communities from climate change. Standards organizations around the world recognize the growing need to consider climate change and extreme weather when creating or updating standards. In 2020, the Standards Council of Canada reported that over 100 standards urgently required updates to account for future climate conditions (SCC, 2021a).

While more standards have been developed or updated to include future climate information, the methods used to integrate climate considerations into standards development have been ad hoc. Standards cover a vast range of products, materials and processes, and there is no singular approach to including climate information in the standard development process.

This section highlights challenges related to integrating climate change into standards development, identified through literature review, surveys and workshops with individuals and organizations involved in the development, review or update of Canadian codes and standards. This Guide aims to support standards writers in minimizing the key challenges associated with integrating climate change into standards.

Uncertainty

One of the most significant challenges identified by standards writers and standards users is the uncertainty associated with climate information. Uncertainty in future projections can create hesitancy to use the data and challenges understanding climate information. Due to the uncertainty associated with future climate information, some engineers involved in standards development have reported that they are unable to estimate the vulnerability of an asset or product to future climate change impacts.

Absence of Guidance and/or Requirements for Climate Change in Standards

Thus far, there have not been any signals from code regulators on a systemic approach for how standards writers and the standards community should manage future climatic effects in standards. There is a general lack of guidance or requirements for methods, metrics, labelling conventions, etc. Without this kind of national-level leadership, fragmented and ad hoc solutions are being, and will continue to be applied.

Gaps in Expertise

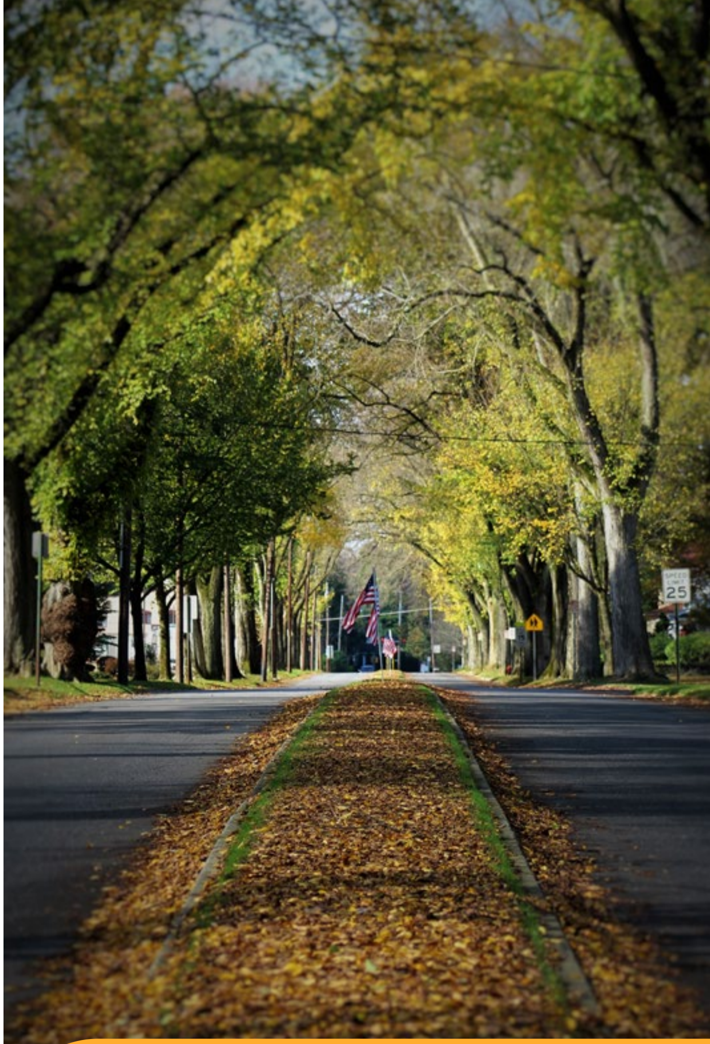
Standards writers and users are not often climate change experts and may not have the training to apply climate change information when developing, revising or using standards. Standards development working groups and technical committee members are typically not recruited based on their knowledge of climate change, but rather on their expertise related to the subject of the standard (technical design, conditions of use, etc.). Accounting for climate change in standards development requires an interdisciplinary approach that involves cooperation and collaboration between organizations and different disciplines to ensure that the appropriate data and projections are selected.

Challenges with Selecting an Approach and Level of Detail for Including Climate Change Information

Standards writers have reported that they have difficulty selecting an approach for integrating climate change information in standards, due to varying methodologies for climate projections and multiple sources for climate data. Varying methodologies are being applied with no best practice approach identified. For example, many municipalities have begun developing their own standards (particularly as it relates to storm water management), which are not directly comparable with each other.

Lack of Detailed Climate Information

Available climate and weather data do not meet the needs of those involved in the design and risk analysis of infrastructure projects. Climate information is scattered across various sources, and the approach to access and use it is inconsistent. Additionally, obtaining projections for specific climate variables, such as extreme precipitation, hail, or for specific remote regions is challenging and data is limited. Finally, many engineers and designers generally require data (modeled and observational) at a localized scale (i.e., at a building scale), typically obtained through high-resolution, downscaled climate model projections. This level of granularity is challenging to obtain and has its own limitations due to uncertainty of downscaled data.



Refer to Annex B, Section 10.1 in this document for examples of standards and codes that include future climate change considerations.

Annex B, Section 10.2 includes highlights of existing technical guidance on using climate information in codes and standards.

3

Understanding Climate Information

This section describes the fundamental aspects of historical and future climate information including climate models, emissions scenarios, climate variables and Traditional Knowledge. Sources of uncertainty and levels of confidence in climate information are described, and guidance is provided for standards writers to manage uncertainties. This section also covers the current availability of climate data and emerging climate information.

Refer to Section 2 of the ***Guide for Integrating Climate Change Adaptation Considerations into Standards*** to learn about climate change, global climate change trends, climate impacts and risks.

3.1 Overview of Climate Change Drivers

Climate change refers to the increase or decrease of statistics (e.g., mean, variability, extremes) for climatic variables such as temperature and precipitation, which persist consistently for an extended period of decades or longer. (ClimateData.ca and IPCC, 2018).0F Climate change influences weather conditions and extreme meteorological events, which in turn impact infrastructure, ecosystems, and communities (NOAA, 2019).

Climate change is caused by natural internal processes and/or external forcings, including:

— Persistent human-caused (anthropogenic) activities such as fossil fuel combustion and land use change, which affect the composition of the atmosphere (IPCC, 2018). Atmospheric changes lead to increasing frequency and magnitude of extreme climate events such as windstorms, tornadoes, and droughts.

— Natural internal climate variability (sometimes referred to as internal climate variability or natural climate variability) can cause the average temperature of the planet to fluctuate annually and over long time periods. Natural fluctuations can be chaotic and unpredictable. An example of a driver of internal climate variability is the El Niño-Southern Oscillation (ENSO) cycle.

— Natural external forcing is characterized by changes such as variations in the sun's energy output or large volcanic eruptions, which can cause the average global temperatures to rise and fall or affect short-term variability of the greenhouse effect (NOAA, n.d.).

3.1.1 Stationary and Non-stationary Climate

Climate information differs from other types of time series data that may be studied as part of the standard development process (e.g., geotechnical data, ambient vibrations). Time series data are stationary if a subset of data from one time period is mostly indistinguishable from a similar subset from any other time period. Stationary data suggests no change in the mean over time, and no change in oscillations from the mean (CSA Group, 2020a). An assumption of climate stationarity is not valid in the case of changing climate.

The climate system is **non-stationary**. Future climate projections show trends in mean climate conditions and changes in the frequency of extreme events, both effects leading to non-stationary climatic loads (CSA Group, 2020a). For example, when observing future projections for precipitation, the mean annual precipitation is likely to change over time, and so will the standard deviation which impacts extremes. Instances of extreme rainfall (oscillations from the mean) are also likely to change in frequency and probability in future time periods. Natural variability also influences the climate system differently over extended time periods.

Climate information cannot be treated as constant for the development or update of standards. Standards for products, built assets, tests or services that are exposed to weather effects must be examined to determine whether any of the requirements are based on the assumption of a stationary climate. If this is the case, standards need to be re-evaluated to determine whether there is a need for modified requirements that address anticipated future climatic loads or effects.

3.2 Climate Models

Climate models represent the active physical processes within, and the interactions between, the atmosphere, ocean, cryosphere, and land surface of the planet. Climate models simulate how the future global climate may change in response to varying natural and human-caused inputs.

General Circulation Models (GCMs) simulate changes in the climate system spanning the entire planet, with a horizontal resolution of between 100-300 km (Charron, 2016). General Circulation Models are sometimes referred to as Global Climate Models. Regional Climate Models (RCMs) are used to simulate dynamic processes of climate change happening in smaller geographic regions, only covering a portion of the planet. There is considerable demand (for example, from those involved in engineering design or standard development) for climate information at a finer scale than the coarse resolution of global climate models. **Downscaling** is a technique used to produce climate information at a finer resolution. For example, RCMs are sometimes used to dynamically downscale global model simulations and reach finer spatial resolution (Laprise, 2008). However, there are trade-offs between using global model simulations and downscaled outputs, which must be understood by users of climate information (see more about uncertainty in Section 3.8).

Read more about downscaling in Section 1.9 of the Guidebook on Climate Scenarios published by Ouranos (2016).

Each climate model represents the climate system with its own level of complexity and parameters for dynamical, physical, and chemical processes. Different climate models result in different climate projections, known as the **inter-model spread** of a model ensemble. An understanding of future climate cannot be obtained through only one model, and climate projections from a single model should not be interpreted as a high-confidence projection.

3.2.1 Model ensembles

Multi-model ensembles are recommended for use by standards writers. Ensembles generally outperform individual climate models and reduce model uncertainties, since they better represent inter-model spread. The fifth phase of the Coupled Model Intercomparison Project (CMIP5) includes several climate modelling groups from around the world and is the most comprehensive and commonly used multi-model ensemble at present (Taylor et al., 2012). In recent years, new modelling groups have been developed through the Coupled Model Intercomparison Project (CMIP6), and have been used to produce the latest climate science findings such as the IPCC Sixth Assessment Report. The process of superseding CMIP5 models with CMIP6 models has commenced and is expected to continue in the coming years.

More information on emerging climate information is provided in Section 3.7.1.

3.3 Climate Change Scenarios

The magnitude of future climate change depends on many factors, including the global trajectory of greenhouse gas emissions, which is challenging to predict. The future concentration of greenhouse gas emissions in the atmosphere depends on demographics, economic development, technological and policy changes, energy supply and demand, and land use changes (Nakicenovic, 2000).

Climate change scenarios (or emissions scenarios) produce modelled simulations of various future trajectories. Scenarios are a simplified and plausible representations of future GHG emissions and associated climate conditions. Scenarios tend to avoid implausible climate situations, reduce inter-model spread and represent a suitable product to support decision-making.

Guidance on scenario selection for standards is provided in Section 5.6.

Most climate models, including the CMIP5 ensemble, use Representative Concentration Pathway scenarios (RCPs). The RCPs were developed for IPCC's Fifth Assessment Report, and describe emissions, atmospheric concentration, and land-use trajectories based on four socio-economic scenarios. The four pathways, as described by the Canadian Centre for Climate Services, include:

— **RCP2.6:** A stringent mitigation scenario where greenhouse gas emissions continue to increase until mid-century, then rapidly and significantly decline. This scenario is considered unrealistically low but is sometimes used in scenario analysis for transition risks and is the only pathway that can ensure success of the Paris Agreement.

— **RCP4.5:** This scenario assumes that greenhouse gas emissions will continue to increase (but more slowly than they are today) until mid-century and then stabilize until the end of the century. However, carbon dioxide concentrations will still end up being much higher than they are today. The IPCC describes this scenario as a "stabilization pathway."

— **RCP6.0:** An intermediate scenario where emissions peak in the latter half of the century and then decline.

— **RCP8.5:** A high emissions scenario which assumes that greenhouse gas concentrations will continue to increase at approximately the same rate as they are increasing today. Of the four pathways described here, this pathway results in the most severe global warming and climate change.

Global climatic changes associated with each of the four pathways appear relatively similar until 2050, when they begin to diverge. For standards writers, scenario selection will depend on the service life and risk tolerance for the product, infrastructure, test, or service within the scope of the standard.

As part of the efforts to update climate information for the National Building Code of Canada and Canadian Highway and Bridge Design Code, climate scientists recognized the need to provide guidance on selecting appropriate climatic design data for specified time horizons of 50 years for buildings (NBCC Table C-2) and 75 years for bridges (CHBDC Annex A3.1). Cannon et al. (2020) developed the data in Table 2 to illustrate the estimated time period in which the global mean temperature (ΔT) relative to 1986-2016 is exceeded under each emissions scenario. A dash ("-") indicates that warming sustained at the level specified by the corresponding ΔT does not occur before 2100.

Table 2: The year at which the indicated global mean warming ΔT relative to 1986-2016 reference period is irrevocably exceeded by the CMIP5 multi-model mean for RCP8.5, RCP6.0, RCP4.5, and RCP2.6 emissions scenarios (Source: Cannon et al., 2020).

ΔT	RCP8.5	RCP6.0	RCP4.5	RCP2.6
+0.5°C	2023			
+1.0°C	2035	2046		-
+1.5°C	2059	2087	-	-
+2.0°C	2069	-	-	-
+2.5°C	2080	-	-	-
+3.0°C	2090	-	-	-

3.4 Time Horizons

Guidance on time horizon selection for standards is provided in Section 5.5.

Climatic changes are observed by comparing the past climate (referred to as the reference or baseline period) to the future climate. **Time horizons** are the period for which the future climate information will be observed. To adequately identify climatic trends, future projections must be observed over a 20 or 30-year period to account for influences such as internal climate variability and inter-annual variability.

Near-term projections usually present climate change through to mid-century (the 2050s). During this period, the absolute magnitude of climate change may be lesser than the magnitude of year-to-year variability (Kirtman et al., 2013). Consequently, climate change under different future emissions scenarios may appear similar in the near term. Long-term time horizons assess climate projections on time scales beyond the mid-21st century. Over longer time horizons, the choice of the emission scenario becomes very important as scenarios tend to diverge.

It is good practice to consider both the medium- and long-term temporal horizons. In the context of standard development, standards writers may instead want to choose one time horizon, depending on the subject matter in the standard, for example the expected service life of the product or asset.

3.5 Climate Variables

Climate variables (or climate parameters) are used to describe an aspect of weather, climate, or a related geophysical property. Broad classes of climate variables include temperature, precipitation and moisture, wind, and snow and ice (Cannon et al., 2020). Examples of climate variables in the National Building Code of Canada are maximum mean daily air temperature, relative humidity, hourly wind pressures, snow load, etc.

Climate variables can be observed to better understand both chronic and acute climate events.

— Chronic (or slow onset) changes include seasonal or annual increases in temperature and variations (increases or decreases) in precipitation. Such changes can be noted by observing changes to mean values over time. Chronic changes are usually more of a concern for day-to-day operations and system use but should be considered in standards which address these.

— Observing changes to extreme climate variables can help plan for acute events such as heat waves, severe storms, flooding, or wildfire. These short-term, high-impact events are usually a concern for design standards. However, the IPCC has stated that Global Circulation Models tend to underestimate the climate extremes, which has important implications for design engineers.

Considering multiple climate variables together can also be helpful to understand the future probability of climate hazards1F , since hazards typically involve interaction between multiple variables, or a combination of variables. However, compound events involving multiple variables also have a lower confidence than individual variables.

More information on confidence levels for climate variables is provided in Section 3.8.2.

Further, some climate variables are more complex than others (such as ice accretion, humidity, snow loads). 2FClimate variables do not share the same degree of confidence. Uncertainties within climate variables arise from lack of determination (such as when the data is not fully representative of the phenomena), or incomplete understanding of the processes (such as when the models do not fully represent the relevant processes leading to the phenomena) (Le Treut et al., 2007). For example, variables such as mean global temperature generally have a high level of confidence. Variables that represent complex meteorological phenomena such as wind, extreme precipitation or seasonal sea ice cover extent generally have a lower level of confidence. Working with complex climate variables often requires a climate expert, because it may be challenging to obtain historical data, generate future projections, analyze trends, and there may be various factors influencing projections that requires expert interpretation.

3.6 Traditional Knowledge

The previous sections have discussed climate change using climate models and scientific methods of understanding future climate change. However, the Traditional Knowledge (TK) of Indigenous people, particularly from Elders, can also be sought when considering changes in climate that impact communities or a region. Traditional Knowledge of the land by Indigenous peoples has been historically ignored and dismissed as anecdotal and unreliable. Today, it is recognized as legitimate, accurate and useful (Indigenous Climate Hub, 2021). Several federal statutes and international agreements recognize and use Traditional Knowledge in reporting and decision-making (including the Canada Oceans Act, Species at Risk Act, Canadian Environmental Protection Act, Convention on Biological Diversity, the Arctic Council, the International Arctic Science Committee, United Nations Framework Convention on Climate Change, and other United Nations bodies) (Indigenous Climate Hub, 2021).

Indigenous people have close relationships with the land and have therefore been able to observe recent changes in the natural environment at a much more local scale than can be determined from climate models or historical weather data. Traditional Knowledge holders may also report on climate changes that scientific instruments do not record. Further, translating Traditional Knowledge into action is an important provision under the adaptation and climate resilience pillar in the Pan-Canadian Framework on Clean Growth and Climate Change.

Traditional Knowledge can be most beneficial when developing local standards (e.g., design criteria, by-laws). Traditional Knowledge can be applied independently of Western scientific knowledge or with it to broaden perspectives. For example, observations can be validated by recorded data for past events or models for future projections. Standards writers should also consider that users may wish to include local or Traditional Knowledge in the application of the standard to specific projects or activities.

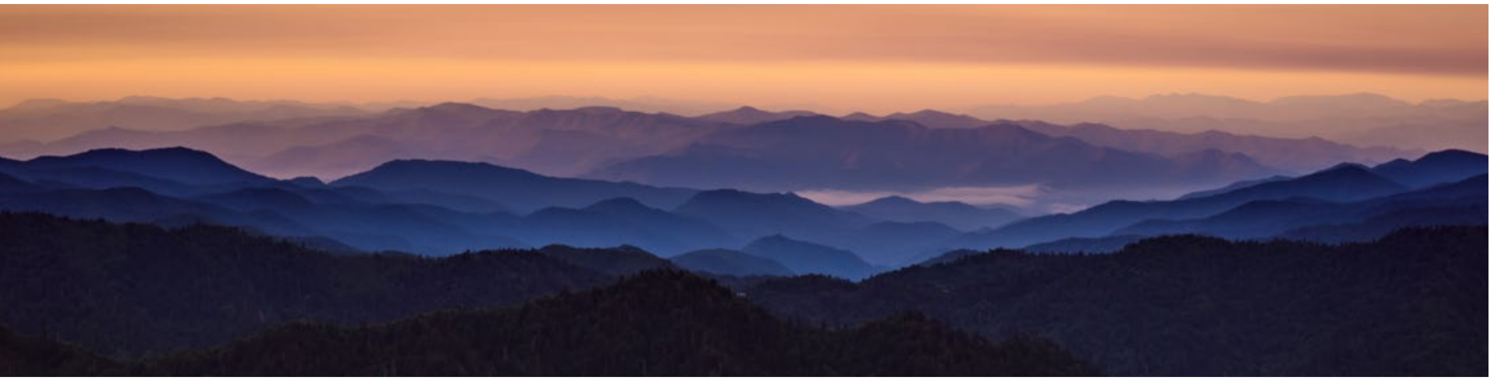
The basis of using Traditional Knowledge is the engagement of community members, Elders, youth, hunters, gatherers. In collecting Traditional Knowledge to inform a standard update or standard development process, meaningful and respectful interaction with Traditional Knowledge holders should be prioritized. There should be inclusive and transparent processes that give space for Indigenous people to participate in standard development. Such efforts require significant and ongoing investment to build trust and relationships. Including Traditional Knowledge in approaches to address climate change through standards will benefit all, given the thousands of years of inherent wisdom in Traditional Knowledge systems, in addition to the current knowledge of present-day climatic changes. and impacts (Prairie Climate Centre, 2022).

EXAMPLE

Traditional Knowledge leading to local standards and policy development: Oneida Nation of the Thames (ON)

This Southern Ontario First Nation community regularly experiences violent winds that cause damages to residential buildings and utilities. Based on observations of trends, supported by insurance data claims and repairs to housing units, the Band Council adopted a policy requiring metal roofs be installed on all new residential buildings.

A subsequent climate risk assessment study (July 2018) confirmed the risks to residential buildings due to high winds and therefore the justification for the metal roof policy. In addition, recommendations were included regarding the use of hurricane ties for new residential buildings and a policy regarding yard maintenance (to avoid flying debris causing injuries or damaging property) (Stantec, Ontario First Nations Technical Services Corporation, 2018).



3.7 Availability of Climate Information

Climate information is not consistently or centrally available for use by standards writers. Historical and future climate information can be obtained for local, regional, and national scales, with varying degrees of accessibility and reliability depending on attributes of the historical data, the model(s) and scale of the projections. Further, different climate data providers offer different climate variables, spatial and temporal scales, and climate scenarios.

Challenges related to historical climate data include:

- Some weather stations in Canada do not have enough historical data (data types, or duration of operation). Incomplete historical data can impact future projections.
- Accuracy of the data may be in doubt, or there may be gaps in the data.
- Some automated stations cut out data above certain intensity thresholds, which can eliminate historical data on extreme events.

For future climate projections, challenges include:

- Low spatial density can mean data is insufficient for standards related to engineering or design.
- Climate data for some variables are not readily available.
- The more localized the data are, the higher uncertainty – even if localized data is needed (such as for extremes).
- Data are scattered across different portals, accessible only by climate experts who are familiar with various sources.

Despite these challenges, climate information has become more readily accessible for users in Canada. The IPCC Assessment Reports provide a wealth of future climate information, such as the **IPCC Sixth Assessment Report (AR6)**. Climate data sources widely used in Canada include (but are not limited to) Environment Canada's National Climate Data and Information Archive for historical data, and North American sources such as the NOAA National Climatic Data Centre and ClimateData.ca (via the Canadian Centre for Climate Services). There are also several regional climate service organizations that specialize in providing climate information, such as the Prairie Climate Centre, Climate West, Pacific Climate Impacts Consortium (BC), Ouranos (QC) and CLIMAtlantic.

The type of climate information used in standard development will depend on the standard. For detailed analysis of climate information, standards writers should engage climate experts to determine the appropriate data sources and format for future projections.

Annex A describes the different methods, use, spatial formats, time periods and available datasets for historical data, climate normal data and future climate projections with examples of sources for climate information (not an exhaustive list).

3.7.1 Emerging Climate Information

Updated climate scenarios called **Shared Socioeconomic Pathways (SSPs)** have been used with the CMIP6 climate model ensemble and are included in the IPCC the Sixth Assessment Report (AR6) (O'Neill et al., 2015). The SSPs consider how societal changes will impact GHG emissions and provide detailed socioeconomic backgrounds for each emissions scenario. The pathways used in the IPCC AR6 are: SSP1-1.9, SSP1-2.6, SSP2-4.5, SSP3-7.0 and SSP5-8.5. They are based on the RCPs and share comparable pathways (e.g., the high emissions scenario of RCP8.5 is similar to SSP5-8.5), which result in the same radiative forcing at the end of the century. However, the warming associated with the SSPs is slightly different due to modelling different mixes of greenhouse gases in the atmosphere and because the climate models have been updated since CMIP5.

CMIP6 data and SSPs are now being included online climate data sources. Over the course of the coming years, the SSP scenarios will gradually replace the RCP scenarios and will become more widely available on public available data portals.

It is likely that CMIP6 SSP projections will become available for some climate parameters before others. While tempting to use the newest data, it is advised to use a consistent approach within standards and update the data in subsequent revisions.

3.7.2 Updating Climate Information for Codes and Standards

The Government of Canada's **Climate-Resilient Buildings and Core Public Infrastructure (CRBCPI)** initiative have published climate change provisions for major codes and standards updates, including the NBCC and CHBDC. Building on the success of CRBCPI, Infrastructure Canada has funded the five-year Climate Resilient Built Environment Initiative, delivered by the National Research Council of Canada, to further support the integration of climate change information into codes, standards, and specifications. In addition to the updates to the climatic data and new climate resilience provisions, sets of proposed code changes and provisions will be prepared and will include the development of:

- A uniform risk-based design approach to replace the current uniform hazard-based design approach, in order to achieve acceptable and uniform reliability levels across Canada.
- Future climatic data, loads and load combinations to include the impacts of climate change on temperature, precipitation and wind.
- An approach to incorporate the non-stationarity of climatic data and target reliability specifications within a given time period or design life (National Research Council, 2019).

3.8 Uncertainty and Confidence in Climate Information

Understanding **uncertainty** is an important part of using and communicating climate information in standards (Prairie Climate Centre, 2019b). Sources of uncertainty in climate information include natural climate variability, climate model inaccuracies (e.g., model resolution or bias), and the future trajectories of GHG emissions (Hawkins and Sutton, 2009). More broadly, relying on different sources for information (scientific literature, climate data providers, stakeholder input, etc.) also creates uncertainty throughout the standard development process, and is not unique to working with climate change.

Natural climate variability

The climate system is so complex that it is not possible (at this time) to capture all processes in a model, so they remain simplified versions of the real world. Natural climate variability may still lead to outcomes that were different than those projected by models.

Model bias

Climate models can be biased (particularly at regional scales) due to uncertainty within the underlying physical processes that make up complex nature of the climate system, and how the model has been "told" to account for these unknown factors (Wilby et al., 1998; Zhuan et al., 2019). Biases can be found when climate model simulations of the historical climate differ from what was observed (Flato et al. 2013). To address model bias, many statistical downscaling processes include a bias-correction step.

Model resolution, regional or downscaled data

General Circulation Models require significant computational capacity and costs, and therefore trade-offs and approximations are built into them. Due to the fact that GCMs are simulating at a global scale, they represent a coarser resolution to reduce the computing demand. There may be a desire to use Regional Climate Models or other downscaled projections, and a belief that the finer the resolution, the more useable the data will be. But while a higher resolution may be important for some variables (extreme events), they will not necessarily yield richer or more useful information (Charron, 2016). As the scale of climate model projections becomes smaller, uncertainty becomes larger.

3.8.1 Relative Importance of Uncertainties

Uncertainty is driven by different factors depending on the future time horizon, shown in Table 3 from the Guidebook on Climate Scenarios (Charron, 2016). For near-term time horizons (< 30 years), natural variability has the greatest influence on uncertainty particularly when considering smaller regions and shorter time scales, and for projections of precipitation (Environment and Climate Change Canada, 2020). Natural variability could even appear to contradict the longer-term trends resulting from anthropogenic climate change, since it may be several decades before the climate 'signal' emerges from the 'noise' of the year-to-year variability (Charron, 2016). For medium-term projections (30-50 years), emission scenarios and inter-model spread have the most impact on uncertainty. For long-term projections (> 50 years), emission scenarios have the most impact on uncertainty (Charron, 2016). Table 3 shows the influence of different sources of uncertainty depending on the time horizon. In the table, the source of uncertainty with the most stars is most relevant to the specified time period.

Table 3: Sources of uncertainty in climate projections over time from Guidebook on Climate Scenarios (Charron, 2016)

Planning horizon	Relative importance of sources of uncertainties			Key source to consider for decision-making
	Natural variability	Emissions scenario	Climate model	
Short term (<30 years)	***	*	**	Natural variability
Medium term (30-50 years)	*	**	**	Emissions scenario and climate model
Long term (>50 years)	*	***	**	Emissions scenario

3.8.2 Confidence

Confidence is used to describe the validity of a finding to factor uncertainty associated with climate models or with a particular climate variable. There is an important distinction between confidence and likelihood – for example, there can be high confidence that an event is unlikely to occur, and low confidence that an event is likely to occur). Confidence in climate projections is important for standard development and should be considered alongside the likelihood of a change occurring.

As part of the analysis of the impact of climate change on climatic design data and codes relevant to the National Building Code of Canada (NBCC) and the Canadian Highway Bridge Design Code (CHBDC), Cannon et al. (2020) grouped design-related climate variables into three tiers according to level of confidence, with Tier 3 variables being the lowest confidence and Tier 1 the highest as shown in Table 4.

Learn more about different tiers of confidence for climate variables in the National Building Code of Canada and Canadian Highway and Bridge Design Code in Section 7 of **An Assessment of the Impact of Climate Change on Climatic Design Data In Canada (2020)**

Table 4: Degrees of confidence in climate information (Cannon et al., 2020)

	Tier 1 (highest confidence)	Tier 2	Tier 3 (lowest confidence)
Explanation	There is high or very high confidence in the future projections for a given level of warming, and high confidence in the evolution of Tier 1 variables. There is an in-depth understanding of the causes of the observed changes and strong evidence from multiple sources. Highest confidence projections have been: — Accessed from reliable data sources; — Generated from enough climate models (i.e., a multi-model ensemble) at a reliable scale; and — Have relatively low levels of uncertainty.	There is medium confidence in the future projections for a given level of warming. There is some understanding of the causes of the observed changes, with some evidence but perhaps less consistent than in Tier 1. It may be challenging to estimate the likelihood of a projected change. Medium confidence projections have been: — Accessed from a reliable source but have relatively large uncertainties; or — Accessed from less reliable sources, but projections have relatively small uncertainties; or — Accessed directly from the scientific literature.	There is low confidence in the future projections for a given level of warming. Projections for variables have not been widely studied or are poorly understood. Lowest confidence projections have been: — Accessed from less reliable sources and have relatively large uncertainties; — Accessed from the scientific literature and then uncertainty ranges are not specified; and — Low confidence datasets may also have low agreement, limited evidence as they have not been widely studied and/or are poorly understood.
Potential suitable uses	Designing new infrastructure or setting design and/or performance requirements, if justified from an engineering perspective and uncertainties are suitably considered to the end of the service life.	Cost/benefit analyses or risk analyses. Could also be used for the exploration of uncertainty associated with design.	Exploring the potential impacts on structural reliability in different warming and load combination scenarios.
Examples of climate variables from NBCC (NRC, 2015) and CHBDC (CSA S6, 2019)	NBCC — Heating degree days; and — Hourly design temperatures (January 2.5% dry bulb, January 1% dry bulb, July 2.5% dry bulb, and July 2.5% wet bulb). CHBDC — Maximum and minimum mean daily air temperatures.	NBCC — Annual total precipitation and annual total rainfall; — Annual maximum 1-day rain (50-year return period); — Annual maximum 15-min rainfall (10-year return period); and — Annual mean relative humidity. CHBDC — Annual mean relative humidity.	NBCC — Annual maximum hourly wind pressures (10 and 50-year return periods); — Annual maximum driving rain wind pressures (5-year return period); and — Annual maximum snow load (50-year return period). CHBDC — Annual maximum hourly wind pressures (10, 25, 50 and 100-year return periods); — Annual maximum ice accretion on exposed surfaces (20-year return period); and — Permafrost regions.

3.9 Managing Uncertainty

Decisions ultimately depend on the amount of uncertainty standards writers and users are willing to accept, and the nature of the eventual consequences. There are several decision-making strategies that can help manage and communicate uncertainty when using climate information. Environment and Climate Change Canada (2018) outlines several strategies (below) for working with uncertainty in climate change, which will depend on the risk tolerance of the decision-maker once risks have been assessed at an appropriate level of detail.

— **Strategy to mitigate high risks:** Include treatment of all high risks, even where uncertainty is high. This means considering all emission scenarios and extremes across multi-model ensemble projections. This strategy comes at a higher cost.

— **Strategy to avoid under-adaptation:** This strategy considers planning to protect against climate impacts as the number one priority.

— **Strategy to avoid over-adaptation:** Balance the need to manage climate risks and impacts against the cost of adaptive actions.

— **No regrets strategy:** Weigh the advantages and disadvantages of all possible options, including the option to do nothing.

There are many strategies that standards writers can use to work with uncertain climate-design parameters. The following list can help standards writers manage uncertainty in the standard development process:

— **Understand the main sources of uncertainty** and the time horizons for which their influence is most significant throughout the design life of the infrastructure, product, service or test (see Section 3.8).

— **Use model ensembles** as opposed to individual models to minimize uncertainty and bias from singular models.

— **Observe the full range (i.e., mean, low and high percentiles) of future climate projections** to help summarize the full range of potential results from ensemble model outputs.

— **Be aware of the trade offs** of using downscaled, localized data (see Section 3.8.1).

— **Engage climate change experts:** Climate change experts can help standards writers understand, manage and communicate uncertainty associated with climate models, scenarios, natural climate variability, and complex climate variables (see Section 4).

— **Document the sources of uncertainty:** This includes being explicit on different dimensions of uncertainties, e.g., clearly stating uncertainties within climate projections, divergence of expert opinions, and confidence in data sources (ISO 14091:2021). Standards writers should also identify avenues of how to reduce the uncertainty during the cycle leading to the update of the standard.

— **Use a risk management approach:** Using risk-based principles to consider climate information in standards allows for uncertainties to be acknowledged and incorporated into the decision-making process (ISO Guide 84:2020). Standards developers are encouraged to select the appropriate risk treatment options and safety factors based on an analysis of uncertainty.

— **Assess impacts and risks:** Conduct a sensitivity and/or risk assessment during standard development to determine how climate change may impact the infrastructure, product, service or test, and how uncertainty factors into risk (See ***Guide for Integrating Climate Change Adaptation Considerations into Canadian Standards***).

— **Conduct quality control on climate information:** Organizations can provide quality control inspections for climate and weather data. Quality control protocols can involve automatic algorithms and human interventions that align closely with best practices from international organizations such as WMO, Météo-France and Oklahoma University (Charron, 2016). These methods assure that the entire supply-chain of climate information is reliable.

— **Plan for adaptive design:** Standards can guide engineers and standards users to plan for adaptive design throughout the design life of the infrastructure, product, service or test as conditions change and more information becomes available (Charron, 2016).

— **Identify operational strategies to reduce residual risks:** Residual risks (such as those caused by uncertainty) can be managed through operations (Charron, 2016). Operational requirements may be appropriate for inclusion in the standard in some cases.

3.9.1 Moving Forward Despite Uncertainty

Extensive validation work has been carried out by the IPCC and other climate science organizations to ensure that the outputs of climate model ensembles are sufficiently accurate to be relied upon for activities such as standard development, government policy and planning, etc. This includes applying the ensembles to the evolution of the climate in the past, for which actual data is available to compare to the model outputs.

It is important to focus on information that is available, as opposed to what is not available. Uncertainty should not prevent the use of climate information in standard development. Instead, standards writers are encouraged to assess the data through a risk-based lens, consult with a qualified professionals, invoke professional judgment, and document decisions made (Standards Council of Canada and Manifest Climate, 2021).

3.10 Section Summary

— Climate change is driven by natural variability (internal variability and external forcings) in addition to human-caused drivers such as fossil fuel combustion and land use change. Natural variability may lead to outcomes that were different from those projected by models.

— General Circulation Models represent the physical processes and interactions between the atmosphere, ocean, cryosphere, and land surface and can simulate the response of the climate system to human-caused emissions. Multi-model ensembles are recommended to reduce uncertainty and biases from single model outputs.

— Climate change scenarios (or emissions scenarios) are modelled simulations considering various socio-economic factors and are a simplified and plausible representation of future GHG emissions and associated climate conditions. In other words, scenarios represent greenhouse gas concentration trajectories, all of which are considered possible depending on future societal choices.

— Climatic changes are presented as differences between the climate (mean, variability, extremes) during the recent past, referred to as the reference or baseline period, and climate in a given future time horizon (e.g., 2050-2080). Historical data are usually based on observed inter-year variability, while future projections are modelled. Climate variability requires that the length of the reference and future periods should be long enough (20 to 30 years) to allow clear climate change trends to emerge.

— Climate variables (or climate parameters) are used to describe an aspect of weather, climate, or related geophysical property. Climate projections are the outputs of climate models and provide predictions of climate variables for a specific climate scenario and time horizon.

— Traditional Knowledge can be used to inform standard development and Traditional Knowledge holders can share perspectives on climate change that are missed by climate modelling and weather station data.

— The IPCC is now in its sixth assessment cycle and has produced the Sixth Assessment Report (AR6) which includes up-to-date modelling from the Coupled Model Intercomparison Project Phase 6 (CMIP6), which is a multi model ensemble for the changing climate system. Climate scenarios used with CMIP6 include new forcing levels called Shared Socioeconomic Pathways (SSPs). CMIP6 data are now being included in common climate data sources and will eventually replace RCPs.

— Uncertainties can result from natural climate variability, the choice of emission scenarios and the inter-model spread, data availability, stakeholder input, and how the infrastructure or product is used, operated and maintained.

— Addressing climate change will always involve making decisions in the face of uncertainty and uncertainty should not prevent the use of climate information in standard development. Strategies to manage uncertainty include selecting a climate model ensemble, observing the full range of climate projection data, documenting sources of uncertainty, using a risk management approach, and planning for adaptive design.

4

Engaging Experts

This section identifies the types of expertise that can support standards writers in the use of climate information, and provides examples of situations when expert input should be sought. This section also identifies key touchpoints to engage qualified professionals and mechanisms that can be used for engagement.

4.1 Types of Expertise for Standard Development

Climate change is a large and rapidly evolving professional field that includes a wide range of expertise. Early in the standard development process, standards writers should identify the types of expertise needed to consider climate change throughout the whole standard development process – from determining the applicability of climate change to the standard, to gathering and analyzing future climate information, to applying climate information to develop or update a standard. Climate services may need to be contracted at various points throughout the standard development process, so needs and potential costs should be identified as early as possible.

Experts should be engaged if standards writers identify the need for a particular subject matter expertise which none of its members have. For example:

— When standards writers require education on the future climate conditions to assess the potential impacts on the subject of the standard.

— When standards writers are unsure about what time horizon, emissions scenarios or climate variables are relevant to the standard.

— To assist with interpretation of future climate projections for application to a new standard or standard update.

— When a specific climate variable or future climate data are not available, or when future climate projections for a complex climate variable is needed.

— When standard writers are unsure how to prioritize or reduce climate risk associated with the standard.

4.2 Key Considerations for Engagement

The following recommendations can help standards writers incorporate climate change perspectives and expertise into the standard development process.

— Depending on the standard, it may be appropriate to include a climate science, climate risk, and climate resilience expert(s) on the technical committees or working group for the standard. A distinct climate change working group may be needed in cases where climate information is prevalent in the standard development process.

— For specific and extensive support with climate data and/or integrating climate information into the standard, it is recommended to retain a professional climate service provider.

— As early as possible, identify the scope and timing that climate change expertise may be needed throughout the standard development or update (will depend on the standard). Plan to engage relevant climate experts at the beginning of the standard development process. Engaging experts after a standard has been developed or updated can lead to rework, especially if important climate considerations have been missed.

— Ensure that experts with appropriate authority and experience are engaged, including relevant geographical context (for example, experts in Northern climatic changes and infrastructure).

— A climate expert may not be familiar with the standard development process. Outline the expectations of experts early on in the process regarding the consensus decision-making environment. It is important communicate how the input from a climate expert can help in the standard development process.

— When identifying relevant and significant climate change issues, standards writers should be aware of and, where possible, incorporate perspectives and develop consensus from a variety of regions and different countries as needed.

— Traditional Knowledge should be incorporated into the standard development process when possible.

— Establish a common language among experts and technical committee members. Different words can have different meanings between disciplines (e.g., risk, mitigation, conservative approach, climatic load, etc.), and therefore its important that everyone begins the process with a shared understanding of key terms.

— The practice of integrating climate change into standards is still quite new. Multiple methodologies exist and will depend on the nature of the standard. It is important that all participants in the standard development process encourage experts to work together, collaborate and share information, and understand that there may be no right way, simply different ways, to arrive at a plausible answer.

4.3 How to Identify Experts

The standard development committee can issue a call of expressions of interest or proposals from the technical community targeted (e.g., climate scientists in academia, NGOs, private sector, etc.). The list below is intentionally general and can serve as a starting place to identify experts to engage in the standard development process.

— Standards Council of Canada and subgroups, such as the Northern Infrastructure Standardization Initiative.

— National and international accredited standards writers.

— Engineers and Geoscientists Associations.

— National organizations specializing in climate science such as Environment and Climate Change Canada, Canadian Centre for Climate Services, National Research Council Canada, and Natural Resources Canada.

— National and/or regional climate data providers such as the Prairie Climate Centre, Ouranos, Climate West, Pacific Climate Impacts Consortium, CLIMAtlantic, etc.

— Academic institutions with recognized faculty in the subject matter.

— Private sector companies such as engineering firms and climate data providers.

— Traditional Knowledge holders.

— Indigenous engineering groups and climate change practitioner networks.

— Non-profit organizations with expertise in climate adaptation, stakeholder engagement, etc.

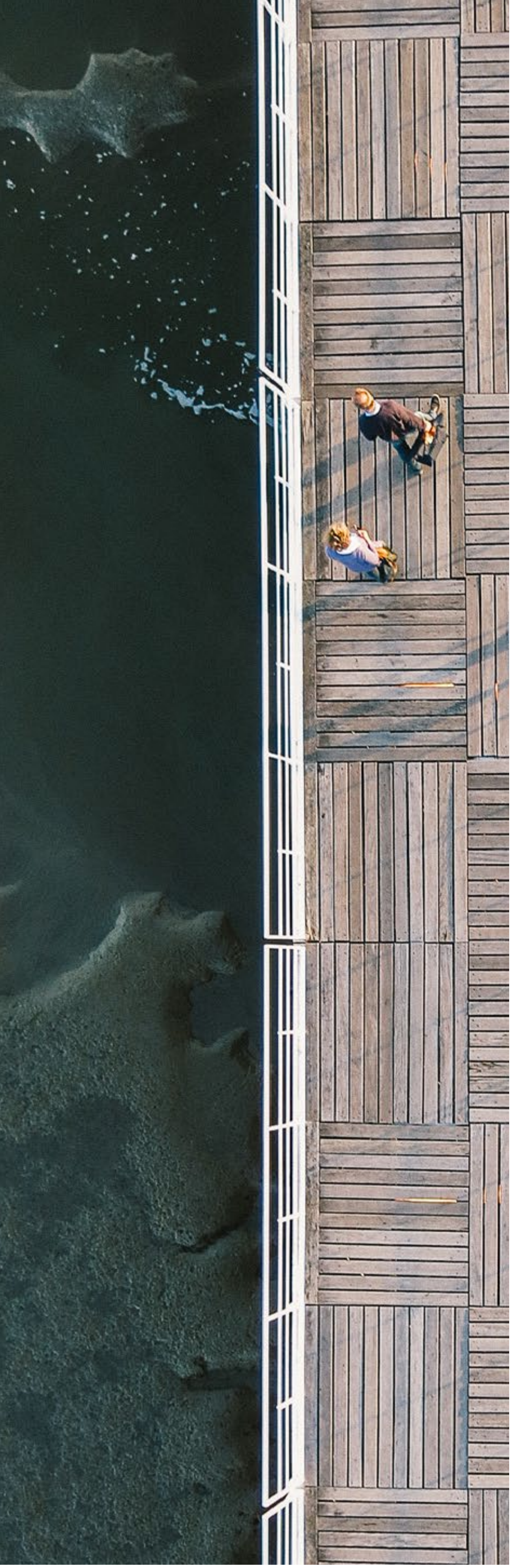
The standard development committee can then review the expertise of those that have expressed interest and select one or more experts. Depending on the composition (industry representation) of the committee, these experts may be non-voting members of the committee.

Table 5 summarizes various types of expertise that may be valuable throughout the standard development process and potential avenues for engagement.

Table 5: Types of expertise for standard development

Stage of Standard Development	Expertise Needed	Method of Engagement
Throughout the entire standard development process	— Individuals who have supported the process of integrating climate change into codes, standards and related instruments in the past (e.g., stakeholders from other standard development organizations or technical committees) who can share lessons learned from other initiatives. — Climate science specialists (climatologists), and/or sector specialists with knowledge of climate risk and resilience measures for the infrastructure, product, service or test within the scope of the standard can participate on technical committees or working groups.	— The standard development committee can invite experienced practitioners and experts to participate in technical committees, working groups, or to inform the standard scoping process.
Work planning and standard scoping (Stage 10 – Proposal Stage for National Standards of Canada)	— Climate science specialists, climate risk experts and/or sector specialists with knowledge of climate resilience can help standards development committees confirm the scope and timing of needs for expertise throughout the standard development process. They can also help inform the scope of work to retain climate services (e.g., climate science) if needed.	— The standards development committee should consider having a climate expert(s) provide input on the standard development plan for when climate expertise would be beneficial. — Plan to include climate science, climate risk, and climate resilience professionals in technical committees and/or working groups, through invitation or by issuing a request for expressions of interest. — If climate change will be a significant component of the standard, consider establishing a climate change working group.
Determining the applicability of climate change to the standard (Stage 20 – Drafting Stage for National Standards of Canada)	— Sector specialists or practitioners working on climate change and infrastructure/environment (dependent on the scope of the standard) can determine how climate change may impact the infrastructure, product, service or test throughout its service life. — Climate risk experts and experts in the scope of the standard (e.g., engineers) can collaborate to determine risk tolerance applicable to the standard.	— Climate risk experts should be included in working groups and/or technical committees. — Ensure opportunities for collaboration between climate experts and subject matter experts for the standard. — Clarify key terms to ensure consistency across different sector specialists.
Gathering and interpreting climate data (Assuming climate change has been deemed relevant to the standard in the previous step) (Stage 30 – Committee Development Stage for National Standards of Canada)	— Climate science specialists should be engaged to confirm selection of model ensembles, emissions scenarios, climate variables, and relevant variables and regions applicable to the scope of the standard (especially for longer life products >50 years). — Climate data providers or climate science specialists can help gather and analyze historical and future data from multiple sources (e.g., expert in permafrost, drought modelling, etc.). — Traditional Knowledge holders can provide recent and historical knowledge of local changes in climate conditions.	— Submit requests to climate data providers (e.g., PCIC, Climatedata.ca, etc.) or retain qualified professionals to provide climate data via contract. — Conduct direct engagement with Traditional Knowledge holders by including them in technical committees or working groups, or by doing additional outreach (with support from engagement experts to ensure respectful and meaningful engagement).

Stage of Standard Development	Expertise Needed	Method of Engagement
Assessing and prioritizing climate risks to the standard (Stage 30 – Committee Development Stage for National Standards of Canada)	— Climate risk experts can apply climate risk management frameworks (such as ISO 14091:2021) to identify and prioritize unacceptable climate risks to the infrastructure, product, service or test in the scope of the standard.	— Climate risk experts should be included in working groups and technical committees. — Third party climate risk experts may need to be retained to complete the risk assessment depending on the scope of the standard and risk tolerance (e.g., if a detailed assessment is needed).
Creating or updating climate change requirements (e.g., climatic loads or design values) for the standard (Stage 30 – Committee Development Stage for National Standards of Canada)	— Climate science specialists can use future projections to help determine changes to climatic loads, climatic effects, design or performance values to address unacceptable risks. Input from experts in the scope of the standard is needed to ensure unacceptable risks can be addressed. — In addition to changes in specific values for a standard, the climate science, risk and resilience experts can help identify solutions and associated costs, operations and maintenance measures, materials and design changes that may be required to address climate risks to the subject of the standard. — Traditional Knowledge holders can share strategies to reduce climate risks and increase resilience through the standard. — It is important that climate expertise is reflective of the geographic scope of the standard (e.g., ensure specific Northern expertise is included if relevant), the range of potential climate risks and impacts, and to incorporate Traditional Knowledge.	— holders, and subject matter experts on technical committees and working Retain climate scientists and professional engineers for updates to specific climatic loads, effects, or to inform new design values. — Climate resilience measures for the standard should be co-developed in collaboration with climate experts, Traditional Knowledge groups. — Additional input can be gathered from experts through an advisory role (i.e., non-voting members). — Ensure working groups and technical committees have adequate Northern representation for standards addressing Northern assets, products, services or tests.
Including climate resilience measures or climate information in the standard (Stage 30 – Committee Development Stage for National Standards of Canada)	— Collaboration with experts in the scope of the standard is important in this stage to ensure that risk management measures are suitable for the scope of the standard and designed for future climate. — Public sector representatives can share knowledge and experiences developing policy, guidelines or requirements related to the subject of the standard (e.g., a municipal engineer who has developed local drainage guidelines using future IDF data, federal agencies working on integrating climate information into codes). — Climate science specialists should provide input on when climate information for the standard must be reviewed and updated.	— Climate science specialists and resilience professionals on technical committees and working groups should help develop the content of the standard, or sector experts can be engaged through an advisory role (i.e., non-voting members). — Climate science specialists (contracted or serving on technical committees) should advise on timelines for the update of climate information or other information included in the standard
Standard is reviewed and approved (Stage 50 – Committee Approval Stage for National Standards of Canada)	— Climate science, risk and resilience professionals should review the content of the standard to ensure climate information is accurately represented and documented in a transparent, accessible manner. — Climate science specialists can respond to questions or comments related to climate information.	— Climate science specialists and resilience professionals on technical committees should participate in the review and approval process.
Standard review (Stage 90 – Review Stage for National Standards of Canada)	— Climate science and risk experts should be re-engaged for standard review to ensure that updated climate information is appropriately used.	— Retain climate experts for updates to future projections or design values as needed. — Include climate science specialists and resilience professionals on technical committees and working groups.



4.4 Section Summary

- Experts from various backgrounds and industries can provide valuable insight, and include Traditional Knowledge holders, climatologists, climate risk specialists, climate change engineers, risk management practitioners, individuals with experience using climate information in standards, and policy experts.
- Climate science specialists, risk management and climate resilience experts, and Traditional Knowledge holders should be engaged if and when the standard development committee identifies the need for a particular type of expertise that none of its members have.
- Experts should be identified and engaged at the beginning of the standard development or update process and needs for climate services should be included in the scope and budget of the standard development.
- Qualified professionals should be engaged through a contract to answer specific questions, conduct an analysis, or produce other material for the technical committee to consider.
- Climate scientists and risk experts should participate on technical committees and working groups, or a climate change committee should be created when climate change is highly relevant to the standard.
- Ensure representation from a wide range of perspectives including those geographically relevant to the scope of the standard (e.g., experts on permafrost for standards dealing with northern built infrastructure).
- Familiarize climate experts with the standard development decision-making process.
- Establish a common set of terms and definitions among experts and technical committee/working group members, as many terms have different interpretations and could lead to confusion.
- Provide meaningful and respectful opportunities to build trust and relationships with Traditional Knowledge holders who are engaging in the standard development process.

5

Using Climate Information in Standards

This section provides guidance on gathering climate data, selecting appropriate scenarios and variables for a standard, and interpreting climate information in the context of the standard. The second half of this section covers various approaches for applying climate information to manage risks and adapt to climate change within a standard. Guidance on documenting processes and determining timelines for standard revisions is also provided.

There are multiple approaches for considering climate information in the standard development process. The approach and the climate information used will vary depending on several factors, including:

- The type of standard
- The impact of future climate changes on the subject of the standard
- The service life of the subject of the standard
- The risk tolerance of the standard's writers and standard's users
- The geographic scale at which the standard will be applied (local, regional, national, etc.)
- The availability of climate information

Research and consultation will be needed early on in the standard development or revision process to determine the most suitable approach for the subject of the standard. For example, standards writers should be aware of best practices for the inclusion of climate information into design criteria, which typically starts through discussions with experts and committees.

More information on engaging climate experts in the standard development process can be found in Section 4.

5.1 Guiding Principles

The principles below apply to the process of considering climate change in standard development or updates to existing standards.

- Addressing climate change in standards is an **iterative** exercise and must reflect new changes and trends as they develop (ISO 84:2020).
- **Engage climate science experts where needed.** Climate science specialists and climate risk experts should be engaged early in the standards development process to help identify and analyze the appropriate climate information for the standard and help manage uncertainty related to climate data.
- Climate change information should include future time horizons and scenarios that are **relevant and contextual** to the design life of the infrastructure, product, service, or test in the standard.
- Standards writers should apply **a risk management approach** when considering climate change in the standard development process.
- Considering climate change in standard development should include analysis **of future impacts of climate change on the product, as well as measures to adapt** and make the product more resilient to climate change risks.

- Standards writers should apply **future climate information** to performance-driven factors where appropriate.
- Climate information in standards should be **adaptable by users in different locations and throughout the lifespan of the standard**, therefore, specific values are not always appropriate in standards.
- Climate information and how it was used, including sources of uncertainty, should be **transparent and clearly documented**.

5.2 Determining the Applicability of Climate Change to the Standard

An important first step is determining whether the infrastructure, product, service or test in the standard is sensitive to climate change. Standards writers should conduct a sensitivity screening to consider degree to which the infrastructure, product, service, or test within the scope of the standard may be adversely affected by climate change. If climate change is deemed relevant to the standard, standards writers should continue on to the subsequent sections of this Guide. Guidance to determine the applicability of climate change to the standard can be found in Section 4 of the ***Guide for Integrating Climate Change Adaptation Considerations into Standards***.

Section 4 of the ***Guide for Integrating Climate Change Adaptation Considerations into Standards***, as well as ***ISO Guide 84:2020*** and ***CEN-CENELEC Guide 32 (2016)*** include guidance on determining the applicability and sensitivity of a standard to climatic changes and impacts.

As part of its Standards in Action campaign, the Standards Council of Canada published a high-level decision-making system for assessing climate sensitivity of existing standards and new standards. More can be found in the report ***Standards in Action: Building a Climate-Resilient Future (2021)***.

5.2.1 Acceptable Level of Risk

To determine how climate information is used in standard development, standards writers need to determine an **acceptable level of risk** (or risk tolerance). Some standards have specifically defined risk tolerance thresholds and therefore the impact of climate would be assessed against these thresholds. In other cases, the risk thresholds may be less defined. Risk tolerance can depend on factors such as expected level of service, health and safety, regulatory requirements, contractual requirements, financial impacts, or recovery from emergency events.

Risk tolerance must inform the analysis of climate information. Standards writers may observe climate variables or extremes that would cause unacceptable risk for a product or standard and incorporate measures to avoid unacceptable risk into the standard.

ISO Guide 84:2020, ISO 31000:2018 and ***ISO 14091:2021*** provide guiding questions to establish risk tolerance.

5.3 Gathering Climate Information for Standards

Once climate change has been deemed materially relevant to the standard, standards writers must identify climate information needs and begin the data gathering process. The following steps can guide standards developers in identifying, accessing, and using climate information in standards development or updates. These steps should occur at the beginning of the standard development process. It is advised to work with climate science specialists to gather the appropriate climate information and to increase knowledge transfer between standards development and climate change communities.

5.3.1 Historical Climate and Weather-Related Impacts

Historical research will help standards writers understand how past conditions may have impacted the infrastructure, product, service, or test for which the standard is being developed or revised. Background research will also help identify which climate variables and impacts should be considered in the standard development process, and the time periods over which they need to be measured. Consult historical climate data (using sources such as Environment and Climate Change Canada's National Climate Data and Information Archive) as well as records of past impacts related to severe weather and climate conditions. Environment and Climate Change Canada's Canadian Climate Normals include station data for several variables over a 30-year period and can be used to put extreme events into context.

Document historical and recent impacts linked to climate or weather, such as physical damages, loss of capacity to provide service, reduction in useful life of the product or other disruptions. Consider the effects of extremes such as hot days, extreme cold, strong winds, heavy precipitation, dry periods, and storm events. If there is data from events that caused damage to the infrastructure or product, it may be possible to investigate how often an event of that magnitude (or greater) may occur in the future under climate change.

EXAMPLE

When developing or updating a standard related to pavement, standards writers could consider historical climate data such as change in mean temperature and precipitation, changes in temperature and precipitation extremes, number of cold days, number of hot days, changes in the frequency of freeze-thaw cycles, and severe storms events. Past climate and weather-related impacts could include changes in the rate of deterioration (could increase or decrease depending on geography and frequency of freeze-thaw cycles), damage such as cracking or potholes, pavement softening and rutting, thermal expansion, and stresses, impacts on pavement construction practices, etc.

Canada's Changing Climate Report (2019) provides a scientific assessment of historical trends and projected future changes for Canada's surface temperature, precipitation, and cryosphere.

The background review should be supplemented by engagement with stakeholders familiar with the infrastructure or product at each stage of its service life (design, production, operations, etc.) to gather information on potential climate interactions and adaptation measures that have not been formally documented. These stakeholders can provide useful local knowledge and practical understanding of the type of product being standardized and how it may be affected by the changing climate. Traditional Knowledge should be included where possible as it is a vital tool for highlighting the experience of climate change of decades and centuries.

5.4 Selecting Climate Models

Future climate information should be based on multi-model ensembles. Selecting the appropriate ensemble will depend on the context of the standard. Standards writers may not need to select an ensemble themselves if using established data providers such as Climatedata.ca, which only offers data from model ensembles. If selecting an ensemble, standards writers should consider the types of climate variables they need. For example, if temperature projections are needed for the standard development process, the Global Climate Models likely provide the best basis for an ensemble. If extreme weather events are of concern, ensemble results that include information on extremes should be chosen (Standards Council of Canada and Manifest, 2021). If localized data for variables such as wind or extreme precipitation are needed, downscaled models may be more appropriate. It is important to recall that downscaling means there will be trade-offs and uncertainty. Climate science experts should be engaged for needs related to downscaling.

Since 2020, Environment and Climate Change Canada has completed extensive research into projected impacts of climate change on infrastructure design values. Results of the study are informing updates to the National Building Code of Canada and Canadian Highway and Bridge Design Code. To complete the study, CMIP5 GCMs were used. Regional data were calculated using a large ensemble of Canadian Regional Climate Models based on CanRCM4–LE simulations. Climate model data used in this project are available on the Government of Canada Open Data Portal and described in Section 2.4 of ***An Assessment of the Impact of Climate Change on Climatic Design Data in Canada (2020).***

Standards writers should clearly document the model ensemble that was used, which is available on the climate data provider's website (if using). Key information such as model selection may not need to be included within the standard itself, but should be documented in a transparent and accessible way, such as in a supplemental report that accompanies the standard. For updates to standards, reference documents may be included in the commentary of the proposed clauses.

5.5 Selecting a Time Horizon

Standards writers should confirm the baseline (reference period) representing a recent historical timeline. Many climate science providers offer baseline data for either 1976-2005, 1981-2010 or 1986-2016. The future time horizon should be selected based on the expected service life of the infrastructure, product, test, or service within the scope of the standard. For example, if the product or asset has a 50-year service life, future projections should span at least 50 years in the future. Even for products with shorter service lives (e.g., 15-year), it is imperative to observe climate projections in reference periods of 20-30 years to improve confidence in model outputs. Observing a single year or shorter time period can lead to less accurate results due to inter-year variabilities. Much like model selection, it is important to document the time horizon that was selected.

EXAMPLE

For a standard related to a mechanical pump where the service life is around 15-20 years, standards writers working on a new standard in the year 2023 could apply a baseline of 1976-2005, 1981-2010 or 1986-2016 and observe future projections for the period of 2025-2050.

5.6 Selecting Climate Scenario(s)

Scenario selection should not be applied uniformly across standards. Expertise from the standard development body and climate experts will likely be needed. Scenario selection will determine just how much global warming is expected in the future and may affect the climatic loads or design values used in the standard.

To determine which scenario(s) to select for standard development, standards writers should first consider:

- The service life of the infrastructure or product
- Risk tolerance
- Objectives of the standard (e.g., protection of life, property)
- Consequences of failure
- Cost efficiency

Projections for more than one future scenario should be observed whenever possible. Looking at multiple scenarios allows for a better understanding of how different emissions trajectories may affect the climate and subsequently the infrastructure, product, service, or test in the standard. Decision makers needing a more in-depth analysis for high-risk projects may require the help of climate specialists to obtain the most appropriate data (CSA Plus 4011:2019).

5.6.1 Risk Management Approaches to Scenario Selection

The following section aims to support scenario selection for standard development. The recommendations are not prescriptive, as scenario selection will depend significantly on the standard and risk tolerance of standard developers and users:

- When possible, a high emissions scenario is recommended to inform standard development. Selecting a scenario that produces the highest risks is important so that risks can be addressed through adaptation within the standard. Higher emissions scenarios lead to more conservative assumptions about future climate, therefore having other implications on cost and the level of requirements included in a standard (CSA Plus 4011:2019). Standards writers may choose to conduct a sensitivity screening and/or risk assessment to determine where conservative approaches are needed, based on risk tolerance.
- If the service life is short (< 50 years), one future scenario may be selected for use in standard development and/or required within the standard. RCP8.5 is recommended when working with a 50-year (or shorter) time horizon, because the differences between forcing scenarios is small until the middle of the century.
- If the service life is 75-years or longer, selecting an appropriate scenario is more complex and at least two scenarios should be examined (Infrastructure Canada Climate Lens, 2019). There are significant differences in scenarios in the latter half of the century (e.g., peak and decline in RCP4.5 compared to continued increase in RCP8.5). For example, the Canadian Electrical Association recommends observing projections for RCP4.5 and RCP8.5 for electrical standards, since climate impacts may be more pronounced at different times from each scenario. Projections from two scenarios can be compared over the specified time horizon, and the scenario producing the highest risks is recommended to be carried forward through the standard development or update process.
- A risk management approach for long-life products would be to use RCP8.5 for effects that are projected to increase (e.g., temperature, precipitation), and current climatic design data for loads that are projected to decrease (such as snow), acknowledging that this could lead to more expensive designs (Cannon et al., 2020). This approach attempts to avoid risk associated with the underestimation of effects in the future.
- A compromise approach (for increasing effects) is to apply design data appropriate for a 50-year time horizon under the RCP8.5 scenario (meaning the design data would reflect +2.5°C mean global warming, occurring in 2069) (Cannon et al., 2020). The design could be expected to perform well at least to the end of this century under lower emissions scenarios, such as RCP6.0, in which average global warming is not projected to exceed 2.5°C this century. If using this compromise approach, standards writers and users should consider whether the product or asset can be effectively adapted to future changes in effect, as a means to reduce the risk that future effects might be greater than projected under RCP6.0.

There may be cases where the nature of the standard does not warrant prescribing a particular scenario. In such cases, it is still pertinent to require a minimum scenario(s) to consider. Standards writers can require a minimum scenario(s) but leave final scenario selection up to the standard user based on design life, target reliability, risk tolerance and geography, meaning users can choose to be more conservative if they desire. Such an approach should be verified by experts who can assess the potential implications of users applying different scenarios when using the standard. If the use of different scenarios by users can result in variations of, for example, useful life, or risks to users of the product, then the standards development committee should be explicit about which scenarios to use.

The choice of scenario(s) should be documented for the standard because practitioners using the standard may be required to find and use the corresponding data. Regardless of scenario selection, the standard should state that the choice of scenario will have to be revised based on new knowledge (actual global emissions, new and improved models, etc.) consistent with the work of the IPCC.

EXAMPLE

For standards related to northern infrastructure built on permafrost, a high emissions scenario (such as RCP8.5) should be observed, at a minimum, to screen for high risks to the asset which may need to be addressed in a standard or through climate resilient design strategies. Permafrost foundations can be high-risk due to warming temperatures, permafrost thaw, and uncertainties about past and future changes caused by limited availability of data. When working with permafrost-related assets or products, standards writers should consider a high emissions scenario as the rate of change impacts permafrost degradation, and there is a risk of maladaptation if future conditions are underestimated. ***CSA Plus 4011:2019 Technical Guide: Infrastructure in permafrost: A guideline for climate change adaptation*** provides a process for assessing the impacts of future climate projections and adaptation for infrastructure on permafrost.

SCENARIO SELECTION FOR 2025 UPDATES TO THE NATIONAL BUILDING CODE OF CANADA (NBCC) AND THE CANADIAN HIGHWAY BRIDGE DESIGN CODE (CHBDC)

The Climate Change Working Group supporting the NBCC update have recommended the use of RCP8.5 and a 50-year time horizon to inform the update of climatic design values. Projections for RCP8.5 generate a mean global temperature increase of +2.5°C over a 50-year time horizon. RCP4.6 and RCP6.0 were ruled out to because the differences between the scenarios were insignificant significant over the 50-year time horizon.

The Climate Change Working Group supporting the CHDBC update recommended the adoption of RCP6.0 and an extended 75-year design life to apply future climatic conditions to the CHBDC. RCP6.0 was selected based on the group consensus informed by professional judgement of design engineers, climate resilience experts and climate scientists and after observing projections for multiple scenarios provided by Environment and Climate Change Canada. The committee determined that designing for RCP6.0 can allow designers to prepare for the impacts of increased global temperatures and high risks over the 75-year design life, while minimizing trade-offs such as costs associated with over-conservative estimates.

Under RCP6.0, the mean global temperature is expected to increase by +2.0°C by 2087 from a baseline of 1986-2016. The code will recommend that designers shall consider the design life of the components impacted by the environment and the design shall function for the projected range of conditions it will be subject to throughout the life of the structure or component, compared to designing for the worst case scenario. For example, for variables that are projected to increase, the projected future value associated with RCP6.0 would be adopted. For values that are projected to decrease in the future, the conservative approach of using the current value would be applied. RCP6.0 will be prescribed as a minimum basis for quantitative and qualitative climate-related design provisions, but code and standards users may choose to consider RCP8.5.

The approach for obtaining temperature, precipitation and wind change projections for sites in Canada that are consistent with RCP6.0 (or any other scenario) is discussed in the ***Guide on Future Climatic Data for Structural Design of Highway Bridges (2021).***

5.7 Selecting Climate Variables

The variables selected and any frequency/intensity thresholds will depend on the type of standard, relevant geographical area(s) and the risk tolerance. For products with known performance standards or design values, it is recommended to observe a range of averages and extremes (the full distribution of the modelled projections) to account for potential climate impacts and to determine if future climatic loads are changing, approaching or exceeding current thresholds. Depending on risk tolerance, effects may need to be updated based on future climate projections. However, where effects are expected to diminish as a result of climate change, some effect values may continue to be based on historical data as a conservative measure.

It will also be important to identify potential new climatic loads, effects or hazards that may emerge during the design life of the product (e.g., earlier thaw, permafrost thaw, etc.). If thresholds or performance values can be set (depending on the product), these new provisions should be included in the standard.

It is crucial to remember that climate variables and data ranges have varying levels of uncertainty that must be understood and documented when using climate information in standards. For example, precipitation has higher internal variability relative to temperature. As a result, precipitation projections are generally said to have medium confidence, with notably lower confidence at regional scales.

More information on tiers of confidence for different climate variables can be found in Section 3.8.2.

5.7.1 Average trends

Design loads within standards and codes are typically based on extreme values, as opposed to averages. Mean values should not be used to estimate extremes. However, average trends can help inform standards in terms of future operating conditions or the general expectation of what the future climate may be. Climate experts can analyze annual trends in specified thresholds (e.g., number of days at, above or below X°C per year) by averaging daily or sub-daily values over a given time period.

5.7.2 Extremes

Climate extremes are crucial for standards writers to understand future risks to design and performance of infrastructure, products and services. An extreme event is described by the IPCC as “the occurrence of a value of a weather or climate variable above (or below) a threshold value near the upper (or lower) ends of the range of observed values of the variable” (2018). Extremes are typically defined in terms of thresholds, percentiles, or return periods relative to a historical period of 30 years or longer. The definition of an extreme value is not precise or uniform, and depends on the event, location, impact, and the context of the standard (Seneviratne et al., 2012).

Extremes can be observed by examining the high and low percentiles of datasets (typically of daily or sub-daily datasets) or by changes in intensity, duration, and frequency of defined events. Extreme value modelling such as the generalized extreme value distribution (GEV) or Gumbel distribution methods are often used to model the probability of extreme events such as annual maximum one-day rainfalls and river discharges (Fontolan et al., 2019).

- Design temperatures are often based on the top and bottom ranges of temperatures. For example, the top 1% and 2.5% of temperatures in the warmest month of the year (July) are used in the National Building Code of Canada.
- Precipitation extremes can be expressed as the probability of annual occurrence (i.e., 1-percent annual exceedance probability [AEP]), otherwise known as a return period (i.e., 100-year flood event). Standards writers can determine the required return period of events in the future and calculate how that threshold relevant to the standard may change with climate projections.

Where the impacts of an asset or product failure are significant, a risk management approach would be to choose the 90th percentile of future climate projections to inform the standard. This approach is consistent with addressing the criticality of the infrastructure, product or service within a system or in the supply chain.

If the standard requires specific design values for explicit extreme events, it is recommended to engage qualified professionals to support a detailed analysis for given regions and different types/levels of extremes, including daily, sub-daily, and sub-hourly events, and different return periods.

5.7.3 Intensity, Duration and Frequency

Intensity-duration-frequency (IDF) projections can help standards writers understand how extreme events may evolve in the future. For example, a 1-hour, 1 in 100-year rainfall event that occurs in the 2080s is likely to have more intense rainfall (mm/h) than it did in the 1980s. The probability or return period of extreme events is also expected to evolve as extreme events become more frequent. For example, the rainfall intensity (mm/h) of a historical 1 in 100-year rainfall may increase in probability such that they are considered 1 in 70-year events in the future.

Return periods have the advantage of being easily understood by those less familiar with climate science. The caveat is that return periods can be mistakenly interpreted literally, for instance, "a 1 in 100-year event occurred this year so it will not happen again for another 99 years," which is not necessarily true as the probability represents any given year. For example, the probability of a 1:100 event occurring at least once in a 30-year period is 26%.

To observe changes in the IDF of rainfall events, standards writers can observe how the intensity (mm/h) changes for an event of a given return period (e.g., 50-year return period) and duration (e.g., 24-hour). The event for which future projections are observed should be selected based on existing guidance, design, or code. If there is no existing guidance or codes applicable to the standard, a climate science specialist will be needed to determine what variables and magnitude of extremes should be observed for the standard. If including requirements for standards users to observe future IDF projections, standards writers must provide guidance on what event should be considered. For example, directing standards users to investigate how the intensity of precipitation will change for a 24-hour event with a 1:50-year return period.

5.7.4 Annual Exceedance Probability (AEP)

An alternative way to communicate changes in extremes is through Annual Exceedance Probability (AEP). AEP is the percent chance of a hazard of a given magnitude or severity occurring or being exceeded in any given year. AEP is based on the average frequency that has been estimated, measured, or extrapolated from records over a large number of years, and is expressed as a fraction of one. For example, a 0.2 AEP flood has a 20% chance of occurring in any given year, which corresponds to a 5-year recurrence-interval flood (adapted from Murphy et al, 2020). AEP has become more frequently used for variables such as wind, and in updates to national codes such as the CHBDC.

5.7.5 Confidence in Extreme Projections

Climate models can underestimate extremes. Confidence is higher in projections that are aggregated to produce longer-term averages of monthly, seasonal, and annual conditions. As a result, projected future extremes produced by global or regional climate models should not be interpreted literally at a point location. Daily and sub-daily values should not also be used on their own as discrete design values, but rather can inform design.

As extremes may be underestimated, standards writers are encouraged to consider risk tolerance and apply conservative measures when incorporating future extremes into standards (e.g., design for exceedance). For example, 5-minute duration precipitation projections have low confidence, and therefore the approach to using these as design criteria must account for uncertainty. To manage uncertainty associated with future precipitation extremes, temperature scaling is sometimes recommended, where the relative change (%) in precipitation extremes is expressed as a function of warming. This approach is more appropriate for 24-hour events compared to sub-daily events. For example, ***CSA PLUS 4013:2019 Technical Guide on the Development, Interpretation and use of Rainfall Intensity-Duration-Frequency (IDF) Information: Guideline for Canadian Water Resources Practitioners*** directs users to apply a 7% increase in intensity-duration-frequency (IDF) curves for precipitation per degree of warming. A climate science specialist should be consulted for scaling methods and approaches.

EXAMPLE

If updating precipitation extremes for an existing standard, the committee should start by identifying existing performance or design thresholds relevant to the standard, and any extreme values used in previous versions of the standard, or in related. For example, 24-hour rainfall (50-year return period) and 15-minute rainfall (10-year return period) were observed for the updates to design values for the National Building Code of Canada and may serve as the basis for analysis. For cases where standards writers are unsure of the types of extreme events to study, it is recommended to engage both climate experts and subject matter experts on the scope of the standard (e.g., engineers) to determine the appropriate extreme values.

The projections must be observed for a specific location relevant to the standard, and due to uncertainty in projections, results must not translate literally to design values nor be applied for a large geographic area due to potential differences in micro-climates within a downscaled grid square. The time horizon and emission scenario should be selected based on the service life of the infrastructure or product (e.g., for an asset with a 50-year design life, projections to at least the 2070s should be observed and a high emission scenario is recommended). The projections may be available in existing peer-reviewed studies or through climate data providers such as ClimateData.ca, or professional climate services may be needed to compute modelled projections of extremes.

Standards writers can then observe how extreme event intensities evolve over the asset/product life cycle, and how the probability of extreme events changes over the time horizon. If standards writers need to know the probability that an event will meet or exceed a specific threshold over a given time period, exceedance probability should be calculated. If future projections for differ from historical or current values, new performance or design values are likely warranted within the standard.

To manage uncertainty of extreme precipitation projections, an alternative is to ‘scale’ future extreme values based on future temperature increases (a variable with much higher certainty). The scaled extreme value can then be tested against existing design values. To update design values for the NBCC, climate scientists applied a technique for scaling extreme 24-hour and 15-minute rain design data by 7% per degree of local annual mean temperature increase (Cannon et al., 2020). This scaling metric may also be called a ‘climate factor.’ A climate science specialist should be consulted for the use of a climate factor.

5.7.6 Complex Climate Variables

Depending on the standard, standards writers will likely need to understand how complex climate variables will evolve in the future. Complex climate variables are those that are difficult to model and/or obtain sufficient data for in certain regions, such as humidity, wind speed, freezing rain, snow melt, ice accretion, and drought, among others. These variables also tend to have low confidence and can also be entangled with other variables. For example, the thickness of ice is affected by several variables such as surface wind speed and air temperature and is hard to estimate due to spatial variations in projected load changes. For standards involving wind, snow and ice loads, maximum values are crucial so that products or assets are designed to withstand those loads. These variables are included in the NBCC and CHBDC.

Climate variables may also be needed as inputs to other types of scientific analysis or modelling, such as the use of future temperature and precipitation projections within hydrological modelling for standards related to flooding or coastal infrastructure. Climate expert input is required for updating climatic load values or modelling to account for the influence of climate change, or adapting values to a regional context.

Key considerations to help standards writers approach using complex variables include:

- Consult with climate science specialists for support with selection, data gathering and application of complex climate variables.
- Projections for complex climate variables typically have low confidence and may not be provided in publicly available climate modelled projections, thus requiring special more in-depth studies.
- Due to model uncertainty, downscaled and/or regional projections for complex climate variables should not be used as literal representations of future conditions in a given place or time.
- Standards writers may consult, if relevant to the subject of the standard, other standards where complex climate data is provided. For example, in updates to the NBCC and CHBDC, technical teams consulted the 2015 NBCC and compared common locations to those in the current CHBDC, to determine whether any future projections for climate variables, such as wind, may be transferrable.
- In some cases, a scaling approach may be used, applying a percent (%) increase per degree of mean local annual temperature.

EXAMPLE

Transportation hydraulic engineers must now account for climate change within hydrologic and hydraulic (H&H) and coastal design practices. There are a range of approaches for incorporating climate projection in hydrologic analyses. For example, future climate projections should be applied to peak flows to inform the design of drainage infrastructure. Future timing and magnitude of sea level rise is also an important consideration for coastal infrastructure.

The hydrological and hydraulic community has been exploring methods to integrate climate change information into their practice and manage the trade-offs of overestimating future flows and sea level rise (increased costs) with the risks of underestimating future climate impacts (increased flooding impacts on surrounding land and structures). ***The Coastal Flood Risk Assessment Guidelines*** (Murphy et al., 2020) provides a framework and methodology for conducting coastal flood hazard and risk assessments to inform the design and rehabilitation of buildings and infrastructure in areas potentially exposed to coastal flood hazards. It also includes recommendations for establishing design criteria for buildings and infrastructure to address coastal flood risk. This resource can be used by standards writers working with standards that include hydrological data.

5.8 Interpreting Climate Information in Relation to the Standard

Standards writers should consider consulting with climate experts to ensure that interpretations of climate information to be used in the standards development process reasonably reflect the most current scientific consensus, and that said information is applied in an appropriate fashion (Standards Council of Canada and Manifest Climate, 2021). The list below provides an overview of trends and observations that standards writers should look for when interpreting future climate information.

— **Note the direction of change:** Different variables and loads may change in different directions (increase or decrease). For example, the period during which snow loads impact a structure are projected to decrease under all future warming scenarios.

— **Observe general trends:** When observing mean projections, trends will likely become apparent for many regions in Canada, such as increasing precipitation in winter or rising annual temperatures. General trends can inform standards writers in defining the relevant climate variables to include in the standard.

— **Observe changes from historic climatic loads relevant to the standard:** If future projections differ from historical or current values, new performance loads will likely need to be developed or updated for the standard.

— **Consider potential new climatic loads, effects or hazards that were not previously considered:** Standards writers should have first identified any existing performance or design thresholds relevant to the standard. The known performance limits of a product, infrastructure, service, or test should be used to identify and define climatic loads where failure may occur.

— **Observe regional variations in climate change:** The nature of climate change will vary not only with time, but also across the different climate regions within Canada. Developers of new or revised standards should consider the impact of any divergence in future climate change across Canadian regions on the infrastructure, product, test, or service within the scope of the standard over its life cycle.

— **Note changes in extremes:** Note how extremes are changing in the future, and whether extremes are becoming more frequent or intense within the service life of the infrastructure, product, service or test. Consider both the change in return period of a given extreme and the intensity of events with different return periods. If future projections for climatic loads differ from historical or current values, new performance or design values are likely warranted within the standard.

— **Be aware of uncertainty:** Keep in mind any uncertainty within the data, and how the sources of uncertainty change over time. For example, some climate variables have lower confidence than others. If climate information has been downscaled to a local scale, it will be important to confirm bias correction.

5.9 Managing Data Gaps

In some cases, it may not have been possible to collect all the future climate information relevant to the standard. Some complex variables have limited data. Data can also be available at a global or national scale, but not applicable or available at regional or local scales.

The following considerations can be used to address climate information gaps.

— Proxy data can be used in some cases where projections for particular climate hazards or variables are not available. For example, climate variables such as mean temperature and precipitation, number of dry days and consecutive dry days, climate moisture index, and evapotranspiration can be used as indicators to help predict future drought conditions. It is important to document the uncertainty and level of confidence of the data, and which indicators have been used as proxy for a particular type of climate data. Climate experts should be engaged to identify potential proxy data.

— Where climate model projections were not available, conduct a search of peer-reviewed literature on the variables or trends of interest. For example, data may not be available on wind projections, but scientific studies and reports may include findings from climate modelling studies undertaken by academics and researchers. Examples of journals with climate information include Nature Climate Change, Journal of Climate, Geophysical Research Letters, and others.

— Not all data gaps can be filled or need to be filled. Always document gaps in climate data and how they were addressed. A risk assessment can help identify gaps that will have the greatest influence on the infrastructure, product, system, or test within the scope of the standard.

— In cases where climate data gaps are inhibiting the standard development process, consult a climate expert, or a national or regional climate data provider that is familiar with available climate projections. For example, when the standards development team requires a precise number for a climate variable that there is not publicly available data for.

5.10 Prioritizing Risks to the Subject of the Standard

If climate impacts have been identified as relevant to the subject of the standard, standards writers are encouraged to complete a qualitative or quantitative risk assessment. The level of detail of the risk assessment will depend on the type of standard (e.g., if it is focused on managing a particular climate risk, a risk assessment would be prudent); risk tolerance (e.g., if risk tolerance is low, a more detailed risk analysis may be needed); and the magnitude of potential climate impacts that have been identified as material or highly relevant. By completing the risk assessment, standards writers can ideally identify a small number (2-4) of relevant climatic risks, ensuring that the efforts spent to address them are proportionate to the severity of the risk and to the scope of the standard. The ***Guide on Integrating Adaptation Considerations into Canadian Standards (2021)*** provides guidance on how to determine which climate risks are most important for the purpose of the standard.

Further guidance on assessing and prioritizing risks can be found in Section 5 of the ***Guide on Integrating Adaptation Considerations into Canadian Standards (2021)***.

ISO 14091:2021 also provides guidance for conducting climate risk assessments.

The risk assessment process should engage experts in both climate change and the subject of the standard. Impacts of climate change at all stages of the product-, service- or testing-life cycle should be considered. ***ISO 14091:2021 Adaptation to climate change — Guidelines on vulnerability, impacts and risk assessment*** can be used as general guidance for completing a risk assessment and provides further guidance on climate impacts on various stages of product life cycles.

5.11 Approaches for Including Climate Information in Standards

This section describes various ways climate change information may be incorporated into standards. The extent and nature of climate information in the standard will vary. The recommendations are general and may apply to any type of standard (e.g., objective-based, performance-based) where climate change has been determined relevant. In many cases, standards writers can draw on elements of the following approaches:

— **Include relevant climate information for design/performance:** Designers prefer to use performance or design values. Where relevant, standards writers should provide climatic loads informed by future climate information. Standards developers may provide guidance to avoid under- or over-design for future climatic loads.

— **Consider a risk-based approach:** Using a risk-based approach to include climate information in standards is considered a good practice by international and national standard development organizations (and in alignment with existing guidance including CEN-CENELEC Guide 32 (2016), ISO Guide 84:2020). Climate risks to the subject of the standard should be identified and unacceptable risks should be flagged. Standards should identify a minimum guaranteed performance level, standard of care, etc., such that standard users may apply a risk-based approach, based on their own organizational risk tolerance.

— **Apply the precautionary principle:** When there are major uncertainties in climate information or risk levels (such as from poorly known outcomes or uncertain likelihood of occurrence), the precautionary principle states that the lack of certainty should not be a reason to delay the implementation of cost-effective measures to mitigate the risks (ISO Guide 84:2020).

— **Identify no- or low- regrets options:** Consider ways to reduce climate risks that yield benefits even in the absence of climate change, and where the costs are appropriate with respect to the potential consequences of the risk. Identify proactive measures such as monitoring, labelling or maintenance measures that can be easily integrated into the standard (e.g., without modifying the design of a product).

— **Allow for adaptive management:** Where reasonable (i.e., when not required to avoid an unacceptable risk) allow for flexibility so that adjustments can be made later in the service life of the product. Adaptative management can be incorporated in the standard to deal with uncertainties related to the impacts of future climate on the product or service.

5.11.1 Updating or Incorporating Climate Change Requirements Within the Standard

Standards writers are advised to include design or performance requirements in standards when potential climate risks are found to be unacceptable or when climate change resilience is an objective. Requirements are generally included if there are performance or design thresholds that may be exceeded due to future climate conditions, and/or if severe or unacceptable risks have been identified through a risk assessment process.

There are various approaches to updating or establishing requirements for standards. Approaches have been drawn from literature review, other existing guidance, and through consultation with climate change professionals and standards writers. Recommended approaches to set climate requirements for standards include:

— Annual Exceedance Probability can be used to set (or update) performance or design values for the standard. Describe the probability of occurrence of extremes that may surpass any known thresholds.

— Provisions to design for exceedance (i.e., Design for 'X') may be incorporated into the standard (CEN-CLC Guide 32:2016). The standard may require users to establish the sensitivity of the infrastructure, product or component against 'X+'. Some municipal standards require "stress tests" for systems, e.g., design load + 20%, in order to identify risks and weak links.

— When there is high uncertainty around future projections for extremes, a scaling approach or 'climate factor' could be applied (i.e., X% increase in intensity per each degree of warming) and can be tested against existing design values.

— Consider where the standard will be applied and if climate information or adaptation needs will differ depending on the region. If needed, include provisions to consider the regional context or provide important information for standard users to tailor the data for regional contexts.

— The standard could include the requirement for labelling that indicates thresholds relevant for use and end of life phase impacts (CEN-CLC Guide 32:2016).

— The standard may include statements that design modifications may be required, dependent on the type of infrastructure, product, service, or test.

— Include 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 projected future climate-induced 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)" (CEN-CLC Guide 32:2016).

— Requirements may be included for monitoring, operations and maintenance, particularly for standards where the product/service is projected to be affected by climate-related events.

There are also several approaches that standards writers can use to reduce climate risks through the standard, that do not require specified thresholds within the standard itself:

— Select a target reliability index or level of safety for design parameters that the standard needs to meet over the life of the product or infrastructure.

— Identify the potential risks if the product performs below design capacity and develop provisions to design for degraded performance.

— Standards users can be directed to consider criticality so that project level decisions can be made on how to address climate risks.

— In some cases, future climate conditions may change so as to **increase** the safety margin of the conventional infrastructure, test or service within the scope of the standard. Projected future performance improvements should be acknowledged by standards developers.

— There may not be a need to drastically modify the design of the product, but it may be necessary to require different manufacturing materials, or operations and maintenance practices in the future. Determine changes to future requirements by adjusting the test values in the standard.

EXAMPLE

A risk management approach based on asset criticality can sometimes be recommended in a standard. For example, a forest service bridge may have a higher probability of failure under lower Annual Exceedance Probability floods than an urban bridge linking a community to a hospital without alternative routes. However, due to its criticality, the bridge to the hospital may be designed using more conservative climate information (e.g., for lowest probability, highest impact extreme rainfall or using a higher emissions scenario). Standards writers and users are not advised to use this approach without clear direction on criticality and climate risk, provided qualified professionals.

5.11.2 Documenting Climate Information within the Standard

Regardless of the approach used to update or develop climate-related requirements, standards must be clear in how climate information has been applied. The standard should:

— Clearly define all terms used to describe climate information in a glossary. Of particular importance are terms that have different definitions for different areas of practice (such as terms used differently by climate scientists, hydrologists, engineers, etc.).

— If climate information is provided directly in the standard (such as in tables), reference the baseline and time horizon(s), climate scenario(s) and relevant geographic location(s).

— Clearly state the regional applicability of the climate information.

— Clearly identify any performance or design thresholds relative to the product, and where climate variables approach or exceed the threshold in the time horizon and scenario.

— Include clear statements on when climate information and results included in the standard need to be updated.

For standards that are applied at large scales with varying climatic conditions, the standard may include regional results. If regional data are provided, or provisions to use regional climate projections are recommended, the implications for uncertainty in projections should be documented (keeping in mind that regional data tend to have lower confidence than global or national scale model outputs).

5.11.3 Revising and Updating Standards

Standards writers must develop timeline for revision of the standard to account for the evolving nature of climate change information, associated impacts, and adaptation measures, and to reflect the expected life cycle of the product.

Clearly state if and when design or performance thresholds need to be reviewed against updated climate projections. If updates are expected to be completed by standards writers or users, expert input and/or additional guidance will be needed.

ISO Guide 84:2020 provides examples for climate change adaptation provisions at every stage of the product lifecycle.

Depending on the scope of standard, it may be necessary to identify adaptation measures for each stage of the life cycle of the product. If there are other standards related to other stages of the product life cycle or aspects of its use, include statements to consider climate impacts and adaptation measures in the use and update of those relevant standards.

5.11.4 Documenting the Approach

If climate information has been analyzed as part of the standard development or update process, it should be documented in a report that is referenced in the standard. Such a report or informative annex is important to document the full details of the future climate analysis, methods, results, limitations, and data sources. For updates to standards, references may also be included in the commentary of the proposed clauses. The report or annex (as well as a summary) should be readily available for standards users, standards writers and for future updates to the standard.

The report may include:

— The methodology used to apply climate information to the standard, including variables, time horizons, scenarios and climate model ensemble.

— Sources of climate data, levels of confidence and associated uncertainties.

— Description of approach to determine updated performance or design values.

— Clear statements on when climate information and results included in the standard need to be updated.

— The risk tolerance that was applied in in order to develop the requirements in the standard, and any risk assessment methods that were used.

— Summary of the impacts of climate change on the infrastructure, test, or service within the scope of the standard in terms of likelihood, significance and consequence, including reference to unacceptable risk levels or thresholds if relevant.

— Commentary on cascading risks (impact chains) that could occur if recommendations are ignored, particularly those that could cause long-term implications to public safety and/or the environment.

— Definitions of all terms used to describe climate information in a glossary.

5.11.5 Supporting Standards Users in Applying Climate Information

It may not be possible or appropriate to include the full extent of climate information in the standard. This may be the case if specific regional, local or site information is needed, but was not available during the development or update of the standard. The standard may also include key timelines or scenarios where updated climate information is required.

In such cases, standards writers may need to include requirements for standards users to apply future climate change information at the project level. However, relying on standards users to apply complex climate information can be risky and lead to misinterpretation and misuse of climate information (particularly where there is no guidance or accepted practice on how to analyze and use such information), and is discouraged. If performance standards have been set but require updates or regional application, the standard user will need the help of climate change experts. Include provisions relating to professional standards or codes of conduct where necessary to ensure the proper steps are taken to appropriately use climate information.

5.11.6 Using an Informative Annex to Provide Climate Change Information with Standards

Climate-related performance or risk management requirements will not always be needed within a standard, such as when risk tolerance is high or if climate impacts were not found to be significant for the product. In other cases, uncertainty may be too high to include prescriptive climate information directly in the standard.

A supplemental document (or informative annex) could be developed to provide standards writers and users with information about the impact of climate change on the product, infrastructure, service, or test within the standard, as well as potential adaptation measures, without being prescriptive in the standard itself. The document should educate readers on the current state of knowledge, highlighting sources of uncertainty and future areas for study. This strategy is useful particularly where performance values are not applicable, or if the full extent of impacts on the product require further study. Standards users and organizations involved in updating the standard can then refer to the document, updating as more information becomes available. The document may even serve as a seed document, which evolves into a standard or technical guide at a later date as knowledge of the topic improves.

Standards writers should consider the following contents for an informative annex:

- Commentary on relevant climate conditions that may impact the infrastructure, product, service or test within the scope of the standard, focusing on the most relevant climate variables and time horizons for the design life.
- Potential risk management or adaptation measures that can reduce risks to the product, infrastructure, test, or service within the scope of the standard.
- Findings from a literature review and/or stakeholder engagement on climate change as it relates to the infrastructure, product, service or test within the scope of the standard.
- Discussion of methods, advice or rules that have been applied in other standards. Include examples or case studies that illustrate how climate change considerations were applied in the past in standards for equivalent products, infrastructure, tests, or services (these would have been collected by the standards developers during the climate impacts analysis).
- Provide guidance to the user on the possible impacts of climate change, and plans to review climatic load values and other requirements in the standard at a later date.

CASE STUDY: INCORPORATING CLIMATE CHANGE INFORMATION TO STANDARDS ON THERMAL COMFORTABLE PLAYGROUNDS

There is an ongoing need to review, update and develop standards to include considerations for the changing climate. In many cases, research and engagement are needed to support standards writers in understanding the impacts of climate change on a product and identifying appropriate measures to adapt. In such cases, an **informative annex** can be submitted to standards writers to support the integration of climate change into a particular standard.

In 2019, the Standards Council of Canada commissioned the National Program for Playground Safety to study how to integrate thermal comfort in the context of climate change into standards for children's playspaces and equipment.

A needs assessment was completed to support recommendations for the update to the CSA Children's playgrounds and equipment standard (CAN/CSA Z614). Then, a literature review and survey were completed, focusing on climate change and extreme heat, children's health and safety, and heat adaptation in urban areas and playgrounds. The results identified several potential risks to children using playgrounds during heat – including thermal burns, heat illness, and sun damage (Kennedy, Olsen, and Vanos, 2020). The literature review and survey occurred over a two-month timeline.

Researchers identified best practices in the design of thermally comfortable playgrounds to account for heat and sun-related risks that may increase due to climate change. Recommendations included passive cooling techniques, addition of green spaces, widening of tree canopies, and planning the orientation of playground equipment to receive less solar radiation (Kennedy, Olsen, and Vanos, 2020). Additional recommendations further work on improving thermal comfort and adapting to climate change in outdoor playspaces were developed, leveraging feedback from the survey. The recommendations were not directly included in the annex but included in the project report as areas for future study.

An informational annex was created for the CSA Group to consider including in the next revision of the CSA Children's playgrounds and equipment standard (CAN/CSA Z614). The informational thermal comfort annex included a summary of design and management practices (for the design stage of the products) that influence thermal comfort in playground areas (Kennedy, Olsen, and Vanos, 2020). At the beginning of May 2019, the draft Annex and report materials were shared with the CSA technical committee responsible for the Z614 standard, for their consideration as they were in the process of updating the standard during this period. The preparation of the annex and report took approximately one month. The 2020 edition of CSA Z614 included an informative annex on thermal comfort, and the project report prepared by the National Program for Playground Safety was published in 2020 by SCC.

5.12 Section Summary

- The approach for including climate change in a standard will depend on many factors including the type of standard and the duration of the cycle leading to its update, relevant climate impacts, risk tolerance, geographic scale and availability of climate information.
- Standards writers should consider a **risk management approach** when considering climate change in the standard development process. Risk tolerance must be established for scope of the standard, considering factors such as expected level of service, health and safety, regulatory requirements, contractual requirements, financial impacts, or recovery from emergency events.
- Standards writers should apply **future climate information** to performance-driven factors where appropriate. To gather climate information for inclusion in the standard development process, standards writers are recommended to:
  - Research historical and recent impacts caused by climate or weather, such as physical damages, loss of capacity to provide service, reduction in useful life of the product or other disruptions.
  - Observe climate projections from a multi-model ensemble.
  - Select a future time horizon based on the life cycle of the subject of the standard. Historical and future reference increments of 20-30 years is recommended.
  - Select a climate scenario(s) depending on the life cycle of the product and the risk tolerance. One scenario may be used for shorter life cycle products (< 50 years). A high emission scenario is recommended to take a risk management approach. For longer life cycle products (> 75 years), projections for two scenarios are needed, and the scenario yielding the highest climate impacts should be selected for use in the standard (if taking a risk management approach).
  - Observe future projections for a range of climate variables (looking at both averages and extreme values) to estimate potential impacts on the product, and to assess whether future climatic loads are changing, approaching or exceeding current thresholds. It will also be important to identify potential new climatic loads, effects or hazards that may emerge during the design life of the product.
- Standards writers are encouraged to complete a qualitative or quantitative risk assessment when climate impacts have been identified as relevant to the subject of the standard.
- Standards writers should consider relevant impacts of climate change at all stages of the product-, service- or testing-life cycle.
- Approaches for including climate information in standards can include:
  - Establishing or updating performance or design requirements based on future climate information.
  - Incorporating risk mitigation and/or climate resilience options for various life cycle stages.
  - Stating requirements and timelines for updating future climate projections.
  - If climate information cannot be included in the standard, an informative annex could be created to document existing climate information, sources of uncertainty, potential climate risks and adaptation measures, and areas for future study.
- Standards must state when climate information or information within the standard should be updated to account for the evolving nature of climate change and the global understanding of climate science.
- Standards writers must document the methodology used to apply climate information to the standard in a report that is referenced in the standard. The report should include the time horizon(s), model ensemble and climate scenarios used, key variables, regional applicability of the data, and unacceptable climate risks and/or thresholds.

6

Checklist

This checklist summarizes key recommendations for using climate change information in the standard development process. This checklist assumes that climate change has been deemed relevant to the scope of the standard and that climate information will be included in the standard development process. Refer to the ***Guide for Integrating Climate Change Adaptation Considerations into Canadian Standards*** to determine relevance of climate change to the standard.

Table 6: Checklist

Standard development stage	Corresponding Step from the Guide for Integrating Climate Change Adaptation Considerations into Canadian Standards (p. 26-27)	Guidance	Resources
Identifying the need to develop or update a standard Stage 00 – Preliminary Stage for National Standards of Canada	Step 1 – Assess Relevance	— Determine if/how climate change is relevant to the infrastructure, product, service or test within the standard.	Section 4 of ***Guide for Integrating Climate Change Adaptation***
Work planning and standard scoping Stage 10 – Proposal Stage for National Standards of Canada	Step 1 – Assess Relevance	— Establish risk tolerance (e.g., what is an unacceptable risk) and objectives related to the standard (e.g., protect life safety) — Consider when climate change expertise may be needed throughout the standard development or update process (e.g., determining applicability of climate change to the standard, using complex climate variables, selecting scenarios for products with long service lives).	ISO Guide 84:2020, ISO 14090:2021

Standard development stage	Corresponding Step from the Guide for Integrating Climate Change Adaptation Considerations into Canadian Standards (p. 26-27)	Guidance	Resources
Formation of Working Group, Technical Committees and/or contracting qualified professionals Stage 10 – Proposal Stage for National Standards of Canada	Step 2 – Seek Expertise	— Issue a call for expressions of interest to a diverse roster of experts who understand climate change in the applicable regions, climate adaptation for the scope of the standard, and/or hold specialized expertise relevant to elements of the standard, including Traditional Knowledge. — Include climate scientists (climatologists), climate risk and climate resilience experts in the technical committees and/or working groups for the standard. If climate change will be a significant component of the standard, consider establishing a climate change working group. — Provide meaningful and respectful opportunities to build trust and relationships with Traditional Knowledge holders who are engaging in the standard development process. — Establish clear understanding of expectations, key terms, and decision-making processes (e.g., consensus-based) with all experts.	Section 4 of this document
Research Stage 20 – Drafting Stage for National Standards of Canada	Step 3 - Gather Information	— Determine the sensitivity of the product, infrastructure, service or test to climate change impacts through consultation with experts and practitioners, including Traditional Knowledge holders. — Gather historical data and identify previous climate impacts (and associated extremes) that have affected the product, infrastructure, service or test. — Select climate model ensemble, engaging climate science experts for needs related to downscaled projections. — Select future time horizons of at least 30-year periods, reflecting the service life of the product, infrastructure, service or test. — Select climate scenario(s) based on the applicable risk tolerance and service life. Ensure multiple scenarios are considered and a risk management approach (high emission scenario) has been applied where possible. — Select relevant climate variables and observe future trends and extremes for the geographic region(s) applicable to the standard. Include observation of the full range of modelled outputs including extremes.	Section 5.2 Section 5.3 Section 5.4 Section 5.5 Section 5.6 Section 5.7
Interpreting climate information Stage 30 – Committee Development Stage for National Standards of Canada	Step 4 – Interpret Information	— Check design values, performance requirements and maximum climatic loads against future climate projections to determine whether they need to be updated or if new climatic loads or effects need to be added to the standard. — Identify unacceptable risks or exceedance of existing performance or design values (if relevant). — Consider potential new loads, climate effects or hazards. — Observe regional variations in climate change. — Note changes in the frequency and intensity of extremes. — Maintain awareness of the sources of uncertainty and how they change over future time horizons.	Section 5.8 Section 3.9

Standard development stage	Corresponding Step from the Guide for Integrating Climate Change Adaptation Considerations into Canadian Standards (p. 26-27)	Guidance	Resources
Assessing climate impacts and risks relevant to the standard Stage 30 – Committee Development Stage for National Standards of Canada	Step 5-8 – Assess Significance, Risks, Understand Life cycle, Examine Climate	— Conduct a risk assessment to determine the priority risks for consideration in the standard. — Identify potential impacts to the infrastructure, product, service or test throughout its life cycle.	Sections 5.2-5.4 of ***Guide for Integrating Climate Change Adaptation Considerations into Canadian Standards***
Updating or incorporating climate change requirements for a standard Stage 30 – Committee Development Stage for National Standards of Canada	Step 9 - Integrate Adaptation	— Design or performance values should be updated if there are thresholds that may be exceeded due to future climate conditions, and/or if severe or unacceptable risks have been identified through a risk assessment process. — Adaptation and resilience measures (such as updated design, safety factors, changes to materials, labelling, provisions for operations and maintenance, etc.) are incorporated into the standard where appropriate. — If appropriate for the standard, performance/service requirements and/or adaptation measures are recommended for future time horizons within the service life. — Determine timing of updates to climate information relevant to the standard.	Section 5.11.1
Standard is drafted Stage 30 – Committee Development Stage for National Standards of Canada	Step 9 - Integrate Adaptation Step 10 – Develop Timeline	— Include updated climatic design values or loads with clear direction for standard users on any necessary checks or regional applicability. — Clearly identify any performance or design thresholds relative to the product, and where climate variables approach or exceed the threshold in the time horizon and scenario (e.g., if adaptive design is needed later in the design life due to scenario selection). — Clearly define key climate-related terms in the standard. — If climate information is provided directly in the standard (such as in tables), reference the time horizon(s) and emissions scenario(s) and relevant geographic location(s). — Clearly state the regional applicability of the climate information, or if standard users must apply regional data. — Document sources of uncertainty and include measures to manage risk associated with uncertainty in the standard. — State that future climate projections and scenarios must be revised based on new knowledge (actual global emissions, new and improved models, etc.) consistent with the work of the Intergovernmental Panel on Climate Change.	Section 5.11.2 Section 3.9 Section 5.11.3

Standard development stage	Corresponding Step from the Guide for Integrating Climate Change Adaptation Considerations into Canadian Standards (p. 26-27)	Guidance	Resources
Supporting technical guidance or informational annexes Stage 30 – Committee Development Stage for National Standards of Canada		— Further information on the climate change analysis, method, limitations, and detailed results can be documented in a supporting report. The standard should reference the report and provide access to a summary for standard users. — For cases where climate information cannot be included in a standard, document any findings from the climate change analysis, including potential climate risks or impacts and adaptation measures that may be further explored in the future. — Identify areas for additional study or opportunities to update other standards or technical documents.	Section 5.11.4-5.11.5
Committee reviews the draft standard for approval Stages 50 and 55 – Committee Approval and Ratification Stages for National Standards of Canada		— Confirm that reviewers understand how and why climate information was included in the standard, so that it is not removed in the review process.	
Publication of standard Stage 60 – Publication Stage for National Standards of Canada		— Share with the standards community how climate change was included in the standard, as there is appetite for more resources and use cases.	
Standard is reviewed and updated Stage 90 – Review Stage for National Standards of Canada		— Follow timelines in the standard for required updates of climate information. — Follow steps above to seek input from qualified professionals and ensure updated climate information is incorporated into the standard. — Document changes to the standard that have resulted from updated climate information or new knowledge.	Section 5.11.3 Section 4

7

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 (Bush and Lemmen, 2019).
Adaptive management	Process of iteratively planning, implementing, and modifying strategies for managing resources in the face of uncertainty and change. Adaptive management involves adjusting approaches in response to observations of their effects and changes in the system brought on by resulting feedback effects and other variables (ISO 14090:2019).
Annual Exceedance Probability (AEP)	The percent probability of a hazard of a given magnitude or severity occurring or being exceeded in any 12-month (365-day) period. Often, AEP represents the probability that a given rainfall total accumulated over a given duration will be exceeded in any one year.
Annual precipitation	Total accumulated precipitation over a 12-month (365-day) period.
Anthropogenic	Resulting from or produced by human activity (Government of Canada, 2008).
Baseline (or reference)	The baseline (or reference period) is the state against which change is measured. A baseline period is the period relative to which anomalies are computed (IPCC, 2018).
Climatology	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 (Government of Canada, 2019).
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 (IPCC, 2018). Climate change occurs due to natural internal processes or external forcing factors, and due to persistent anthropogenic changes in the composition of the atmosphere or in land use.
Climate information	Refers to climatic data that describe either past conditions, obtained from meteorological observations (stations, satellites, radars), or the future, obtained from the outputs of climate models (ClimateData.ca, n.d.).

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) 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 (Government of Canada, 2008). 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 climate normals for some locations based on a minimum of 15 years of data (Government of Canada, 2016). Climate normals for some elements are derived from less than 30 years of record but can still be considered useful.
Climate parameters	A specific set of weather conditions or climate trends deemed to be relevant to the elements at risk under consideration. The parameter may be a single variable, such as mean monthly temperature, or a combination of variables, such as wind combined with rainfall.
Climate projections	Portions of a climate model simulation that forecast the future (Roy, Fournier, and Huard, 2017).
Climate resilience	The capacity of a community, business, or natural environment to anticipate, prevent, withstand, respond to, recover from a climate change related disruption or impact, and prepare for future similar or more intense changes (Infrastructure Canada, 2019).
Climate risk	The risk that the changing climate may impose negative consequences on society including natural ecosystems, the built environment, human health and well-being, business and the economy (also refer to the definition of Risk) (Standards Council of Canada and Manifest Climate, 2021).
Climate scenario	A plausible representation of the future development of emissions of substances that are radiatively active (e.g., greenhouse gases (GHGs), aerosols) based on an internally consistent set of assumptions about driving forces (such as demographic and socio-economic development, technological change, energy, and land use) and their key relationships. Concentration scenarios, derived from emission scenarios, are often used as input to a climate model to compute climate projections (IPCC, 2018).
Climate simulations	End-product of climate models; the results produced by solving a climate model's equations for a certain time period (Roy, Fournier, and Huard, 2017).
Climatic load	The effects on an exposed product, service, built or natural asset, 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 (Standards Council of Canada and Manifest Climate, 2021).
Climate variability	Climate variability refers to variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate on all spatial and temporal scales beyond that of individual weather events. Variability may be due to natural internal processes within the climate system (internal variability), or to variations in natural or anthropogenic external forcing (external variability) (IPCC, 2018).
Climate variable	A variable that can be measured directly in the field (at meteorological stations for example) or that is calculated by climate models (ClimateData.ca., n.d.).
CMIP5	Coupled Model Intercomparison Project, Phase 5. A coordinated climate modeling exercise involving 20 climate-modeling groups from around the world. The output from CMIP5 ensemble experiments is used to inform international climate assessment reports, such as those from the IPCC (ClimateData.ca., n.d.).

Confidence	The robustness of a finding based on the type, quantity, quality, and consistency of evidence (e.g., mechanistic understanding, theory, data, models, expert judgment) and on the degree of agreement across multiple lines of evidence (IPCC, 2018).
Cooling degree-day	Measure of the quantity of cooling required in a year. In Canada, 18°C is considered the temperature above which cooling is required to maintain comfort inside buildings. Daily cooling degree-days are the number of °C a given day's mean temperature is above 18°C. For example, if the mean daily temperature is 22°C, the cooling degree-day value is 4°C. Annual cooling degree-days are the sum of daily cooling degree-days (PCC, 2019a).
Design load	The total load on a system for the most severe combination of loads and forces which it is designed to sustain.
Downscaling	A procedure in which information known at large resolutions is used to make predictions at finer resolutions, such as regional or local scales (Roy, Fournier, and Huard, 2017). Two different approaches are statistical downscaling and dynamical downscaling.
Element at risk	Built or natural assets and their components, products, activities (such as operations and maintenance, testing), services or people that can be impacted (positively or negatively) by meteorological events.
Emissions scenario	See climate scenario.
Ensemble	A set of simulations encompassing multiple global or regional climate models, and/or simulations from the same model (Roy, Fournier, and Huard, 2017).
Exposure	The presence of people; livelihoods; species or ecosystems; environmental functions, services, and resources; infrastructure; or economic, social, or cultural assets in places and settings that could be adversely affected by meteorological events and climate change (IPCC, 2018).
Extreme (weather) event	An event that is rare at a particular place and time of year. 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.
Freeze-thaw cycle	Count of days where maximum temperature is above 0 C and the minimum temperature is below 0 C. Under these conditions, it is likely that some water at the surface was both liquid and solid at some point during the day (PCC, 2019a).
General circulation model (GCM)	A complex mathematical representation of the major climate system components (atmosphere, land surface, ocean, and sea ice), and their interactions (GFDL). Also referred to as Global Climate Models.
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 (H2O), carbon dioxide (CO2), nitrous oxide (N2O), methane (CH4) and ozone (O3) 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 (Government of Canada, 2008).
Hazard	The potential occurrence of a natural or human-induced physical event or trend, or physical impact, that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, and environmental resources (IPCC, 2018).

Heating degree-day	Measure of the quantity of heating required in a year. In Canada, 18°C is considered the temperature below which heating is required to maintain comfort inside buildings. Daily heating degree-days are the number of °C a given day's mean temperature is below 18°C. For example, if the mean daily temperature is 10 C, the heating degree-day value is 8 C. Annual heating degree-days are the sum of daily heating degree-days (PCC, 2019a).
Heat wave	Extended period of extreme heat. A heat wave is usually defined as a period of three or more consecutive days with maximum daytime temperatures above 30°C (PCC, 2019a). The temperature range that defines a heat wave may vary by region and can include the night-time temperatures.
Historical data	Data collected by weather stations available near a specific location during a certain past period.
Impact	The effects of climate-related physical events or trends on natural and human systems (ISO 14090:2019).
Intensity-duration-frequency (IDF) curve	Intensity-Duration-Frequency curves relate short-duration rainfall intensity with its frequency of occurrence and are often used for flood forecasting and urban drainage design (ClimateData.ca., n.d.).
Inter-model spread	The range of future projections resulting from different climate models.
Interaction	The interface between weather events and/or climate trends and elements at risk or their components. When an element at risk experiences a weather event and/or climate trend it may respond positively or negatively. This interrelationship between the element at risk and the weather event and/or climate trend may cause an infrastructure response (ICLR and CRI).
Natural climate variability	Natural variability can be caused by internal, semi-cyclical phenomena such as El Niño and North Atlantic Oscillation ("internal variability"), or external forcing such as volcanic activity and changes to solar output (Climatedata.ca, n.d.). Natural variability is distinct from variability from human-caused external forcing (e.g., emissions). Both result in changes to the earth's average temperature and may lead to outcomes that are different than those projected by climate models.
National Standard of Canada	A National Standard of Canada is recognized as the official Canadian standard in a particular subject area or topic, approved by the Standards Council of Canada.
Mitigation	In the context of climate change, mitigation is often defined as a human intervention to reduce the sources or enhance the sinks of greenhouse gas emissions. Risk mitigation means the reduction of the severity of climate impacts; this can be achieved by various risk treatment options. This report uses mitigation as a term to describe actions taken to reduce or avoid risks.
Permafrost	Ground (soil or rock and included ice and organic material) that remains at or below 0°C for at least two consecutive years (Government of Canada, 2008).
Probability	A measure representing the chance of an event occurring.
Range	The spectrum of output data from an ensemble of simulations or scenarios (ClimateData.ca., n.d.).

Representative Concentration Pathways (RCP)	Time series of emissions and concentrations of the full suite of greenhouse gases and aerosols as well as chemically active gases and land use. Four RCPs were selected as the basis for the climate projections used in the Fifth Assessment Report published by the IPCC. Each RCP provides only one of many possible scenarios that would lead to the specific radiative forcing characteristics. RCP2.6 leads to the least warming and reflects a future shaped by aggressive and immediate efforts to drastically reduce greenhouse gas emissions. RCP4.5 and RCP6.0 lie between the extreme low and high scenarios, and model futures in which some mitigation of emissions prevents the extreme warming projected by RCP8.5 (ClimateData.ca., n.d.).
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 (Government of Canada, 2008).
Return period	Statistical measurement representing the average time between the occurrence of two events.
Risk	The potential for adverse consequences where something of value is at stake and where the occurrence and degree of an outcome is uncertain. In the context of the assessment of climate impacts, risk is often used to refer to the potential for adverse consequences of a climate-related hazard, or of adaptation or mitigation responses to such a hazard, on lives, livelihoods, health and well-being, ecosystems and species, economic, social, and cultural assets, services (including ecosystem services), and infrastructure. Risk results from the interaction of vulnerability (of the affected system), its exposure over time (to the hazard), as well as the (climate-related) hazard and the likelihood of its occurrence (IPCC, 2018).
Risk assessment	The overall process of risk identification, risk analysis and risk evaluation (Infrastructure Canada, 2019).
Risk management	Coordinated activities to direct and control an organization with regard to risk (ISO 31000:2018). Plans, actions, strategies, or policies to reduce the likelihood and/or consequences of risks or to respond to consequences (IPCC, 2018).
Sensitivity	A measure representing the degree to which a system is adversely or favorably affected by a hazard or by climate change. Its effect can be direct (i.e., a change in crop yield in response to a change in temperature) or indirect (i.e., damage caused by an increase in the frequency of river flooding due to the rise in sea level) (ISO14091:2021).
Shared Socioeconomic Pathways (SSPs)	Shared Socioeconomic Pathways (SSPs) represent the current generation of socioeconomic scenarios in climate change research. The SSPs offer a systematic exploration of possible socioeconomic futures in terms of widely different predispositions to mitigate and adapt to climate change (Talebian, 2021). The five alternative socio-economic futures include: sustainable development (SSP1), middle-of-the-road development (SSP2), regional rivalry (SSP3), inequality (SSP4), and fossil-fuelled development (SSP5) (Kriegler et al., 2016; Riahi et al., 2017).
Slow onset	Slow onset events refer to the risks and impacts from increasing temperatures, loss of biodiversity, land and forest degradation, glacial retreat, ocean acidification, sea level rise and salinization (UNFCCC).
Standards	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 (Roy, Fournier, and Huard, 2017).
Standards writers	Individuals that participate in the creation, update, or modification of a standard.
System	Set of interrelated, interacting or interdependent elements (ISO14091:2021).

Threshold	A value representing the intensity of a climate event that triggers an undesirable asset, product, or service response. The climate parameter establishes the general weather or climatic conditions while the threshold defines specific conditions (intensity or frequency of events) that must be achieved to negatively or positively impact the elements at risk under consideration. In some cases, there can be several thresholds for a specific climate parameter. This is required when the intensity or frequency of events may elicit different responses in the elements at risk.
Time horizon	A future time period of interest over which the outputs of climate simulations are examined or for which future scenarios are produced. Horizons typically encompass a 30- or 20- year period. For example, horizon 2050 often corresponds to the years 2041-2070 (ClimateData.ca, n.d.).
Traditional Knowledge	Traditional knowledge refers to the knowledge, innovations, and practices of Indigenous and local communities around the world (Secretariat of the Convention on Biological Diversity, 2007).
Uncertainty	An expression of the degree to which a value is unknown. Uncertainty can 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) (Government of Canada, 2008). Sources of uncertainty specific to climate information include natural climate variability, climate model inaccuracies (e.g., model resolution or bias), and the future trajectories of GHG emissions (Hawkins and Sutton, 2009).
Vulnerability	The degree to which a service or an asset can cope with a given climate change impact. It is a function of its exposure, its sensitivity to the intensity or frequency of the hazard, and its adaptive capacity.
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 (Government of Canada, 2008).
Wind gust	A brief increase in wind speed, usually measured in less than 20 seconds.

8

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9

Annex A: Resources for Climate Information

- The Canada in a Changing Climate Report (2019) details how and why Canada's climate has changed and what changes are projected for the future. It was released by Environment and Climate Change Canada as part of a broader national assessment to advance knowledge on Canada's changing climate, climate impacts, and adaptation measures. The CCCR includes historical trends in Canada as well as future climate projections. The detailed scientific assessment in the report considers many of the climatic design variables required for built assets' codes and standards, such as heating degree days, total annual precipitation and 24-hour precipitation.
- The Intergovernmental Panel on Climate Change (IPCC) regularly develops international assessment reports which describe the latest science and knowledge around future emissions scenarios, climate modelling, climate impacts and response options. The most recent report is the Sixth Assessment Report suite of documents, being released in 2021 and 2022.
- The National Research Council is leading efforts to improve the availability of climate information through the Climate Resilient Buildings and Core Public Infrastructure initiative. The initiative is unfolding over a five-year period and will support the integration of climate resilience into building and infrastructure design, guides, and codes (Infrastructure Canada, 2020). In collaboration with partners including Environment and Climate Change Canada, the initiative has published ***An Assessment of the Impact of Climate Change on Climatic Design Data in Canada (Cannon et al., 2020)***. This assessment provides future-looking climate data, including temperature, precipitation and wind data, based on over 660 locations across Canada to be used by building and infrastructure codes and standards. This data will be implemented in the 2025 Canadian Highway Bridge Design Code (CHBDC) and will be submitted for consideration by the committees of National Building Code of Canada (NBCC) for its 2025 edition. In addition to the updates to the climatic data and new climate resilience provisions, sets of proposed code changes and provisions will be prepared and will include the development of:
  - A uniform risk-based design approach to replace the current uniform hazard-based design approach, in order to achieve acceptable and uniform reliability levels across Canada;
  - Future climatic data, loads and load combinations to include the impacts of climate change on temperature, precipitation and wind; and
  - An approach to incorporate the non-stationarity of climatic data and target reliability specifications within a given time period or design life (National Research Council, 2019).

Table 7: Resources for historical and future climate information

Type of Data	Method	Use	Spatial	Time period	Sample Available Datasets (not exhaustive list)
Historical	There are four methods for determining the historical data. The dataset can be: — Measured directly over the historical period from station observations; — Calculated from measurements; — Spatially interpolated grid data from a network of station data; and — Modelled using climate models over the historical period.	Can be used as a baseline for climate model projections, to identify climate threshold for previous known events and to calculate the climate normal datasets.	Station data is represented as a point. Modelled historical data is given as a grid cell. Grid cells can vary in resolution.	Climate data can be available from sub-hourly time periods to decades or longer. This ensures that short weather events such as intense precipitation as well as the long-term state of the climate can be accurately described.	Canadian Historical Data Climatic Research Unit gridded Time Series National Climate Data and Information Archive
Climate Normals	Calculated from direct measurements over the historical time period. Current "normal" time period is based on 1981-2010 and is updated every 10 years.	Climate normal data is used to show typical climate conditions for the historical period.	Normals data is represented as a point.		Canadian Climate Normals
Future	Modelled from an ensemble of GCMs or RCMs	Used to project the expected future climate as a result of anthropogenic climate change.	Modelled projections are given as a grid cell. Grid cells can vary in resolution. Modelled projections can also be downscaled to a point.		IPCC AR6 Climate Change 2021: The Physical Science Basis Canadian Centre for Climate Services (climatedata.ca) Climate Atlas Provincial climate data providers such as Ontario Climate Data Portal, Pacific Climate Impacts Consortium

10

Annex B: Examples of National Codes and Consensus Standards that Consider Climate Change or have been Updated to Include Climate Change

Future climate information has become more prevalent in Canadian standards and regulatory codes. Over the last decade, new consensus standards have been developed, and existing codes and standards revised, to help engineers and decision makers reduce climate risks to infrastructure and communities, such as:

10.1 National Codes

Multiple national codes (National Building Code of Canada, Canadian Highway Bridge Design Code, National Energy Code of Canada, Canadian Electric Code, and the National Fire Code of Canada) have been updated or are currently under review to incorporate updated climate parameters. The National Research Council has been one of the key providers of research and guidance to ensure that up-to-date and accurate future climate information, design values and other relevant considerations are included in codes - which in turn, should flow into the engineering and design process. Through the Climate Resilient Building and Core Public Infrastructure Initiative, the National Research Council has developed resources and publications such as ***An Inventory of Methods for Estimating Climate Change-Informed Design Water Levels for Floodplain Mapping, and An Assessment of the Impact of Climate Change on Climatic Design Data in Canada*** (Cannon et al., 2020), which support the process of updating codes and standards to account for future climate in Canada. In support of interim measures to address changing climatic loads, the National Research Council sponsored programs at CSA Group and ULC Standards that resulted in the revision of several dozen National Standards of Canada to incorporate requirements for adaptation to climate change. The publication of the revised editions of these standards was completed by mid-2019. Updates to codes and standards completed through the program can be found on the Government of Canada web page for the Climate-Resilient Buildings and Core Public Infrastructure Initiative.

National Building Code of Canada (NBCC-2015)

The 2015 National Building Code of Canada (NBCC) has some of the most comprehensive information about historic climate conditions of all Canadian standards. Climate design criteria are defined in the form of climate design data for all major towns and cities across the country (see NBCC 2015, Table C-2). The design data are defined for every climate variable based on the analysis of the instrumental data of surrounding weather stations from Environment and Climate Change Canada. Historical data was used to determine the climatic design data, meaning the design criteria does not account for present and future climate conditions. The design data must now be updated to correspond to future climate conditions, which is expected in the upcoming edition of the NBCC in 2025.

Canadian Highway Bridge Design Code (CSA-S6:19)

The Canadian Highway Bridge Design Code requires that environmental factors, including impacts of climate change, shall be considered (CSA-S6:19, Section 15.4.5). Clause 2.4 includes provisions to "Design for Sustainability," encouraging "environmental protection by reducing greenhouse gas emissions and pollution of water, air, and soil; minimizing of consumption of materials and energy; and ensuring adaptation of the structure to the changing climate over its service life. Design loads are currently based on historical climatic and environmental information that were updated in 2019. Through the Climate-Resilient Buildings and Core Public Infrastructure Initiative, partners (including Environment and Climate Change Canada, Pacific Climate Impacts Consortium, and RWDI) have developed future-looking climate projections including temperature, precipitation and wind data based on over 660 locations across Canada. The data will used by building and infrastructure codes and standards and will be implemented in the 2025 Canadian Highway Bridge Design Code.

Canadian Electrical Code, Part I (25th Edition), Safety Standard for Electrical Installations (CSA C22.1:21)

For over 90 years, the Canadian Electrical Code, Part I, has been updated to keep up with sector challenges and improvements. In 2021 several Climate Change Adaptation requirements were introduced into the CE Code Part I. As a result of a climate change adaptation initiative between CSA Group and the National Research Council Canada, the Code now contains new requirements for electrical installations subject to damage from flooding.

10.1.1 Northern Infrastructure Standards

In 2011, in partnership with Crown-Indigenous Relations and Northern Affairs Canada, the Standards Council of Canada launched the Northern Infrastructure Standardization Initiative (NISI) to respond to the urgent impacts of climate change on buildings and infrastructure in Canada's North. NISI initiatives are determined using a prioritization framework established by the Northern Advisory Committee (NAC), including representatives from the Northwest Territories, Nunavut, Yukon, and Nunavik and Crown-Indigenous Relations and Northern Affairs Canada (CIRNAC) with knowledge of the unique issues facing Northern infrastructure and buildings (Standards Council of Canada, 2021).

In addition to championing many of the standards produced to date for Northern communities, the NAC also identifies and supports opportunities for training, uptake, and integration of standards into policy and other requirements. For example, NISI offers free training courses consisting of a core course (NISI Foundations) and three modules. The NAC includes representatives from the Northwest Territories, Nunavut, Yukon, and Nunavik and Crown-Indigenous Relations and Northern Affairs Canada (CIRNAC). The NISI program facilitated the development of several new National Standards of Canada. Some notable examples are identified below:

Thermosyphon Foundations for Buildings in Permafrost Regions (CSA S500:21)

This standard helps to ensure the ongoing stability of new buildings constructed on permafrost with thermosyphon-supported foundations in Canada's North (Standards Council of Canada, n.d.).

Moderating the Effects of Permafrost Degradation on Existing Building Foundations (CSA S501:21)

Permafrost degradation can destabilize structures. This standard outlines the steps to maintain, assess and mitigate the effects on existing buildings (Standards Council of Canada, n.d.).

Managing Changing Snow Load Risks for Buildings in Canada's North (CSA S502:21)

Some Arctic regions have experienced an increase in snowfall and extreme snow events. These events cause excess loads on buildings which can lead to structural damage. This standard informs communities about safe snow removal methods for rooftops to help ensure the safety of buildings and occupants (Standards Council of Canada, n.d.).

Community drainage system planning, design, and maintenance in northern communities (CSA S503:20)
This standard provides requirements for ensuring a community's drainage systems are up to the task, specifying minimum planning, design, and maintenance requirements and considering the unique needs of Northern communities (CSA Group, 2020b).

The standard provides a go-to reference for governments in Canada's North that can be incorporated into policy and regulation. Since published in 2015 (and updated in 2020), it has been implemented in numerous communities across Nunavut including Clyde River, Kugluktuk, Cape Dorset, Hall Beach, and Rankin Inlet. The standard is referenced by the Société D'Habitation du Quebec's Housing Construction in Nunavik – Guide to Good Practices, by the Government of Nunavut's Good Building Practices Guideline, and by the Government of the Northwest Territories Good Building Practices.

Fire resilient planning for northern communities (CSA S504:19)

The standard specifies requirements for fire resilient community planning, building design, materials for new developments, and also for re-locatable industrial, commercial, or residential structures in northern regions.

Techniques for Dealing with High Winds and Snow Drifting as It Pertains to Northern Infrastructure (CSA S505:20)

Community members have noted that wind conditions have been changing as a result of the warming climate. This standard provides guidance to building operators and owners when dealing with changing wind patterns and strengths, and their impacts on snow drifting.

Risk-Based Approach for Community Planning in Northern Regions (BNQ 9701-500)

The objective of the standard is to support community planning decision-making in Northern regions. The standard specifies the minimum requirements for the planning, preparation, and the approval of potential construction maps. Maps support a risk management approach to the siting and design of expansions to communities, in particular in areas where new subdivisions are required to accommodate community growth.

10.1.2 Standards on Future Intensity-Duration-Frequency Curves for Stormwater Management

Short duration high intensity (SDHI) precipitation events pose a significant challenge in terms of stormwater management. Intensity-duration-frequency (IDF) curves are probability functions used to describe the expected return period of a maximum rainfall intensity or precipitation amount for a given duration generally ranging from minutes to 24 hours. IDF curves are commonly used in stormwater drainage design or flood frequency for urban or small watersheds. They are usually calculated by fitting a probability distribution on historical weather station data.

Within the current National Building Code of Canada, stormwater design criteria use SDHI precipitation values derived from historical values. Accounting for future IDF curves influenced by climate change is challenging, considering that General Circulation Models from which most climate projections are derived lack the adequate spatial or temporal resolution to inform the expected changes in SDHI precipitation events. However, there are examples at the national, provincial, and municipal levels of guidelines or requirements to account for climate change in IDF curves.

At the national scale, the CSA PLUS 4013:2019 Technical Guide entitled ***Development, interpretation, and use of rainfall intensity-duration-frequency (IDF) information: Guideline for Canadian water resources*** practitioners was updated in 2019 to suggest using the Clausius-Clapeyron relationship to apply a safety factor of 7% per degree of warming to all IDF statistics. However, this relationship is valid for the capacity of the atmosphere to store humidity and is not directly linked with extreme precipitation statistics. It is also important to note that the scaling rates between temperature and percent increase in precipitation intensity vary across different geographies (e.g., higher for maritime climate and lower for continental climate), precipitation durations (higher scaling rate for shorter duration) or models (Cannon et al., 2020).

At the provincial scale, in Quebec, the Ministère des Transports du Québec (Transports Québec) acknowledges that climate change, including extreme precipitation, will have significant impacts on transportation infrastructure (MTQ, 2018). Mailhot et al. (2012) modeled extreme precipitation for Canada based on a regional climate model ensemble. Their results indicate that the median relative changes from the recent past to the 2041-2070 period range from 12 to 18% in Quebec depending on the statistics. The same authors provided recommendations to the Quebec government to update IDF values by 18-20% (Table 2). However, this method only considers the median of the model ensemble distribution, which is misleading when designing to minimize risks, as 50% of the models' project increases superior to the median. Therefore, depending on the risk tolerance, the inclusion of safety factors through the use of the 90th percentile may be necessary.

The BC Ministry of Transportation and Infrastructure (BCMoTI) requires engineering design work to evaluate risks and include adaptation measures to the impacts of future climate change, weather extremes and climate-related events, as well as changes in average climate conditions. This policy applies to all new projects, as well as rehabilitation and maintenance projects.

Table 8: Example - Recommended increase on the IDF statistics for different regions of Quebec (Mailhot et al. 2014)

Region	Recommended increase
North of 55° N latitude	18%
Between latitudes of 51° N and 55° N	18%
Saint Lawrence Estuary	18%
Western Quebec south of 51° N	18%
Southern Quebec	20%

Municipalities across Canada have also included future IDF data in their stormwater management practices and flood mitigation activities. For example, the City of Fredericton requires its major systems upgrades to be designed for 100-year events plus 20%, and its minor systems upgrades to be designed for 10-year return period events (2-year or 5-year return periods were in the past the municipal norm). Examples include:

— The City of Vancouver building bylaw requires the use of future weather files for the design of heating and cooling systems.
— In 2016, the Town of Creston in BC integrated climate change into future rainfall intensity curves within their Drainage Bylaw corresponding the service life of the proposed drainage design.
— The City of Burnaby also requires the analysis and design to use climate change IDF curves, stating that current climate IDF curves are only suitable for temporary infrastructure, moderate change IDF curves are suitable for low to medium risk minor systems (i.e., pipes, ditches), and high change IDF curves are suitable for high-risk major systems (i.e., culverts/bridges).

10.1.3 Other Examples of Standards and Guidelines Including Climate Change

Climate considerations are present in a wide range of standards, although the specificity of climate design criteria, the recognition of the engineering challenges associated with climate change, or the granularity of climate information vary considerably from one to the other. The following list is a small sample of standards considering climate change. Additional lists of projects under the Standards to Support Resilience in Infrastructure Program (2016–2021) can be explored in Annex A of ***Standard Council of Canada's report Standards in Action: Building a Climate Resilient Future (2021)***.

Flood Resilient Design of New Residential Communities (CSA W204:19)

The standard was developed through Standards Council of Canada's Standards to Support Resilience in Infrastructure Program. It covers the protection of new residential communities from flood hazards and states that users of the standard should consider applying adjustments to current IDF values to take into account climate uncertainties. Canadians can access these standards for free until June 2024.

Planning, Design, Operation, and Maintenance of Municipal Wastewater Treatment in Northern Communities using Lagoon and Wetland Systems (CSA W203:19)

This standard was developed through Standards to Support Resilience in Infrastructure Program. It includes updated research on northern wastewater treatment performance and outlines best practices for planning, designing, operating, and maintaining these systems.

Climate change adaptation for wastewater treatment plants (CSA S900.2.21)

This standard aims to provide a user-friendly framework and tool to use to assess climate change risks and prioritise actions to build resilience. It provides guidance on climate change data sources, how these can be used to determine impacts and adaptation measures.

Antennas, Towers, and Antenna-Supporting Structures (CSA-S37-18)

The standard includes high-level discussion on how climate change is expected to affect wind and ice loads for antennas, towers, and antenna-supporting structures, based on a literature review. The standard acknowledges that decision-makers and engineers should refer to specialists to obtain the best data and discuss associated uncertainties. The standard also includes informative annexes on climate change adaptation.

High wind safety for low-rise residential and small buildings (and Increasing High Wind Safety for Canadian Homes: A Foundational Document for Low-Rise Residential and Small Buildings) (CSA S520:20)

This national standard is being developed as of 2022. It began as a Region of Durham guidance document on wind safety. The Region engaged with the Standards Council of Canada and the Institute for Catastrophic Loss Reduction to develop into a best practices document that could be applied nationally.

The best practices document offers recommendations for improving wind safety through new or modified requirements. It offers "no regrets" (low cost, high reward) adaptation measures that can be applied regardless of uncertainty around future wind projections. The document also includes the return on investment and different levels of wind risk across Canada.

10.2 Existing Guidance on Integrating Climate Change into Standards

Several guidance documents and companion documents (examples below) have been published which provide standards and code developers with additional information relevant to the standard's infrastructure type, sector, region and discuss climate risks and adaptation options. The aim of the guidance documents is to help standards developers ensure that relevant information is considered and potentially integrated into standards, or at a minimum, consulted as part of the standards development process. Examples of guidance and companion documents include:

Guide for integrating climate adaptation in Canadian standards (Standards Council of Canada, 2021)

The Guide preceded this technical companion, and provides an overview of key steps and processes for understanding the impacts of climate change subject of the standard and the steps for considering climate change in the standard development or update process. It provides series of guiding questions to help determine the applicability of climate change adaptation to a given standard, and provides a flow chart to help standards developers integrate climate change adaptation into standards, where appropriate.

Guide for addressing climate change adaptation in standards (CEN-CLC Guide 32:2016)

The European Committee for Standardization and European Committee for Electrotechnical Standardization published the guide in 2016 to support European standards technical committees in identifying relevant climate impacts and incorporating climate adaptation considerations into new and revised standards. It includes a series of decision trees with questions on the nature of the standard and available climate information. The guide also offers various tools and options for integrating climate information and climate risk management into the development of the standard and the standard itself.

This guidance document is aligned with the principles of ***CEN-CENELEC Guide 32 (2016)***.

Guidelines for addressing climate change in standards (ISO Guide 84:2020)

The ISO Guide 84 draws on information from ***CEN-CENELEC Guide 32 (2016)***. It outlines a framework and principles that standards developers can use to develop their own approach to addressing climate change on a subject-specific basis. It includes guidance for standards developers to address climate adaptation and emission reduction in standardization.

This guidance document is aligned with the climate risk management principles of ISO Guide 84:2020.

Technical Guide: Infrastructure in Permafrost: A guideline for climate change adaptation (CSA PLUS 4011:19)

The guideline outlines methods to estimate the sustainability of engineered structures on permafrost foundations over their service lives in northern Canada. The objective is to mitigate climate-change induced risk of system failure at the design stage.

Technical Guide: Design and construction considerations for foundations in permafrost regions (CSA PLUS 4011.1:19)

Developed through the Standards to Support Resilience in Infrastructure Program. This guideline includes updated information on trends and the condition of permafrost throughout Canada, and how climate change may continue to affect permafrost regions in the future. It also provides an assessment tool to evaluate the climate-related risks to ground conditions at proposed construction sites and steps to incorporate climate-related analysis into planning and design processes.

Development of Climate Change Adaptation Solutions Within the Framework of the CSA Group Canadian Electrical Code Parts I, II and III (2019)

This report discusses gaps in current electrical codes and standards, best practices in climate adaptation, and potential recommendations for future updates to the Canadian Electrical Code Series (CE Code). It is based on stakeholder engagement with cross-country experts in climate change and electrical infrastructure systems. The report provides recommendations and approaches for addressing climate adaptation in the CE Code.

An Assessment of the Impact of Climate Change on Climatic Design Data in Canada (Cannon et al., 2020)

The report provides an assessment of how climatic design information in the National Building Code of Canada (NBCC 2015, Table C-2) and Canadian Highway Bridge Design Code (CHBDC/CSA S6:2014, Annex A3.1) may evolve due to climate change. Each key variable is discussed in detail along with future projections and discussion of uncertainty and risk management. The results will inform updates to design values relevant to the 2025 edition of NBCC and the 2025 edition of the CHBDC.

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