Draft technical guide related to the Strategic Assessment of Climate Change: Assessing climate change resilience

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Executive summary

In August 2019, the *Impact Assessment Act* (IAA) came into force. The IAA establishes a new process for considering environmental, health, social and economic effects of projects that will undergo a federal impact assessment. Under the IAA, the impact assessment (IA) process must take into account, among other factors, any relevant regional or strategic assessment, any change to the designated project that may be caused by the environment and the extent to which the effects of the designated project hinder or contribute to the Government of Canada's ability to meet its commitments in respect to climate change.

Canada's climate change commitments, include the Paris Agreement, [1] the Pan-Canadian Framework on Clean Growth and Climate Change, [2] and the Government of Canada's strengthened climate plan, *A Healthy Environment and a Healthy Economy*. [3] Both *A Healthy Environment and a Healthy Economy* and Budget 2021 proposed measures for climate adaptation and resilience, including measures to better understand and prepare for climate-related disasters and to mitigate their impacts. Taken together, these build on the successes of the Pan-Canadian Framework on Clean Growth and Climate Change.

In 2020, Environment and Climate Change Canada (ECCC) published the Strategic Assessment of Climate Change (SACC) [4] to enable consistent, predictable, efficient and transparent consideration of climate change throughout the federal impact assessment process. The SACC states that technical guides would be developed to provide additional details on specific elements. [5]

This *Assessing Climate Change Resilience* Technical Guide (from here on referred to as "technical guide") complements the SACC and provides proponents with a consistent and coherent approach to assessing how a designated project is resilient to, and at risk from, both the current and future impacts of a changing climate. Specifically, the technical guide outlines key principles and provides general directions on two interrelated elements:

- The scope of climate change information required; and
- A framework for assessing risk (a 5-step process with guiding questions) and considering climate change resilience at the project level.

Information in this guide may also be used to inform the review for projects on federal lands and outside Canada under the IAA, projects regulated by the Canada Energy Regulator, and regional assessments. [6]

With the publication of this draft, ECCC is providing an opportunity for the public to comment on the technical guide until May 13, 2022. ECCC plans to publish a final version in 2022.

Glossary

Adaptation

Adaptation refers to adjustments in ecological, social, or economic systems in response to actual or expected climatic stimuli and their effects or impacts. It refers to changes in processes, practices, and structures to moderate potential damages or to benefit from opportunities associated with climate change. Actions / measures that reduce the negative impacts of climate change, while taking advantage of potential new opportunities.

Climate

The average, or expected, weather and related atmospheric, land, and marine conditions for a particular location. In statistical terms, it is the mean and variability of relevant measures over a period of time ranging from months to thousands or millions of years. The classical period for averaging these variables is 30 years, as defined by the World Meteorological Organization.

Climate change

A persistent, long-term change in the state of the climate, measured by changes in the mean state and/or its variability. Climate change may be due to natural internal processes, natural external forcings such as volcanic eruptions and modulations of the solar cycle, or to persistent anthropogenic changes in the composition of the atmosphere or in land use.

Climate change resilience

The ability of a system (built, natural, social or economic) to anticipate, withstand, recover, adapt to and transform in response to a climate-related hazard.

Climate related 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. In this Guide, the term hazard refers to climate-related physical events or trends or their physical impacts.

Climate impact

The effects on natural and human systems of extreme weather and climate events and of climate change. Impacts generally refer to effects on lives, livelihoods, health status, ecosystems, economic, social, and cultural assets, services (including environmental), and infrastructure due to the interaction of climate changes or hazardous climate events occurring within a specific time period and the vulnerability of an exposed society or system. Impacts are also referred to as consequences and outcomes. The impacts of climate change on geophysical systems, including floods, droughts, and sea level rise, are a subset of impacts called physical impacts.

Confidence

Confidence in the validity of a result is based on the type, amount, quality, and consistency of evidence (for example, mechanistic understanding, theory, data, models, expert judgment) and the degree of agreement across multiple lines of evidence. Confidence is expressed qualitatively. Five qualifiers are used to express assessed levels of confidence in findings (very low, low, medium, high, and very high) in IPCC (2013) and in Canada's Changing Climate Report (Bush and Lemmen, 2019).

Designated project

One or more physical activities that (a) are carried out in Canada or on federal lands; and (b) are designated by regulations made under paragraph 109(b) of the IAA or designated in an order made by the Minister under subsection 9(1) of the IAA. It includes any physical activity that is incidental to those physical activities, but it does not include a physical activity designated by regulations made under paragraph 112(1)(a.2) of the IAA. For the purposes of this guide, the term "designated project" has been shortened to "project".

Earth system model

A coupled atmosphere–ocean general circulation model in which a representation of the carbon cycle is included, allowing for interactive calculation of atmospheric CO_2 or compatible emissions. Additional components (for example, atmospheric chemistry) may be included. Coupled atmosphere–ocean general circulation models provide a comprehensive representation of the climate system, among the most comprehensive of the suite of climate models currently available.

Effects

The *Impact Assessment Act* provides that effects means, unless the context requires otherwise, changes to the environment or to health, social or economic conditions and the positive and negative consequences of these changes.

Global climate model

Complex computer simulation of the climate system usually including interacting simulations of the atmosphere, ocean, ice and land surface. The climate system can be represented by models of varying complexity. Climate models are developed and used at climate research institutions around the world to make projections of future climate, based on future scenarios of greenhouse gas and aerosol forcing. See also Earth System Model.

Likelihood (in quantifying climate change uncertainty)

The chance of a specific outcome occurring, where this might be estimated probabilistically. The likelihood of a result occurring is based on quantified measures of uncertainty expressed probabilistically (based on statistical analysis of observations or model results, or expert judgment). Likelihood is expressed quantitatively.

Likelihood (in risk analysis)

Is the chance of an event or an incident happening (that is, a Climate Hazard), whether defined, measured or determined by qualitative or quantitative means.

Projects undergoing a federal impact assessment

Projects under the IAA, as well as projects under review by lifecycle regulators (for more information see section 1.2 of the Strategic Assessment of Climate Change).

Representative concentration pathway

Scenario of future greenhouse gas concentrations, and other anthropogenic forcings, for the period beginning in 2006 based on various possible levels of human emissions. Representative Concentration Pathways (RCPs) are identified by a number indicating the change in radiative forcing by the end of the 21st century. RCP2.6 represents a low emission pathway with a radiative forcing of roughly 2.6 W/m^2, RCP4.5 and RCP6 represent intermediate emission pathways, and RCP8.5 represents a pathway with continued growth in greenhouse gas emissions, leading to a radiative forcing of roughly 8.5 W/m^2 at the end of the century. The word representative signifies that each RCP provides only one of many possible scenarios that would lead to the specific radiative forcing characteristics. The term pathway emphasizes that not only the long-term concentration levels are of interest, but also the trajectory taken over time to reach that outcome.

Risk assessment

The overall process of risk identification, risk analysis and risk evaluation.

Scenario (forcing scenario, emission scenario)

A plausible representation of the future based on a coherent and internally consistent set of assumptions. A forcing scenario is a possible future evolution of greenhouse gas concentrations and other anthropogenic forcings. An emission scenario describes a possible future evolution of emissions of greenhouse gases, and other climate drivers. They assist in climate change analysis, including climate modelling and the assessment of impacts, adaptation, and mitigation. The likelihood of any single emissions path described in a scenario is highly uncertain.

Valued component

In the context of Impact Assessment, these are environmental, health, social, economic or additional elements or conditions of the natural and human environment that may be impacted by a proposed project and are of concern or value to the public, Indigenous peoples, federal authorities and interested parties. Valued components may be identified as having scientific, biological, social, health, cultural, traditional, economic, historical, archaeological and/or aesthetic importance. (from: Glossary of terms)

Vulnerability

A condition or set of conditions determined by physical, social, economic and environmental factors or processes that increase the susceptibility (or exposure) of aspects of a project (or related valued components) to the possibility of harm due to the impacts of hazards.

Acronyms

CCCR
Canada's Changing Climate Report

CCCS
Canadian Centre for Climate Services

ECCC
Environment and Climate Change Canada

GCM
Global Climate Model

GHG
Greenhouse Gas

IA
Impact Assessment

IAA

Impact Assessment Act

IAAC

Impact Assessment Agency of Canada

IDF

Intensity Duration Frequency

IPCC

Intergovernmental Panel on Climate Change

PMF

Probable Maximum Flood

PMP

Probable Maximum Precipitation

RCM

Regional Climate Model

RCP

Representative Concentration Pathway

SACC

Strategic Assessment of Climate Change

SSP

Shared Socioeconomic Pathway

TISG

Tailored Impact Statement Guidelines

VC

Valued Component

1 Introduction

1.1 Objective

The purpose of this technical guide is to provide proponents of projects that may require a federal impact assessment, pursuant to the *Impact Assessment Act* (IAA), with additional guidance on how to consider a project's resilience to climate change. This document supplements the Strategic Assessment of Climate Change (SACC). [7] The SACC defines climate change resilience as "the ability of a system (built, natural, social or economic) to anticipate, withstand, recover, adapt to and transform in response to a climate-related hazard."

The information provided throughout the impact assessment process by proponents and others will inform the Minister's public interest determination under the IAA. More specifically, paragraphs 63(b) and 63(e) provide that the Minister's public interest determination includes consideration of, among other factors, the extent to which the adverse effects within federal jurisdiction and the adverse direct or incidental effects that are indicated in the impact assessment report in respect of the designated project are significant; and the extent to which the effects of the designated project hinder or contribute to the Government of Canada's ability to meet its environmental obligations and its commitments in respect of climate change.

Information in this guide may be adapted for projects on federal lands and outside Canada under the IAA, projects regulated by the Canada Energy Regulator, and regional assessments.

1.2 Context

The Paris Agreement is an international agreement to strengthen the global response to the threat of climate change. It establishes a global goal on enhancing adaptive capacity, strengthening resilience and reducing vulnerability to climate change. Adaptation and climate resilience also constitute one of the pillars of the Pan-Canadian Framework on Clean Growth and Climate Change, which recognizes that the impacts of climate change are already being felt across Canada. Climate change may alter the likelihood or magnitude of sudden weather events such as extreme precipitation that can contribute to flooding, as well as contribute to longer-term changes such as sea level rise, permafrost thaw and changes to migration patterns. Changes related to warming are already evident in many parts of Canada, and are projected to continue in the future with further warming. If not properly considered, such changes may cause issues such as equipment failures that can threaten the environment and human health and safety, interrupt essential services, disrupt economic activity, and incur high costs for recovery and replacement.

In December 2020, the Government of Canada announced *A Healthy Environment and a Healthy Economy*, Canada’s strengthened climate plan to accelerate the fight against climate change. *A Healthy Environment and a Healthy Economy* includes measures to make Canada more resilient to a changing climate. Enhancing resilience will not only help Canadian communities adapt to the current realities of a changing climate, it will reduce losses in productivity and economic losses from climate-related disasters, and it will enhance the health, well-being, and safety of Canadians and communities.

Where an Impact Statement is required, the scope of information required related to climate change resilience, including how the project is resilient to, and at risk from, both the current and future impacts of a changing climate will be tailored to the project in the Tailored Impact Statement Guidelines (TISG). The TISG will be provided to the proponent by the Impact Assessment Agency of Canada (IAAC) at the end of the Planning Phase, and will set out the scope of factors to be considered. [8]

1.3 Using this document

This technical guide complements other policy and guidance documents, in particular, the SACC, that support the impact assessment process. [9] It is assumed that readers of this document have a good understanding of the impact assessment process. [10]

This guide is intended to aid proponents in undertaking climate change resilience assessments, as required by the project-specific TISG. This technical guide does not replace project-specific information requirements in the TISG, but rather complements those guidelines. It provides project proponents with additional direction in fulfilling the requirements for information and studies required by the TISG for the Impact Statement.

This technical guide is intended to be applicable to all types of projects requiring an impact assessment regardless of their environmental setting. It provides general methodological guidance rather than detailed instructions. This is because resilience assessment information requirements for different projects can vary widely depending on the nature of the specific project (for example, a mine versus a hydropower project) including its specific location and setting. Additionally, the availability and characteristics of climate change information are not uniform for all climate variables. This guidance is thus not intended to be exhaustive or prescriptive and proponents are expected to apply it in the context of the underlying project using best-available practice. This technical guide does not provide specific requirements in terms of risk treatment or adaptation measures to enhance project resilience to climate change.

Under the IAA, an impact assessment must consider the potential environmental, health, social, and economic effects, including the interactions among those effects and their long-term consequences. Health, social and economic vulnerabilities to climate change that can be linked to the project should be considered where they have been identified. The impacts the project may have on any Indigenous group, and on their practice of rights and culture are also factors to be considered in the Impact Statement, as informed by those Indigenous communities and rights holders.

ECCC plans to review and update this technical guide as required to incorporate advances in climate change science.

2 Climate change in Canada and relevance in impact assessment

Climate change is a global phenomenon. The Earth’s climate system is warming and other aspects of climate are changing consistent with this warming. Global surface temperature for the period 2011 to 2020 was 1.09°C [0.95 to 1.20 uncertainty range] above pre-industrial levels (defined as 1850-1900) (IPCC 2021). This increase has been attributed primarily to increasing atmospheric concentrations of greenhouse gases from anthropogenic activities (IPCC 2013; 2021). Increases in global temperature have had a myriad of impacts across the global climate system (IPCC 2013; 2021). For example, rising temperatures have caused changes in the hydrological cycle, global mean sea level has risen and the oceans have become more acidic. Quantifying changes in many extremes of climate and weather is more challenging than quantifying changes in mean climate conditions because extremes occur infrequently and the observational data needed to derive adequate statistics about the historical occurrence rate of extremes are often lacking.

In Canada, climate has warmed and further warming is projected for the future. Over a 70 year period in the recent past (1948 to 2016), average warming across Canada was 1.7°C (about double the global mean) and was strongest in the winter season (Zhang et al. 2019). The warming trend in Canada's north over the same time period has been even more pronounced at 2.3°C. As noted for the global scale, changes in Canada are not restricted to temperature alone, with changes observed throughout the climate system. Many of these physical changes are summarized in *Canada's Changing Climate Report* (Bush and Lemmen 2019); several key figures from this report are provided in Annex A. On average, permafrost temperatures have increased, sea ice concentration has declined, glaciers have lost mass, terrestrial snow cover has decreased, and streamflow timing has changed (earlier freshet). These changes in climate can exacerbate other changes in more complex or compound events such as floods, coastal erosion, wildfires, landslides and droughts. Changes in extremes, especially in temperature, have also been identified – increases in hot nights and decreases in cold extremes, for example.

Many of the changes that have been observed are projected to continue into the future with increasing global warming (for example, temperatures averaged across Canada, Figure 3). Increases in total annual and seasonal precipitation are projected for much of Canada but decreases are projected for much of southern Canada during the summer season by end of century under a high emissions scenario (Figure 4). Changes in shorter duration extreme precipitation are now emerging across broad regions of the country but are often not yet noticeable (that is, statistically detectable) at regional-local scales due to large natural background variability in precipitation (Kirchmeier-Young and Zhang 2020). Nonetheless, intensification of local-scale extreme precipitation is expected in the future due to thermodynamic effects on atmospheric moisture (Figure 5). These changes in climate and the natural environment are expected to have widespread impacts that encompass human domains (social, health, political) and economic domains.

As with global projections based on a range of emission scenarios, the magnitude of projected temperature changes in Canada are higher towards the end of the century (Figure 3). The uncertainty inherent to climate change projections also increases towards the end of the century. For projects planned and designed based on historical climate conditions alone, this means that, as time progresses, many aspects of the climate, and thereby aspects of the surrounding environment, are likely to diverge increasingly from the conditions for which the project was originally designed. Stationarity in climate can no longer be assumed (Milly et al. 2008, 2015). Some climate hazards may increase in frequency or magnitude in the future such as those related to intensification of short-duration precipitation extremes, while there may be a reduction in the frequency or magnitude of some climate hazards such as reduced cold extremes or snow loads in some areas. Thus, for projects being reviewed under the impact assessment process, with a long operational lifetime, or with aspects that remain sensitive to climate over the long-term or in perpetuity (for example, water-related infrastructure), potential changes in the likelihood of climate hazards must be considered over a project's lifetime if long-term climate resilience is to be achieved.

3 Assessing climate change resilience in the impact statement

Under the IAA, the impact assessment process must take into account any change to the designated project that may be caused by the environment. Given the changes in observed and projected future climate for Canada outlined above, it is important for proponents to consider how well the project is able to withstand the potential impacts of a changing climate over its lifetime. In order to evaluate a project's resilience to climate change, the proponent should properly characterize and assess potential changes in the occurrence of climate hazards (exposure) and their associated threats to the proposed project (vulnerability), environment and valued components (VCs) (for example, through accidents or malfunctions) and outline approaches to treat or reduce the risks identified.

The proponents of projects undergoing a federal impact assessment must provide clear documentation for all of the steps taken in their assessment of climate change resilience, including assumptions made, details on information supporting conclusions, uncertainties and preferred approaches and/or design decisions for managing risks (and changes to risks) associated with climate change. This should include clear documentation of the climate data or information utilized (including why it was selected) and indicate how it was used to characterize changes to climate-related hazards and risks, including details on the consideration of uncertainty and methods of analysis. Pertinent and current climate data and information should be utilized and interpreted for relevant project components and stages with clear demonstration of how these data have been transformed into information about exposure to climate-related hazards and risks to the environment and VCs over the project lifetime.

This guide focuses on the climate change resilience aspects of physical activities and incidental activities, specifically the consideration of the effects of climate change on the project. [11] Climate change may also affect the environment around the project, which could include effects on the valued environmental, health, social and economic components (VCs) related to the project that could alter the context for, and impacts of, a project. These effects on VCs and their baseline conditions, should be considered in the effects assessment in the Impact Statement. [12] Climate change information provided in the climate change resilience assessment can inform effects assessments throughout the Impact Statement.

3.1 Climate information for use in climate change resilience assessments

A climate change resilience assessment must use up-to-date information on historical or observed climate to define a present-day baseline, and projected climate change scenarios to assess how hazards and their probability of occurrence will evolve in the future.

The proponent must use a multi-model ensemble of climate change projections (see section 3.1.1), when available, and consider uncertainty and the level of confidence in projections of the climate variables of interest (see section 3.1.2) to ensure that they are interpreted and used correctly in project planning and design. When providing and interpreting climate change information, the proponent must provide a description of methodologies, data sources and assumptions used as well as a rationale for the approaches taken. Annex B provides additional guidance on the use of climate change information in the climate change resilience assessment including commonly used climate design elements (such as those related to extreme precipitation) and associated methodologies. Annex C provides a list of some available climate and climate change resources for consideration.

General context information on potential climate change can be obtained from assessments and special reports such as those prepared by the Intergovernmental Panel on Climate Change (for example, IPCC 2012, 2013, 2019, 2021) or those prepared specifically for Canada such as *Canada's Changing Climate Report* (Bush and Lemmen 2019) or other assessment reports prepared by credible sources such as regional climate service providers, qualified consultants or professionals, or the broader scientific literature. [13]

The Indigenous Knowledge gathered through the IA process must be taken into account, or considered in the climate change resilience assessment. Indigenous Knowledge should include experienced historical climatic and environmental changes, and challenges faced during response and recovery to climate-related risks, particularly to inform the past and present-day baseline. Specific guidance on how Indigenous Knowledge is to be managed and included in assessments under the IAA is provided by the IAAC in Section 3 of their Practitioner's guide. [14]

3.1.1 Climate change projections: Use of a multi-model ensemble

Climate change projections from global climate models (or Earth system models) provide the best scientific means for considering potential future changes of relevance to a project. It is not scientifically defensible to simply extend trends in observational records into the future. Numerous climate models have been developed by climate modeling groups from around the world (for example, Figure 3 from Canada's Changing Climate Report uses 29 models). At present, there is no objective way to identify the 'best' model from among this selection of models, with respect to quality of future simulations. This is because each model has slightly different ways of treating and incorporating aspects of the climate system and thus results for the same sets of forcing conditions differ from model to model.

The magnitude of potential climate change in the future also depends largely on future GHG emissions, which themselves depend on future population growth, per capita energy usage, emerging energy technologies, global mitigation initiatives and other uncertain socioeconomic conditions. Since we are not certain how the future will unfold, a range of future forcing scenarios have been developed representing low to high future emissions. The magnitude of all metrics of climate change depends significantly on the future emissions pathway that society follows, particularly after mid-century as these emissions scenarios increasingly diverge. Probabilities (or likelihoods) are not ascribed to these different future forcing scenarios and they are all deemed plausible. However, from a practical standpoint, as emissions continue to increase, low forcing scenarios become more difficult to achieve (Millar et al. 2017). A final source of uncertainty in future climate conditions relates to random natural variations in the climate system. Consideration of a range of climate projections that encapsulate model, emission and natural variability uncertainty from an ensemble of climate models (that is, a multi-model ensemble) for a range of future forcing scenarios (low to high) is the best way to consider these uncertainties. For these reasons, project proponents must consider projections from a multi-model ensemble, when available, for a range of forcings (at minimum a low and high and forcing scenario) in their climate change resilience assessment.

3.1.2 Considering uncertainty and the level of confidence when evaluating the likelihood of a climate hazard

The proponent must carefully consider a range of projected change to evaluate uncertainty, including estimates of the level of confidence in the projections of changes to the likelihood of a given climate hazard of interest. As noted in Annex B, the level of confidence in projections for different climate parameters (or different spatial scales or locations) are not uniform. Confidence in temperature related parameters is generally higher than for precipitation related parameters and more complex compound events (such as floods) and extremes. If there is low confidence in the projections for a particular parameter (for example, projections of future wind speed), the likelihood estimate for the future is more uncertain than projections for parameters for which confidence is high. Note that likelihood is only one aspect of determining risk; low-probability hazards may be associated with catastrophic risks if the impacts (consequences) of these hazards is extremely high (section 3.2.4). Quantified likelihood statements are not provided for variables with low confidence (see Annex B). Qualitative analysis using professional judgement may be necessary where there is a lack of adequate information and resources available. Annex B provides a more detailed discussion of the confidence and likelihood of climate projections and provides references to the scientific literature where calibrated confidence assessments are discussed for climate projections in a Canadian context (Bush and Lemmen, 2019; Cannon et al. 2020). Additionally, the likelihood of the different future emission scenarios is not known, as they will be influenced by future social, economic and technical development, and as such, are very difficult to predict precisely. As such, this uncertainty should be evaluated by considering projections from a range of scenarios (at minimum low and high emission scenarios) as described in section 3.1.1.

3.2 General framework for assessing climate-related risks

Proponents assessing the climate change resilience of a proposed project must identify and assess climate change related risks to their project. The ISO 31000 Risk Management Standard [15] provides a general risk management approach that includes gathering information, assessing risk and developing a risk treatment plan. A general framework for assessing climate-related risks and developing a risk treatment plan is presented and summarized below (Figure 1). ECCC recommends that proponents follow this five-step process, and offers additional guidance on these steps in sections 3.2.1 to 3.2.5.

Other approaches to the one presented in sections 3.2.1 to 3.2.5 can be used provided that proponents apply and document information on climate risks using a methodology that is consistent with the approach outlined in the ISO 31000 Risk Management Standard and that all information outlined in section 3.2 is included.

[1] Scores could be a quantitative estimate (e.g. likelihood or probability of occurrence) or based on a qualitative ranking (high to low).
[2] 'Evolving' here recognizes that climate change hazards may differ during different phases of a project.
[3] 'Risk thresholds' are identified by the proponent as a means to identify climate hazards associated with unacceptable risks.

Figure 1: A general framework for assessing climate-related risks and developing a risk treatment plan.

▶ Long Description

Once the proponent has assessed the risks related to climate change and developed a risk treatment plan, they will be required to use this information to provide a concluding statement on the project's expected overall resilience to climate change (Section 3.3).

Assessment of a project's climate related-risks and development of a risk treatment plan may not require the same level of effort and detail for each individual project, as this depends on the potential vulnerabilities and complexity of interactions. The degree of uncertainty, which may increase with time, also adds to the level of effort. The depth of assessment required to understand risks associated with potential future climate change is a product of both the magnitude of climate change projected for an area, the sensitivity or vulnerability of particular aspects of a project to those changes and the consequences of any risks to the environment or valued components associated with those changes.

3.2.1 Step 1: Establishing the project context

In this initial step, the proponent must identify essential characteristics of the context and design of the project that will warrant further consideration in the identification of the climate hazards for the duration of the project. The proponent must consider and include the following key elements:

- Project location and setting
    - Consider the location and setting of the proposed project, including the ecological and topographic setting. Is it a permafrost region; is it on the coast where infrastructure may be threatened

    by sea level rise effects on storm surge; is it in a drought prone region; what is the terrain stability, etc.
  - Projected changes in climate are not uniform across the country (for example, the greatest temperature increases are projected to occur in Canada’s north)
- Project lifetime including all phases: construction, operations, decommissioning and abandonment
  - A project’s exposure and vulnerability to climate hazards may change for different project phases (for example, where tailings need to remain water covered after operations have ceased, dry conditions may become more important than during the operations phase of a mine)
  - For projects where the climate hazard identified is consistent for all phases, relevant aspects of the climate may differ from the baseline period over which the project was established (for example, total annual precipitation may increase; return periods for extreme events may decrease)
  - The length of climate records and projections should, where possible, cover the full lifetime of the project (see Annex B for discussion of length of projections)
  - For short-term projects, or for specific short-term components of any given project, the recent historical record (if up-to-date and properly characterized) may suffice to characterize the range of likely climate variability for the project area
- Project type and design elements
  - Consider the project type and the design elements of the proposed project
  - Climate related vulnerabilities for a particular type of project may be informed in part by previous environmental or impact

assessments and the operational history of similar projects, as well as case studies

The following is a non-exhaustive list of guiding questions to assist proponents in establishing the project context.

Establishing the project context - Guiding questions

- What is the planned project lifespan and what is the duration of each phase of the project
- Where is the project to be located
- What is the ecological setting of the project (for example, on the coast or near a glacier-fed river) and topographic setting
- What is the project type and relevant design elements

3.2.2 Step 2: Identifying climate hazards

In this step, the proponent must identify the climate hazards relevant for a specific project. In this guide, a climate hazard relates to climate-related physical events (for example, a heavy precipitation event), longer-term trends (for example, increasing winter temperatures) or their physical impacts (for example, permafrost thaw). Climate hazards of relevance may differ/change during different phases of the project, in particular if the lifespan of the project is long.

The proponent should begin by evaluating the sensitivities of all aspects of the project to the historical (or baseline) climate of the area (including means and extremes). Elements of the project that are designed in accordance with known exposure or vulnerability to current weather/climate conditions (including means, extremes and inter-annual and seasonal variability) are likely to remain sensitive and, in some cases, become more exposed because of future changes in those same design elements (for example, water management structures designed with current return periods for extreme events). Climate hazards may change through different phases of the project. For example, water balance and drought conditions may become more important (that is, pose greater risk) during mine closure if water cover needs to be maintained over mine tailings. In other cases, the cumulative effects of climate change in the project's vicinity could alter site conditions such that the project's effects on the environment may change. For example, changes in conditions from the baseline may alter aspects of the environment such that the project's potential effect on the environment may change through time (for example, an ecosystem may become more vulnerable to particular effects of a project). Furthermore, climate hazards may have more than one potential consequence and cascading and cumulative effects are possible.

The proponent must consider the following key elements when identifying climate hazards.

- Identify climate-sensitive project components and phases (or vulnerabilities)
    - The proponent must carefully consider all aspects of the proposed project and identify those that may be vulnerable to climate change bearing in mind project location (including consideration of topographic and ecological setting) and duration/lifetime as above but also the type of project and climate-sensitive design aspects
- Identify climate change hazards relevant to project vulnerabilities
    - Effects of climate change on a project must be considered including identification of those effects that may potentially impact the environment or valued components if they were to cause an accident, malfunction or infrastructure failure (for example, projected changes in return period for extreme events)

- Obtain or generate hazard-relevant past and future climate information
    - Key climate parameters and hazards should include the identification of relevant (that is, those related to current and future vulnerabilities) trends in variables such as precipitation and temperature, including level of confidence associated with trends and sources of information. Additional parameters will be applicable on a project-by-project basis (see Annex B)
    - Hazard identification includes the consideration of both extreme events (sush as, heat waves, flooding, extreme precipitation) as well as impacts from incremental or slow-onset events (such as, permafrost thaw).

The following is a non-exhaustive list of guiding questions to assist proponents in identifying climate hazards.

Identifying climate hazards - Guiding questions

- What components of the project (including for example, physical elements and human resources) are vulnerable to climate and potential future climate change over the project's full lifetime? Have you considered all phases of the project
- What are the specific elements of climate that pose a hazard to the vulnerable components of the project
- What climate change information is needed to evaluate potential future changes in climate hazards? What climate information is available and what needs to be considered when using climate projections

3.2.3 Step 3: Risk analysis

The objective of the risk analysis is to understand the level of risks that the identified climate hazards pose to a project based on their likelihood of occurrence and potential consequences. To do this, proponents must evaluate how the frequency or magnitude of the climate hazards and related impacts and consequences may change in the future and how vulnerable the project is to these changes (for example, is there a threshold of response or is the response linear). Each climate change hazard may result in multiple consequences and may interact with several elements of the project. The risks associated with a climate hazard are related to their likelihood of occurrence and their potential consequences to the project, environment and other VCs. It is important that each risk (and changes to each risk resulting from climate change) is evaluated separately, which will allow each risk to be individually rated to determine any differences in priority for risk treatment.

Proponents must consider all potential climate interactions of the project and what risks they pose (independently and collectively) to the surrounding environment and valued components. The proponent should consider Indigenous Knowledge when performing the risk analysis.

The proponent must include information on the following key elements in their risk analysis:

- Likelihood of climate hazard occurrence for present and future project lifespan
  - Likelihood is an estimate of the probability or frequency of an event happening over a specified time period. The likelihood of a climate hazard occurring can be assessed quantitatively using available climate data and information (for example, a flooding event with a return period of 100 years has a 1% probability of occurring in any given year). Climate changes could include

    increases in the frequency or magnitude of extreme events (for example, an increase in Probable Maximum Precipitation (PMP) or in the magnitude of an extreme event of a specified return level) or result in longer timescale changes at a project location such as permafrost warming and thaw or increased risks to infrastructure associated with rising sea level. The proponent must evaluate, to the extent possible, how likely these changes are to occur based on an assessment of future projections including consideration of their confidence and projection uncertainty (see section 3.1.2 for additional information on uncertainty). Projected climate changes could, for example, be considered in terms of their magnitude, probabilities of exceedance for extreme events or for crossing thresholds for longer-term changes. The proponent should indicate, with rationale, the time period or time steps for which the likelihood of the future climate hazards have been assessed.
  - The proponent must describe the approach they have taken to develop measures to analyze the likelihood (in other words either quantitative estimates or qualitative scores or ranks) for the future likelihood of the various climate hazards that pose risks to the project related to potential future changes in climate.
- Potential consequences for each hazard/component interaction
  - The proponent must describe the potential impacts of climate hazards. The consequences of the impacts associated with each climate hazard should be ranked. For the purpose of this guidance, the term impact is used to describe the interaction of a climate hazard on an element or component of the project, while a consequence is the result of that impact (that is the effect). For example, extreme precipitation in the project area (climate hazard) can overload inputs into a wastewater treatment facility (impact),

which results in an increased risk to public health and the surrounding environment (consequence or effect). Impacts and consequences (effects) may depend on how vulnerable the project elements are to the changes in weather and climate extremes and mean conditions. The assessment of the potential severity of future climate hazards will likely depend - although to differing extents for each hazard and time period under consideration - on the climate change scenario used in the evaluation.
    - The proponent must describe the approach they have taken to develop scores for the consequences (that is the severity of effects) of the various climate hazards to the project, and thereby surrounding environment, related to potential future changes in climate.

The following is a non-exhaustive list of guiding questions to assist proponents in performing a risk analysis.

Risk analysis - Guiding questions

- What changes in the project-specific climate hazards are anticipated in the future
- How do the projected changes in climate hazards relate to changes in the likelihood of the project's exposure to these hazards
- How likely is each climate hazard to occur over the project lifetime (Likelihood)
- What are the potential effects of exposure to each climate hazard on the project, the surrounding environment and valued components (VCs)
- What is the severity of the potential effects of exposure to each climate hazard on the project, the surrounding environment and

valued components (VCs) (presented as scores or ranks) (Consequence)

3.2.4 Step 4: Risk evaluation

Risk evaluation involves comparing the results of the risk analysis, undertaken in the previous step (step 3), with risk criteria that allow risks to be ranked and acceptable and unacceptable risks to be identified. This risk evaluation provides the basis for identifying when risk treatment and adaptation measures are necessary. A common method to evaluate the level of risk associated with a particular hazard is to use a risk evaluation matrix that compares estimates of both likelihood and consequence concurrently to generate evolving per-climate hazard risk rankings. [16]

Table 1 provides an example of a general framework for evaluating risk based on estimates of consequence and likelihood. If a climate hazard is assessed to have a high likelihood of occurring for a particular present or future time period, and is associated with high consequence effects (for example, risk of failure of water related infrastructure and subsequent release of contamination to the environment), it poses a higher risk overall for that time period and potential treatment should be developed (see Section 3.2.5). In this example, the legend below the table details the criteria for application of controls for the various levels of risk (for example, extreme risks require immediate controls).

Table 1: An example of a Risk Evaluation Matrix. Risks from weather and climate events (that is, climate hazards), for discrete present and future periods, are evaluated based on their likelihood of occurrence (“Likelihood”) and the consequence of potential impacts (“Consequences”) [17]

-	**Likelihood: Very Low**	**Likelihood: Low**	**Likelihood: Moderate**	**Likelihood: High**	**Lik Ve**
Consequences: Very High	Moderate Risk	High Risk	High Risk	Extreme Risk	Ext Ris
Consequences: High	Low Risk	Moderate Risk	High Risk	High Risk	Ext Ris
Consequences: Moderate	Low Risk	Low Risk	Moderate Risk	High Risk	Hig
Consequences: Low	Negligible Risk	Low Risk	Low Risk	Moderate Risk	Mo Ris
Consequences: Very Low	Negligible Risk	Negligible Risk	Low Risk	Low Risk	Lo

Extreme risk requires immediate controls.
High risk requires high priority control measures.
Moderate risk requires some controls to reduce risk to lower levels.
Low risk indicate that controls are likely not required.
Negligible risk indicate that risk events do not require further consideration.

This approach allows for the ranking or prioritization of risks; the proponent must identify the unacceptable risks. The risks to the project can be evaluated, as relevant, under different future time periods and different emission scenarios for each project element (or component) and climate hazard. The risk criteria applied by the proponent to evaluate when a risk is substantial enough to warrant management or treatment should be identified clearly.

The proponent must consider and include the following key elements:

- Summary of all the risks that have been identified for each climate hazard
- Risks ranked (or prioritized for action) based on concurrent estimates of both their likelihood and consequence (Table 1 provides an example)
- Identification of unacceptable risks

The proponent must document and consider uncertainties associated with the climate change information used (see sections 3.1.1 and section 3.1.2 and Annex B) and uncertainties in their estimates of the vulnerability of project elements and potential impacts. The proponent must consider likelihood and how the likelihood affects the reliability or confidence in the risk assessment.

Likelihood cannot be equally “measured" or “estimated” for climate projections for all variables and the proponent should consider how this ultimately affects the reliability or confidence in the risk assessment. If the proponent determines that climate change risks do not exist for the project or are negligible (thus not warranting further consideration) a clear rationale must be provided. If this decision is reached because projections do not identify adverse changes in relevant climate parameters for the future, the proponent should keep in mind that because of uncertainties in climate projections, a range of results should be considered. A finding of mixed or minimal projected changes should be considered in this light. In other words, a lack of certainty for a projected change is not equivalent to certainty that there will be no change. As an example, projections of changes in storm intensity for coastal British Columbia are subject to high uncertainty, but this uncertainty cannot be interpreted as certainty that changes will not occur in the future.

The following is a non-exhaustive list of guiding questions to assist proponents in performing a risk evaluation.

Risk evaluation - Guiding questions

- How will the overall risks associated with the climate hazards (based on estimates of their likelihood and potential consequences) be ranked for evaluation
- What is the rationale for the risk ranking criteria that have been applied
- What overall risk ranking requires treatment or adaptation measures and why

3.2.5 Step 5: Risk treatment and adaptation measures

Once the proponent has identified the unacceptable risks, they must determine appropriate methods to manage or reduce them to acceptable levels. Risk treatment options could include design or operational management modifications to reduce the projects vulnerabilities to an acceptable level, or adaptive management approaches to reduce risks and adapt to future changes. It may be useful to consult existing guidance documents in this regard (see Annex D). For example, the dam safety document (Ouranos 2015) proposes some risk treatment measures for dams.

The proponent must consider and include the following key elements:

- Risk treatment for unacceptable risks
  - The proponent must clearly identify the risk treatment options that have been considered for each of the climate hazards that pose an unacceptable risk to the project, environment or valued components, at present or in the future

    - The proponent must clearly describe and justify the option(s) selected
    - The proponent must include information on when the selected risk treatment options will be applied
    - The proponent must provide an estimation of the risk to the project and consequently the environment and VCs that are assumed by selecting a particular management approach and identify any contingency measures or ongoing monitoring or other measures necessary to evaluate their effectiveness
- Monitoring and review strategy
    - The proponent must include information on how the selected risk treatment approach (es) will be monitored and follow-up requirements. For example, if an adaptive approach is selected, would it be applied when a certain threshold of climate change is reached? The trigger point for adaptive action should be identified beforehand and the response time to put adaptive measures in place should also be considered. Some project types may be more flexible in terms of risk treatment or adaptive management approaches than others where some risks may be unavoidable

The following is a non-exhaustive list of guiding questions to assist proponents in identifying risk treatment options and adaptation measures.

Risk treatment and adaptation measures - Guiding questions

- What can be done to reduce or adapt to the unacceptable risks posed by the identified climate hazards to decrease potential impacts to the project itself and thereby effects to the surrounding environment and VCs
- What are the limitations or risks associated with the treatment or adaptation plans selected

- What, if any, long-term monitoring will be required to inform adaptation or evaluate the effectiveness of any adaptation measures

3.3 Statement on the project's resilience to climate change

Once the proponent has applied the general risk assessment framework outlined in section 3.2 (or a similar approach) to evaluate climate change risks to the project, they must provide a statement on their assessment of the proposed project's resilience to potential future climate change. This approach is summarized below in Figure 2. This assessment of resilience is to be informed by their evaluation of the risks (including consideration of uncertainties and level of confidence) that climate change poses to the project, surrounding environment and VCs, and the likely effectiveness of the risk treatment and adaptation plans that they have selected.

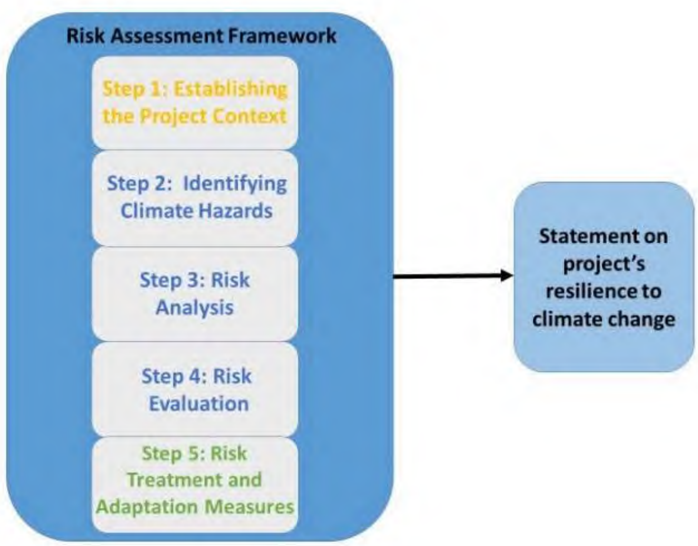

Figure 2: Approach for assessing a project's resilience to climate change based on risk assessment (as detailed in Figure 1).

▶ Long description

Following the general methodological framework and guidance provided in this technical guide does not guarantee that potential changes to all climate-related hazards and risks associated with a project as a result of climate change have been adequately identified or addressed. A successful evaluation of the climate change resilience of a project depends on proper identification of climate hazards and evaluation of their consequences, likelihood of occurrence and appropriate risk treatment options. Pertinent climate change information should be utilized and interpreted for relevant project components and stages according to best-practice. The proponent is responsible for proper identification of all aspects of a project that may be at increased risk due to future climate change; this requires identification and consideration of elements of project design and management as well as the climate parameters and their expected future trends in accordance with best-practice. Finally, the climate change resilience assessment seeks to identify, evaluate and manage risks to the project in order to inform the assessment of climate change risks associated with the project’s design. The science and the risk assessment do not determine the extent to which risks are significant or acceptable.

4 Conclusion

This technical guide provides a framework for proponents to assess climate change resilience at the project-level. The main steps for each project involve the identification of climate hazards, consideration of the potential impacts of those hazards on the project and evaluation of the magnitude of consequences (that is, potential effects) of those impacts on the project and other valued components. This information, along with consideration of the likelihood of these hazards occurring, informs a risk analysis and development of appropriate treatment options. This technical guide also provides guidance on the availability and use of future climate change projections in the resilience assessment process and on required documentation of approaches taken, including assumptions made and considerations of uncertainty.

This technical guide complements the SACC by providing general guidance on how to identify, evaluate and make plans to adapt to the risks associated with potential future climate change. It also provides guidance that can help to enhance each project's resilience to climate change. Furthermore, it will inform and support impact assessment decisions.

5 Next steps and contact information

Stakeholders and Indigenous peoples are encouraged to submit comments on this draft technical guide by May 13, 2022. Comments are to be submitted by email to:

Strategic Assessment of Climate Change – Draft Technical Guide

Environment and Climate Change Canada
351 St. Joseph Boulevard, 12th Floor
Gatineau, QC K1A 0H3
Email: escc.sacc@ec.gc.ca

Following the publication of this draft technical guide and a review of comments received, the final technical guide is planned to be published in 2022.

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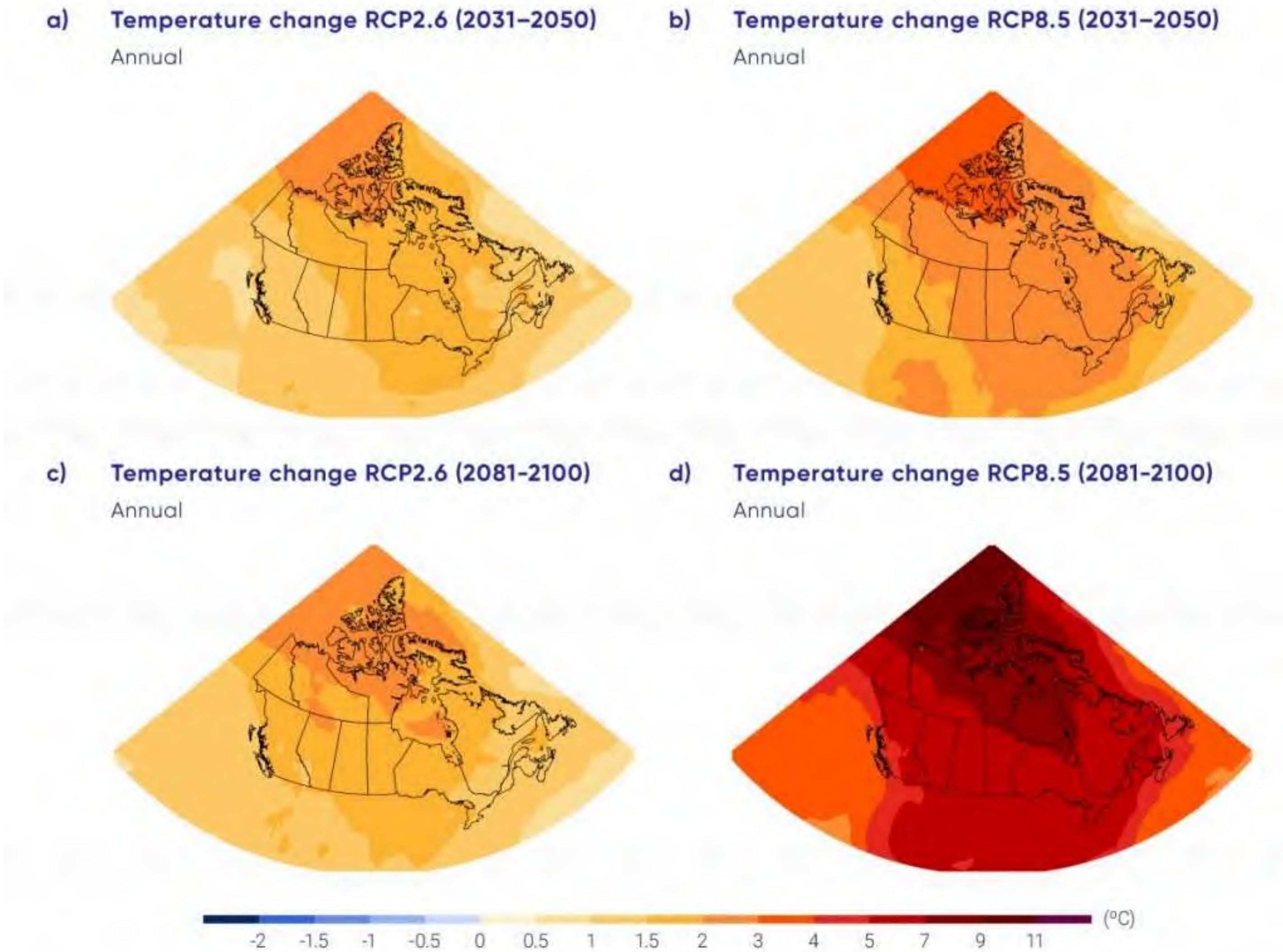
Annex A: Overview of projected changes in Canadian climate (temperature and precipitation)


a) Temperature change RCP2.6 (2031–2050)
Annual
b) Temperature change RCP8.5 (2031–2050)
Annual
c) Temperature change RCP2.6 (2081-2100)
Annual
d) Temperature change RCP8.5 (2081-2100)
Annual
-2 -1.5 -1 -0.5 0 0.5 1 1.5 2 3 4 5 7 9 11
(°C)

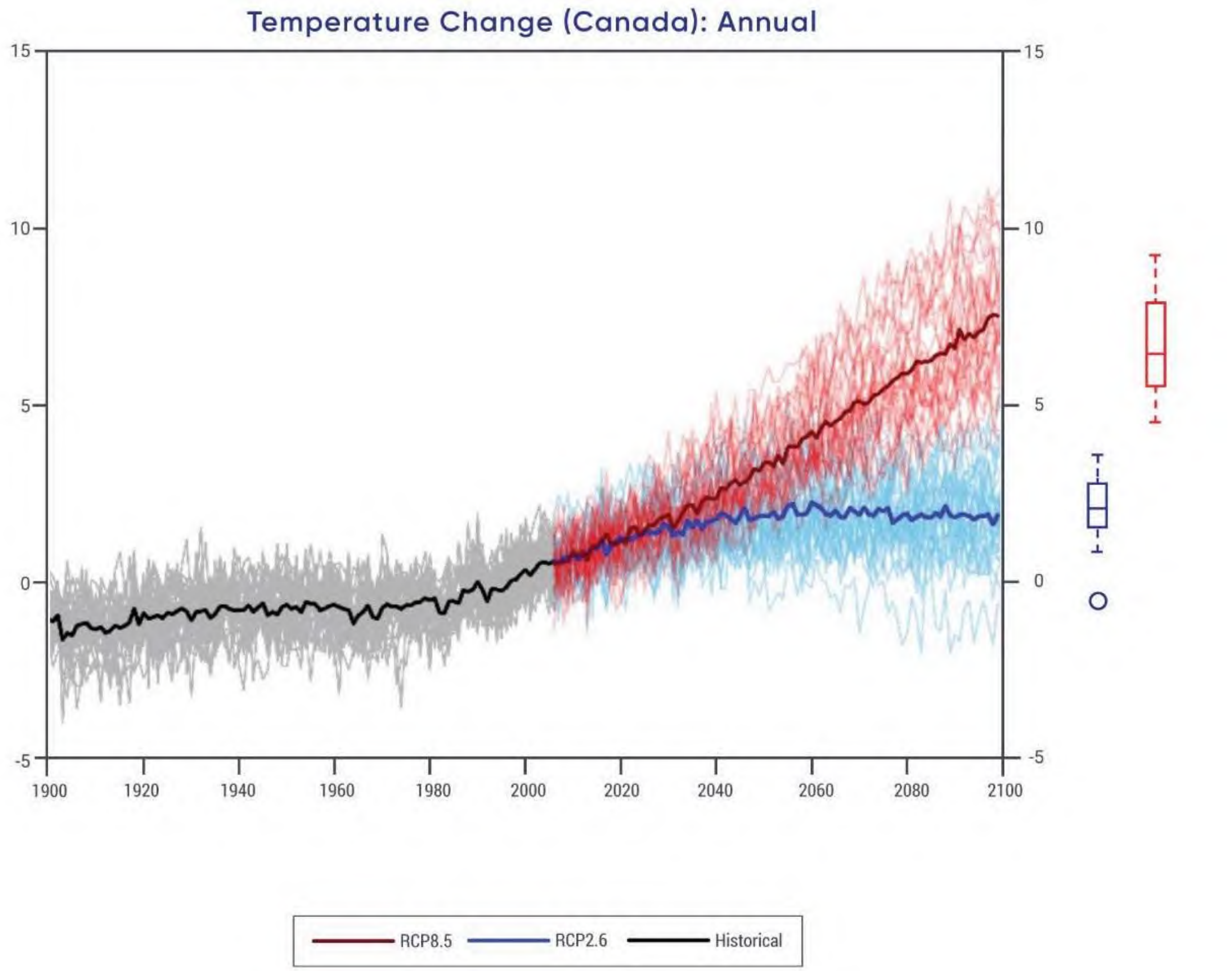
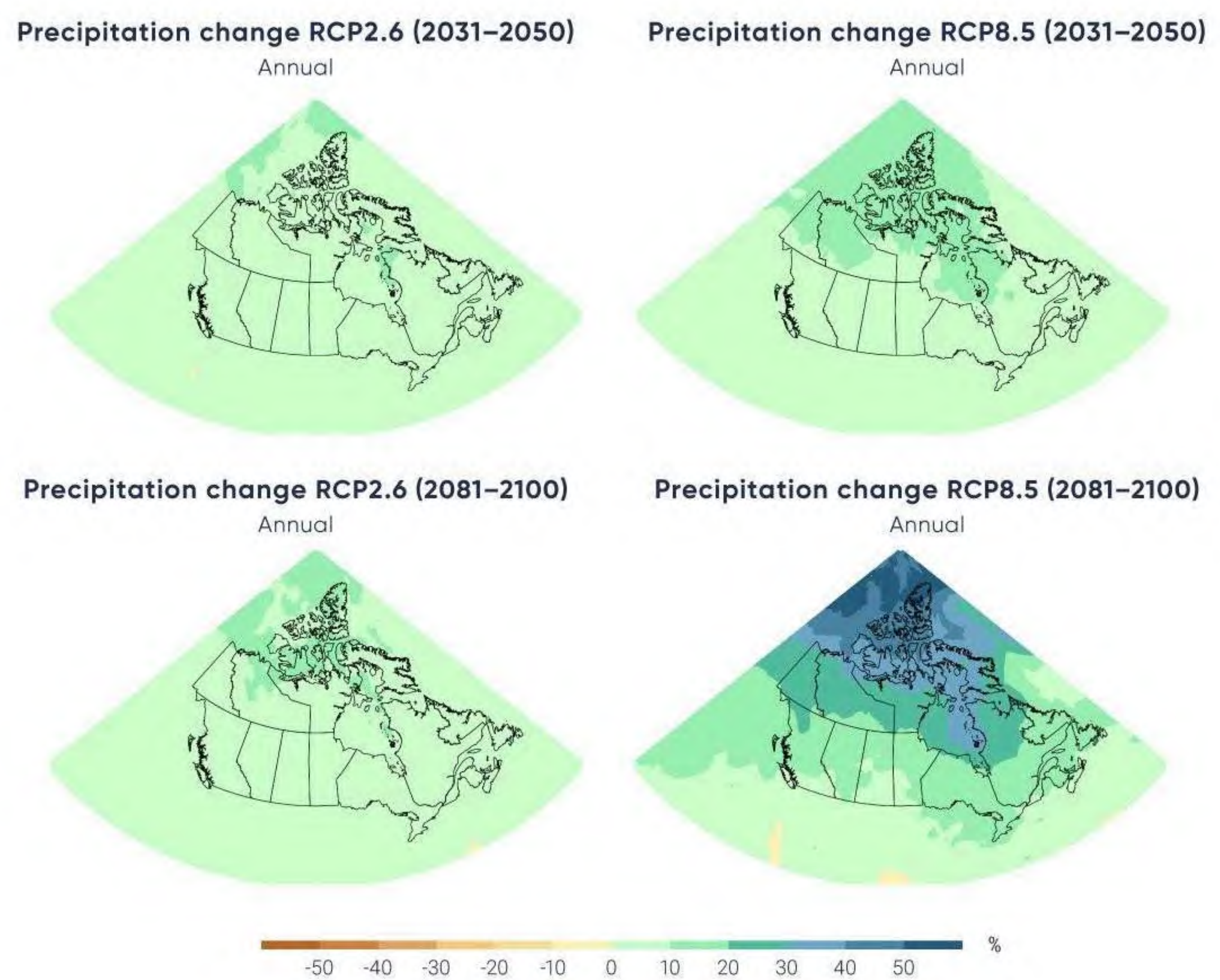


Figure 3: Maps and time series of projected annual mean temperature change, (°C) as represented by the median of the fifth phase of the Coupled Model Intercomparison Project (CMIP5) multi-model ensemble. Changes are relative to the 1986–2005 period. The upper maps show temperature change for the 2031–2050 period and the lower maps, for the 2081–2100 period. The left-hand maps show changes resulting from the low emission scenario (RCP2.6), whereas the right-hand maps show changes from the high emission scenario (RCP8.5). The time series at the bottom of the figure shows the temperature change averaged for the Canadian land area and over the 1900–2100 period. The thin lines show results from the individual fifth phase of the Coupled Model Intercomparison Project (CMIP5) models, and the heavy line is the multi-model mean. The spread among models,

evident in the thin lines, is quantified by the box and whisker plots to the right of each panel. They show, for the 2081–2100 period, the 5th, 25th, 50th (median), 75th, and 95th percentile values. [18]

▶ Long description

(a) Annual precipitation (% change)



(b) Summer precipitation (% change)

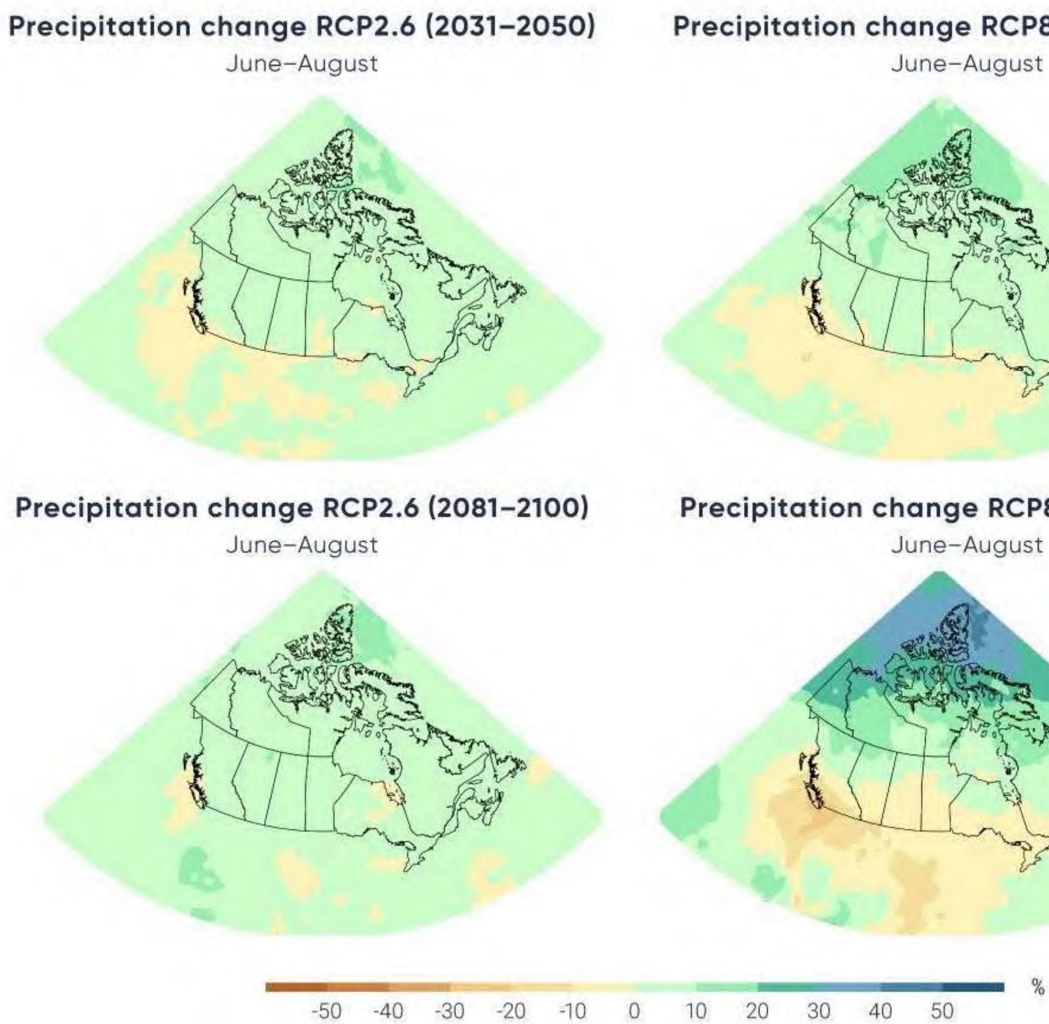
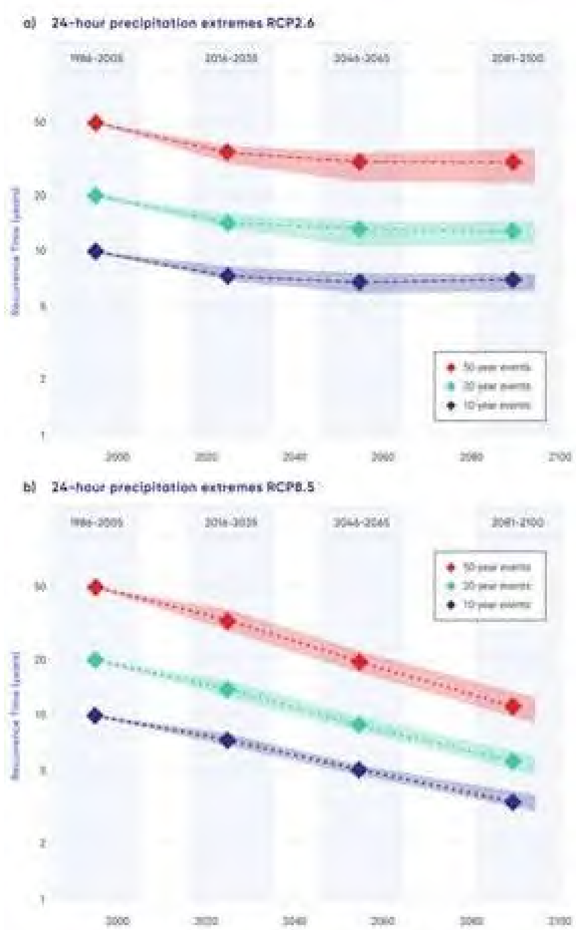


Figure 4: Maps of projected (a) annual mean and (b) summer mean precipitation change (%) as represented by the median of the fifth phase of the Coupled Model Intercomparison Project (CMIP5) multi-model ensemble. Changes are relative to the 1986–2005 period. The upper maps in (a) and (b) show precipitation change for the 2031–2050 period and the lower maps, for the 2081–2100 period. The left-hand maps show changes resulting from the low emission scenario (RCP2.6), whereas the right-hand maps show changes from the high emission scenario (RCP8.5). [19]

▶ Long description

(i) 24-hour precipitation extremes



(ii) Annual maximum temperature

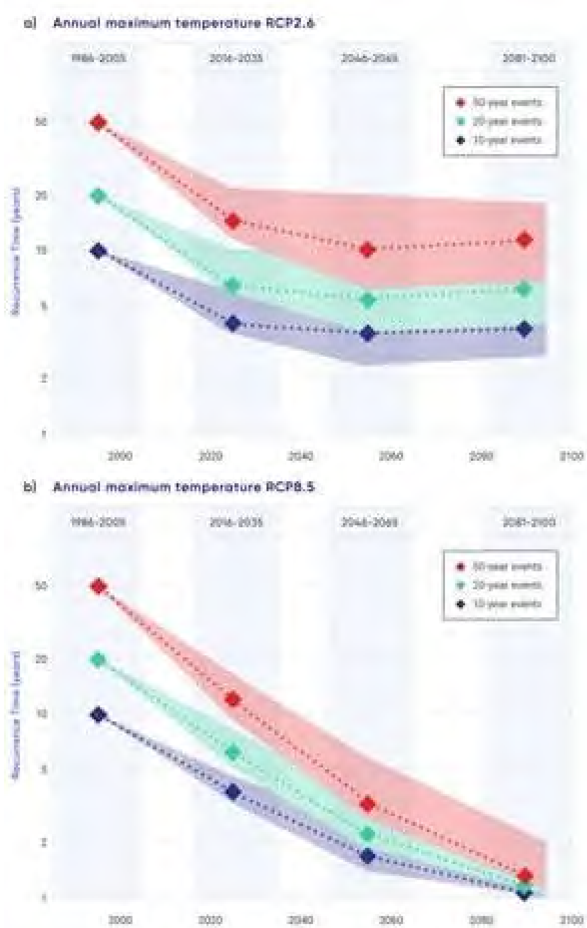


Figure 5: Projected changes in recurrence time (in years) for (i) annual maximum 24-hour precipitation and (ii) annual highest temperatures that occurred, on average, once in 10, 20, and 50 years in the late century across Canada, as simulated by Earth system models contributing to the fifth phase of the Coupled Model Intercomparison Project (CMIP5) under a low emission sce¬nario (RCP2.6; upper) and a high emission scenario (RCP8.5; lower). The projections are at global climate model resolution, and the processes that produce 24-hour extreme precipitation at local scale are not well represented. Therefore, projections should be interpreted with caution. The shading represents the range between the 25th and 75th percentiles. [20]

▶ Long description

Annex B: Guidance on using climate change information in resilience assessments under the IAA

This Annex provides further guidance to proponents on how climate change data and information can be incorporated into climate change resilience assessments. The topics covered reflect guidance commonly provided by ECCC in the IA (and formerly EA) process (for example, guidance on consideration of potential changes in extreme precipitation). However, this Annex is not exhaustive. It provides best practices that proponents should consider when conducting their resilience assessment. Proponents are responsible for identifying and applying best-practices that are most relevant to the project in question. Many of the analyses that may be necessary (for example, downscaling, hydrological modeling) require specialized training and expertise. The relevant analyses must be conducted by qualified professionals to ensure proper application and interpretation of climate change information in impact assessment.

As climate change science is continually evolving, project proponents should consult the most recent credible scientific literature. When providing and interpreting climate change information, the proponent must provide a description of methodologies, data sources and assumptions used as well as a rationale for the approaches taken. As noted in Section 3.1, information from Canadian and international assessments and special reports, as well as other relevant scientific literature, can be used to acquire a general idea of how climate may change in the project region. Additional climate information for a range of climate parameters can be obtained from a number of sources (see Annex C for examples). The proponent should consider the general guidance below in their use of climate change data and information in their resilience assessment.

(i) Identification and consideration of appropriate climate and climate-related variables

The proponent should consider projected changes in relevant climate parameters, extreme weather and climate events, and more complex events such as floods and droughts where relevant to the project. The evaluation should be comprehensive and not focus, for example, on mean annual temperature and precipitation alone when risks posed by changes in other variables are of greater relevance to the project. Climate-related factors that may warrant consideration based on a project's location and sensitivities include factors such as wind, waves, sea ice extent or duration, wildfire risk, sea level change, permafrost thaw, changes in snow cover or soil moisture conditions, changes to freshwater levels and streamflow timing and magnitudes, or changes in severe climate events (for example, extreme hot days or heavy precipitation events). The confidence in the projections or expected changes for these different variables is not uniform and requires careful consideration in subsequent evaluations and analysis.

At times, climate projections for a project area are incorporated into additional modeling such as thermal modeling for permafrost, water balance and hydrologic modeling. It is thus very important that appropriate climate projections (appropriate parameters and spatial and temporal scale) be considered in any additional modeling to ensure that the full range of potential changes are identified and that the uncertainties can be evaluated. Where climate change projections are used in additional modeling undertaken by the proponent, clear documentation including a rationale for data selection must be provided along with details on the methodology employed.

It is likely that for many project locations, changes in several relevant climate parameters may occur simultaneously in the future, and that these changes will occur on top of naturally occurring climate variability. This implies that impact or effects studies need to consider how these changes will act together to influence the project and its potential effects. The effects of changes in each climate variable should not only be considered in isolation. As an example, site water balance may be expected to change because of projected changes in temperature, precipitation and evaporation.

(ii) Consideration of the varying level of confidence in projections for different climate variables

Numerical values for projected future climate do not have the same precision as the observed meteorological and climatic data, and as such, they should not be treated as real data. Additionally, the level of scientific confidence in projected climate change is not the same for all climate variables as they involve processes of different complexities and with differing levels of uncertainty. [21] Confidence in projected future temperature change is high, especially at large scales. This is because temperature change is affected by well understood physical mechanisms - increases in atmospheric greenhouse gases result in global temperature increase due to changes in the atmosphere’s energy balance. There is lower confidence in projected precipitation change, particularly in precipitation extremes and at smaller spatial scales. Confidence for compound events such as drought, which is affected by changes in both temperature, precipitation and other factors, may be lower than that for the individual contributing factors.

Proponents should consider the level of confidence in the projections for the climate variables they are using in the climate change resilience assessment (particularly when assessing likelihood during risk analysis and evaluation) to ensure appropriate analysis and interpretation. For example, in their “Assessment of the Impact of Climate Change on Climatic Design

Data in Canada", Cannon et al. (2020) specifically considered the level of scientific confidence in future projections in different climate variables for large regions Canada. To do this, they applied a multi-tiered approach to projecting climate design values: Tier 1 (temperature variables: high to very high confidence), Tier 2 (precipitation and moisture variables: medium confidence) and Tier 3 (wind, snow and ice: low or very low confidence). Cannon et al. (2020) also describe the types of analysis that may be supported by projections for climate variables from the different tiers (for example, Tier 1: direct application of values with appropriate consideration of uncertainties, Tier 2: cost benefit analysis or risk assessment or Tier 3: exploring potential impacts of climate change). This illustrates that the proponent should take care to ensure that projections are not used inappropriately. For example, Tier 3 variables such as wind speed, should not be taken literally as "data" and applied directly in design without appropriate consideration of the level of scientific confidence.

(iii) Use of a multi-model ensemble to project future climate

The rate of climate change and associated impacts can provide important historical context for a given area of interest. Past climate trends in an area can offer some benchmark for adding context to help interpret projections of future climate, but changes (or lack of changes) in the past are not predictors for the future because past changes have been affected by both human-induced climate change as well as natural variability internal to the climate system. There is therefore no scientific basis for extrapolation of observed climate trends into the future to provide estimates of future change. The strength and sign (that is, increase or decrease) of trends can be dependent on the start and end dates used for their calculation. Simply extrapolating a trend from local or regional historical climate data records does not provide a reliable projection. The best means of projecting future climate is to use output from global climate models (GCMs) or Earth System Models (ESMs) which use the basic principles of physics to reflect atmospheric, ocean and terrestrial system responses to changing climate forcing (for example, greenhouse gas concentrations) over time.

The proponent should consider a range of projected future climates (that is, a range of scenarios) from multiple climate models. [22] Several factors contribute to the range in projected future climates: (1) differences in how climate models represent complex physical and biogeochemical processes, (2) the irreducible uncertainty in the climate system which shows up as natural climate variability and (3) different scenarios of future emissions.

Future emissions will be influenced by social, economic and technical development, and as such, are very difficult to predict precisely. As a result, emissions scenarios are used as input to climate models to project plausible future climate. The scenarios describe possible future releases of greenhouse gases, aerosols and other pollutants to the atmosphere from human-made and natural sources as well as land use changes. These estimates are based on assumptions of future socio-economic development, population growth, technological development and other factors. [23] Running global climate models with a range of different emission scenarios yields a range of plausible future climate change.

The majority of climate model simulations and associated impact studies in the published literature extend to 2100. Simulations beyond 2100 are available (although there are much fewer than available to 2100; in other words, there is a smaller sample size for ensembles) and they are more uncertain as there is less information on how society (that is, the trajectory of future emissions and mitigation measures) and the climate system itself will evolve. CO_2 (the main contributor to anthropogenic warming) has a long lifetime (century-scale) in the atmosphere and many aspects of the climate system have slow response times and feedbacks. Thus, unless society is able to actively remove CO_2 from the atmosphere (that is, lower emissions below zero), the global temperature increase achieved when emissions become net zero will be effectively irreversible for multiple centuries. These factors should be considered by proponents of projects with aspects that will remain sensitive to climate conditions beyond 2100.

The best practice for reflecting uncertainty is to use a range of projections (that is, not the mean or median alone) from an ensemble of climate models for a range of emission scenarios. Once an ensemble has been established, simply using the ensemble mean or median (50th percentile) does not capture the range of changes that may occur. Evaluation of the range of possible changes is particularly important, and common scientific practice, when evaluating future climate change impacts. A probability of occurrence has not been ascribed to the different future scenarios. It is recommended that the proponent consider the range of emissions scenarios in their climate change resilience assessment and be mindful that beyond mid-century the scenarios diverge increasingly. The essential point here is that the proponent should consider what a projection value really represents and carefully consider how to take the uncertainty into account in their design and operations. Whatever emissions scenarios are considered as the basis for project design, planning and management, the risks to the project and subsequently the environment and VCs associated with that approach should be articulated clearly by the proponent. The proponent should demonstrate that, for the scenario(s) selected, they have considered the risk to the project and surrounding environment and VCs to fully inform the risk treatment measures that they propose to implement.

(iv) Consideration of potential changes in extreme precipitation

The spatial resolution of typical global climate model output is coarse (around 100–250 km). Climate model output at an individual grid cell therefore represents averages over areas of tens of thousands kilometres. The projected climate values given by climate models cannot be interpreted literally as a measured value (for example, amount of precipitation or surface air temperature) at a point location. At low spatial resolution, there is generally greater confidence in projected changes from the historical average than in the projected values themselves. Information at finer spatial scales may be needed for particular applications (such as hydrological models). Dynamical (using RCMs) and statistical downscaling methods have been used to generate higher resolution climate datasets. However, higher spatial resolution datasets do not necessarily indicate higher-quality or more valuable climate information for all applications and it is recommended that users of projections evaluate whether they really need high-resolution climate scenarios or whether they could make effective use of lower-resolution climate change scenarios (for example discussion see Flato et al. 2019).

In a warmer world, the magnitude or intensity of short duration (<1 day) extreme precipitation events is projected to increase. This means that events that have the same return period (for example, a 1:20 year event) would be expected to be stronger in the future. Thus, the level of protection that is designed for the current climate cannot be maintained unless adaptation measures are in place. Stationarity in design values based upon past climate conditions can no longer be assumed and the proponent should use the best available method to characterize climate related effects on the project. For example, this is an important consideration where water management infrastructure is designed to withstand the effects of a changing climate over the next century.

Return periods based on current climate can be expected to decrease for many warm climate extremes and short duration precipitation extremes in the future. For precipitation extremes across Canada, the relative change in event frequency is expected to be larger for more extreme and rarer events. In terms of local scale precipitation (especially extremes), climate models generally do not include all of the physical processes that produce local intense rainstorms (such as convection). Thus, future projections of extreme precipitation at a point location or small spatial scale (either obtained directly from GCM output or downscaled GCM products) are unlikely to be robust (Li et al. 2019). Estimates of future short duration precipitation extremes that are based on statistical relationships fitted between local-scale observed extreme precipitation and modelled simulations are also unlikely to be robust. This is because the amount of information on changes in local-scale observed extreme precipitation contained in short records is not sufficient to constrain a regression (that is, model the statistical relationship) between local and larger scale simulations.

A more robust alternative approach is to base future projections on a comprehensive assessment that integrates climate science understanding and model projections over a large region. The recent Canadian Standards Association (CSA 2019) guidance on IDF for Canadian Water Resources practitioners provides such an assessment. The CSA guidance outlines the use of a simple scaling technique to obtain future precipitation projections, by increasing historical precipitation by a certain percentage proportional to the projected temperature increase for the region. A strength of this approach is that there is greater confidence in temperature projections derived from a multi-model ensemble than similar projections of changes in precipitation. Useful estimates of possible changes in extreme precipitation for a project location can be achieved by adjusting precipitation based on a range of temperature projections over the project lifetime. The proponent is referred to the CSA guidance document for more detailed technical information on this approach.

When floods occur, there are usually multiple contributing factors. This makes projecting future changes in flood events very challenging. Some contributing factors will be affected by human-induced climate warming, and some will change due to other human influences (such as changes to the landscape). As well, natural climate variability will continue to play a role. Projected increases in extreme rainfall in a warmer climate are expected to increase the likelihood of rain-generated flooding in some regions (Bonsal et al. 2019, p.292). However, as noted above, flood events are related to more factors than just extreme precipitation events alone (such as, snowpack, land use changes, etc.). Given that the extreme-precipitation related component of flooding is expected to intensify in the future, this may also effect flood events. The proponent should consider how these potential changes will influence design values such as PMP (Kunkel et al. 2013) and PMF in addition to other possible climate-related changes (for example, changes in glacial meltwater discharge in summer months, changes in snowpack, rain-on-snow events, river ice-jam events, etc.) appropriate for the project type and location.

Annex C: Climate and climate change information resources

Disclaimer: Provided below is a list of resources potentially useful in assessment of a project’s climate change resilience. However, this list of resources is not intended to be exhaustive or prescriptive nor can it be assumed that the most up-to-date version of resources are listed. Proponents are ultimately responsible for obtaining the best quality information that is applicable to their specific project.

Climate and Climate Change Information Resources

Case studies

Map of Adaptation Actions: Government of Canada repository of case studies from across Canada to see how communities and sectors are adapting to a changing climate.

Climate information and datasets

Canadian Centre for Climate Services: The Canadian Centre for Climate Services (CCCS) works with partners and stakeholders to provide Canadians with information and support to consider climate change in their decisions. The CCCS provides access to climate data, training and support on the use of climate information, and opportunities to collaboratively develop new climate information and data products. The information can be used to help understand and plan for changes, identify and reduce risks, and build climate resilience.

Canadian Climate Data and Scenarios site: Canadian Climate Data and Scenarios (CCDS) site provides users access to a range of climate datasets and products including access to observations, historical datasets, seasonal forecasts, derived products and future projections.

CanCoast Coastal Sensitivity Indices Version 2.5.6.: CanCoast is a geospatial database of the physical characteristics of Canada's marine coasts. CanCoast includes: wave-height change with sea ice (early and late 21st century); sea-level change (early and late century); ground ice content; coastal materials; tidal range; and backshore slope.

Climate Atlas of Canada: The Climate Atlas of Canada is an interactive tool developed for users to learn about climate change in Canada. It combines climate science, mapping and storytelling. The primary source of climate model data presented in maps, charts and tables are based on CMIP5 statistically downscaled scenarios.

ClimateData.ca: ClimateData.ca is a climate data portal. The goal of this portal is to support decision makers across a broad spectrum of sectors and locations by providing the most up to date climate data in easy to use formats and visualizations. Data can be visualized in map or local time series format and can be downloaded for specific stations (historical) or grid cells (future).

ClimateWest: ClimateWest is a non-profit organization and a regional hub for climate services in Manitoba, Saskatchewan, and Alberta, empowering people, communities, businesses, and governments to address risks and opportunities caused by a changing climate.

Government of Canada Historical Climate Data: Access to historical weather, climate data, and related information for numerous locations across Canada. Datasets include: hourly and daily stations observations, monthly climate summaries, Canadian Climate Normals and Engineering Climate Datasets (including Intensity-Duration-Frequency (IDF) files).

Government of Canada Water Level and Flow: Access to information and data on surface water levels and flows across Canada. It includes access to real-time and historical hydrometric data, hydrometric station and network data (station name, location, drainage area, data type, gauge type, stream order), and tools to browse and extract hydrometric information including access to and supporting information for the Reference Hydrometric Basin Network; a set of stream gauge stations with long records and minimal human impacts that are appropriate for climate change studies.

Natural Resources Canada (Canada Forest Service) regional, national and international climate modeling: Historical spatial climate models at a variety of time steps covering Canada and the United States.

Natural Resources Canada Permafrost datasets: This includes Canada-wide maps of permafrost contains datasets and maps across Canada. Historical data are available in grid and image format.

Natural Resources Canada Sea-level projections: Access tabulated values of relative sea-level projections in Canada and the adjacent mainland US.

Open Science and Data Platform: Explore information about cumulative effects and development activities in Canada: The Open Science and Data Platform provides access to environmental data and scientific publications that can be used to understand the cumulative effects of human activities. By looking at science, environmental data and information about development activities across the country, we can learn about potential impacts to support better decisions in the future.

Ouranos: Ouranos is a consortium on regional climatology and adaptation to climate change, providing climate scenarios and services to multiple partners in Quebec, across Canada and around the world.

Pacific Climate Impacts Consortium: The Pacific Climate Impacts Consortium (PCIC) is a regional climate service centre at the University of Victoria that provides practical information on the physical impacts of climate variability and change in the Pacific and Yukon Region of Canada. User can access a range of resources such as daily gridded meteorological datasets, gridded hydrologic model output, and statistically downscaled datasets.

Power Analytics and Visualization for Climate Science (PAVICS): PAVICS is a virtual laboratory facilitating the analysis of climate data. It provides access to several data collections ranging from observations, climate projections and reanalyses. It also provides a Python programming environment to analyze this data without the need to download it.

Guidance

CSA PLUS: 4011:19: Technical Guide: Infrastructure in permafrost: A guideline for climate change adaptation : Guidance outlining methods to estimate the sustainability of engineered structures on permafrost foundations over their service lives in northern Canada. It is applicable to all new infrastructure in permafrost regions, including those for resource development.

CSA PLUS 4013:19: Technical Guide: Development, interpretation and use of rainfall intensity-duration-frequency (IDF) information: Guideline for Canadian water resources practitioners: Guidance for Canadian water resources practitioners designed for professionals with a role in the planning, design, management, inspection, and regulation of stormwater, drainage, wastewater, and flood management systems. It is not a design text book, but rather a resource for understanding the derivation, and application in water system planning and design, of rainfall intensity-duration-frequency (IDF) information.

Guidance on Good Risk Assessment Practices in Climate Change Risk Assessment: Canadian Council of Ministers of the Environment (CCME) publication intended to serve as a guide to inform good practices in conducting climate risk assessments across jurisdictions.

Reports

A Guidebook on Climate Scenarios: Using Climate Information to Guide Adaptation Research and Decisions: This guidebook produced by Ouranos supports decision-makers in understanding climate information, modelling, and how climate change scenarios can be used to inform adaptation.

Arctic Monitoring and Assessment Programme: The Arctic Monitoring and Assessment Programme is one of six Working Groups of the Arctic Council. The webpage links to a number of scientific reports related to climate and climate change in the Arctic.

Canada in a Changing Climate: Advancing our Knowledge for Action: The reports in this series provide information about past and future changes in Canada's climate, the related social, economic and environmental impacts and adaptation actions to address them.

Climate-Resilient Buildings and Core Public Infrastructure: an assessment of the impact of climate change on climatic design data in Canada: This report provides an assessment of how climatic design data relevant to users of the National Building Code of Canada (NBCC 2015, Table C-2) and the Canadian Highway Bridge Design Code (CHBDC/CSA S6 2014, Annex A3.1) might change as the climate continues to warm.

Government of Canada Climate Change Publications: A repository of Government of Canada published reports and assessments. This includes Canada's Changing Climate Report related to how and why Canada's climate has changed and what changes are projected for the future, and a series of collaborative, national and sectoral science assessments that present the latest knowledge on climate change impacts and adaptation for Canadians.

For more resources, please see the Canadian Centre for Climate Services' Library of Climate Resources.

Annex D: Climate change risk and resilience assessment resources

Some jurisdictions have developed guidance for consideration of climate change in their environmental assessment processes and some sectors have independently developed sector-specific guidance that outlines some of the common climate change risk factors associated with particular types of development projects such as mines. Additionally, other countries and independent bodies such as the International Association for Impact Assessment have developed guidance documents. Other useful guidance for evaluating risks associated with climate change have been developed (not necessarily for use in formal environmental assessment) is provided below.

Disclaimer: The documents and links below may be useful resources to supplement this Technical Guide but do not replace or supersede the instructions provided in this guide, the SACC or the or the requirements set out in the TISG, the *Impact Assessment Act* or its regulations. Furthermore, this list is not exhaustive and is not meant to denote any preference or evaluation of information quality.

Suggested resources

Atlantic Climate Adaptation Solutions Association, 2012. 7 Steps to Assess Climate Change Vulnerability in Your Community.

Canadian Council of Ministers of the Environment, 2021. Guidance on Good Practices in Climate Change Risk Assessment.

ICLEI Canada, 2014. Changing Climate, Changing Communities Guide.

Infrastructure Canada, 2019. Climate Lens – General Guidance.

Public Safety Canada, 2013. All Hazards Risk Assessment Methodology Guidelines 2012-2013.

Incorporating Climate Change Considerations in Environmental Assessment: General Guidance for Practitioners. 2003. Prepared by The Federal-Provincial-Territorial Committee on Climate Change and Environmental Assessment. Available on the Impact Assessment Agency website.

ISO, 2021. - ISO 14091:2021 - Adaptation to climate change — Guidelines on vulnerability, impacts and risk assessment

ISO, 2019. - ISO 14090:2019 - Adaptation to climate change — Principles, requirements and guidelines

Ontario Government: "Consideration of climate change in the environmental assessment in Ontario"

"Climate Change in Impact Assessment: International Best Practice Principles", 2018. International Association for Impact Assessment

"Best practices for consideration of climate change in Project-level Environmental Assessments" by OCCIAR and RSI

1 The Paris Agreement is an international agreement to strengthen the global response to the threat of climate change, building on the United Nations Framework Convention on Climate Change. The Paris Agreement, which entered into force in November 2016, established a collective long-term goal to hold the increase in the global average temperature to well below 2 degrees Celsius above pre-industrial levels, and to pursue efforts to limit that increase to below 1.5 degrees.

2 The Pan-Canadian Framework on Clean Growth and Climate Change, adopted on December 9, 2016, is a comprehensive plan to reduce emissions across all sectors of the economy, accelerate clean economic growth and build resilience to the impacts of climate change.

3 A Healthy Environment and a Healthy Economy

4 Strategic Assessment of Climate Change

5 See SACC section 2.2 Technical guides for more information

6 See SACC section 1.2 Application for more information

7 Strategic Assessment of Climate Change

8 The scope of factors to be considered is set out in the IAA in subsection 18(1.2)

9 Practitioner’s Guide to the Impact Assessment Act

For Canada Energy Regulator (CER)-regulated projects, proponents should also refer to the guidance provided in the CER Filing Manual for specific requirements.

10 For more information on the impact assessment process, please consult the IAAC website.

11 This refers to the physical activities as set out in the Physical Activities Regulations Schedule, found at: Physical Activities Regulations.

12 Baseline conditions here refers to the existing environmental, health, social and economic components, interrelations and interactions as well as the variability in these components, processes and interactions over time scales and geographic boundaries appropriate to the project. This information is requested via the Tailored Impact Statement Guidelines and is to be provided for relevant VCs (that is, those that may be impacted by the project) in the Impact Statement. Baseline climate conditions refers to historical climate of the project area.

13 Information about the environmental, social and economic impacts of climate change on Canada and adaptation actions that are or could be used to address them can be found in the reports in the Canada in a Changing Climate: Advancing our Knowledge for Action

14 Practitioner's Guide to Federal Impact Assessments under the Impact Assessment Act.

15 International Organization for Standardization.

Note that this standard is not a climate change standard. Rather it defines general risk management principles that can be modified to apply to climate change assessments (for example by repeated applications for present and future conditions).

16 Evolving here recognizes that climate change hazards may differ during different phases of a project.

17 Source: Infrastructure Canada - Climate Lens, Annex G, Table 3.

18 Source: Figure 4.8. Canada's Changing Climate Report, 2019, p. 137-138. (Zhang et al. 2019)

Projected Temperature change based on CMIP5 multi-model ensembles - Open Government Portal

Canada's Changing Climate report supplemental datasets - Open Government Portal

19 Source: Figure 4.18 and 4.19. Canada's Changing Climate Report, 2019, p.163-166. (Zhang et al. 2019)

Projected Precipitation change based on CMIP5 multi-model ensembles - Open Government Portal

Canada's Changing Climate report supplemental datasets - Open Government Portal

20 Source: Figure 4.12 and Figure 4.20, Canada's Changing Climate Report, 2019, p. 149 and 170. (Zhang et al. 2019)

Canada's Changing Climate Report

21 The IPCC assessment reports and other assessment based reports (such as *Canada's Changing Climate Report*) use a calibrated language to communicate the degree of certainty of results (Mastrandrea et al., 2011). The level of scientific **confidence** in climate projections is based on a number of factors including the availability, quality and level of agreement of evidence. Based on this review of evidence, the level of confidence is classed into five categories ranging from very high to very low. Generally, evidence is most robust when there are multiple, consistent independent lines of high-quality evidence. When confidence is very high or high, and sufficient evidence is available, quantified **likelihood** assessments are made. These quantified likelihood statements range from virtually certain to occur (99%–100% probability) to exceptionally unlikely to occur (0%–1% probability).

22 More information about how to access and use historical and future climate data can be obtained from the Canadian Centre for Climate Services (CCCS), established by the Government of Canada so that Canadians have the information and support they need to understand and reduce the risks from climate change.

23 The forcing scenarios used by the international modeling community are updated periodically. The IPCC Fifth Assessment (AR5) reported on modeling using Representative Concentration Pathways (RCPs; van Vuuren et al. 2011). These are a set of emission scenarios that range from a low emission scenario characterized by active GHG mitigation (RCP 2.6), through intermediate scenarios (RCP 4.5), to a high emission scenario (RCP 8.5). Modeling in the previous IPCC report (AR4) used “SRES scenarios” (IPCC, 2000). The IPCC Sixth Assessment (AR6) reports on modeling results using shared socioeconomic pathways (SSPs; e.g., Riahi et al. 2017).

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