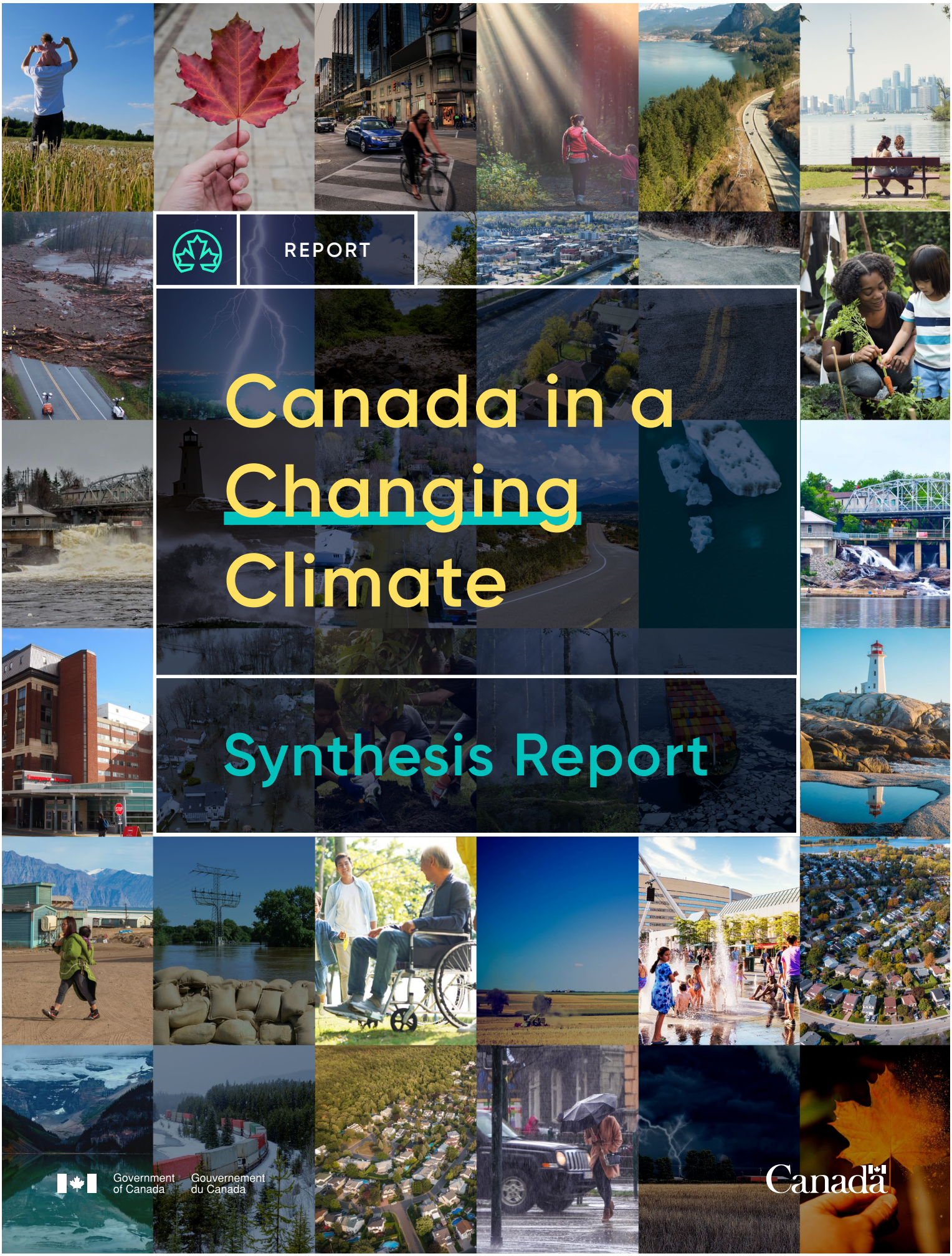

REPORT
Canada in a Changing Climate
Synthesis Report
Government of Canada
Gouvernement du Canada
Canada

Recommended Citation:

Lulham, N., Warren, F.J., Walsh, K.A. and Szwarc, J. (2023). Canada in a Changing Climate: Synthesis Report; Government of Canada, Ottawa, Ontario.

The digital interactive version of the report is available at: www.ChangingClimate.ca/Synthesis. The report is also available at: adaptation.nrcan.gc.ca

Aussi disponible en français sous le titre :
Le Canada dans un climat en changement : Rapport de synthèse

For more information about the National Knowledge Assessment, contact the Assessment Secretariat at:
nrcan.adaptation.rncan@nrcan-rncan.gc.ca

Cat. No.: M34-84/2023E-PDF

ISBN: 978-0-660-68099-6

This report is part of *Canada in a Changing Climate: Advancing our Knowledge for Action*, the National Knowledge Assessment of how and why Canada's climate is changing; the impacts of these changes on our communities, environment, and economy; and how we are adapting.

To find out more, please visit: <https://natural-resources.canada.ca/climate-change/canada-in-a-changing-climate/19918>

Table of Contents

Acknowledgements

We would like to acknowledge the National Assessment Advisory Committee for their valuable guidance and input throughout the process:

Gord Beal, Chartered Professional Accountants Canada

Robert Capozi, New Brunswick Climate Change Secretariat

Stewart Cohen, Independent Climate Scientist, Environment and Climate Change Canada (retired)

Ellen Curtis, Physical and Health Education Canada

Susan Evans, Ontario Ministry of Agriculture, Food and Rural Affairs

Elaine Fox, Government of Manitoba

Pierre Gosselin, Institut national de santé publique du Québec

Sara Holzman, Government of Nunavut

Ewa Jackson, ICLEI Canada

David Lapp, Engineers Canada (retired)

Caroline Larrivée, Ouranos

Fred Lipschultz, U.S. Global Change Research Program

Patricia Manuel, Dalhousie University

Linda Mortsch, University of Waterloo

Graeme Reed, Assembly of First Nations

Marjorie Shepherd, Environment and Climate Change Canada

Jim Vanderwal, Fraser Basin Council

Thomas White, Natural Resources Canada

Many people also contributed directly to this report, providing supporting text, reviewing content and assisting with editing. We would like to thank the following for their help:

Peter Berry

Richard Boyd

Craig Brown

Elizabeth Bush

Meredith Caspell

Chris Derksen

Al Douglas

Dariel Helmesi

Anne Kendrick

Paul Kovacs

David Pearson

Marie-Hélène Tremblay

Rebekka Schnitter

Key conclusions

Canada's ageing infrastructure is at high risk from climate change (see Section 2.1)

Adaptation is increasingly urgent for reducing climate risks to infrastructure, which provides safe spaces for living and working and supports our energy, transportation and water treatment systems. Many approaches are being developed and used to reduce climate risks and improve the resilience of Canada's infrastructure.

Climate change is harming our health (see Section 2.2)

With climate change already negatively affecting the health of Canadians and their health systems, urgent adaptation action is needed to reduce the risks. Continued and coordinated efforts are critical for protecting the health of Canadians from current and future climate change impacts.

Our food and natural resources are highly climate-sensitive (see Section 2.3)

Failing to adjust how we manage natural resource and food production sectors in a changing climate would threaten local economies and jobs, and have consequences for transboundary resource management, Canada's supply chains and our involvement in global trade. Various adaptation options are being implemented in these sectors to reduce climate risk and impacts.

The business case for adaptation is strong (see Section 2.4)

Climate change impacts already cost Canadians billions of dollars each year, and costs will continue to rise. There is a strong business case for adaptation, with the benefits (including avoided costs) gained through adaptation measures generally exceeding the costs of implementation.

Nature-based approaches save money and provide many benefits (see Section 2.5)

Nature-based approaches to adaptation are often more cost-effective and deliver a suite of co-benefits. Protecting vulnerable ecosystems is also essential for preserving the services that they provide and for maintaining biodiversity.

Improved incentives and coordination can help close Canada's adaptation gap (see Section 2.6)

In Canada, progress on adaptation remains slow, with relatively few examples of implemented actions despite growing losses. Greater incentives, fewer barriers and improved coordination across sectors and scales will help close the adaptation gap.

Local-level adaptation plays a leading role in our climate change response (*see* Section 2.7)

Local governments and Indigenous communities in Canada are already experiencing climate change impacts on their infrastructure, economies and well-being. Together with local partners, they are well positioned to take action on adaptation given their local knowledge and Indigenous Knowledge, strong social networks and connections to the land.

Self-determined and Indigenous-led climate action supports reconciliation (*see* Section 2.8)

Indigenous Knowledge Systems, and Indigenous rights and governance are critical to establishing just, equitable, decolonized and sustainable approaches to overcoming the climate crisis. Recognizing that humans, culture and the natural world are inseparable, and that we share responsibility for future generations, is essential to these approaches.

Adaptation can promote equity (*see* Section 2.9)

Existing social, economic and health inequities are often exacerbated by climate change impacts. Engaging with those most affected by climate change is essential for ensuring that adaptation measures address these inequities.

Now is the time for the private sector to step up on adaptation (*see* Section 2.10)

Businesses face a range of direct and indirect risks from climate change. It is vital to engage and empower the business community and other private sector stakeholders if we are to progress at the scale needed to reduce current and future climate change risks and take advantage of potential opportunities.

Preface

The release of this Synthesis Report marks an important milestone for Canada's National Knowledge Assessment process. Over the last six years, we have worked with more than 650 experts from across the country to produce a total of six reports. While building on the knowledge foundation provided by past Assessment processes, we have introduced many new approaches and covered new themes and issues. New voices have been added, and we are especially excited to have included an Indigenous-led report, *For our Future: Indigenous Resilience Report* (forthcoming). These reports provide a strong and credible knowledge base to inform decision making.

At the same time, we must acknowledge the immense changes seen in Canada over the six years since the current Assessment process started. Due to the timing of knowledge collection and analysis, and the publication process, many of the latest changes and impacts have not been captured within this suite of reports. For example, following a global pandemic that affected all aspects of our lives, Canada has experienced several major climate events. These include the destructive Category 4 Hurricane Fiona in the Atlantic region in 2022 and the widespread, devastating wildfires across much of Canada in 2023. Such events clearly demonstrate that there is still much work to be done on adaptation to increase our resilience in the face of a changing climate. The urgency for action has also amplified, with mounting evidence that climate impacts, even at lower levels of global warming, can cause severe and sometimes irreversible consequences.

On a positive note, there have also been significant developments on the climate change agenda. Canada now has its first ever National Adaptation Strategy, which was developed through consultation with governments, experts, stakeholders and rights-holders across the country and released in 2023 (Government of Canada, 2023). This whole-of-society strategy includes a framework to help reduce risks and build climate-resilient communities. It also includes goals, objectives and targets to help ensure that investments now and in the future are targeted and effective.

It is our hope that this Synthesis Report, and the other reports produced through this Assessment process, will help inform the decisions and actions that are urgently needed today to help ensure that we and future generations can survive and thrive in Canada's changing climate.

1.0 Introduction

The global climate is changing at an alarming rate. Global surface temperature has increased by over 1.0°C since pre-industrial times and will continue to rise until at least mid-century under all emissions scenarios considered by the Intergovernmental Panel on Climate Change (IPCC, 2023a). In Canada, both past and future warming are about double the magnitude of global warming, with even greater warming in northern regions (*see* CCCR-4[1]).

"There is a rapidly closing window of opportunity to secure a liveable and sustainable future for all." (IPCC, 2023a)

Along with rising temperatures, a warming climate involves changes in precipitation patterns; more frequent and intense extreme events; declines in snow, ice and permafrost; changes in water quality and quantity; ocean warming; and sea-level rise. Such changes are already affecting many aspects of life in Canada—our health and well-being, economies, environment, culture and even our identities. The need for climate action has never been so urgent. Adapting our processes, practices and structures (*see* Box 1) is critical to reduce the growing risks from climate change. Climate change mitigation is also essential: without deep global reductions in greenhouse gas (GHG) emissions this decade, on a path to net zero emissions by around mid-century, global warming is projected to exceed 1.5°C. Surpassing this threshold would have widespread and devastating consequences in Canada and globally (IPCC, 2022). It is imperative that actions and decisions be informed by the best available information.

Box 1: The adaptation process

Adaptation refers to measures that reduce the negative impacts of climate change or that take advantage of potential new opportunities. Climate change adaptation builds resilience and reduces risk related to current and future climate change impacts. It involves adjusting plans, policies and actions, and can be reactive (i.e., occurring in response to climate change impacts) or anticipatory (i.e., occurring before impacts of climate change are observed).

1 The following short forms for each of the National Knowledge Assessment reports, followed by the chapter number, are used to refer readers to specific chapters for more information. See Annex 1 for the report citations. Readers are encouraged to use chapter-specific citations, where appropriate.
CCCR: *Canada's Changing Climate Report* <https://changingclimate.ca/CCCR2019/>
NIR: *National Issues Report* <https://changingclimate.ca/national-issues/>
RPR: *Regional Perspectives Report* <https://changingclimate.ca/regional-perspectives/>
HCCC: *Health of Canadians in a Changing Climate* <https://changingclimate.ca/health-in-a-changing-climate/>
IRR: *For our Future: Indigenous Resilience Report*

Adaptation is often portrayed as a cycle (*see* Figure 1), which encompasses a number of steps, from becoming aware of climate change and the need to adapt, all the way through to learning and adjusting post adaptation implementation. It is, by nature, iterative, and although presented as a sequential process, organizations may take different pathways. Throughout the process there is an ongoing need to build capacity to adapt and mobilize knowledge.

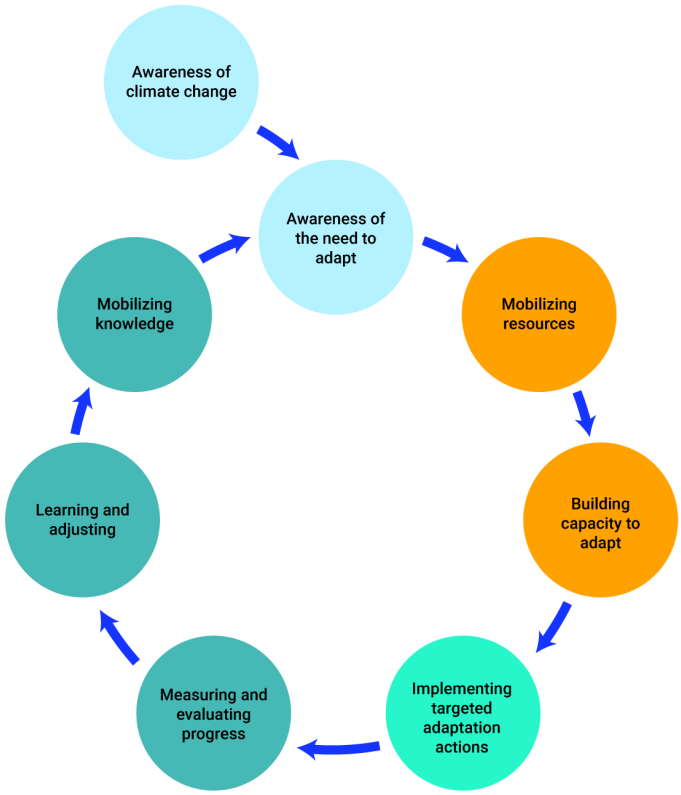


Figure 1: The adaptation cycle. Source: Modified from Eyzaguirre and Warren, 2014.

1.1 Assessment scope and process

In 2017, the Government of Canada launched its fourth National Knowledge Assessment process, *Canada in a Changing Climate: Advancing our Knowledge for Action*, with the goal of assessing, synthesizing and sharing the latest knowledge on climate change impacts and adaptation in Canada to help inform and advance decision making. Led by Natural Resources Canada, this multi-year, collaborative initiative delivered a series of authoritative reports (*see* Figure 2) that assess how and why Canada's climate is changing; the impacts of these changes on our communities, environment and economy; and how we are adapting. The Headline Statements, Key Findings and Key Messages from each of these five Assessment reports are included in Annex 2.

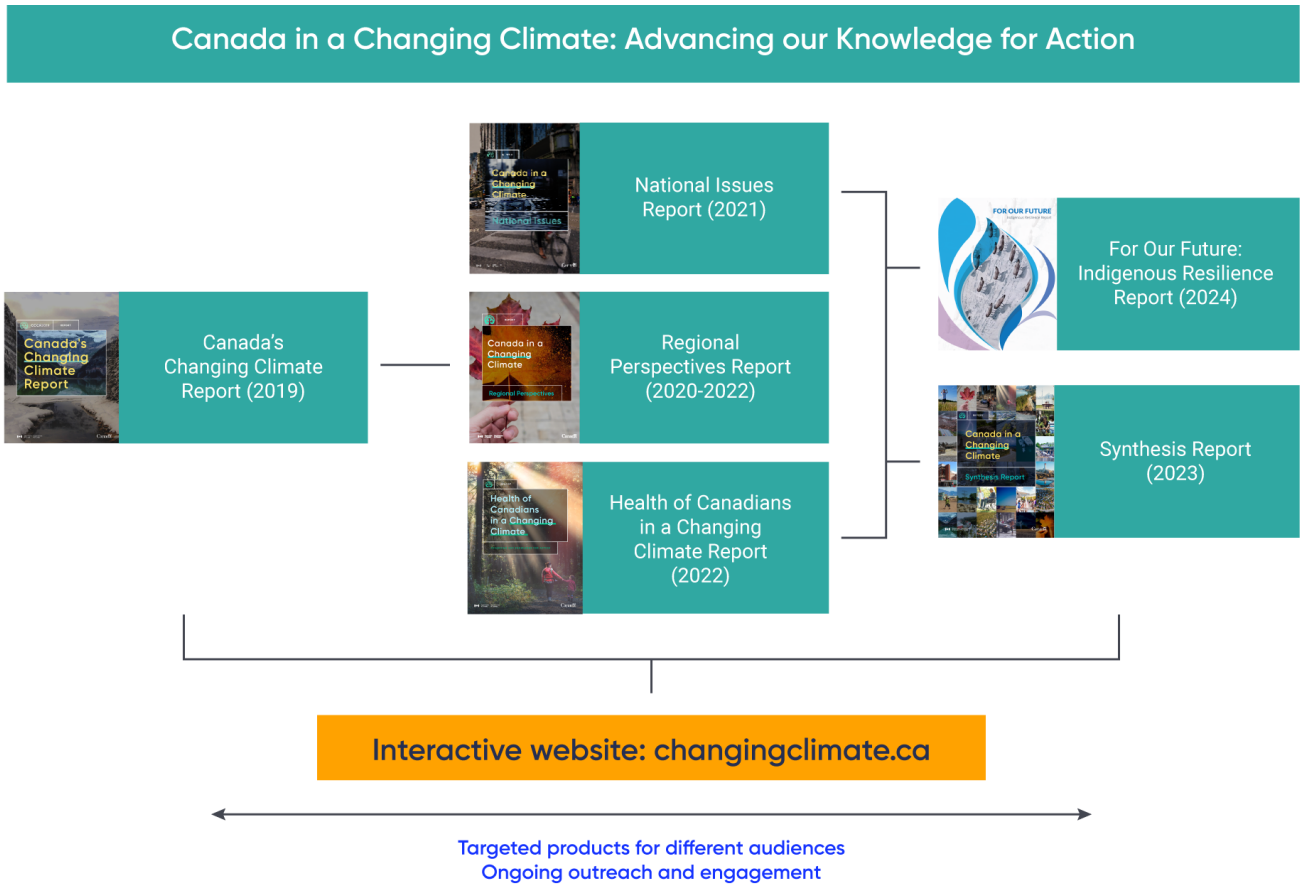


Figure 2: Overview of the reports produced through the National Knowledge Assessment process.

The Assessment process has drawn on a broad partnership of subject-matter experts and Assessment users, including from universities, professional and non-governmental groups, Indigenous organizations, the private sector and all orders of government. Enhanced engagement was a priority throughout, to ensure the credibility, rigour and usefulness of the reports. Starting with a scoping meeting in 2016, experts, target audiences and members of the public were invited to provide input, including through workshops, conference sessions, surveys and online engagement. External review was critical to ensuring that the Assessment reports are credible and relevant: over 300 invited and self-registered expert reviewers provided more than 10,000 comments to the author teams. The many steps of the multi-year Assessment process are outlined in Figure 3.

The Assessment reports draw from existing knowledge on climate change science, impacts and adaptation. Sources include peer-reviewed literature, broader literature, practitioner perspectives, Indigenous Knowledge and local knowledge. Enhanced inclusion of Indigenous Knowledge was a particular priority for the current Assessment process. Production timelines necessitated cut-off dates for incorporating new knowledge sources and literature; as such, the reports may not reference the newest available literature or knowledge on a given topic.

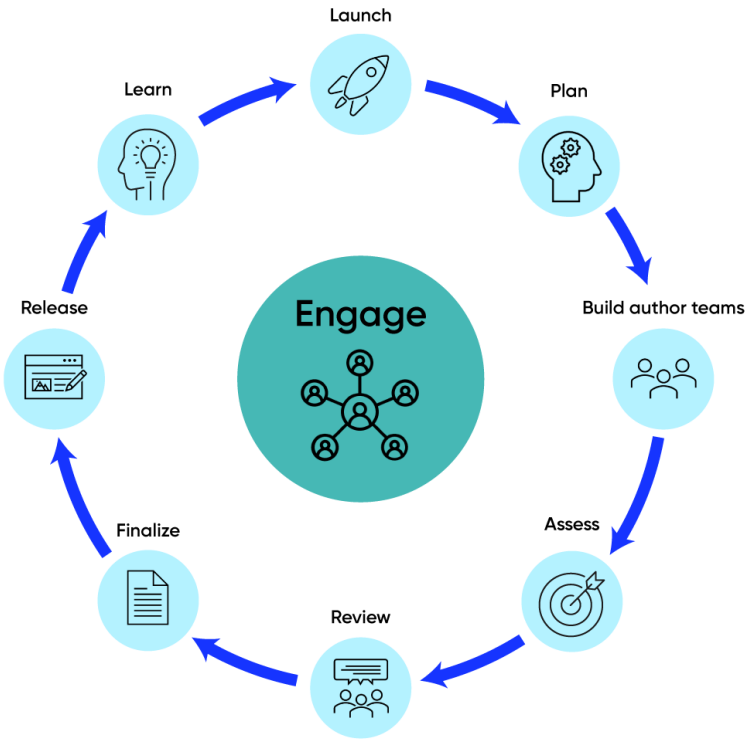


Figure 3: Overview of the steps involved in Canada's National Knowledge Assessment process.

1.2 The climate science foundation

The conclusions of *Canada's Changing Climate Report* (CCCR), the foundational climate science report of the Assessment process, underscore the urgency for action to both mitigate and adapt to climate change. A strong body of evidence confirms that Canada's climate is changing, with changes documented across its regions, in the atmosphere, on land and in the surrounding oceans.

Additional global warming is unavoidable, as some additional GHG emissions are inevitable (*see* CCCR-3). Many climate trends already underway in Canada will therefore continue. These include more extreme heat, less extreme cold, longer growing seasons, increases in annual precipitation, earlier spring peak streamflow, shorter snow and ice cover seasons, thinning glaciers, thawing permafrost and rising sea levels along many Canadian coastlines (*see* Table 1). However, regional variation exists, and understanding these variations is important for informing adaptation plans. For example, while global sea level is unequivocally rising, relative sea level along Canadian coastlines is also influenced by local factors. These factors lead to rates of sea-level rise in some coastal areas that are higher than the global average, while in some other areas relative sea level is falling due to post-glacial rebound (*see* CCCR-7). In the Arctic and Atlantic Canada, the loss of sea ice will further increase the risks of coastal damage from sea-level rise and storm surges.

Table 1: Assessment of observed changes, their attribution, and future changes for a select set of climate indicators from Canada's Changing Climate Report (CCCR) (Bush and Lemmen [Eds]., 2019) and from reports contributing to the IPCC Sixth Assessment.

Confidence/likelihood not assessed for this finding	Low Confidence	Medium Confidence	Likely / High Confidence	Very Likely / Very High Confidence	Virtually Certain	Fact

	CANADA			GLOBAL
CLIMATE INDICATOR	HISTORICAL CHANGE ASSESSMENT (CCCR)	HUMAN CONTRIBUTION ASSESSMENT (CCCR)	PROJECTED CHANGES – (CCCR)	IPCC SIXTH ASSESSMENT REPORT CONCLUSIONS
Average air temperature {CCCR-4} {IPCC SYR SPM A.1; IPCC SYR 3.1.1}	Annual and seasonal mean temperatures across Canada have increased, with the greatest warming occurring in winter.	More than half of the observed warming in Canada is due to the influence of human activities.	Projected increases in mean temperature in Canada are about twice the corresponding increases in global mean temperature, regardless of the emission scenario.	Human activities, principally through emissions of greenhouse gases, have unequivocally caused global warming.
	The best estimate of mean annual temperature increase between 1948 and 2016 is 1.7°C for Canada as a whole, about twice			Continued greenhouse gas emissions will further affect all major climate system components and many changes will be irreversible on centennial to millennial timescales.

	CANADA			GLOBAL
Extreme temperatures {CCCR-4} {IPCC WGI SPM A.3.1}	Extreme warm temperatures have become hotter, while extreme cold temperatures have become less cold.	Most of the observed increase in the coldest and warmest daily temperatures of the year in Canada from 1948 to 2012 can be attributed to anthropogenic influence.	Extreme warm temperatures are projected to become hotter in the future, while extreme cold temperatures are projected to become even less cold.	Hot extremes (including heatwaves) have become more frequent and more intense across most land regions since the 1950s, while cold extremes (including cold waves) have become less frequent and less severe. Human-induced climate change is the main driver of observed changes in hot extremes and cold extremes.
Annual average precipitation {CCCR-4} {IPCC WGI SPM A.1.4)	Annual mean precipitation has increased, on average, in Canada.	The observed increase in Canadian precipitation is at least partly due to human influence.	Annual precipitation is projected to increase everywhere in Canada over the 21st century.	Globally averaged precipitation over land has increased since 1950. Human influence contributed to the pattern of observed precipitation changes since the mid-20th century.

	CANADA			GLOBAL
Extreme precipitation {CCCR-4} {IPCC WGI CH. 11, WGI SPM B.2.4}	For Canada as a whole, observational evidence of changes in daily extreme precipitation amounts is lacking.	Not applicable.	In the future, daily extreme precipitation is projected to increase.	Human influence has contributed to the intensification of heavy precipitation at the continental scale in Northern America. Heavy precipitation events will intensify and become more frequent in most regions with additional global warming.
Cryosphere extent and mass {CCCR-5} {IPCC WGI SPM A.1.5, TS 2.5}	Over the past three decades, the proportion of Canadian land and marine areas covered by snow and ice have decreased, and permafrost temperatures have risen.	Detection and attribution studies show that climate change induced by human activity has driven observed changes to the cryosphere.	Further reductions in the cryosphere extent over the coming decades are *virtually certain*, as temperatures are projected to increase under all future emission scenarios.	Over recent decades, widespread loss of snow and ice has been observed, and several elements of the cryosphere are now in states unseen in centuries. Human influence was the main driver of observed reductions in Arctic sea ice since the late 1970s, the widespread retreat of glaciers, and the Northern Hemisphere spring snow cover decrease since 1950.

	CANADA			GLOBAL
Seasonal stream flow {CCCR-6} {IPCC WGI, TS Box TS.6}	Over the last several decades, spring peak streamflow following snowmelt has occurred earlier, with higher winter and early spring flows. In some areas, reduced summer flows have been observed.	Although no Canadian studies have directly attributed change in streamflow timing to anthropogenic climate change, there is strong reasoning that observed changes in streamflow seasonality are partly attributable to anthropogenic warming.	Seasonal changes in streamflow are projected to continue, with corresponding shifts from more snowmelt-dominated regimes toward rainfall-dominated regimes.	In response to cryosphere changes, there have been changes in streamflow seasonality, including an earlier occurrence of peak streamflow in high-latitude and mountain catchments.
Ocean properties {CCCR-7} {IPCC WGI SPM A.1.6, B.5.1.}	Oceans surrounding Canada have warmed, become more acidic, and less oxygenated, consistent with observed global ocean changes over the past century.	There is strong evidence of human-induced changes during the past century in key ocean-climate properties—such as temperature, sea ice, acidity, and dissolved oxygen—off Canada.	Ocean warming and loss of oxygen will intensify with further emissions of all greenhouse gases, whereas ocean acidification will increase in response to additional carbon dioxide emissions.	The global upper ocean has warmed since the 1970s. Past GHG emissions since 1750 have committed the global ocean to future warming. Ocean acidification will continue to increase in the 21st century. Ocean oxygen levels will continue to decrease in the 21st century.

	CANADA			GLOBAL
Sea level rise {CCCR-7} {IPCC WGI SPM A.1.7, B.5.3}	Relative sea level has increased in the Atlantic, Pacific, and western Arctic regions of Canada over the last century and even exceeded the global rate of change in southern Atlantic Canada, where land is subsiding.	Changes in sea level relative to Canada's coastline are affected by global sea level rise and also by vertical land motion (land uplift or subsidence).	Where relative sea level is projected to rise (most of the Atlantic and Pacific coasts and the Beaufort coast in the Arctic), the frequency and magnitude of extreme high water level events will increase.	Human influence was the main driver of the observed increases in global mean sea level since at least 1971. Global mean sea level will continue to rise over the 21st century.

Sources: **IPCC SYR SPM:** IPCC, 2023a; **IPCC SYR:** IPCC, 2023b; **IPCC WGI SPM:** IPCC, 2021a; **IPCC WGI TS:** Arias et al., 2021; **IPCC WGI CH. 11:** Seneviratne et al., 2021.

The most severe impacts of climate change are often related to changes in climate extremes. A careful assessment of changes in these extremes was undertaken in the CCCR, which found strong evidence for observed changes in extreme temperature. However, at the time of the assessment, the observational record had not yet shown evidence of consistent increases in short-duration precipitation extremes across the country. Importantly, both extreme hot temperatures and extreme precipitation events are projected to become more frequent and intense. The former will increase the severity of heatwaves and contribute to increased risks of drought and wildfire, while the latter will increase risks of urban and inland flooding. Of note, the combination of warmer temperatures and smaller snowpacks in the future leads to uncertainty about future changes in snowmelt-related flooding.

A supplement to the CCCR, published in 2022, provided Canadians with an expert perspective on the consistency of the CCCR findings with those from the IPCC's then most recent science assessment report (IPCC, 2021b). While the IPCC report did not assess changes in climate for Canada as a whole, many of the global and regional findings were confirmed as being consistent with, and in some cases strengthening the evidence for, the CCCR's conclusions (*see also* Table 1).

2.0 Key conclusions

This Synthesis Report draws from the findings of the other reports produced through the current National Knowledge Assessment process (*see* Figure 2) to identify the 10 key conclusions discussed in this section. These key conclusions illustrate the main challenges that climate change is posing to our country, and the steps we are taking to adapt.

Three takeaway messages encapsulate the 10 key conclusions:

- **Climate change impacts—and adaptation actions—are particularly evident in certain critical sectors and ecosystems.** Throughout the Assessment reports, it is evident that Canada's climate is changing, with the impacts felt across the country. But these impacts are especially pronounced for infrastructure, human health, natural resources and the functioning of ecosystems. In response to these impacts, we are seeing examples of adaptation actions being implemented—providing evidence, inspiration and impetus for further action.
- **Canada's economy is affected by the large and rising costs of climate change impacts.** Our economy is highly sensitive to climate change, with extreme events having particularly large and disruptive impacts, and both direct and indirect costs. Economic analyses have shown that adaptation can reduce the projected costs of climate change, with avoided damages generally exceeding the costs of adaptation measures.
- **Rapid, informed and coordinated action is needed to close Canada's large adaptation gap.** As our knowledge around climate change impacts and adaptation continues to advance, lessons are emerging on how to move forward. These include the importance of reducing barriers and increasing incentives, continuing to stimulate action at the local level, increasing Indigenous-led climate action, addressing social and economic inequities, and increasing private sector engagement in adaptation.

2.1 Canada's ageing infrastructure is at high risk from climate change

Adaptation is increasingly urgent for reducing climate risks to infrastructure, which provides safe spaces for living and working and supports our energy, transportation and water treatment systems. Many approaches are being developed and used to reduce climate risks and improve the resilience of Canada's infrastructure.

Canada's infrastructure provides critical services for Canadians, including wastewater and stormwater management, access to drinking water, energy production and distribution, and the movement of goods and people. It also includes public buildings (such as health facilities) and private buildings (such as homes and businesses). Much of Canada's infrastructure is ageing, with approximately one third in need of retrofit or replacement due to its poor condition (Project Steering Committee, 2016). The Council of Canadian Academies (2019) identified infrastructure as the top sector at risk to climate change impacts in Canada, but also the sector with the greatest potential for adaptation.

Most of Canada's existing infrastructure was designed based on historical climate conditions, and much has been in use well beyond its intended capacity and lifespan (*see* NIR-2). As a result, the integrity and performance of this infrastructure is being put to the test, even under current climate conditions. We are already seeing examples of service decline and failure across the country (*see* NIR-2; IRR). Compared with urban areas, rural and remote communities—including those located in northern Canada—experience higher risks to health, safety and well-being from critical infrastructure decline or failure. This is due to their geographic isolation, reliance on limited access points into and out of their communities, and limited access to services (*see* Sections 2.7 and 2.9; IRR; Table 3.8 in NIR-3).

The cost of damage to infrastructure from climate change and extreme weather events is growing, with wide-ranging impacts for Canadians. It is estimated that $5.3 billion per year will be needed over the next 50 years to reduce climate risks to municipal infrastructure in Canada, including roads, facilities, sewer systems and buildings (Insurance Bureau of Canada and Federation of Canadian Municipalities, 2020). This figure is conservative and underestimates the full investment needed to protect Canada's infrastructure, since it only considers municipally owned infrastructure, certain climate risks and not the full range of impacts (*see* NIR-6). Climate change is also increasing risks to health facilities, which has important implications for health service delivery, particularly in the wake of climate disasters (*see* Sections 2.2 and 2.9; HCCC-3; HCCC-10).

Given the interdependence between different infrastructure systems, damage from climate change and extreme weather events can produce cascading impacts, with wide-ranging social and economic implications (*see* Section 2.9; RPR-3). For instance, transportation disruptions affect supply chains and create risks to other sectors of the economy (*see* NIR-7). Damage to roads, bridges or public transit can prevent people from getting to work, bringing their kids to school or daycare, or accessing healthcare (*see* NIR-6). Damaged infrastructure also disrupts the delivery of critical services such as electricity or drinking water, which extends to people living in areas not directly affected by the climate hazard (*see* NIR-6). Identifying interdependencies is increasingly considered an important step in reducing climate risks (C40 Cities and AECOM, 2017).

Many approaches are being developed, tested and used to reduce climate risks and improve the climate resilience of Canada's infrastructure. These include:

- guidelines, codes and standards that consider future climate conditions (such as standards developed through the Northern Infrastructure Standardization Initiative);
- infrastructure risk assessments (such as the Public Infrastructure Engineering Vulnerability Committee Protocol developed by Engineers Canada) to assist with decision making and prioritizing adaptation actions;
- incentive-based tools (such as local improvement charges and development cost charges); and
- the growing use of green infrastructure (such as rain gardens or retention ponds to reduce storm runoff) and low-impact development approaches (see NIR-2; RPR-3).

Many of these approaches can be applied together, and often deliver a range of co-benefits to communities.

Asset management is another approach that communities are increasingly using to assess, monitor and manage their infrastructure assets, including natural assets such as wetlands and urban forests (*see* NIR-2; RPR-3). Incorporating climate change considerations into asset management practices helps communities better understand how climate change affects service levels, so they can make decisions accordingly (*see*

Case Story 2.1 in NIR-2; Federation of Canadian Municipalities, 2018). There are also a growing number of training opportunities related to strengthening climate resilience for communities and professionals working on the design and management of infrastructure (*see* Box 2).

Box 2: Protecting Canada's infrastructure in a changing climate

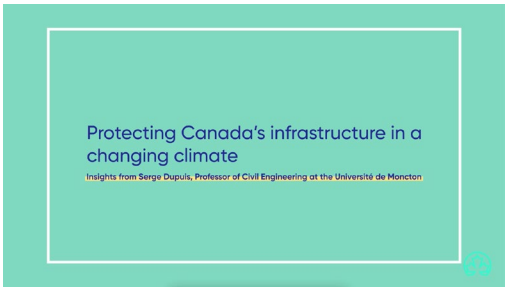
Insights from Serge Dupuis, Professor of Civil Engineering, Université de Moncton

Ageing infrastructure across Canada faces a daunting array of challenges in a changing climate. According to civil engineering professor Serge Dupuis (*see* Video 1), the greatest challenge is the increase in extreme weather events: "Existing and past design criteria were never intended to [address] these extreme [circumstances]." New Brunswick's roads and bridges, for example, are threatened by both inland and coastal flooding related to sea-level rise, storm surges and rivers swollen by extreme rainfall events.

To prepare for these changes, engineering professionals need greater awareness and guidance to meet Canada's changing infrastructure needs. Through Natural Resource Canada's Building Regional Adaptation Capacity and Expertise (BRACE) Program (2017–2022), Université de Moncton managed a team that helped members of the engineering profession better contribute to climate change adaptation. "We [hosted] in-person workshops and technical webinars. We even partnered in developing and hosting a certified risk assessment training course to better prepare our infrastructure professionals to tackle this oncoming extreme weather."

Managing coastal flood risk in New Brunswick is a collaborative process, involving different orders of government. For instance, the provincial government has funded the development of localized maps that show future flood risk. Using these maps, along with LIDAR data and federal government data on climate extremes, Université de Moncton has been able to pinpoint areas that will be more vulnerable to flooding in the future. This work, in turn, informs how local governments can prepare for the consequences of flooding.

Having the right information is crucial to climate-proofing infrastructure. "Engineering professionals," says Professor Dupuis, "need data on how much rain is falling in a certain period […] to help us manage the sizing of infrastructure, [such as] culverts. [They need to know] the number of heat days, the number of freeze-thaw days. This type of information helps us better design, manage or replace some of the infrastructure we have now."



Video 1: Video interview with Serge Dupuis, Professor of Civil Engineering at the Université de Moncton, on improving the climate resilience of infrastructure. <https://vimeo.com/886517548/1b4df0fb62>

2.2 Climate change is harming our health

With climate change already negatively affecting the health of Canadians and their health systems, urgent adaptation action is needed to reduce the risks. Continued and coordinated efforts are critical for protecting the health of Canadians from current and future climate change impacts.

Climate change is increasing risks to human health and well-being, affecting Canadians across the country (*see* Figure 4; HCCC-all chapters; NIR-3; RPR-6; IRR) and causing severe and sometimes catastrophic impacts. Climate change increases health risks through complex and interconnected social, environmental, cultural and economic pathways that impact individuals and communities (*see* HCCC-1; IRR). Populations that are disproportionately affected include Indigenous Peoples, women, children, youth, older adults, low-income individuals, people experiencing homelessness, people living with pre-existing physical and mental health conditions, and certain occupational groups, such as outdoor workers and first responders. Rapidly scaled adaptation and a significant reduction of GHG emissions are critical for protecting our health from future climate change impacts.

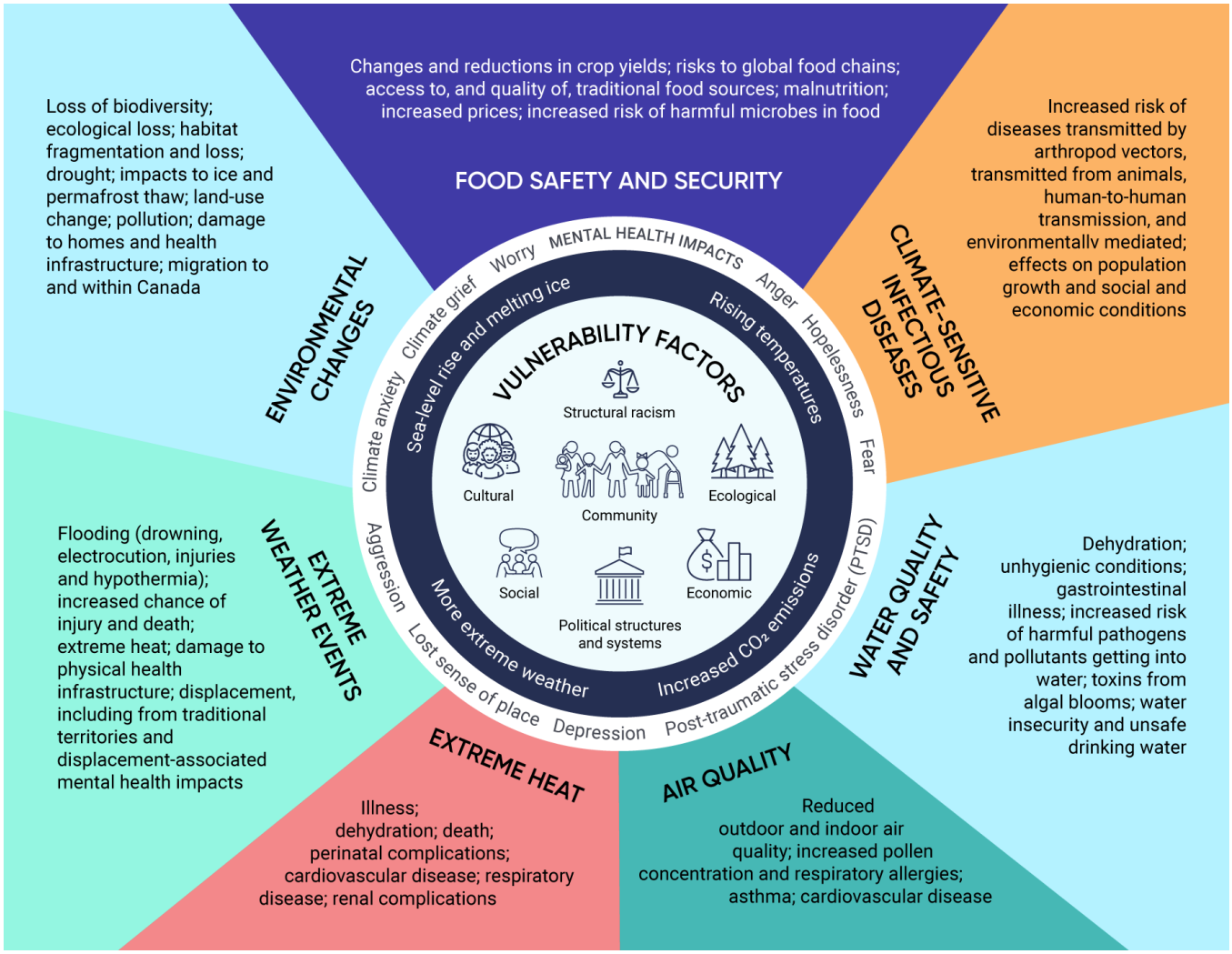


Figure 4: Examples of risks of climate change to health in Canada. See the *Health of Canadians in a Changing Climate* report for more information. Source: Charness et al., 2023.

Natural hazards

Heatwaves, floods, wildfires, coastal erosion and droughts are examples of natural hazards whose frequency and/or intensity are influenced by climate change and pose important health risks for Canadians (*see* HCCC-3). For example, heat events can lead to cardiovascular and respiratory problems, pregnancy complications (*see* HCCC-3; RPR-2; RPR-3) and hundreds of deaths in affected communities (*see* HCCC-3). Flood damage can make homes unsafe, such as by introducing mould, fungi and bacteria or by causing loss of power (*see* HCCC-3; HCCC-9; HCCC-10). Severe floods can result in drowning, injury, and hypothermia and lead to evacuation, with accompanying physical and mental health impacts for communities (*see* NIR-6). Long-term displacement, including from traditional territories, has had significant impacts on the health and well-being of affected Indigenous Peoples (*see* HCCC-4; RPR-6; NIR-3; NIR-6; IRR).

Air quality

Climate change is affecting air quality in Canada, and many air pollutants contribute to climate change. Exposure to key air pollutants, including fine particulate matter and ozone, increases the risk of a range of adverse health outcomes and premature death (*see* HCCC-5). For instance, wildfire smoke can exacerbate existing health problems such as asthma, chronic obstructive pulmonary disease and cardiovascular diseases, leading to premature death for many Canadians each year (*see* Box 3; HCCC-3; RPR-6). Smoke plumes can travel several thousand kilometres, threatening the health of large numbers of people in distant communities and contribute to premature deaths (*see* HCCC-5).

Infectious Diseases

Climate change also poses serious risks to the health of Canadians from many diseases that could emerge or spread within Canada due to continued warming. These include diseases transmitted by insects (e.g., West Nile virus) or animals (e.g., rabies) or spread from human to human (e.g., seasonal influenza), and those acquired by inhaling bacteria found in the environment (e.g., Legionnaires' disease). Climate change is a key driver in the northward spread of Lyme disease (*see* RPR-3): human cases in Canada increased from 144 in 2009 to 2025 cases in 2017 (*see* Figure 6.5 in HCCC-6).

Food and water safety and security

Climate change increases food safety and security risks by disrupting critical components of food systems, including food processing, transportation and distribution, and food preparation activities (*see* IRR). For example, changes in sea ice coverage and thickness challenge traditional hunting activities in the North while increasing risk of injury. The increased frequency and severity of storms and heavy precipitation can lead to food contamination by transporting harmful pathogens from the ground and sewage to water sources used to wash or process foods or irrigate crops (*see* HCCC-7). Globally, the changing climate has been identified as a major driver of increasing food prices—such as through supply chain disruptions due to extreme weather events—which can increase household food insecurity and lead to poor nutrition (*see* Box 9.2 in NIR-9; HCCC-8).

The quality of drinking water, which is critical for health and well-being, is also at risk from climate change (*see* HCCC-7; NIR-4). Many Indigenous communities across Canada face significant challenges accessing safe drinking water, which can be exacerbated by climate change (*see* HCCC-2; IRR). Heavy rainfalls can contaminate private wells and even municipal systems (*see* NIR-4), while increased droughts and wildfires can affect water availability and quality (*see* RPR-3). Poor water quality can lead to dehydration, unhygienic conditions, and a range of water-borne diseases, among other health risks (*see* HCCC-7).

Mental health

An important concern for many health authorities is the growing risk to mental health from climate change. Examples include the worsening of existing mental illness (e.g., psychosis), new-onset mental illness (e.g., post-traumatic stress disorder) and mental health stressors such as grief, worry, anxiety and vicarious trauma (*see* Figure 4; HCCC-4; NIR-3; IRR). Evidence suggests that without further adaptation measures, the toll on mental health related to climate change impacts in Canada is likely to rise with continued warming.

Health systems

Health systems in Canada are not prepared for climate change. Climate change is increasing risks to health facilities, health services and supply chains, and making it increasingly difficult for public health personnel to carry out essential operations (*see* HCCC-10). Recent floods, wildfires, extreme heat events, and severe storms have had impacts on health facilities, including forcing health care centres and hospitals to close temporarily, evacuate patients, or cancel operations and other services (*see* HCCC-10). Significant gaps exist in actions taken by health authorities to protect Canadians from current climate change impacts. Few provinces and territories have comprehensive or substantive measures to protect health as part of their broader climate change strategies and even fewer have a separate action plan or strategy to prepare individuals and health systems (*see* HCCC-10).

Addressing growing risks to health

Many health risks associated with climate change can be reduced through adaptation (*see* HCCC-10), and health authorities are beginning to plan and take action on this front. For example, since Montreal implemented an extreme heat action plan, the number of daily deaths has decreased five-fold, with the greatest decreases among seniors (Benmarhnia et al. 2016).

Adaptation can help make communities healthier and build the climate resilience of health systems through preventative measures such as:

- vulnerability and risk assessments;
- enhanced surveillance of climate change impacts on health;
- integrated early warning and response systems (such as for extreme heat events, floods, pollen seasons, wildfires);
- health professional training; and
- public education and outreach.

Well-designed efforts to adapt to climate change impacts and reduce GHG emissions can result in very large and near-term co-benefits to health. For example, taking action on air pollution could help Canada avoid thousands of premature deaths annually by the middle of the century (*see* HCCC-5). Continued and

coordinated efforts to address health-related climate risks are critical for reducing vulnerability to current and future impacts.

Box 3: Protecting our health in a changing climate

Insights from Dr. Courtney Howard, Emergency Physician in Yellowknife, NWT

Working in emergency medicine in communities across northern Canada, Dr. Courtney Howard has seen firsthand how climate change impacts such as prolonged wildfires, changing sea ice and thawing permafrost are affecting people's health (*see* Video 2). "I serve a patient population that is already coping with temperatures two-and-a-half to three degrees Celsius warmer than when an 80-year-old elder was born," she says.

According to Dr. Howard, health facilities, supply chains and medical practitioners across Canada should be taking steps now to better prepare for the kinds of emergencies that her patients are already experiencing. For example, hospitals need to ensure they have backup energy sources during heatwaves and ventilation systems equipped for extreme weather. In 2014, the operating room in Yellowknife had to close in the middle of a wildfire crisis because its air exchange system drew in smoke from the outdoors. After emergency room visits for asthma doubled and pneumonia cases rose by 50%, local physicians are now encouraged to refill inhalers for high-risk individuals before wildfire season begins.

"[W]e need to be making sure that we […] build health systems and health infrastructure for the climate that we are going to have this century", says Dr. Howard, "as opposed to the climate we [had] last century."

Climate change should also be factored into physician training, she says: "A global survey […] done recently showed that less than 15% of medical students worldwide are learning about climate change and health in their curricula." She is confident that knowing more about how climate change affects human health will help her colleagues better protect patients and communities now and in the decades to come.

Dr. Howard also points to the many things that individuals and communities can do to support each other through events that can have negative health outcomes, such as checking on elderly neighbours during heatwaves. Ultimately, she says, "our neighbors are the people who are going to help us prepare for the worst consequences of climate change."

Video 2: Interview with Dr. Courtney Howard, emergency physician in Yellowknife, NWT and a Clinical Associate Professor in the Cumming School of Medicine at the University of Calgary, on climate change impacts and adaptation related to human health. <https://vimeo.com/886513808>

2.3 Our food and natural resources are highly climate-sensitive

Failing to adjust how we manage natural resource and food production sectors in a changing climate would threaten local economies and jobs, and have consequences for transboundary resource management, Canada's supply chains and our involvement in global trade. Various adaptation options are being implemented in these sectors to reduce climate risk and impacts.

Certain economic sectors in Canada are particularly sensitive to changes in climate, as they rely on favourable weather conditions and are vulnerable to extreme weather. These include natural resource sectors such as forestry and mining, and food production sectors such as agriculture, aquaculture and fisheries (*see* NIR-7) that are crucial to our livelihoods. Many rural, remote and Indigenous communities in Canada derive as much as 50–100% of their base income from food and natural resource sectors (*see* Figure 3.4 in NIR-3).

Forestry

Canadian forests are increasingly at risk from wildfire and drought. While forest fires are a natural element of forest ecology, climate change is expected to increase their frequency, severity and size (*see* Figure 7.1 in NIR-7; NIR-5; RPR-6). This threatens timber supply, habitat and biodiversity, along with ecosystem services such as carbon storage (*see* Box 5.2 in NIR-5), water quality regulation, protection against landslides, and the cultural and social values that forests offer to neighbouring communities (*see* NIR-4; NIR-5). The economic costs of wildfire can also be extensive. For example, the 2016 Fort McMurray wildfire resulted in almost $4 billion in insured losses (Insurance Bureau of Canada, 2019). It also inflicted a range of indirect costs, including healthcare expenses associated with pollution from the fire (*see* Section 2.9; NIR-7; RPR-3). The social, mental and physical health impacts of wildfire and smoke affect both neighbouring and distant communities (*see* HCCC-3; 4; NIR-3).

Climate change is driving disturbances such as pest infestations (e.g., spruce budworm) that affect the structure, composition, health and resilience of Canada's forests. In the past, responses to climate-related impacts on forests were primarily reactive, as was the response to the mountain pine beetle outbreak in Western Canada. More recently, new knowledge resources, tools and protocols have been developed to help practitioners proactively manage these impacts. Examples include a practical guidebook for mainstreaming climate change into forest management planning (Edwards et al., 2015); guidance documents for private woodlot owners (Ontario Woodlot Association, 2015); and SeedWhere, a decision-guidance tool to assist in forest regeneration (*see* Box 3.4 in RPR-3).

Various adaptation options are being implemented to reduce the risk and impact of disturbances in Canada's forests (*see* Box 4). These include active fuel management (e.g., thinning, debris removal and prescribed burning); adjusting harvest schedules; forest management planning; and assisted migration of tree species to more climate-suitable locations (*see* NIR-7; RPR-2; RPR-3; RPR-5; IRR). FireSmart activities (such as vegetation management) and emergency preparedness plans are also being used to increase community resilience to wildfire (*see* NIR-7; IRR).

Box 4: Adapting forestry practice to manage climate risks

Insights from Carine Annecou, Forest Engineer with the Conseil régional de l'environnement du Centre-du-Québec

Forestry plays a vital role in Quebec's economy, generating jobs and exports in timber, furniture, pulp and paper, and maple syrup. But these forests are increasingly at risk of wildfire, drought and pests.

Forest engineer Carine Annecou has been working to develop a guidebook on silviculture strategies for managing climate-related risks to forest stands in the Centre-du-Québec region (*see* Video 3). She has found, in exploring the vulnerability of Quebec's forests, that it is equally important to talk about resilience.

"I talk about risk instead of vulnerability, because it allows me to talk about resilience too," she says. "How can a forest adapt [to climate change], and how can we help it to adapt?"

Consulting with a wide range of stakeholders has been key to finding approaches that increase forest resilience. "A message to my colleagues," says Ms. Annecou, "is to work in collaboration with all stakeholders. That is the strength of our approach. No matter what your trade, if it's possible to collaborate with other forestry trades, it brings a lot of options into discussion at the table."

Along with bringing in diverse perspectives to find suitable adaptation options, Ms. Annecou encourages individuals and forestry specialists to strengthen diversity in the forests themselves—whether on a tiny piece of land or on a larger scale. Given the uncertainty about how forests will adapt to climate change and the population pressures they face, "you have to start thinking about the forest in a more complex way," she says.

"[Y]ou have to vary the species, you have to vary the heights, and you have to vary the diameters to give these stands a chance to grow […] All of these options are broad strokes, but they're part of the recognized remedies now."

Video 3: Interview with Carine Annecou, Forest Engineer with the Conseil régional de l'environnement du Centre-du-Québec, on climate change impacts and adaptation in Quebec's forestry sector. <https://vimeo.com/886512878/15706ab1ee>

Mining

Climate change presents risks to the Canadian mining industry at every stage of the mining cycle, from exploration to restoration. For example, shorter periods of frozen ground can make access to certain exploration sites more difficult. However, the end of the cycle is most affected by climate change, largely due to impacts on mine tailings management and the reclamation of waste storage sites (*see* NIR-7). It is critical to ensure that long-term tailings management considers changes in climate so that these toxic materials are not released into the environment (*see* NIR-7; RPR-2). New methods, tools and guidance are needed to ensure that tailings containment and reclamation methods can withstand both extreme weather and slow-onset climate changes such as permafrost degradation (*see* NIR-7).

Climate change could also result in some new opportunities. For example, a longer warm season would allow more time for mapping and the delivery of raw materials. Increased access to new mining sites made possible by longer ice-free seasons in Canada's North could also provide economic opportunities, but needs to be considered within the context of potential impacts on northern people, societies and cultures, and ecosystems (*see* RPR-6).

Fisheries and aquaculture

The Canadian fisheries and aquaculture industries are impacted by changes in ocean temperature and chemistry, with implications for livelihoods and fisheries management. Climate-related factors (such as ocean warming) combined with non-climate-related factors (such as overfishing) are affecting changes in the distribution and abundance of various fish species (*see* NIR-7; IRR). For instance, ocean warming is shifting the distribution of snow crab—the second most valuable fishery in Atlantic Canada (*see* Case Story 7.3 in NIR-7). Ocean acidification is impacting the development and overall health of lobster—the most lucrative fishery in Atlantic Canada—in the Gulf of Maine, Bay of Fundy and Scotian shelf (*see* Case Story 7.5 in NIR-7). Impacts on fish species can also affect Indigenous Peoples' ability to access traditional foods and exercise cultural practices, with implications for health and well-being (*see* Section 2.8 and Case Story 5.1 in RPR-5; IRR).

These impacts present a major socioeconomic concern in Canada, particularly in the Atlantic provinces, where many coastal communities depend on fisheries for livelihoods and their local economy (*see* RPR-1; RPR-2; IRR). Species monitoring and management practices that improve habitat protection are two adaptation options being implemented to address the impacts of climate change on Canadian fisheries (*see* RPR-2; IRR). For example, in Western Canada, new provisions added to the Canada-U.S. Pacific Salmon Treaty will help reduce the impacts of climate change on salmon stocks through enhanced conservation measures.

Agriculture

Some Canadian producers stand to benefit from changes in climate, including through longer growing seasons and the increased potential for speciality crops, such as the expansion of wine-growing regions in Quebec and Atlantic Canada (*see* RPR-1; RPR-2). However, these benefits may be largely offset by negative

impacts, such as increases in extreme precipitation, increased drought and growing risks of pests and diseases (*see* RPR-1; RPR-2; RPR-3; RPR-4; RPR-5). Canadian farms are adapting to a changing climate by using a range of strategies such as zero-till agriculture, crop rotation and precision irrigation (*see* NIR-7; RPR-4), although gaps in planning, implementation and evaluation remain. Continued collaborative efforts at the farm, regional and provincial level will help to ensure that the agriculture sector adapts to Canada's changing climate.

Global trade

Climate change impacts on Canada's natural resource and food production sectors also pose trade-related risks, particularly for the export of primary products such as timber, minerals, fish and agrifood (*see* NIR-6; NIR-7; NIR-9). Canada depends on international trade and will increasingly experience economic repercussions from climate change impacts elsewhere in the world. International trade involves a complex network of global supply chains. Climate-induced disruptions to production—such as damage to ports from extreme weather, and road and rail closures due to flooding—can have economic ripple effects across sectors and borders (*see* NIR-9).

To minimize climate-induced disruptions, proactive adaptation will be required. This could include promoting growth in sectors and regions that could counteract projected scarcities in other countries from climate change impacts, reducing dependency on imported staples, diversifying trade partners and addressing weaknesses in trade institutions (*see* NIR-9).

2.4 The business case for adaptation is strong

Climate change impacts already cost Canadians billions of dollars each year, and costs will continue to rise. There is a strong business case for adaptation, with the benefits (including avoided costs) gained through adaptation measures generally exceeding the costs of implementation.

Over the last several decades, direct costs from extreme weather events, such as wildfires, floods, droughts and storms, have been rising (*see* NIR-6). The total economic impact of these events is even higher, since the costs do not include the indirect losses as business-to-business purchases along supply chains are adversely affected. Many types of extreme weather events are projected to continue increasing in frequency and severity as the climate warms (*see* CCCR-4; CCCR-6; CCCR-7). This increases the risk of more public safety emergencies, with rising economic consequences.

Climate change is affecting nearly every economic sector in Canada, from goods producing sectors (such as agriculture, forestry, mining [*see* Section 2.3] and manufacturing) to service sectors (such as real estate, health care and tourism), with important economic implications. For instance, during the record warm winter of 2011–2012, Ontario's ski market experienced a 10% decrease in overall skier visits and a 17% decrease in the length of the ski season, compared to a climatically-normal winter over the 1981–2010 period (*see* NIR-7; Rutty et al., 2017). Similar impacts on visits and season length were observed in the Quebec market in the

record warm winter of 2015–2016, with skier visits reduced by 12.5% (*see* NIR-7; Association des Stations de Ski du Québec, 2016).

In addition to these tangible losses, climate change impacts have a wide range of social, cultural and environmental costs, such as illness and premature deaths (*see* Section 2.2), reduced ecosystem services (*see* Section 2.5) and loss of sites of cultural importance (*see* Section 2.9). For instance, coastal erosion has already destroyed some Indigenous archaeological sites in Kouchibouguac National Park (*see* Figure 1.13 in RPR-1). These intangible or "non-market" costs of climate change are harder to calculate in dollar terms and are frequently left out of economic analyses (*see* NIR-6). Likewise, indirect impacts on the economy and consequences for future economic growth are often omitted. As a result, many estimates of projected climate-related costs are likely very conservative.

Without new adaptation actions, one study estimated the projected annual costs for Canada by 2050 in the range of $30–62 billion (2019 dollars), depending on the GHG emissions scenario and underlying rate of economic growth, with a 5% chance that costs could exceed $131 billion. By 2075, the same study projected annual costs in Canada in the range of $74–319 billion, with a 5% chance they will exceed $1,185 billion (*see* NIR-6; NRTEE, 2011). Economic assessments of climate change impacts have also been performed for several cities across Canada, including Edmonton, Halifax and Mississauga (*see* NIR-2; NIR-6), and have been prepared for several climate-sensitive sectors (such as forestry, agriculture and coastal areas). These assessments suggest that climate change will present some opportunities, but the economic impacts overall will be large and overwhelmingly negative.

The agricultural sector, for example, may benefit from a longer growing season in a warmer climate, particularly in the Prairie provinces, although farmers will also be challenged by increased variability in precipitation, extreme weather events and invasive pests (*see* Section 2.3; NIR-6; NIR-7; RPR-4). Some tourism sectors (such as agri-tourism, golf and outdoor recreational activities) will benefit from extended warm seasons (*see* RPR-2). Climate change may also create new markets for innovative products and services (*see* NIR-6).

In addition to projecting the costs of inaction (i.e., the costs of continuing a business-as-usual approach in the face of climate change), economic analysis helps to inform adaptation planning. It can help business leaders and other decision makers to identify how much they need to invest in adaptation; what kinds of adaptation actions are needed and when they should be implemented; and how the costs and benefits of adaptation will be distributed (*see* NIR-6).

Transitioning to a climate-resilient and low-carbon economy that interweaves climate change adaptation and mitigation efforts requires substantial investment (*see* NIR-8). As a certain amount of warming is inevitable (*see* CCCR-4), major investments in adaptation are needed as not all economic impacts through mid-century can be avoided through GHG mitigation. Fortunately, economic decision-support tools (such as cost-benefit analysis and cost-effectiveness analysis) show that adaptation can reduce the projected costs of climate change, with avoided damages often exceeding the costs of implementing adaptation measures (Global Commission on Adaptation, 2019; Lempert et al., 2018). The Global Commission on Adaptation (2019) found that $1 invested in climate change adaptation could generate economic benefits (avoided damages) in the range of $2–10. A review of 60 Canadian adaptation projects found that "soft-engineering" actions, such as beach nourishment, were more efficient investments than "hard-engineering" measures, such as concrete

walls and rock armour. Soft-engineering solutions saved on average $10 for each $1 invested, compared with savings of $3 for each $1 invested in hard-engineering (*see* Case Story 6.5 and Appendix 6.4 in NIR-6).

In addition to avoided damages, actions to adapt to climate change can produce many co-benefits (*see* Case Story 6.6 in NIR-6; Figure 5.15 in NIR-5), though they are generally not accounted for in economic analyses. These include reduced GHG emissions, improved health and safety, preservation of cultural heritage and more equitable outcomes (*see* NIR-6). The inclusion of these co-benefits in economic analyses enhances the already strong business case for investment in adaptation. Economic analysis has shown, however, that proactive investments in adaptation are unlikely to completely offset projected economic damages, given the breadth and depth of climate change impacts, and the technical, ecological and economic barriers (*see* Section 2.6; NIR-6).

2.5 Nature-based approaches save money and provide many benefits

Nature-based approaches to adaptation are often more cost-effective and deliver a suite of co-benefits. Protecting vulnerable ecosystems is also essential for preserving the services that they provide and for maintaining biodiversity.

Ecosystems are an integral element of our lives and landscapes. In Canada, they include wetlands, forests, grasslands, tundra, lakes and rivers, and coastal and marine areas. In addition to their natural beauty and positive impact on our quality of life and health, they provide a range of provisioning and regulating services (*see* Table 2 for examples; Table 5.1 in NIR-5), many of which can support climate change adaptation (*see* NIR-2; NIR-5; RPR-2; RPR-3; IRR). For example, wetlands help regulate water, forests improve cooling and air quality, and natural coastal structures protect against sea-level rise and flooding (*see* NIR-2; NIR-5; RPR-1; RPR-5). Protecting ecosystems also helps mitigate climate change by maintaining carbon sinks (*see* Box 5.2 in NIR-5; RPR-3).

Climate change is affecting the capacity of Canada's ecosystems to provide services upon which many communities rely. Impacts on ecosystems often have cascading effects in areas such as employment and job security, food security, and water quality and availability (*see* Figure 5.9 in NIR-5; IRR), with disproportionate consequences for the country's most vulnerable populations (*see* NIR-2; NIR-3; NIR-6). These impacts are expected to be widespread and cumulative and are critical to consider in developing climate change adaptation policies and actions (*see* NIR-3; IRR).

Table 2: Examples of ecosystem services

REGULATING SERVICES	PROVISIONING SERVICES (MATERIAL)	PROVISIONING SERVICES (NON-MATERIAL)
• Air and water purification • Climate regulation • Carbon sequestration • Pollination • Regulation of water quality and quantity	• Food and feed • Energy • Medicines • Raw materials	• Recreation • Spirituality and identity • Improved mental health • Culture

Nature-based approaches to adaptation encompass using natural infrastructure (such as wetlands for coastal protection), applying ecosystem-based approaches (such as conservation and restoration), using natural asset management, and enhancing protected areas (*see* NIR-5; IRR). These adaptation approaches work to enhance and benefit from the services that ecosystems provide (*see* Table 3 for examples). Interest in, and application of, these approaches is growing in Canada and internationally. Much of their appeal stems from the fact that these approaches are flexible and cost-effective relative to "hard" approaches (such as the use of seawalls or other built infrastructure) (*see* NIR-5; NIR-6; RPR-1; RPR-2). They also offer a range of co-benefits—including carbon sequestration, temperature regulation and recreation opportunities—that further increase their cost-effectiveness (*see* NIR-6).

Table 3: Examples of nature-based approaches for adapting to climate change

NATURE-BASED APPROACH	LOCATION	GOALS/ECOSYSTEM SERVICES	FAST FACT	SOURCE
Maintaining Ontario's Greenbelt	Hamilton, Ottawa and Toronto, ON	Provide flood protection, carbon sequestration, recreation and refuge from urban heat	One study values the ecosystem services provided by the Greenbelt at over $3.2 billion/year (Green Analytics, 2016).	Case Story 5.8 in NIR-5

NATURE-BASED APPROACH	LOCATION	GOALS/ECOSYSTEM SERVICES	FAST FACT	SOURCE
Using the urban forest to mitigate the heat island effect	Kingston, ON	Reduce extreme heat, improve air quality and reduce stormwater runoff	Ecosystem services from Kingston's urban forest generate an estimated $1.87 million/year (SENES Consultants Ltd., 2011).	Case Story 5.7 in NIR-5
Municipal natural asset management and service delivery	Gibsons and Nanaimo, BC	Manage natural assets such as woodlands, wetlands and creeks in urban areas as part of a municipal sustainable infrastructure strategy	The Municipal Natural Assets Initiative provides a method to value ecosystem services and is improving understanding of the municipal services nature provides.	Case Story 5.9 in NIR-5
Restoring tidal wetlands and their ecosystem services	Truro, NS	Sequester carbon, reduce flood risk and provide storm buffer for long-term community safety, protection of coastal ecosystem and fish nursery habitat	Managed retreat in tandem with restoration of the tidal wetland ensured a cost-effective solution for long-term community safety.	Case Story 5.5 in NIR-5
Act respecting the conservation of wetlands and bodies of water	Province of Quebec	Enhance ecosystem connectivity and resilience, protect water resources and shorelines, and provide quality habitat for biodiversity	Under this Act, regional county municipalities must prepare regional plans for water bodies and for the wetlands that cover some 10% of Quebec's surface area.	RPR-2

NATURE-BASED APPROACH	LOCATION	GOALS/ECOSYSTEM SERVICES	FAST FACT	SOURCE
Ungava Peninsula Caribou Aboriginal Round Table	Ungava Peninsula, QC	Ensure recovery of the migratory caribou herd and sustainability of caribou in the Nunavik territory	Conservation decision making for the species is supported by a long-term caribou management strategy that draws on Indigenous and scientific knowledge and the tracking of caribou migration patterns using satellite tags.	Case Story 2.1 in RPR-2
Promoting ecosystem-friendly shoreline development through the Green Shores program	Province of British Columbia	Provide capacity building, tools and best practice standards to encourage shoreline development approaches that protect the land from flooding and erosion	An economic analysis of one project supported through the program found that for every $1 spent, social welfare increased by $2.50 (Eyzaguirre et al., 2020).	Case Story 5.6 in NIR-5

Despite their clear benefits and growing uptake, nature-based approaches are often not the preferred option. This is seen particularly with respect to water-related infrastructure, where "hard" or built options tend to dominate the dialogue and decisions. In Atlantic Canada, hard infrastructure (such as rock riprap and seawalls) is almost always chosen by private property owners, municipalities and industries to protect against coastal erosion, despite evidence that natural infrastructure is cost-effective and more resilient (*see* NIR-5; RPR-1). In some cases, built and natural approaches are combined to provide additional and complementary services. For instance, in many cities, municipal stormwater runoff systems integrate green roofs, bioswales (sloped, vegetated surfaces), bioretention ponds, rain gardens and urban trees to control and reduce runoff (*see* Figure 5; NIR-2; NIR-4).

Figure 5: Images of different nature-based approaches for addressing stormwater runoff: a) Parking lot of the Kortright Centre in Vaughan, Ontario with integrated bioretention (photo courtesy of Daniel Philippi, 2022); b) Bioswale along Elm Drive in Mississauga, Ontario (photo courtesy of Daniel Philippi, 2022); and c) Green roof on the District School Board of Niagara's Walker Living Campus at the Woodend Conservation Area, Ontario (photo courtesy of Jocelyn Baker, 2023).

An important consideration when planning nature-based approaches is how ecosystems themselves are vulnerable to climate change and other stressors. Nature-based approaches rely on healthy ecosystems. Already, there is evidence in Canada that climate change is affecting the capacity of some ecosystems to provide services, and climate change impacts are projected to intensify over the coming decades (*see* NIR-5). These include impacts from extreme weather events (*see* NIR-5), invasive species, shifts in species' ranges (*see* RPR-2; RPR-3; RPR-4; IRR) and coastal squeeze (*see* RPR-1; RPR-2). These impacts combine with other stressors, such as land development, air pollution, invasive species and overexploitation, to put ecosystems at risk.

Efforts to conserve and protect ecosystems can therefore be seen as important elements of adaptation plans and strategies (*see* Box 5; NIR-5; RPR-2; RPR-3; IRR). These include actions such as increasing ecosystem connectivity (as with habitat corridors or protected spaces), protecting biodiversity, restoring habitat, strategically restricting water withdrawals, identifying and protecting specific areas or species and limiting other stressors, such as human development and industrial activities (*see* RPR-3; IRR). These efforts are especially important when sensitive ecosystems are relied upon to enhance adaptive capacity (*see* NIR-2) and provide regulating services (*see* NIR-5).

"Integrating ecosystem conservation into decision making in all economic sectors is important in order to maintain ecosystem services." (*see* RPR-2)

Indigenous Knowledge and leadership are making important contributions to plans and strategies for conserving and protecting ecosystems (*see* RPR-3; IRR). This can be seen in Indigenous Protected and Conserved Areas (IPCA), where Indigenous Peoples support ecosystem health and biodiversity while safeguarding Indigenous rights, notably self-determination (*see* Section 2.8; Case Story 5.4 in NIR-5; IRR).

Box 5: Harnessing nature-based approaches for adapting to climate change

Insights from Michelle Molnar, Technical Director at the Municipal Natural Assets Initiative

According to Michelle Molnar, Coordinating Lead Author of the Ecosystem Services chapter of the *National Issues Report*, Canada is uniquely positioned to use nature-based approaches for adapting to climate change, as one of five countries that together host 70% of the world's untouched wilderness (*see* Video 4). It is also important to manage ecosystems to preserve the many services they provide. Protecting these, says Ms. Molnar, will take a change of mindset:

"When we're thinking about ecosystems, we need to start incorporating systems thinking […]. At a very basic level, we need to adapt very different spatial and temporal scales to our thinking. Physical impacts and consequences of climate change and extreme events do not stop or start at human-defined boundaries, [like] political boundaries. And social time frames are very different from the time frames adapted by nature. So, really, a different way of thinking is probably the greatest need for ecosystems."

Across Canada, Ms. Molnar sees examples of how nature-based approaches are being used to address the impacts of climate change, including by restoring natural floodplains and coastlines to deal with increased flood risk. "At the end of the day," she says, "we're finding that nature-based [approaches] are often cost effective, they're very flexible and they offer a broad range of co-benefits."

Depending on their priorities, communities can harness these approaches in different ways: "In some areas, this might [involve] conserving important parts of an ecosystem, and in more urban areas, it might be bringing nature into the city, through anything from street trees to green walls."

The exploration of nature-based approaches is still in its early days. *Canada in a Changing Climate* is Canada's first national knowledge assessment to consider the impacts of climate change on ecosystems and the services they provide, as well as the role of nature-based approaches in adaptation. For Ms. Molnar, this is an important start: "Future assessments, we're hoping, will build on this chapter to capture and reflect learnings, because nature-based [approaches] and ecosystem services are areas of fast-evolving research."

Video 4: Video interview with Michelle Molnar, Technical Director of the Municipal Natural Assets Initiative, on the need for preserving ecosystems and incorporating nature-based approaches to adaptation. <https://vimeo.com/886515665>

2.6 Improved incentives and coordination can help close Canada's adaptation gap

In Canada, progress on adaptation remains slow, with relatively few examples of implemented actions despite growing losses. Greater incentives, fewer barriers and improved coordination across sectors and scales will help close the adaptation gap.

Canadians recognize climate change as one of the greatest threats facing our country, and are already feeling its impacts. This is reflected in the increasing adaptation planning occurring within all orders of government, in all regions of the country, and across many sectors and businesses. However, planning is not translating into action fast enough to address current and projected changes in climate.

While promising examples of adaptation are being implemented across the country (*see* Table 3, Table 5, and Table 6), the *Canada in a Changing Climate* Assessment reports have found that current efforts are insufficient to close a widening adaptation gap—current levels of adaptation are not yet able to offset negative climate change impacts and enable benefits from new opportunities (*see* NIR-6). This conclusion is also supported by a benchmarking survey conducted with the experts involved in the current Assessment process (*see* Box 6). Further evidence can be seen in the increasing damage and associated costs caused by extreme weather events (*see* Section 2.4; NIR-6). Gradual changes in climate, such as sea-level rise (*see* NIR-3; RPR-1; RPR-5; RPR-6) and thawing permafrost in Canada's North (*see* RPR-6), are also causing the adaptation gap to grow.

"There is a tendency to overestimate the capacity of adaptation planning to deliver intended outcomes." (*see* NIR-2)

Box 6: Benchmarking adaptation in Canada

At the end of the current Assessment process, Advisory Committee members and Coordinating Lead Authors were invited to help establish a benchmark for adaptation progress in Canada, drawing on their expertise and knowledge (more than 50% of respondents have over 15 years of experience working on adaptation). Future Assessments will aim to compare progress on adaptation against this benchmark.

All 23 respondents either strongly or very strongly agreed that action on adaptation in Canada is not keeping pace with the level needed to address observed and projected climate change impacts. The top three barriers and constraints limiting progress on adaptation were deemed to be:

- lack of coordination among key stakeholders;
- climate change not being prioritized as an issue; and
- limited resources.

While there are examples of adaptation underway at different stages and at different scales (local, regional, provincial/territorial, national), most experts felt that Canada as a whole is still currently at the stage of adaptation planning, rather than implementing actions to address risks (*see* Figure 6).

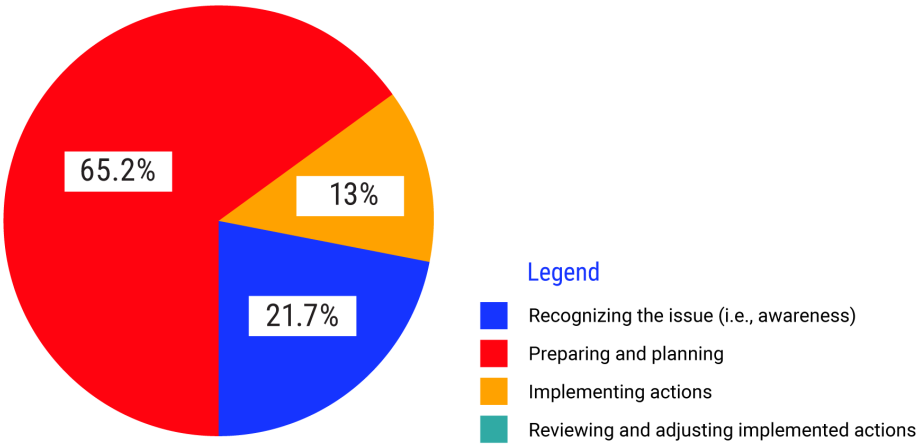


Figure 6: Views of Assessment Coordinating Lead Authors and Advisory Committee Members on Canada's current stage of adaptation. Note: A fourth option—"reviewing and adjusting implemented actions"—was not selected by any respondents.

There were mixed opinions among the group about whether there is evidence of adaptation limits—the point at which severe risks can no longer be avoided through adaptation—being reached in Canada, but these experts recognized that northern Canada and many coastal areas are particularly challenged by a changing climate. When asked what is most needed to advance adaptation in Canada, the group signaled the need for coordinated action, more inclusive and equitable approaches to adaptation, better understanding of synergies and trade-offs, increased private sector action and financing, and for adaptation to be prioritized within different orders of government.

Much research has examined the various barriers that are limiting the implementation of adaptation initiatives (*see* Table 4 for examples; Table 2.3 in NIR-2; Box 3.6 in RPR-3). Across the board, the most frequently identified barriers relate to financial resources, although capacity challenges are also commonly identified. This has been the trend over time, with similar patterns reported in 2008 (Lemmen et al.), 2014 (Warren and Lemmen) and 2016 (Lemmen et al.).

Table 4: Examples of barriers to adaptation

BARRIER TO ADAPTATION	SPECIFIC EXAMPLE
Insufficient financial resources	A lack of funds and resources was cited as a primary reason why health facilities were not undertaking climate change resilience assessments (*see* HCCC-10).
Lack of human resources capacity	Capacity challenges are often more evident in communities and organizations that are most vulnerable to climate change risks, including in rural, northern and Indigenous communities (*see* IRR; NIR-3; NIR-4).
Constraining policies or regulations	Government transfers for flood protection measures and disaster aid provide incentives to continue growth in flood-prone coastal areas, even when retreat or relocation would maximize public welfare (*see* NIR-6).
Limited access to relevant data and information	Communities in Ontario that are undertaking risk assessments or adaptation planning identified a lack of actionable climate information as a barrier (*see* RPR-3).
Poor coordination and/or understanding of roles	A study in Ontario found that adaptation was hindered by poorly defined roles and responsibilities for water infrastructure, and insufficient coordination among government departments (*see* RPR-3).
Market failures	Businesses and households may lack information on climate risks; in some situations, information is known to some actors (e.g., homeowners) but not others (e.g., potential buyers and insurers) (*see* NIR-6).
Behavioural barriers	Self-directed adaptation by businesses and individuals is not always adequate or efficient for addressing climate risks (*see* NIR-6; RPR-2).
Technological barriers	Snow-making equipment may not be able to sustain snow cover at lower-altitude ski resorts as the climate warms (*see* NIR-6; NIR-7).

BARRIER TO ADAPTATION	SPECIFIC EXAMPLE
History of colonization	The lack of recognition of Indigenous rights to natural resources has constrained the ability of the Stó:lō people to adapt to the effects of climate change on salmon (*see* Case Story 5.1 in RPR-5).
Barriers to equitable participation	Some groups and individuals may be excluded from participating in adaptation planning and processes by factors such as financial burdens, travel requirements, language and childcare needs (*see* HCCC-9).

As a wealthy developed country with a highly educated population and abundant resources, Canada is well-positioned to be a leader on climate change adaptation. Reaching our potential will require overcoming barriers that have hindered progress to date—addressing them directly through funding programs and capacity building and by creating an enabling environment for adaptation. This may entail using both carrot and stick approaches such as grants, taxes and charges to encourage positive change; removing incentives that encourage development in at-risk areas; promoting engagement and collaboration through networks and other trust-building initiatives; and providing sources of guidance, such as decision-support tools and data interpretation services. Overall, there is a relatively clear and growing sense of *what* needs to be done to create a more enabling environment, with less clarity on the *who* and the *how*. There is general agreement, however, that there are roles for all to play in fostering a more enabling environment for adaptation, including all orders of government through policies, legislation and regulations (*see* NIR-6).

It is also becoming evident that even if enabling conditions were optimized, adaptation can be undermined by behavioural biases and motivations. These factors can affect whether people will use available information in an efficient and effective manner. At worst, they can lead to decision inertia, delays in action and misguided decisions (*see* NIR-6).

The *Canada in a Changing Climate* Assessment reports present a number of recurring suggestions for moving from adaptation planning to successful implementation, closing the adaptation gap. These include:

- **Improving coordination** among all stakeholder groups (including the private sector) and all governments involved in adaptation. This is in addition to the collaboration needed to ensure that decisions are well-informed (including by Indigenous Knowledge), aligned and inclusive (see NIR-2; NIR-3; RPR-2; RPR-3; IRR).
- **Adopting an adaptive management approach**, which features an iterative process of monitoring, predictive modelling, evaluation and learning (see NIR-3; NIR-4; NIR-6; RPR-3; RPR-4).
- **Building the business case for adaptation** to provide decision makers with the evidence and confidence needed to invest in adaptation measures and maximize co-benefits (see Section 2.5; NIR-6).

- **Providing mechanisms to help fund the implementation of adaptation measures**, where needed.
- **Addressing data and knowledge gaps** that may be causing delays in implementation (see Annex 3; all chapters of NIR and RPR).

"Adaptive management provides a structured, iterative process of robust decision making in the face of uncertainty." (*see* NIR-4)

2.7 Local-level adaptation plays a leading role in our climate change response

Local governments and Indigenous communities across Canada are already experiencing climate change impacts on their infrastructure, economies and well-being. Together with local partners, they are well positioned to take action on adaptation given their local knowledge and Indigenous Knowledge, strong social networks and connections to the land.

Communities across Canada are already experiencing climate change impacts, including damage to infrastructure, disruptions to businesses and jobs, and consequences for health and well-being. How they are affected largely depends on their geographic location, population size and demographics, and other contextual factors. Impacts are being caused by extreme weather events (such as flooding, drought, extreme heat [*see* Case Story 3.5 in RPR-3] and wildfire) and slow-onset changes (such as rising sea level, diminishing snow and ice, thawing permafrost and shifts in precipitation).

Characteristics that increase the vulnerability of Canada's cities and towns to climate change include ageing infrastructure, high-density populations, degraded ecosystems and being located near water bodies (*see* Figure 7). As such, climate change can cause costly damage for cities and towns, with devastating consequences for their residents. For instance, several urban areas—including Toronto, Fredericton, Calgary and parts of southern Quebec—have experienced significant and costly floods in recent years (*see* NIR-2; RPR-2; RPR-4). Calgary's 2013 flooding event caused more than $6 billion in damage, including over $400 million to municipal infrastructure (*see* RPR-4; City of Calgary, 2017). Similarly, the 2013 flooding event in Toronto cost more than $1 billion in insured losses, with uninsured losses that were much higher (*see* Table 3.1 in RPR-3).

Figure 7: Assets and challenges for cities, towns, and rural and remote communities related to climate change impacts and adaptation. Sources: Brown et al., 2021; Vodden and Cunsolo, 2021.

Compared with larger urban centres, rural and remote communities tend to have access to fewer financial, human and formal institutional resources (*see* Figure 7). Furthermore, damage to critical transportation infrastructure (such as roads or bridges) from extreme weather events can severely limit the movement of goods and people and limit access to essential services, especially where there are few roads into and out of a given community (*see* Case Story 3.3 in NIR-3).

As the order of government that is closest to people, municipalities have a key role to play in adaptation, including by driving collaboration with different groups and removing barriers to adaptation. Local governments (such as Surrey, British Columbia; Edmonton, Alberta; and Montreal, Quebec) are increasingly planning for climate change through dedicated adaptation plans or by integrating climate change considerations into other municipal policies and plans (*see* Box 7). There are also many promising examples of local adaptation actions being implemented across the country, including low-impact development (such as the use of permeable pavement and bioswales) and nature-based approaches (such as increasing the size of urban forests and restoring coastal wetlands) (*see* Section 2.5; NIR-2). Many Indigenous communities—including the Tsleil-Waututh Nation (*see* Case Story 2.5 in NIR-2), the Georgina Island First Nation (*see* Case Story 3.6 in RPR-3) and the Lennox Island Mi'kmaq First Nation—are also advancing on adaptation planning (*see* Case Story 1.8 in RPR-1).

However, implementation of adaptation plans and actions continues to be a challenge for many local governments and Indigenous communities, and the level of implementation is not keeping pace with the growing risks posed by climate change. A 2018 survey of 180 local governments across Canada found that while more than half had initiated formal adaptation planning discussions in their community within the last four years, they are sometimes ad hoc and reactive, and often do not result in implementation (McMillan et al., 2019). Barriers to implementation (*see* Section 2.6) often relate to financing, lack of access to or understanding of decision-support tools, competing priorities, governance and professional silos (*see* NIR-2).

Urgent action is imperative for minimizing negative impacts on cities, towns and smaller communities, and for leveraging opportunities (*see* Table 5 for examples of local level adaptation). Strategic and proactive implementation of local adaptation plans and actions is beginning to emerge, and will help to increase adaptive capacity and climate resilience now and in the future.

Table 5: Examples of local-level climate change adaptation

TITLE	DESCRIPTION	SOURCE
Adaptation planning in Edmonton and Calgary, AB	Calgary's Climate Resilience Plan (2018) identifies climate risks and vulnerabilities to city services and operations, and outlines the business units responsible for addressing those risks. The City of Edmonton instead used a phased approach to develop its adaptation strategy, undertaking a risk assessment, economic analysis, and engaging diverse stakeholders through thematic workshops.	Case Story 4.5 in RPR-4
Coastal Flood Adaptation Strategy in Surrey, BC	Approximately 20% of Surrey's land lies within a coastal floodplain, with several sectors at risk of flooding. The development of their Coastal Flood Adaptation Strategy involved engagement with diverse stakeholders and partners. Strategic directions were developed through an iterative adaptive design process, which identified 46 adaptation options, including 13 major infrastructure projects.	Case Story 5.2 in RPR-5
Brampton, ON Lighthouse Project: Supporting vulnerable populations during extreme weather events	The Brampton Lighthouse Project is a collaboration between the local government and 20 faith-based organizations (FBOs). This collaboration allows FBOs to support vulnerable populations during extreme weather and non-climate-related emergencies.	Case Story 2.4 in NIR-2
Enhancing infrastructure resilience in Fredericton, NB to reduce flood risk	Persistent flood risk has resulted in over two decades of efforts to ensure that the City's infrastructure is more resilient. Adaptation actions included sizing culverts 20% above a 1:100 return period and using rail-corridor trails as alternative transportation routes when flooding disrupts vehicle traffic.	Case Story 2.1 in NIR-2
Local adaptation in the Great Lakes Basin	Adapting to climate change in the Great Lakes Basin requires transboundary leadership and coordination among all orders of government, organizations and agencies. Local governments in Ontario, Quebec and several U.S. states are working together on pilot projects, which include a platform to share data and resources for local adaptation and provide opportunities for building technical capacity.	Case Story 3.3 in RPR-3

TITLE	DESCRIPTION	SOURCE
Policies and measures for reducing flood risk in the City of Calgary, AB	In 2013, Calgary experienced its largest flood since 1897, with damage totalling $6 billion. The City has taken a holistic approach to reducing flood risk, employing multiple strategies at the watershed, community and property levels.	Case Story 4.1 in RPR-4
Adaptation measures and co-benefits through the upgrading of Rue Saint-Maurice in Trois-Rivières, QC	Significant upgrades were made to a 1.3 km stretch of Rue Saint-Maurice in Trois-Rivières, QC, using a combination of built and natural infrastructure, and delivering a range of co-benefits. The project aimed to reduce the urban heat island effect, beautify the landscape, improve neighbourhood safety for pedestrians and motorists, and improve stormwater management.	Case Story 2.6 in NIR-2
Project for the protection and rehabilitation of the Anse du Sud shoreline in Percé, QC	Severe storms in 2016 and 2017 destroyed more than 200 metres of the Anse du Sud boardwalk, prompting the Town of Percé to undertake adaptation measures, including beach replenishment, to protect tourist infrastructure along the coast and in the city centre.	Case Story 2.3 in RPR-2

Box 7: Using a systems approach to strengthen local adaptation

Insights from Duane Nicol, Chief Administrative Officer, City of Selkirk, Manitoba

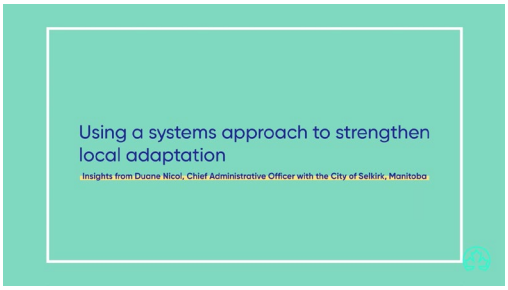
The small city of Selkirk in southeast Manitoba is no stranger to overland flooding from heavy rain events. Chief Administrative Officer Duane Nicol has seen two major events in the last decade that have overwhelmed storm sewer systems, flooding homes (*see* Video 5). "The primary issue," he says, "is really intense storm events throughout the year, but primarily in springtime."

For other municipalities looking at how to adapt to a changing climate, Mr. Nicol suggests taking the long-term view: "[We] know [climate change] is going to be around for decades. We are going to be dealing with this, learning from it, and slowly adapting to the changing environment. […] [O]ur infrastructure systems, our cultural systems, our social systems have all taken decades and centuries to evolve to this point. […] And so evolution, not revolution, is going to be the order of the day."

Climate action, he says, is not about investing in "signature projects" that make a name for individual city leaders. He points to the less exciting, but essential work of integrating climate change considerations into everyday frameworks that determine how infrastructure and other assets are managed. "If you change the decision-making criteria, if you change the framework, […] what you're going to do is take every one of those dollars and turn them into climate action dollars."

He also stresses the importance of clear communication and bringing people on board. This involves "making sure that […] we talk about any of the co-benefits and […] why making this change in the infrastructure or the way we operate our municipality actually benefits you, the citizen."

Mr. Nicol feels that assessments such as *Canada in a Changing Climate* are an important tool for communities like his, enabling local leaders to learn from what others are experiencing. "We do not have the capacity in smaller municipalities, [where] the same person that's your Chief Administrative Officer is also probably your finance person. [B]eing able to look at what's already been thought through and done, and to borrow some of those ideas, makes it really, really easy to implement in your own capacity."



Video 5: Interview with Duane Nicol, Chief Administrative Officer with the City of Selkirk, Manitoba on climate change impacts and adaptation in his community. <https://vimeo.com/886514873>

2.8 Self-determined and Indigenous-led climate action supports reconciliation

Indigenous Knowledge Systems, and Indigenous rights and governance are critical to establishing just, equitable, decolonized and sustainable approaches to overcoming the climate crisis. Recognizing that humans, culture and the natural world are inseparable, and that we share responsibility for future generations, is essential to these approaches.

First Nations, Inuit and Métis peoples and their homelands are disproportionately affected by climate change, and face growing climate risks (*see* Box 8; IRR; HCCC-2; NIR-2; NIR-3; RPR-2). These impacts can magnify existing environmental, health and socioeconomic challenges, including structural inequities that Indigenous Peoples have faced for generations as a result of colonialism (*see* IRR). Adaptation efforts will require addressing ongoing inequities, such as those related to housing, water security, access to health care and education (*see* HCCC-2; NIR-3; IRR; Inuit Tapiriit Kanatami [ITK], 2019; EPCCARR, 2018). Indigenous governments, moreover, emphasize that climate change constitutes a state of emergency not only for their Peoples, but for their homelands and the ways in which they live in relationship with the land, water, ice, animals and plants (*see* IRR; Reed et al., 2022).

Box 8: Examples of key climate change risks for Indigenous Peoples

Climate change risks are growing in many Indigenous communities, including risks to food, water and energy security, infrastructure, mental health and wellness, livelihoods, culture and identity (*see* IRR; HCCC-2; NIR-3; EPCCARR, 2018).

Indigenous food systems, in particular, are experiencing significant and unique impacts (*see* RPR-2; RPR-6; IRR; ITK, 2021). Not only has climate change affected the distribution, quality and quantity of nutrient-dense traditional and wild food sources, it has also affected access to store-bought foods, which is increasingly compromised by the growing expense and precariousness of supply chains, especially in the Indigenous communities that make up the vast majority of Canada's remote, fly-in communities (*see* IRR; NIR-5; RPR-6). Affordable grocery items are often of poor nutritional quality, compared with traditional foods, and cannot replace the role that the harvest, processing and sharing of traditional foods play in Indigenous Knowledge Systems, cultures, identities and economies (*see* HCCC-2; NIR-3; RPR-2; RPR-5; IRR; ITK, 2021). Resupply is also compromised by ageing air infrastructure, hazardous and mobile sea ice, and the growing loss of winter roads that depend on frozen river and lake ice or frozen permafrost.

First Nations, Inuit and Métis leaders on climate change issues in Canada have long emphasized that reconciliation requires new approaches to engaging with Indigenous Knowledge Systems and respect for Indigenous-led policy and research on climate change mitigation and adaptation—especially in decision making. There is a need to better understand Indigenous rights-based approaches in order to respect and apply Indigenous concepts of sustainability, including interconnectedness between social and ecological systems, without significantly undermining their meaning (*see* IRR). Indigenous Knowledge Systems play an important role in enhancing the adaptive capacity and resilience of Indigenous Peoples and their reciprocal relationship with the natural world (*see* IRR; HCCC-2; NIR-3; RPR-4; RPR-5; RPR-6).

Indigenous climate policies and actions prioritize Indigenous Knowledge Systems and the need to rebalance the relationship between human societies and the natural world (*see* Table 6 for examples). They also recognize that Indigenous Peoples have the inherent right to self-determination and to advance climate actions that are interdependent, multi-dimensional and simultaneously advance climate change adaptation, decarbonization and decolonization (*see* Box 9; IRR; Reed et al., 2021).

Canada's strengthened climate plan explicitly recognizes the importance of supporting Indigenous Peoples' self-determined climate actions and their critical role in advancing Canada's reconciliation with Indigenous Peoples (Environment and Climate Change Canada, 2020). Indigenous Peoples have made key contributions to Canada's climate discussions in recent years and play critical roles advocating for climate action, including in the following areas: education, land-based learning and healing, clean energy, Indigenous Knowledge and science strategies, adaptation planning and implementation, and political action and diplomacy (*see* IRR; NIR-2; NIR-3; ITK, 2019).

Canada can continue to draw important insights for understanding how our colonial history has driven the climate crisis and the ways in which Indigenous Peoples have disproportionately shouldered the impacts, from a number of seminal reports (Pikialasorsuaq Commission, 2019; Truth and Reconciliation Commission

of Canada, 2015; Qikiqtani Truth Commission, 2013; United Nations, 2007; Government of Canada, 1996; Berger, 1977). It is only through a reconciliation process that recognizes Canada's collective colonial past that Indigenous-led climate governance will be meaningfully supported by non-Indigenous governments, and a path toward the respectful interweaving of Indigenous Knowledge Systems with conventional scientific approaches can be created (*see* Case Story 6.5 in RPR-6; IRR; NIR-5).

Ultimately, Indigenous climate policies are key to restoring Indigenous Peoples' relationships with land and water, and for providing pathways to wellness where the "reconciliation between Indigenous Peoples and the Crown requires our collective reconciliation with the Earth" (Borrows, 2018).

Table 6: Examples of First Nations, Inuit and Métis climate action

TITLE	DESCRIPTION	SOURCE
Intersections of climate change and Indigenous traditions: the Northern Tutchone People of the Selkirk First Nation	The Northern Tutchone People of the Selkirk First Nation in the Yukon have adapted their salmon fishing camps with youth in mind to maintain cultural practices as critical pathways to mental, physical and spiritual well-being in the face of declining salmon populations.	Case Story 5 in IRR
"The eyes and ears for the land and water": The rising tide of Indigenous Guardians programs and expansion of Indigenous Protected and Conserved Areas in Canada	Across Canada, there are now close to 100 Indigenous Guardians programs. These programs support monitoring of climate change, the environment and protected areas; ecological restoration; public and youth education; conservation; and sustainable economic development planning.	Case Story 8 in IRR
Preserving Tłı̨chǫ culture in the face of declining Barren-ground caribou populations	The Tłı̨chǫ Dǫtaàts'eedı̨ program ("to share food among the people") paired more than 100 young adults in four Tłı̨chǫ communities with 60 experienced harvesters to harvest wild foods and distribute some 4,000 kg of fish and meat to community Elders. The program addresses the impacts of climate change while supporting Tłı̨chǫ food security, values and culture.	Case Story 5.3 in NIR-5

TITLE	DESCRIPTION	SOURCE
Confronting rising seas on Lennox Island, PEI	The Mi'kmaq Confederacy of PEI combines oral histories with instrumental data to identify climate trends. It has identified areas of coastal vulnerability now prioritized for adaptation programs to protect cultural values.	Case Story 1.8 in RPR-1
Peavine Métis Settlement FireSmart Program	Community members are using Indigenous Knowledge and information from provincial fire authorities to combine traditional burning practices with fireguard and fuel break strategies to manage fires in ways that reflect and protect cultural norms and values.	Box 2.3 in HCCC-2
Supporting Inuit wellness, strength, resilience and cultural continuity in Nunatsiavut, Labrador	Inuit communities of Nunatsiavut at the forefront of climate change have designed programs to support Inuit wellness, strength, resilience and cultural continuity. This includes the Aullak, Sangilivallianginnatuk (Going Off, Growing Strong) program, which brings youth and experienced harvesters together to support social and cultural connections, and community food security.	Case Story 3.5 in NIR-3
Community climate change resilience planning in the Tsleil-Waututh Nation	The Tsleil-Waututh Nation is developing a culturally relevant community planning process aimed at institutionalizing climate resilience throughout its governance. Early work has included hazard mapping and exposure-sensitivity analysis and reflects the Nation's sacred obligations to care for the lands, waters and air.	Case Story 2.5 in NIR-2
BC First Nations Climate Change Strategy	The Strategy aims to identify actions to reduce GHGs, strengthen Indigenous climate leadership in BC, reduce vulnerability to impacts, and build capacity, understanding and resilience in First Nation communities.	Box 5.2 in RPR-5

Box 9: Self-determination is critical for Indigenous climate action

Insights from Dr. Deborah McGregor, Canada Research Chair on Indigenous Environmental Justice

First Nations, Métis and Inuit recognize the existential threat that climate change poses to their cultural survival. Given the long shadow of colonization in Canada, Indigenous Peoples seek their own pathways forward, finding approaches based on their deep knowledge and experience.

Dr. Deborah McGregor, a contributing author of the *For Our Future: Indigenous Resilience Report*, points to emerging examples of Indigenous-led adaptation, largely seen in resolutions and declarations by Indigenous authorities at different levels (*see* Video 6). The Assembly of First Nations (AFN), for example, is developing a national climate change strategy, following the declaration of a First Nations Climate Emergency in 2019 (AFN, 2019). Inuit Tapiriit Kanatami (ITK) has also defined a climate strategy that addresses common Inuit climate priorities (ITK, 2019). Other Indigenous communities are working on plans and policies at a local level.

What defines Indigenous-led adaptation strategies? Dr. McGregor highlights a number of common threads: "They center the U.N. Declaration on the Rights of Indigenous Peoples, Indigenous Knowledge, Indigenous relationships to the land, future generations and relationships with the non-human world […] Spirituality is another theme that you don't often *see* in other climate change policies."

Indigenous-led adaptation, she says, has to be rooted in the specific lived experience of Inuit, Métis and First Nations Peoples. Indigenous Peoples need to "trust [our] own traditions, because that's what enabled us to survive despite genocidal policies, displacement from land, residential schools and other threats to our survival. It was [thanks to] our own knowledge, our own way of life, our own language, our own governance, our own laws and people."

In most cases, Indigenous Peoples are still only consulted on strategies and processes determined by outsiders. However, Dr. McGregor sees hope in the National Knowledge Assessment process, *Canada in a Changing Climate*. Where past assessments underrepresented Indigenous expertise, she is encouraged at the broad and holistic scope of knowledge and experience that the *For Our Future: Indigenous Resilience Report* captures. This report, in particular, she says, "really made an effort to include […] diverse perspectives in Indigenous communities, but it was impossible to do it in one report. So, to me, it's […] an opening. It's like giving people a tiny glimpse of what's possible and what's there."

Video 6: Video interview with Deborah McGregor, Canada Research Chair in Indigenous Environmental Justice, on perspectives related to self-determination and Indigenous-led adaptation.
<https://vimeo.com/889966380>

2.9 Adaptation can promote equity

Existing social, economic and health inequities are often exacerbated by climate change impacts. Engaging with those most affected by climate change is essential to ensure that adaptation measures address these inequities.

Climate change affects different groups of people in different ways. It can be particularly disruptive for those disadvantaged by pre-existing inequities (*see* IRR; HCCC-9), increasing their vulnerability and decreasing their adaptative capacity (*see* HCCC-9; NIR-2; NIR-3). Vulnerability to climate change is influenced by many factors, including demographics (such as age, gender or housing status), socioeconomic status (such as income levels or working conditions), geography (such as where one lives and works, or accesses healthcare services) and culture (such as ethnicity and Indigeneity) (*see* NIR-2; NIR-3; IRR).

Some populations and communities are also at higher risk of experiencing climate-related health impacts. Determinants of health, including many of the factors mentioned above, play a key role in increasing or decreasing an individual's adaptive capacity, and their exposure or sensitivity to climate-related health risks (*see* Figure 8). For example, certain occupations (such as in agriculture, landscaping or construction) are highly exposed to climate hazards, such as extreme heat (*see* RPR-2). Systemic drivers of health inequities—such as racism and historic and ongoing colonization—also increase vulnerability to climate change, which increases risks to communities already disproportionately burdened by illness, including First Nations, Inuit and Métis communities and racialized populations (*see* HCCC-2; HCCC-9; NIR-3; RPR-4; IRR).

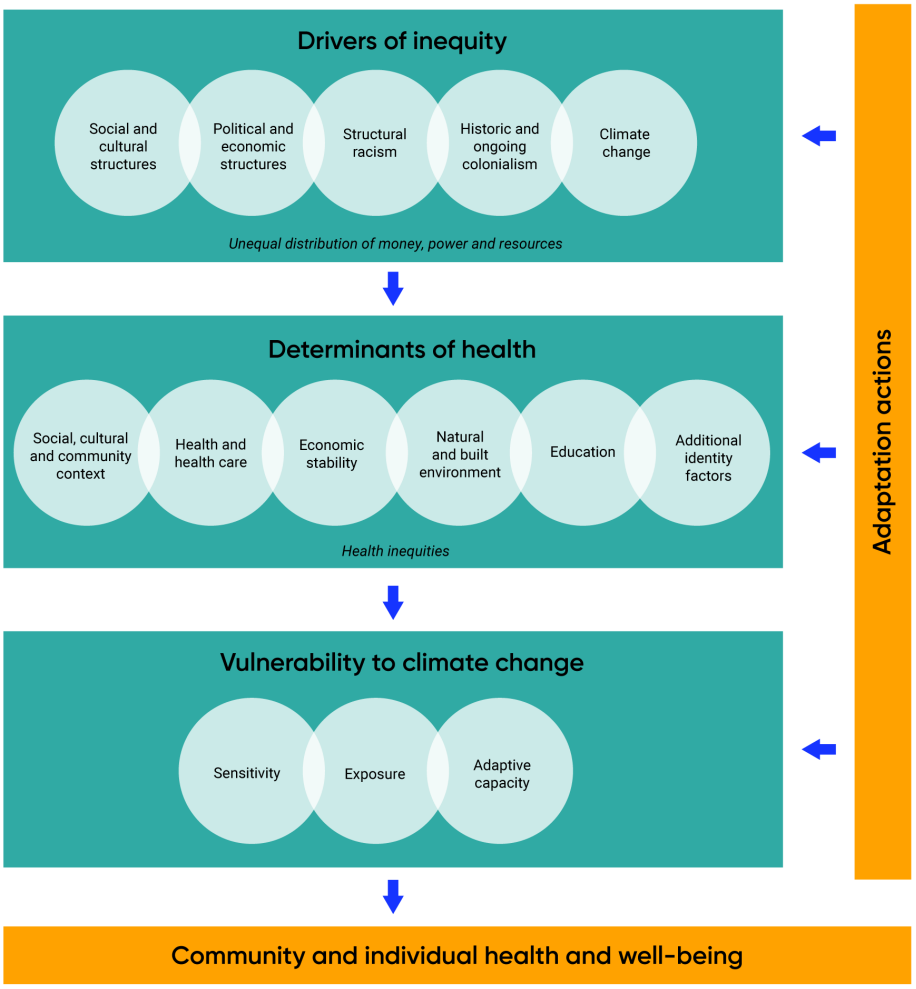


Figure 8: Climate change and health equity framework. Source: Schnitter et al., 2022.

Location is also an important factor shaping vulnerability to climate change impacts. For instance, people living in rural and remote communities often experience more environmental, social, economic, cultural and health impacts from climate change than those living in urban areas. This is largely due to their relative isolation, limited access to services (such as health care), reliance on sparse critical infrastructure for basic needs, and frequent dependence on climate-sensitive natural resources for their livelihoods (*see* Section 2.7). Coastal communities are increasingly at risk of displacement or relocation from extreme storms, erosion and rising sea levels. While adaptation options such as managed retreat may be possible, there are many important considerations, recognizing that livelihoods and identity in many of these locations are inherently intertwined with cultural and historic connections to place.

Climate change is having tangible and intangible impacts as ecosystems and landscapes change, particularly in rural and remote areas where connection to the land is embedded in identity and cultural practice (*see* NIR-3; IRR). People living in northern Canada, for instance, often live in close proximity to their environment and rely on the land to support their livelihoods, well-being, culture and identity (*see* RPR-6). Even small

changes in climate and the environment can disrupt peoples' lives and connection to place. This is particularly pronounced for Indigenous communities, whose cultural practices (such as hunting, fishing, trapping and gathering) and connection to land are affected by changes such as decreased sea ice, disruptions to food and water sources, and changes to wildlife and plants (*see* IRR; RPR-6). Further, recent studies have explored how climate change is limiting access to places of cultural significance, altering the inter-generational transmission of Indigenous Knowledge, and damaging or destroying landscapes and sites of cultural and social significance (*see* NIR-3; RPR-1; RPR-2; RPR-5; RPR-6). These intangible losses can also fuel ecological anxiety and grief (*see* RPR-6; IRR) as well as other mental health challenges (*see* HCCC-4; NIR-3).

Despite climate risks and existing inequities, many communities continue to demonstrate resilience. Many rural and remote communities benefit from heightened social capital and access to Indigenous Knowledge and/or local knowledge, which strengthens their adaptive capacity (*see* NIR-3; RPR-6; IRR). For example, the Eenou community of Mistissini in northern Quebec outlined several measures to monitor and address changing ice conditions in its *Climate Change Adaptation Action Plan*, drawing from Indigenous Knowledge Systems (*see* RPR-2; Grand Council of the Crees, 2019; Cree Nation of Mistissini and Cree Nation Government, 2018).

It is important that adaptation planning processes be equitable and that adaptation actions strive to benefit those most in need (*see* IRR). If equity outcomes are not considered during planning and implementation, measures can have unintended consequences that fail to benefit—or even harm—disadvantaged groups or deepen existing inequities (*see* IRR). For example, a study in Toronto found that racialized and low-income populations had less access to green space compared to communities that were predominantly white (*see* HCCC-9). Green space has been shown to reduce health risks related to urban heat islands and extreme heat.

To ensure that adaptation measures benefit those at highest risk, without exacerbating inequities and vulnerability, decision makers have a range of options. These include inclusive and equitable processes of community engagement that foster wide participation in adaptation planning, and participatory monitoring and evaluation of adaptation measures to assess if and how they have enhanced equity and reduced vulnerability. Decision-making tools—such as asset mapping, heat stress mapping, social vulnerability mapping (*see* Case Story 1.6 in RPR-1) and enhanced data collection—can also help authorities to better understand existing conditions and inequities in their communities, and how these factors interact with climate change. With this information, they are better equipped to identify populations and regions that are at increased risk and to plan and act accordingly. For example, social vulnerability mapping in Nova Scotia has identified populations at higher risk of adverse outcomes from climate change impacts such as coastal flooding, and can guide interventions to lower these risks and prepare for emergencies (*see* Case Story 1.7 in RPR-1).

Greater equity can be a co-benefit of well-designed and targeted adaptation strategies and actions (*see* Table 6.3 in NIR-6). For example, the City of Greater Sudbury partnered with Greater Sudbury Transit to make all transit trips free of charge during extreme heat events, which ensured more equitable access to cooling centres (*see* HCCC-9). The importance of equitable climate change adaptation is increasingly recognized, as is the need to ensure diverse voices are included in planning, implementing and delivering adaptation initiatives (*see* Case Story 2.3 in NIR-2).

2.10 Now is the time for the private sector to step up on adaptation

Businesses face a range of direct and indirect risks from climate change. It is vital to engage and empower the business community and other private sector stakeholders if we are to progress at the scale needed to reduce current and future climate change risks and take advantage of potential opportunities.

Much of the literature on climate change adaptation in Canada focuses on the role of governments, with less attention paid to the private sector. Yet climate change presents great risks and opportunities to businesses across the country (*see* Box 10 and Table 7). These include direct risks to their facilities, supply chains and employee health and well-being, as well as indirect risks related to global trade patterns, shipping and distribution, and access to raw materials (*see* Figure 9; NIR-8; NIR-9). Such risks can in turn increase financial losses by reducing revenues and productivity, while increasing insurance and other operating costs and capital expenditures (*see* NIR-8). Adaptation also offers businesses potential opportunities (*see* Section 2.4), including through access to new markets, more favourable conditions for certain activities, and shifting patterns of comparative advantage. Overall, adaptation is imperative for the private sector to remain competitive in a changing climate.

"Climate change risks and opportunities are business issues." (*see* NIR-8)

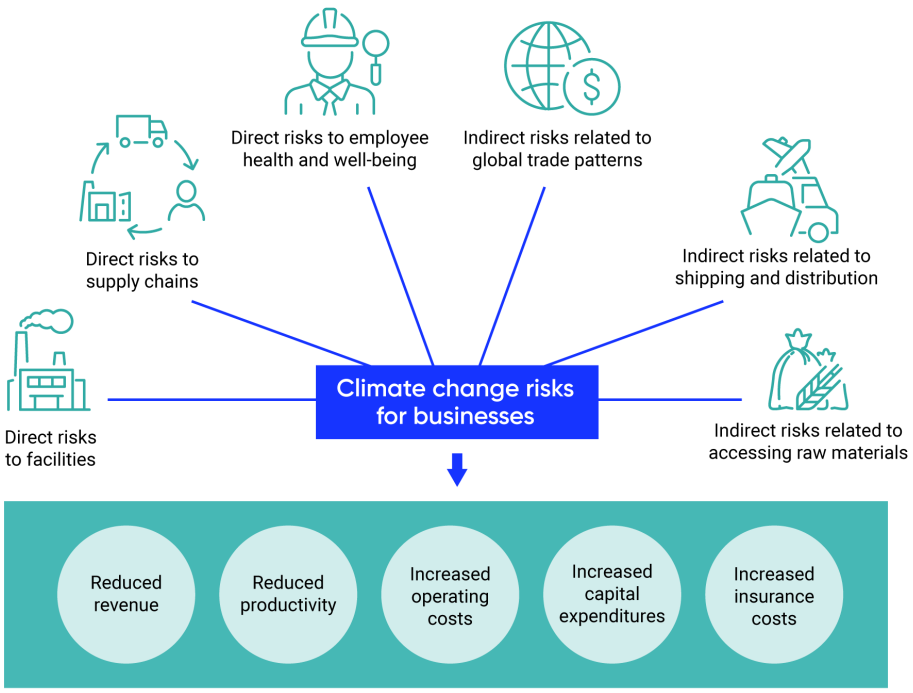


Figure 9: Climate change risks to businesses.

However, evidence to date suggests that adaptation in Canada's private sector has been limited, with most businesses neither taking action, nor planning to engage in adaptation (*see* NIR-7; NIR-8; NIR-9). This could be due in part to underreporting, issues of confidentiality, competition and limited understanding of what constitutes adaptation to climate change (*see* NIR-7; NIR-8). While the number of examples of private-sector adaptation is growing, most tend to be small in scale, piecemeal and reactive (*see* NIR-7). Overall, accelerating adaptation within the private sector is clearly needed to help close Canada's ever-widening adaptation gap (*see* Section 2.6; NIR-6; NIR-7; NIR-8).

In addition to barriers and drivers (*see* Section 2.6), other factors can encourage or limit adaptation action in the private sector. Requiring financial disclosure of climate risks and opportunities, for example, has been recognized as a way to drive climate action by encouraging companies to become more climate resilient (*see* NIR-8). It is also an important tool for revealing the climate change risks that companies are facing (*see* NIR-8; NIR-9). Publicly traded companies are legally required to disclose material risks, such as damage and disruption from extreme weather events, limited water availability due to drought, and volatile energy costs due to shifting demand. Additional voluntary disclosure often happens through company reporting processes (*see* NIR-8). Experts question, however, whether this provides sufficiently detailed and comprehensive disclosure of climate risks (*see* NIR-8). The Task Force on Climate-related Financial Disclosures (2017; 2019) provides recommendations for improvements (*see* Box 8.2 in NIR-8), while initiatives such as the Carbon Disclosure Project and the Sustainability Accounting Standards Board framework are other mechanisms that encourage progress in this area (*see* NIR-8).

Private sector action can also be encouraged through initiatives that clearly demonstrate the business case for adaptation (*see* Section 2.4). It is clear that the economic benefits of adaptation typically exceed the costs (*see* Section 2.4; NIR-6). However, the evidence base is fragmented and insufficient to fully inform business decisions, which are often complex due to competing priorities and the need to consider trade-offs. Calculations are further complicated by uncertainties inherent in climate change and economic projections, future discount rates and accounting for co-benefits, which can be difficult to quantify (*see* NIR-6). Case studies of implemented adaptation actions that clearly lay out the process followed, assumptions made, costs incurred and the results observed would play an important role in stimulating action in the private sector. For example, The Co-operators, a Canadian-based insurance company with branches across the country, worked with Chartered Professional Accountants of Canada to develop a proactive adaptation strategy for managing climate change risks and opportunities. This included creating new insurance products and engaging with stakeholders to enhance community resilience in the face of extreme precipitation and flooding events (*see* Map of Adaptation Actions).

Incentives are another recognized way to increase private sector action on adaptation (*see* NIR-6; NIR-7; NIR-8; RPR-1). These can include grants to increase resilience to physical risks (such as flooding and storms) or to encourage sustainable practices (such as in agriculture; *see* RPR-5). Incentives to adaptation can either reward positive measures, such as through reduced insurance premiums and tax-breaks (*see* NIR-8), or discourage negative actions, such as through charges and taxes. Often provided by various orders of government, financial incentives need to be carefully designed to achieve their goal (*see* Section 2.6; NIR-6). Governments can further encourage adaptation by providing clear policies, legislation and regulations (*see* Section 2.6). This helps to guide private sector decisions, provide reassurance that investments in adaptation are supported by the government (*see* RPR-5) and create a more level playing field. Governments can also

contribute by providing access to timely, reliable and easily-interpreted climate data and tailored climate services (such as the Canadian Centre for Climate Services).

Transitioning to a climate-resilient and low-carbon economy requires substantial investment (*see* NIR-8). Public sector financing alone is insufficient for meeting this need (*see* NIR-6)—the private sector has an important role to play in helping to bridge the finance gap, with help from governments in addressing market and behavioural barriers to action (*see* NIR-7).

Table 7: Examples of private sector adaptation to reduce climate risks to operations and assets

TYPE OF ADAPTATION	EXAMPLES	INVESTMENT REQUIRED	MOTIVATIONS
"Soft" adaptation measures	Risk assessments, organizational policies, adjustments in operational practices, education and awareness, new partnerships	Low to moderate	Often related to social responsibility
"Hard" adaptation measures	Building or renovating structural defenses, relocating infrastructure or offices, divesting from climate-exposed property and sectors	Significant	Often in response to extreme events
Financial disclosure of climate risks	Disclosing material climate-related risks such as potential for damaged assets, operational disruptions, or disruptions to supply or distribution chains)	Low to moderate	Legislative requirement to report material risks
Investments in risk modelling	Investments by insurance companies in catastrophe risk models, flood risk maps	Moderate	Enhanced ability to assess and valuate risks

Sources: NIR-7; NIR-8; Averchenkova et al., 2016.

Box 10: Mobilizing private sector adaptation

Insights from Paul Kovacs, Founder and Executive Director of the Institute for Catastrophic Loss Reduction at Western University

With more than 25 years of experience in assessing catastrophic loss, Paul Kovacs believes there is a sound body of knowledge available to help businesses better prepare for climate change (*see* v). "It is clear that there is a greater effort evident in the private sector to understand what these risks are and to understand options to put protection in place," he says.

The challenge is getting them to move from awareness to action. "It's essential that [they] become much more active in preparing for climate extremes," says Mr. Kovacs. "We need a whole-of-society solution to the threat of climate change and [its] adverse impacts […]. We're seeing good signs of interest and willingness to act, but turning that into protective action has yet to happen."

In dollar terms alone, much is at stake. According to Mr. Kovacs, Canadian businesses experienced billions of dollars worth of preventable damage due to climate change and weather extremes in 2022 alone. Over the last 40 years, damage caused by severe weather has doubled every five to ten years. These rising costs are a key reason why more and more companies are assessing risks and considering what protective measures to put in place.

"The potential for positive outcomes through climate preparedness is very, very large in Canada," says Mr. Kovacs. "We can stop the trend of rising losses by applying the knowledge that we have, but it requires large investments in protective action by businesses all across the country."

Video 7: Video interview with Paul Kovacs, Founder and Executive Director of the Institute for Catastrophic Loss Reduction at Western University, on private-sector adaptation. <https://vimeo.com/886516568>

3.0 Conclusion

Our knowledge and understanding of Canada's changing climate—along with the expected impacts and our adaptation options—have grown significantly in recent years. This is evident in the thousands of references cited in the *Canada in a Changing Climate* Assessment reports. The knowledge base has broadened too, with much of the literature focusing on new and emerging issues, such as the importance of addressing equity in the context of adaptation, and the need to integrate multiple sources of knowledge in adaptation decisions, particularly Indigenous Knowledge Systems. Throughout this report, we have highlighted some of the promising advances on adaptation, while recognizing that much more work is needed to close Canada's adaptation gap.

For the first time in the National Knowledge Assessment process, authors of most of the reports were explicitly asked to identify key knowledge gaps and emerging issues. This has helped set a baseline and will inform future research, with the goal of closing gaps and expanding the existing knowledge base. These knowledge gaps are summarized in Annex 3.

Overall, it is clear that climate change is already having profound impacts on Canada and that many of these impacts will amplify in the future. The examples presented within this report provide only a snapshot of the wide-ranging risks we are facing. The actions we do or do not take now and in the near term will have a long legacy.

Ongoing adaptation must be accompanied by climate change mitigation to limit the level of global warming. With global action, we still have the chance to shape our long-term future and prevent many of the most extreme risks from being realized, though that window is rapidly closing (IPCC, 2023a). There is no denying that these are daunting challenges. However, they can also be seen as an opportunity. Climate change gives us impetus and motivation to make systemic changes in our society, economy and environment that would make our country a better place to live, work and play. Planned adaptation, for example, not only reduces climate risks, but can also increase overall resilience, help address underlying inequities, advance reconciliation and better protect the natural environment. There are roles for all—from individuals to households, communities, businesses and governments of all types—to better incorporate climate change adaptation within day-to-day decisions, policies and processes, and long-term mandates.

4.0 References

Arias, P.A., Bellouin, N., Coppola, E., Jones, R.G., Krinner, G., Marotzke, J., Naik, V., Palmer, M.D., Plattner, G.-K., Rogelj, J., Rojas, M., Sillmann, J., Storelvmo, T., Thorne, P.W., Trewin, B., Achuta Rao, K., Adhikary, B., Allan, R.P., Armour, K., Bala, G., Barimalala, R., Berger, S., Canadell, J.G., Cassou, C., Cherchi, A., Collins, W., Collins, W.D., Connors, S.L., Corti, S., Cruz, F., Dentener, F.J., Dereczynski, C., Di Luca, A., Diongue Niang, A., Doblas-Reyes, F.J., Dosio, A., Douville, H., Engelbrecht, F., Eyring, V., Fischer, E., Forster, P., Fox-Kemper, B., Fuglestvedt, J.S., Fyfe, J.C., Gillett, N.P., Goldfarb, L., Gorodetskaya, I., Gutierrez, J.M., Hamdi, R., Hawkins, E., Hewitt, H.T., Hope, P., Islam, A.S., Jones,C., Kaufman, D.S., Kopp, R.E., Kosaka, Y., Kossin, J., Krakovska, S., Lee, J.-Y., Li, J., Mauritsen, T., Maycock, T.K., Meinshausen, M., Min, S.-K., Monteiro, P.M.S., Ngo-Duc, T., Otto, F., Pinto, I., Pirani, A., Raghavan, K., Ranasinghe, R., Ruane, A.C., Ruiz, L., Sallée, J.-B., Samset, H., Sathyendranath, S., Seneviratne, S.I., Sörensson, A.A., Szopa, S., Takayabu, I., Tréguier, A.-M., van den Hurk, B., Vautard, R., von Schuckmann, K., Zaehle, S., Zhang, X. and Zickfeld. (2021): Technical Summary *in* Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (Eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 33–144. <https://doi.org/10.1017/9781009157896.002>

AFN [Assembly of First Nations] (2019). Declaring a First Nations Climate Emergency. Annual General Assembly, July 23, 24, 25; Fredericton, New Brunswick. Resolution No. 5/2019. Retrieved August 2023, from <https://afn.bynder.com/m/5a3de3c7f6cf08b5/original/05-2019-Declaring-a-First-Nations-Climate-Emergency.pdf>

Association des Stations de Ski du Québec (2016). Congrès 2016: Le Québec a atteint le 5,125 millions de jours/ski pour la saison 2015-2016. Tourismexpress. Retrieved June 2020, from <https://tourismexpress.com/nouvelles/congres-assq-2016-le-quebec-a-atteint-le-5-125-millions-de-jours-ski-pour-la-saison-2015-16>

Averchenkova, A., Crick, F., Kocornik-Mina, A., Leck, H. and Surminski, S. (2016). Multinational and large national corporations and climate adaptation: Are we asking the right questions? A review of current knowledge and a new research perspective. *WIREs Climate Change*, *7*(4), 517–536. Retrieved June 2020, from <https://doi.org/10.1002/wcc.402>

Benmarhnia, T., Bailey, Z., Kaiser, D., Auger, N., King, N. and Kaufman, J. S. (2016). A Difference-in-Differences Approach to Assess the Effect of a Heat Action Plan on Heat-Related Mortality, and Differences in Effectiveness According to Sex, Age, and Socioeconomic Status (Montreal, Quebec). *Environmental Health Perspectives, 124*(11), 1694–1699. Retrieved September 2023, from <https://doi.org/10.1289/EHP203>

Berger, Thomas. (1977). Northern Frontier Northern Homeland: The Report of the Mackenzie Valley Pipeline Inquiry: Volume One. Minister of Supply and Services Canada. Report No. CP32-25/1977-1. Retrieved August 2023, from <https://publications.gc.ca/site/eng/9.700299/publication.html>

Borrows, J. (2018). Earth-Bound: Indigenous Resurgence and Environmental Reconciliation *in* Resurgence and Reconciliation: Indigenous-Settler Relations and Earth Teachings, (Eds.) M. Asch, J. Borrows and J. Tully. Toronto Press, Toronto, Ontario, 49–82. Retrieved August 2023, from <https://doi.org/10.3138/9781487519926>

Brown, C., Jackson, E., Harford, D. and Bristow, D. (2021). Cities and Towns, Chapter 2 *in* Canada in a Changing Climate: National Issues Report, (Eds.) F.J. Warren and N. Lulham. Government of Canada, Ottawa, Ontario, 26–102. Retrieved August 2023, from <https://changingclimate.ca/national-issues/chapter/2-0/>

C40 Cities and AECOM (2017). C40 Infrastructure Interdependencies and Climate Risks Report. Retrieved February 2020, from <https://unfccc.int/sites/default/files/report_c40_interdependencies_.pdf>

Charness, K., Collie, J., Fatima, S. and Berry, P. (2023). Risks of Climate Change to Health in Canada. Health Canada, Ottawa, Ontario.

City of Calgary (2017). Flood Mitigation Measures Assessment Report and 2016 Flood Resiliency Update. Retrieved June 2020, from <https://www.calgary.ca/UEP/Water/Pages/Flood-Info/Stay-informed/Flood-Mitigation-Measures-Assessment.aspx>

Council of Canadian Academies (2019). Canada's Top Climate Change Risks. Ottawa, Ontario. Retrieved February 2020, from <https://cca-reports.ca/wp-content/uploads/2019/07/Report-Canada-top-climate-change-risks.pdf>

Cree Nation of Mistissini and Cree Nation Government (2018). Community Proposal: Climate Change Adaptation Action Plan. Retrieved November 2021, from <https://www.cngov.ca/news-issues/current-issues/community-proposal-climate-change-adaptation-action-plan/>

Edwards, J. E., Pearce, C., Ogden, A. E. and Williamson, T. B. (2015). Climate Change and Sustainable Forest Management in Canada: A Guidebook for Assessing Vulnerability and Mainstreaming Adaptation into Decision Making. Canadian Council of Forest Ministers, Climate Change Task Force, 172 p. Retrieved June 2020, from <https://www.ccfm.org/pdf/Vulnerability%20Guidebook_June2_EN.pdf>

Environment and Climate Change Canada (2020). A Healthy Environment and a Healthy Economy: Canada's Strengthened Climate Plan to Create Jobs and Support People, Communities and the Planet. Retrieved March 2023, from <https://www.canada.ca/en/services/environment/weather/climatechange/climate-plan/climate-plan-overview/healthy-environment-healthy-economy.html>

EPCCARR [Expert Panel on Climate Change Adaptation and Resilience Results] (2018). Measuring Progress on Adaptation and Climate Resilience: Recommendations to the Government of Canada. Her Majesty the Queen in Right of Canada. Retrieved May 2020, from <http://publications.gc.ca/collections/collection_2018/eccc/En4-329-2018-eng.pdf>

Eyzaguirre, J., Boyd, R., Prescott, S., Morton, C., Nelitz, M. and Litt, A. (2020). Green Shores 2020: Impact, Value and Lessons Learned, Final Project Report. Prepared by ESSA Technologies Ltd. for the Stewardship Centre for British Columbia. Retrieved March 2021, from <http://stewardshipcentrebc.ca/PDF_docs/greenshores/Resources/Green%20Shores%202020_%20Impact,%20Value%20and%20Lessons%20Learned_%20Full%20Report_July2020.pdf>

Eyzaguirre, J. and Warren, F. (2014). Adaptation: Linking Research and Practice, Chapter 9 *in* Canada in a Changing Climate: Sector Perspectives on Impacts and Adaptation, (Eds.) F.J. Warren and D.S. Lemmen. Government of Canada, Ottawa, Ontario, 253–286. Retrieved September 2023, from <https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/earthsciences/pdf/assess/2014/pdf/Full-Report_Eng.pdf>

Federation of Canadian Municipalities (2018). How to Develop an Asset Management Policy, Strategy and Governance Framework Guide. Retrieved February 2020, from <https://fcm.ca/sites/default/files/documents/resources/guide/how-to-develop-asset-management-policy-strategy-mamp.pdf>

Global Commission on Adaptation (2019). Adapt now: a global call for leadership on climate resilience. Global Commission on Adaptation, 81 p. Retrieved August 2020, from <https://gca.org/reports/adapt-now-a-global-call-for-leadership-on-climate-resilience/>

Government of Canada (1996). Report of the Royal Commission on Aboriginal Peoples. Report prepared for the Government of Canada by the Royal Commission on Aboriginal Peoples. Ottawa, Ontario. Retrieved August 2023, from <https://www.bac-lac.gc.ca/eng/discover/aboriginal-heritage/royal-commission-aboriginal-peoples/Pages/final-report.aspx>

Government of Canada (2023). Canada's National Adaptation Strategy: Building Resilient Communities and a Strong Economy. Retrieved September 2023, from <https://www.canada.ca/en/services/environment/weather/climatechange/climate-plan/national-adaptation-strategy.html>

Grand Council of the Crees (2019). Envisioning Responses to Climate Change in Eeyou Istchee: Report on the Regional Forum on Climate Change. Environment and Remedial Works, Cree Nation Government. Retrieved September 2020, from <https://www.cngov.ca/wp-content/uploads/2019/07/eastmain-climate-change-report_pdf3.pdf>

Green Analytics (2016). Ontario's Good Fortune: Appreciating the Greenbelt's Natural Capital. Report prepared for The Friends of the Greenbelt Foundation by Green Analytics, 92 p. Retrieved March 2021, from <https://d3n8a8pro7vhmx.cloudfront.net/greenbelt/pages/2825/attachments/original/1485878510/OP_20_Web_version_2017.pdf?1485878510>

Insurance Bureau of Canada (2019). Facts of the Property and Casualty Insurance Industry in Canada, 41st edition. Retrieved June 2020, from <http://assets.ibc.ca/Documents/Facts%20Book/Facts_Book/2019/IBC-2019-Facts.pdf>

Insurance Bureau of Canada and Federation of Canadian Municipalities (2020). Investing in Canada's Future: The Cost of Climate Adaptation. Retrieved March 2023, from <https://fcm.ca/en/resources/investing-in-canadas-future>

IPCC [Intergovernmental Panel on Climate Change] (2021a). Summary for Policymakers *in* Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, (Eds.) V. Masson-Delmotte, P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu and B. Zhou. In Press.

IPCC [Intergovernmental Panel on Climate Change] (2021b). Climate Change 2021: The Physical Science Basis (Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change), (Eds.) V. Masson-Delmotte, P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu and B. Zhou. Cambridge University Press, Cambridge, United Kingdom and New York, New York, USA. Retrieved September 2023, from <https://dx.doi.org/10.1017/9781009157896>

IPCC [Intergovernmental Panel on Climate Change] (2022). Climate Change 2022: Impacts, Adaptation, and Vulnerability (Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change), (Eds.) H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem and B. Rama. Cambridge University Press. Cambridge University Press, Cambridge, United Kingdom and New York, New York, USA, 3056 p. Retrieved January 2023, from <https://doi.org/10.1017/9781009325844>

IPCC [Intergovernmental Panel on Climate Change] (2023a). Summary for Policymakers *in* Climate Change 2023: Synthesis Report (Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change), (Eds.) IPCC Core Writing Team, Lee, H. and Romero J. IPCC, Geneva, Switzerland, 1–34. Retrieved September 2023, from <https://doi.org/10.59327/IPCC/AR6-9789291691647.001>

IPCC [Intergovernmental Panel on Climate Change] (2023b). Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, Lee, H. and Romero, J. (Eds.)]. IPCC, Geneva, Switzerland, 35-115. Retrieved July 2023, from <https://doi.org/10.59327/IPCC/AR6-9789291691647>

ITK [Inuit Tapiriit Kanatami] (2019). National Climate Change Strategy. Retrieved March 2023, from <https://www.itk.ca/national-inuit-climate-change-strategy/>

ITK [Inuit Tapiriit Kanatami] (2021). Inuit Nunangat Food Security Strategy. Retrieved August 2023, from <https://www.itk.ca/projects/inuit-nunangat-food-security-strategy/>

Lemmen, D.S., Warren, F.J., Lacroix, J. and Bush, E. (Eds.) (2008). From Impacts to Adaptation: Canada in a Changing Climate 2008. Government of Canada, Ottawa, Ontario, 448 p. Retrieved March 2023, from <https://natural-resources.canada.ca/sites/nrcan/files/earthsciences/pdf/assess/2007/pdf/full-complet_e.pdf>

Lemmen, D.S., Warren, F.J., James, T.S. and Mercer Clarke, C.S.L. (Eds.) (2016). Canada's Marine Coasts in a Changing Climate. Government of Canada, Ottawa, Ontario, 274 p. Retrieved March 2023, from <https://natural-resources.canada.ca/sites/nrcan/files/earthsciences/pdf/assess/2016/Coastal_Assessment_FullReport.pdf>

Lempert, R., Arnold, J., Pulwarty, R., Gordon, K., Greig, K., Hawkins Hoffman, C., Sands, D. and Werrell, C. (2018). Reducing Risks Through Adaptation Actions in Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II. (Eds.) D.R. Reidmiller, C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock and B.C. Stewart. U.S. Global Change Research Program, Washington, D.C., USA, 1309–1345. Retrieved August 2020, from <https://nca2018.globalchange.gov/downloads/NCA4_Ch28_Adaptation_Full.pdf>

McMillan, T., Causley, D., Hanna, K., Lulham, N., Seasons, M. and Boddy, S. (2019). Local adaptation in Canada: Survey report. Retrieved February 2020, from <http://ok-cear.sites.olt.ubc.ca/files/2019/06/Local-Adaptation-in-Canada-Full-web.-1.pdf>

NRTEE [National Round Table on the Environment and the Economy] (2011). Paying the Price: The Economic Impacts of Climate Change for Canada. Ottawa, Ontario, 162 p. Retrieved August 2020, from <http://nrt-trn.ca/wp-content/uploads/2011/09/paying-the-price.pdf>

Ontario (2015). Managing Your Forest in a Changing Climate. Retrieved June 2020, from <https://docs.ontario.ca/documents/4491/managing-your-woodlot-in-a-changing-climate.pdf>

Pikialasorsuaq Commission (2019). Pikialasorsuaq Leaders Statement. Retrieved August 2023, from <https://pm.gc.ca/en/news/backgrounders/2019/04/04/pikialasorsuaq-leaders-statement>

Project Steering Committee [Canadian Construction Association, Canadian Public Works Association, Canadian Society for Civil Engineering and Federation of Canadian Municipalities] (2016). Informing the Future: Canadian Infrastructure Report Card. Retrieved February 2020, from <http://canadianinfrastructure.ca/downloads/Canadian_Infrastructure_Report_2016.pdf>

Qikiqtani Truth Commission (2013). QTC Final Report: Achieving Saimaqatigiinnhiq. Qikiqtani Truth Commission. Inhabit Media Inc., Iqualuit, Nunavut and Toronto, Ontario. Retrieved August 2023, from <https://www.qtcommission.ca/en/reports/qtc-final-report-achieving-saimaqatigiingniq>

Reed, G., Brunet, N.D., Longboat, S. and Natcher, D.C. (2021). Indigenous guardians as an emerging approach to indigenous environmental governance. *Conservation Biology, 35*(1), 179–189. Retrieved December 2022, from <https://doi.org/10.1111/cobi.13532>

Reed, G., Brunet, N.D., McGregor, D., Scurr, C., Sadik, T., Lavigne, J. and Longboat, S. (2022). Toward Indigenous visions of nature-based solutions: an exploration into Canadian federal climate policy. *Climate Policy, 22*(4), 514–533. Retrieved March 2023, from <https://doi.org/10.1080/14693062.2022.2047585>

Rutty, M., Scott, D., Johnson, P., Steiger, R., Pons, M. and Vilella, M. (2017). Using ski industry response to climatic variability to assess climate change risk: an antalogue study in Eastern Canada. *Tourism Management, 58*. Retrieved March 2023, from <https://doi.org/10.1016/j.tourman.2016.10.020>

Schnitter, R., Moores, E., Berry, P., Verret, M., Buse, C., Macdonald, C., Perri, M. and Jubas-Malz, D. (2022). Climate Change and Health Equity *in* Health of Canadians in a Changing Climate: Advancing our Knowledge for Action, (Eds.) P. Berry and R. Schnitter. Government of Canada, Ottawa, Ontario. Retrieved August 2023, from <https://changingclimate.ca/health-in-a-changing-climate/chapter/9-0/>

SENES Consultants Ltd. (2011). Kingston's Ur ban Forest Management Plan: a plan for city-owned trees. Prepared for the City of Kingston by SENES Consultants Ltd. Retrieved March 2021, from <https://www.cityofkingston.ca/residents/environment-sustainability/nature-forests-gardens/urban-forest-management-plan>

Seneviratne, S.I., Zhang, X., Adnan, M., Badi, W., Dereczynski, C., Di Luca, A., Ghosh, S., Iskandar, I., Kossin, J., Lewis, S., Otto, F., Pinto, I., Satoh, M., Vicente-Serrano, S.M., Wehner, M. and B. Zhou, (2021): Weather and Climate Extreme Events in a Changing Climate *in* Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, Eds. Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu and B. Zhou. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1513–1766. Retrieved March 2023, from <https://doi.org/10.1017/9781009157896.013>

Task Force on Climate-Related Financial Disclosures (2017). Final Report: Recommendations of the Task Force on Climate-Related Financial Disclosures. Retrieved June 2020, from <https://www.fsb-tcfd.org/publications/final-recommendations-report/>

Task Force on Climate-Related Financial Disclosures (2019). 2019 Status Report. Retrieved July 2020, from <https://www.fsb-tcfd.org/publications/tcfd-2019-status-report/>

Truth and Reconciliation Commission of Canada (2015). Truth and Reconciliation Commission of Canada: Calls to Action. Retrieved August 2023, from <https://ehprnh2mwo3.exactdn.com/wp-content/uploads/2021/01/Calls_to_Action_English2.pdf>

United Nations (2007). United Nations Declaration on the Rights of Indigenous Peoples. Resolution No. 61/295. Retrieved August 2023, from <https://www.un.org/development/desa/indigenouspeoples/wp-content/uploads/sites/19/2018/11/UNDRIP_E_web.pdf>

Vodden, K. and Cunsolo, A. (2021). Rural and Remote Communities, Chapter 3 *in* Canada in a Changing Climate: National Issues Report, (Eds.) F.J. Warren and N. Lulham. Government of Canada, Ottawa, Ontario. Retrieved August 2023, from <https://changingclimate.ca/national-issues/chapter/3-0/>

Warren, F.J. and Lemmen, D.S., (Eds.) (2014). Canada in a Changing Climate: Sector Perspectives on Impacts and Adaptation. Government of Canada, Ottawa, Ontario, 286 p. Retrieved March 2023, from <https://natural-resources.canada.ca/sites/nrcan/files/earthsciences/pdf/assess/2014/pdf/Full-Report_Eng.pdf>

Annex 1: *Canada in a Changing Climate: Advancing our Knowledge for Action* National Knowledge Assessment reports

Berry, P. and Schnitter, R., editors (2022). Health of Canadians in a Changing Climate: Advancing our Knowledge for Action; Government of Canada, Ottawa, Ontario. <https://changingclimate.ca/health-in-a-changing-climate/>

Bush, E. and Lemmen, D.S., editors (2019). Canada's Changing Climate Report; Government of Canada, Ottawa, Ontario. <https://changingclimate.ca/CCCR2019/>

Warren, F. and Lulham, N., editors (2021). Canada in a Changing Climate: National Issues Report; Government of Canada, Ottawa, Ontario. <https://changingclimate.ca/national-issues/>

Warren, F., Lulham, N. and Lemmen, D.S., editors (2021). Canada in a Changing Climate: Regional Perspectives Report; Government of Canada, Ottawa, Ontario. <https://changingclimate.ca/regional-perspectives/>

Reed, G., Fox, S., Littlechild, D., McGregor, D., Lewis, D., Popp, J., Wray, K., Kassi, N., Ruben, R., Morales, S. and Lonsdale, S. (forthcoming). For Our Future: Indigenous Resilience Report. Ottawa, Ontario.

Annex 2: Headline Statements, Key Findings and Key Messages from reports produced in the 2016-2023 National Knowledge Assessment process

Box A1: Headline Statements from Canada's Changing Climate Report (2019)

1. **Canada's climate has warmed and will warm further in the future, driven by human influence.** Global emissions of carbon dioxide from human activity will largely determine how much warming Canada and the world will experience in the future, and this warming is effectively irreversible (CCCR-2.3; CCCR-3.3; CCCR-3.4; CCCR-4.2).
2. **Both past and future warming in Canada is, on average, about double the magnitude of global warming.** Northern Canada has warmed and will continue to warm at more than double the global rate (CCCR-2.2; CCCR-3.3; CCCR-4.2).
3. **Oceans surrounding Canada have warmed, become more acidic, and less oxygenated, consistent with observed global ocean changes over the past century.** Ocean warming and loss of oxygen will intensify with further emissions of all greenhouse gases, whereas ocean acidification will increase in response to additional carbon dioxide emissions. These changes threaten the health of marine ecosystems (CCCR-2.2; CCCR-7.2; CCCR-7.6).
4. **The effects of widespread warming are evident in many parts of Canada and are projected to intensify in the future.** In Canada, these effects include more extreme heat, less extreme cold, longer growing seasons, shorter snow and ice cover seasons, earlier spring peak streamflow, thinning glaciers, thawing permafrost and rising sea level. Because some further warming is unavoidable, these trends will continue (CCCR-4.2; CCCR-5.2; CCCR-5.3; CCCR-5.4; CCCR-5.5; CCCR-5.6; CCCR-6.2; CCCR-7.5).
5. **Precipitation is projected to increase for most of Canada, on average, although summer rainfall may decrease in some areas.** Precipitation has increased in many parts of Canada, and there has been a shift toward less snowfall and more rainfall. Annual and winter precipitation is projected to increase everywhere in Canada over the 21st century. However, reductions in summer rainfall are projected for parts of southern Canada under a high emission scenario toward the late century (CCCR-4.3).
6. **The seasonal availability of freshwater is changing, with an increased risk of water supply shortages in summer.** Warmer winters and earlier snowmelt will combine to produce higher winter streamflows, while smaller snowpacks and loss of glacier ice during this century will combine to produce lower summer streamflows. Warmer summers will increase evaporation of surface water and contribute to reduced summer water availability in the future despite more precipitation in some places (CCCR-4.2; CCCR-4.3; CCCR-5.2; CCCR-5.4; CCCR-6.2; CCCR-6.3; CCCR-6.4).
7. **A warmer climate will intensify some weather extremes in the future.** Extreme hot temperatures will become more frequent and more intense. This will increase the severity of heatwaves, and contribute to increased drought and wildfire risks. While inland flooding results from multiple factors, more intense rainfalls will increase urban flood risks. It is uncertain how warmer temperatures and smaller snowpacks will combine to affect the frequency and magnitude of snowmelt-related flooding (CCCR-4.2; CCCR-4.3; CCCR-4.4; CCCR-5.2; CCCR-6.2).

8. **Canadian areas of the Arctic and Atlantic Oceans have experienced longer and more widespread sea-ice-free conditions.** Canadian Arctic marine areas, including the Beaufort Sea and Baffin Bay, are projected to have extensive ice-free periods during summer by mid-century. The last area in the entire Arctic with summer sea ice is projected to be north of the Canadian Arctic Archipelago. This area will be an important refuge for ice-dependent species and an ongoing source of potentially hazardous ice, which will drift into Canadian waters (CCCR-5.3).
9. **Coastal flooding is expected to increase in many areas of Canada due to local sea-level rise.** Changes in local sea level are a combination of global sea-level rise and local land subsidence or uplift. Local sea level is projected to rise, and increase flooding, along most of the Atlantic and Pacific coasts of Canada and the Beaufort coast in the Arctic where the land is subsiding or slowly uplifting. The loss of sea ice in Arctic and Atlantic Canada further increases the risk of damage to coastal infrastructure and ecosystems as a result of larger storm surges and waves (CCCR-7.5).
10. **The rate and magnitude of climate change under high versus low emission scenarios project two very different futures for Canada.** Scenarios with large and rapid warming illustrate the profound effects on the Canadian climate of continued growth in greenhouse gas emissions. Scenarios with limited warming will only occur if Canada and the rest of the world reduce carbon emissions to near zero early in the second half of the century and reduce emissions of other greenhouse gases substantially. Projections based on a range of emission scenarios are needed to inform impact assessment, climate risk management, and policy development (CCCR-all chapters).

Note: Each statement is cross-referenced to specific sections in chapters of the main report, where supporting evidence can be found. There is high confidence or more associated with each of these statements, which are consistent with, and draw on, the key messages in each of the chapters.

Box A2: Key Findings from *Canada in a Changing Climate: Regional Perspectives Report* (2020–2022)

1. **Canada's regions are experiencing climate change in different ways, with varied impacts on communities, ecosystems, infrastructure and natural resources.** Provincial, territorial and local governments are responding with adaptation plans, policies and actions to address priority risks, but further work and resources are needed to better plan for climate change impacts at the regional level, as well as enhance regional capacity on adaptation (RPR-all chapters).
2. **Climate change is increasing human health risks in all of Canada's regions and deepening existing inequities.** Climate change is having impacts on human health, including through growing risks related to extreme heat, extreme weather, vector-borne diseases, and changes to sea ice and permafrost in the north. While there are promising examples of adaptation planning and implementation at the regional level to address health risks, more work is needed to better understand and respond to climate change impacts on mental health and existing inequities (RPR-all chapters).
3. **Adaptation is vital for Canada's agriculture and natural resource sectors to remain competitive in a changing climate.** Across Canada's regions, the agriculture, energy, mining and forestry sectors face risks related to changes in temperature and rainfall patterns and the emergence of new pests. Producers in all climate-sensitive sectors need to adapt their decision making, practices and operations to changing climate conditions (RPR-1; RPR-3; RPR-4; RPR-5).

4. **Collaboration is key to managing water resources threatened by climate change.** Rising temperatures and changing precipitation patterns are affecting the quality and availability of water resources in several regions across Canada. Approaches such as adaptive management, enhanced collaboration and transboundary coordination between different orders of government and stakeholders is needed to reduce negative impacts on agriculture, human health and industry (RPR-2; RPR-3; RPR-4).
5. **Indigenous Peoples are deeply affected by climate change, and draw on their knowledge and inherent resilience to address impacts.** Climate change is altering landscapes and ecosystems across Canada's regions, which sustain hunting, fishing and other land-based activities that are essential to the culture and identify of Inuit, First Nations and Métis Peoples. There are growing examples of Indigenous-led adaptation plans and actions, which integrate Indigenous Knowledge and draw on Indigenous leadership in environmental stewardship and governance of natural resources (RPR-1; RPR-3; RPR-5; RPR-6).
6. **Preserving ecosystems and implementing nature-based approaches can play an important role in climate change adaptation across Canada's regions.** Forests, wetlands and coastal vegetation help address climate change through the delivery of services, including reducing erosion and flood risks. Nature-based approaches are increasingly being used across Canada's regions to address climate change (RPR-1; RPR-2; RPR-3).

Box A3: Key Findings from *Canada in a Changing Climate: National Issues Report* (2021)

1. **Communities of all sizes across the country are experiencing the impacts of climate change on their infrastructure, health and well-being, cultures and economies.** Local action to reduce climate-related risks is increasing, although limited capacity is challenging the ability of many communities to act (NIR-2; NIR-3).
2. **Changes in climate are threatening the vital services that Canada's ecosystems provide and are negatively impacting our water resources.** Effective coordination, cooperation and adaptive management, as well as conservation efforts, can help to reduce impacts. Nature-based approaches to adaptation that maintain or restore ecosystems, such as wetlands, are a cost-effective and sustainable means of moderating climate change impacts and building resilience (NIR-2; NIR-4; NIR-5).
3. **While climate change will bring some potential benefits, overall, it will impose increasing economic costs on Canada.** A changing climate affects all sectors of Canada's economy through impacts on production, operations and/or disruption to supply chains. Disclosure of climate-related risks is emerging as a key driver of adaptation in the private sector (NIR-6; NIR-7; NIR-8).
4. **We must look beyond our borders when assessing the impacts of a changing climate for Canada.** Climate change impacts occurring elsewhere in the world, as well as the steps that other countries take—or do not take—to adapt, can strongly affect food availability, trade and immigration. These impacts place additional stress on Canada's communities, businesses and government services (NIR-9).
5. **Large gaps remain in our preparedness for climate change, as demonstrated by recent impacts of extreme weather events, such as floods and wildfires.** Accelerating progress on adaptation through rapid and deliberate plans and actions is vital for Canada's economic and social well-being (NIR-all chapters).
6. **Lessons on good practices are continuing to emerge and are helping to guide successful adaptation.** These include empowering strong leadership, collaborating broadly and adopting flexible management approaches. Incorporating diverse perspectives and sources of knowledge, such as Indigenous Knowledge Systems, is also imperative for effective adaptation (NIR-all chapters).

Box A4: Headline Statements from the *Health of Canadians in a Changing Climate Report* (2022)

1. **Climate change is already negatively impacting the health of Canadians.** Climate change has been a driver of recent health effects related to rising temperatures and extreme heat, wildfires and the expansion of zoonotic diseases into Canada, such as Lyme disease (HCCC-3; HCCC-5; HCCC-6).
2. **Health risks will increase as warming continues, and the greater the warming, the greater the threats to health.** Projected increases in the frequency and severity of intense precipitation events, urban flood risk, droughts, extreme heat, wildfires and storms will directly affect health by causing more illness, injuries and deaths, without greater adaptation efforts. The current burden of mental ill health in Canada is likely to rise as a result of climate change. Disruptions to food systems and water resources; worsening of air pollution; the emergence and re-emergence of climate-sensitive infectious diseases; and increasing demands on health systems will continue to threaten Canadians' health (HCCC-2; HCCC-3; HCCC-4; HCCC-5; HCCC-6; HCCC-7; HCCC-8).
3. **Some Canadians are affected more severely by climate change, as exposure and sensitivity to hazards and the ability to take protective measures varies across and within populations and communities.** Growing climate change impacts worsen socioeconomic conditions harmful to health, such as poverty, and amplify health inequities. Combined with increasing rates of chronic diseases, social isolation and an aging population, climate change exacerbates impacts on health. People disproportionately affected by climate change include children and pregnant people; First Nations, Inuit, and Métis peoples; people with chronic illnesses; outdoor workers; low-income individuals; and people with disabilities (HCCC-2; HCCC-3; HCCC-9).
4. **The effects of climate change on health systems in Canada—for example, damage to health facilities and disruptions to health services and operations—are already evident and will increase in the absence of strong adaptation measures.** Health infrastructure, operations, health financing, health care, public health programming, supply chains and the health workforce can be impacted by extreme weather events and by chronic stresses from longer-term warming, reducing access to and quality of care to Canadians. Health facilities and services in rural and remote areas, and health systems that have not assessed and managed risks, face the greatest threats. Compounding climate change hazards that can arise—for example, when extreme heat occurs with drought and a wildfire—pose severe risks to individuals and the health systems they rely on (HCCC-10).
5. **Efforts to prepare for climate change are known to reduce risks and protect health.** We must take action now. Many health authorities are working with decision makers in other sectors, such as emergency management, to take actions to protect people, communities and health systems. This is called adaptation. Adaptation measures must be scaled up rapidly and substantially if current and future health impacts are to be reduced (HCCC-10).
6. **The health impacts of climate change on First Nations, Inuit and Métis peoples are far-reaching, with disproportionate impacts on their communities, including food and water security and safety, air quality, infrastructure, personal safety, mental health and wellness, livelihoods, culture and identity.** Indigenous Peoples have been adapting to changing environments since time immemorial. Indigenous Knowledge Systems and practices are equal to Western scientific knowledge and contribute to Indigenous Peoples' survival, adaptation, and resilience. Preparing for climate change requires addressing determinants of health and ongoing health inequities. It also requires that Indigenous Peoples' rights and responsibilities over their lands, natural resources and ways of life are respected, protected and advanced through Indigenous-led climate change mitigation, adaptation, policy and research (HCCC-2).
7. **To successfully protect all Canadians from the health impacts of climate change, decision makers must pursue adaptation actions that are inclusive and equitable and consider the needs of racialized, marginalized and low-income populations.** Existing health inequities could be made worse unless future adaptation and greenhouse gas mitigation efforts are designed to address them. Redressing inequities and strengthening determinants of good health, such as improving access to health care and housing quality, can help reduce the impacts of climate change on individual health (HCCC-2; HCCC-9).

8. **Increased efforts to reduce greenhouse gas emissions are required to help protect the health of Canadians.** The continued emission of greenhouse gases into the atmosphere will impose limits on our ability to adapt, and lead to more severe impacts on health. The health sector can show leadership in reducing its carbon footprint and improving environmental sustainability while building resilience to future climate change impacts (HCCC-10).
9. **Reducing greenhouse gas emissions can provide very large and immediate health co-benefits to Canadians.** The economic value of the health co-benefits can help to offset the implementation costs of measures. Health co-benefits of taking action on air pollution are estimated to include thousands of avoided premature deaths annually in Canada by the middle of the century (HCCC-5; HCCC-10).

Box A5: Key Messages from the *For Our Future: Indigenous Resilience Report* (forthcoming)

1. **Indigenous Peoples have unique strengths for responding to environmental and climate changes.** Indigenous Peoples have responded to impacts of environmental and climate change before, are actively responding today, and will continue to respond into the future. Our communities have unique strengths to deal with the climate crisis, despite facing disproportionate climate change impacts and challenges related to the ongoing legacy of colonialization.
2. **Climate change is one of many crises that Indigenous Peoples face.** Climate change creates serious disruption not just to the environment and economy, but to culture, language, knowledge transfer, ceremony, identity, and health and well-being. These impacts are interrelated and intersect with multiple other crises that First Nations, Inuit and Métis face.
3. **Indigenous Knowledge and lived experiences are important components of climate action.** To best respond to the impacts of climate change, Indigenous observations, knowledge systems, and diverse lived experiences—with special attention to gender-diverse people, women and youth—must be included in all levels of climate change research, approaches, and decision making. First Nations, Inuit and Métis have always had unique and diverse indicators and methods for observing, monitoring and assessing change.
4. **The food, water and energy nexus is central to First Nation, Inuit and Métis climate leadership.** Food sovereignty is at the heart of Indigenous cultures. The nexus of food, water and energy sovereignty is a key priority for First Nations, Inuit, and Métis. In each context, reasserting authority and decision-making is enabling a redistribution of power towards First Nations, Inuit and Métis. The revitalization of meaningful Indigenous economies based on relationships with the Land, Water, and Ice are central to this redistribution and to Indigenous-led climate action.
5. **Self-determination is critical to Indigenous-led climate action.** Self-determination and governance are key rights and aspirations for First Nations, Inuit and Métis Peoples in the face of climate change. We must recognize and address how the impacts of climate change affect our ability to determine our own futures, govern ourselves and how we adapt our governance structures to the impacts of climate change.

Annex 3: Examples of knowledge gaps identified in the most recent *Canada in a Changing Climate* National Knowledge Assessment reports

ADDRESSING KNOWLEDGE GAPS REQUIRES WORK AT THE INTERSECTION OF ADAPTATION AND:

Agriculture

- Better understanding of how agriculture could expand beyond the Prairie eco-zone and into treed zones.
- Research on the vulnerability of the Chignecto Isthmus and its role in food security for Atlantic provinces.

Climate change communication

- Better tools and approaches for communicating with the public about climate change, particularly on changes that are less visible and/or have slower onset.
- Better understanding of the motives and perspectives that inspire people to learn about climate change, how quickly and effectively such learning is advancing, and the potential uses of technology for learning and knowledge-sharing in rural and remote communities.
- Further research to overcome communication barriers and develop climate science communication pathways.

Community-level adaptation

- Comprehensive assessments to better understand how climate change affects travel safety for rural and remote communities, particularly in northern Canada.
- Research on proactive adaptation options at the community level, including relocation.

Emergency management

- Lessons from recent examples of emergency management in response to extreme weather events.
- Better understanding of the convergences and disparities between emergency management, disaster risk reduction and adaptation.

ADDRESSING KNOWLEDGE GAPS REQUIRES WORK AT THE INTERSECTION OF ADAPTATION AND:

Climate change mitigation

- Better understanding of the links and synergies between climate change mitigation and adaptation efforts.

Data, projections and flood mapping

- Further information on how communities and practitioners can best access and use climate data to implement adaptation options.
- More comprehensive collection and analysis of local data that affect the ability to forecast climate change variability.
- Improved projections of wind and clouds, and of changes in forest fire behaviour.
- More research on how the frequency and magnitude of storms will affect coastal regions.
- Improved data to better project and plan for future cascading changes, feedbacks and new types of disturbance.
- Updated flood risk mapping in many parts of Canada, and improved strategies for reducing flood risk.
- Best practices on incorporating model projections of future climate scenarios into adaptation planning.

Economics of adaptation

- Research and guidance to better quantify direct (e.g., damage from a flooding event) and indirect costs (e.g., disruption in service delivery) of climate change impacts.
- Research to better understand the economic consequences of extreme events and catastrophes.
- Further research to resolve uncertainty around the aggregate results of national-level studies of net economic consequences.
- Research on economic costs in specific regions (e.g., the Prairie provinces, the territories, the interior of British Columbia, Ontario) and among First Nations, Inuit and Métis peoples.

Social resilience and equity

- Further research on how climate change disproportionally affects vulnerable and marginalized groups and their adaptive capacity.

ADDRESSING KNOWLEDGE GAPS REQUIRES WORK AT THE INTERSECTION OF ADAPTATION AND:

Ecosystems and nature-based approaches

- Better valuation and use of nature-based approaches to meet needs normally provided by "hard or engineered" infrastructure.
- Better understanding of the threats to ecosystems and their functioning from pests, pathogens, weeds and invasive species.

Human health

- Broader understanding of compounding mental health concerns (including ecological grief) associated with climate change.
- Better understanding of current and projected climate-related impacts, and vulnerabilities facing individuals and health systems (e.g., health policies, programs, services, infrastructure, and supply chains critical for health), including to rural, remote, and Northern health systems.
- Better understanding of the long-term impacts of changing temperature and precipitation regimes on food and water safety and security, particularly in Indigenous communities.
- Identification of equitable and effective adaptation measures for reducing health risks from current climate variability and projected climate change.

Indigenous-led adaptation

- Better understanding of how to decolonize climate change research, assessments and actions to advance Indigenous-led climate governance and policy.
- Additional research on the intersections between climate change and Indigenous law and language.
- Stronger consideration of gender, especially the knowledge, perspectives and experiences of Indigenous women, non-binary and 2SLGBTQQIA+.
- Support and invest in First Nations, Inuit and Métis to develop and realize Indigenous-led climate actions. This includes research, monitoring and development, new technologies and approaches, and entrepreneurship.

International considerations

- Research to explore the implications of the opening of the Northwest Passage, and the longer ice-free season in northern parts of Canada (e.g., impacts from increased shipping, etc.).
- Research on how climate change affects production and international trade.
- Research to better understand the implications for Canada of climate change-related displacement and migration.

ADDRESSING KNOWLEDGE GAPS REQUIRES WORK AT THE INTERSECTION OF ADAPTATION AND:

Monitoring, evaluating and assessing adaptation progress

- Enhanced place-based monitoring of environmental, health and social impacts related to climate change and adaptation.
- Better inventories of climate change impacts, risks and adaptation actions, including examples of sector- or region-appropriate adaptation actions.
- Better monitoring of adaptation actions, and development of suitable indicators and methodologies for measuring progress.

Natural resource extraction

- Better understanding of potential new opportunities for extraction and export of previously inaccessible mineral, oil, and gas resources.
- Better understanding of the costs and benefits of increased natural resource extraction associated with climate change, particularly its implications for northern societies and cultures.
- Further research on climate change impacts in rural resource sectors, such as mining, oil and gas, and tourism in Canada.

Water resources

- Better understanding of the impacts of climate change on salinity transition zones, which can affect the quality and availability of drinking water.
- Better understanding of the impacts of extremes in water levels that can accommodate both high water and low water scenarios over time.
- Increased knowledge of how climate change is affecting groundwater drinking supplies.