A CANADIAN INITIATIVE

CLIMATE PROSPERITY

// REPORT 02

DEGREES OF CHANGE: CLIMATE WARMING AND THE STAKES FOR CANADA

National Round Table on the Environment and the Economy | Table ronde nationale sur l'environnement et l'économie

Canada

THIS IS NOT JUST ABOUT COPING WITH CLIMATE CHANGE, BUT PROSPERING THROUGH IT.

A CANADIAN INITIATIVE

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The NRTEE is also grateful for the feedback on various parts or iterations of the diagram (and supporting documents) received from: Greg J. Boland, Alain Bourque, Michael Brklacich, Ross D. Brown, Ian Burton, Stewart Cohen, Michael Demuth, Steve Fick, Greg Flato, Joel S. Smith, Sharon Smith, and John Stone. Reviewers provided many constructive suggestions, but we did not ask them to endorse the diagram. Their contributions were important, helpful, and very much appreciated. The final product remains that of the NRTEE.

The NRTEE wishes to thank the Climate Research Division at Environment Canada for the timely feedback they provided on this report with a final review of our presentation of the scientific research within it, prior to our report being released.

The Royal Canadian Geographical Society (RCGS) was our partner in presenting the *Degrees of Change* diagram and related research from our Climate Prosperity program in the October issues of Canadian Geographic, Géographica, the Canadian Atlas Online, and to students across Canada through a series of lesson plans. The NRTEE wishes to thank Andre Préfontaine, president and publisher; Gisèle Jacob, RCGS past president; Louise Maffett, RCGS executive director; Eric Harris, editor-in-chief of Canadian Geographic, and all of our colleagues at RCGS for helping to bring the story of climate change to Canadians in a renewed and meaningful way.

We would also like to acknowledge the dedication and hard work of the Secretariat staff. The diagram and report benefited from the early vision, analytical, and written contributions of William McDowall, former NRTEE Policy Advisor. The background research and editorial assistance of Joëlle Boutin, Suzanne Loney, and James Wellstead, former NRTEE research assistant, were most helpful in finalizing the report.

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MESSAGE FROM THE CHAIR

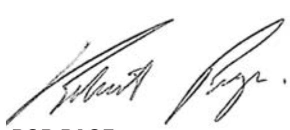
No greater environmental and economic challenge faces Canada and Canadians than climate change. From melting sea ice in the Arctic to the pine beetle infestation in British Columbia to more extreme weather events, a warming globe from increased greenhouse gas emissions is making its effects known right here at home. Global temperatures have already increased by 0.78 degrees Celsius from pre-industrial times. Temperatures in Canada, meanwhile, have increased by 1.3 degrees Celsius since 1948. Canada and Canadians need to know what this could mean for us. And we need to think now about how best to adapt to it.

The NRTEE's new report, *Degrees of Change: Climate Warming and the Stakes for Canada*, illustrates and explains in a uniquely Canadian way what climate change could mean for our country. As a large country spanning five time zones and sheltered by three coasts, we can expect different effects in different places. Understanding how this will occur can help Canadians plan and adapt to the consequences of a climate change.

We need to mitigate the speed and magnitude of climate change by reducing the amount of greenhouse gases Canada and the world pumps into the atmosphere. But we must also adapt to the inevitable forecasted effects of climate change stemming from the carbon pollution and greenhouse gas concentrations already there. Years, even decades, of warming lie ahead because of this. We can expect more change and escalating levels of impacts going forward.

It is clear that there are real risks to both Canada's environment and economy from the impacts of climate change. But we also know there can be opportunities for Canada to gain and prosper through it economically and socially if we plan for what's ahead. We gain the business opportunities from being a technical leader in adaptation.

The NRTEE hopes this report will help Canadians learn more about what we can expect from climate change and what we can do about it. We present it in recognition of the attention already paid to the importance of climate change adaptation by the federal government. It builds on work already produced and ideas being considered by government departments and agencies in partnership with provinces, territories and municipalities. We believe our report will assist governments, businesses, communities, and others to begin the necessary planning and actions to adapt and prosper in a climate changing world.



BOB PAGE
NRTEE Chair

MESSAGE FROM THE PRESIDENT AND CEO

Degrees of Change: Climate Warming and the Stakes for Canada is about Canada in a climate changing world. The earth is warming and Canada is already experiencing this change at an even faster rate than other nations. Climate change promises to be both pervasive and pernicious. What will it mean to Canada? How will it impact us? What can we expect?

These are the questions the NRTEE explores with our second report in our *Climate Prosperity* series on the risks and opportunities of climate change to Canada.

Its centre-piece is our unique *Degrees of Change* diagram. This diagram illustrates the likely impacts of climate change on our country from today's levels of warming to over 5 degrees Celsius. You can now see in one place, how and where Canada and Canadians could be affected by warming temperatures and changing precipitation across a number of impact areas, ranging from ecosystems to human health to water resources and more. While climate change is global, its impacts are local and we need a Canadian map to show a Canadian story.

We need to understand what this will mean and how we can adapt and prosper through the stresses and uncertainties of climate change. Our new report helps frame this issue for Canadians by making visible what could lie ahead. It sets the stage for a national conversation on how best to adapt to a changing climate and a warming globe.

The NRTEE began this conversation with the Royal Canadian Geographical Society which published our *Degrees of Change* diagram as part of dedicating its October issues of Canadian *Geographic* and *Géographica* to the Round Table's *Climate Prosperity* research. This report provides the full details, scientific background, and policy context for climate change impacts on Canada and what we can start to do about it.

DAVID McLAUGHLIN
NRTEE President and CEO

ABOUT US

Emerging from the famous Brundtland Report, *Our Common Future*, the National Round Table on the Environment and the Economy (NRTEE or Round Table) has become a model for convening diverse and competing interests around one table to create consensus ideas and viable suggestions for sustainable development. The NRTEE focuses on sustaining Canada's prosperity without borrowing resources from future generations or compromising their ability to live securely.

The NRTEE is in the unique position of being an independent policy advisory agency that advises the federal government on sustainable development solutions. We raise awareness among Canadians and their governments about the challenges of sustainable development. We advocate for positive change. We strive to promote credible and impartial policy solutions that are in the best interest of all Canadians.

We accomplish that mission by fostering sound, well-researched reports on priority issues and by offering advice to governments on how best to reconcile and integrate the often divergent challenges of economic prosperity and environmental conservation.

The NRTEE brings together a group of distinguished sustainability leaders active in businesses, universities, environmentalism, labour, public policy, and community life from across Canada. Our members are appointed by the federal government for a mandate of up to three years. They meet in a round table format that offers a safe haven for discussion and encourages the unfettered exchange of ideas leading to consensus.

We also reach out to expert organizations, industries, and individuals to assist us in conducting our work on behalf of Canadians.

The *NRTEE Act* underlines the independent nature of the Round Table and its work. The NRTEE reports, at this time, to the Government of Canada and Parliament through the Minister of the Environment. The NRTEE maintains a secretariat, which commissions and analyzes the research required by its members in their work.

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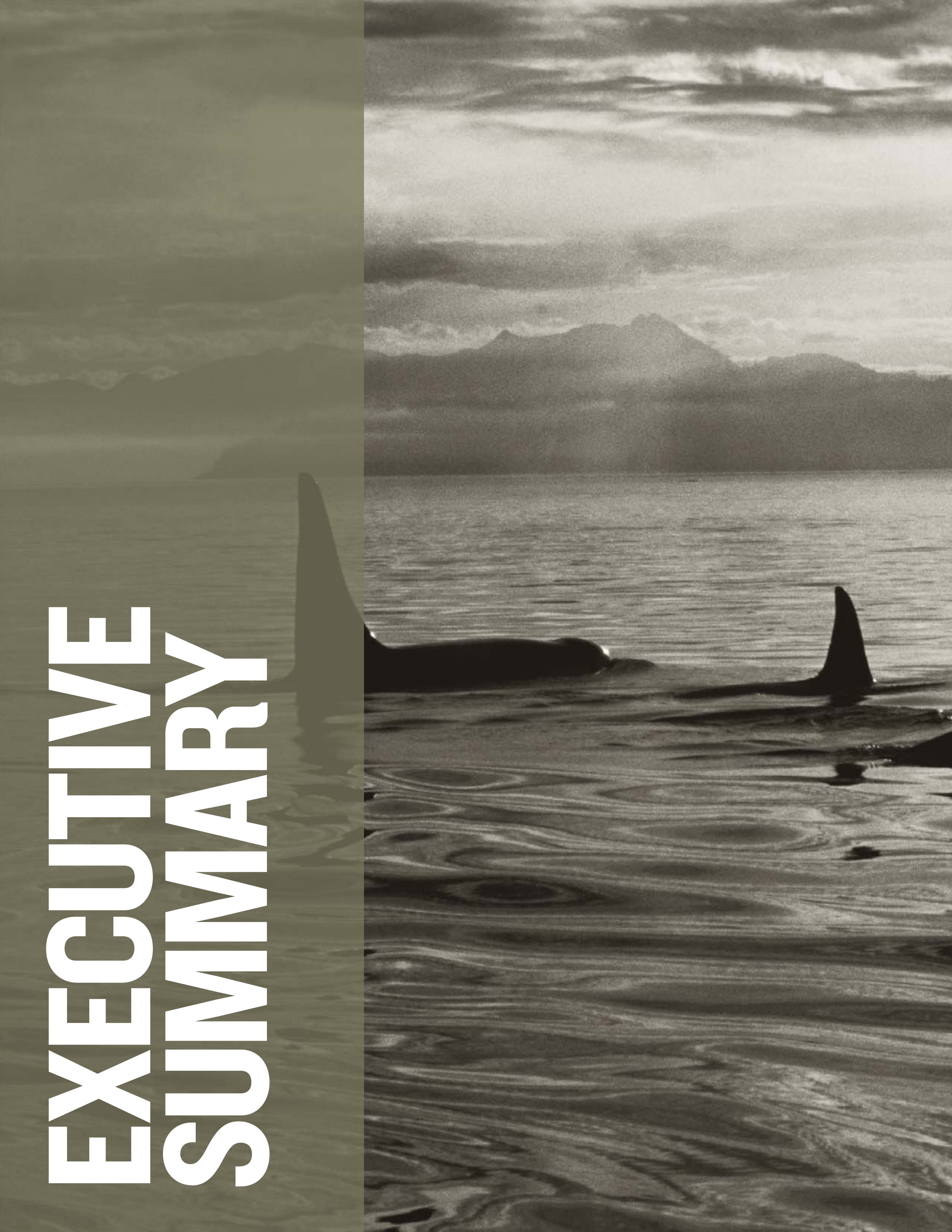


0.0 // EXECUTIVE SUMMARY

0.0 EXECUTIVE SUMMARY

Degrees of Change explains the implications of a changing climate for Canada and Canadians. It is the second report in the *Climate Prosperity* series by the National Round Table on the Environment and the Economy (NRTEE) on the economic risks and opportunities to Canada of climate change.

Examining what the impacts of climate change will mean to our environment and what a global low-carbon transition will mean to our economy, *Climate Prosperity* offers new insights and analysis into shaping Canada's public policy responses to this most extraordinary challenge.

This *Degrees of Change* report illustrates the expected impacts of a changing climate for Canada and how adapting to these impacts now will be necessary to secure our prosperity in an uncertain climate future. In Canada and across the globe, we are already seeing the effects of warming temperatures and changing climate conditions. As climate change persists, we can expect, for example, further melting of glaciers and sea ice, rising sea levels, earlier springs, shifts in the distribution of animals and plants, and increasingly volatile weather. No region and no aspect of our geography will be immune; but impacts will vary in time and intensity.

That is why the NRTEE has developed a uniquely Canadian diagram to illustrate the effects of climate change across eight areas of importance to our country and Canadians. Based on a vast array of published scientific literature, it maps scientifically accepted climate-related impacts, current and projected, to a global temperature scale. It puts global political commitments of keeping world temperatures below 2 degrees Celsius (°C) into perspective by showing what different levels of warming could mean to Canada. From ecosystems to human health to water resources to communities and infrastructure and more, *Degrees of Change* demonstrates just how pervasive and pernicious climate change could be. Both risks and potential opportunities — as we currently know them — are presented.

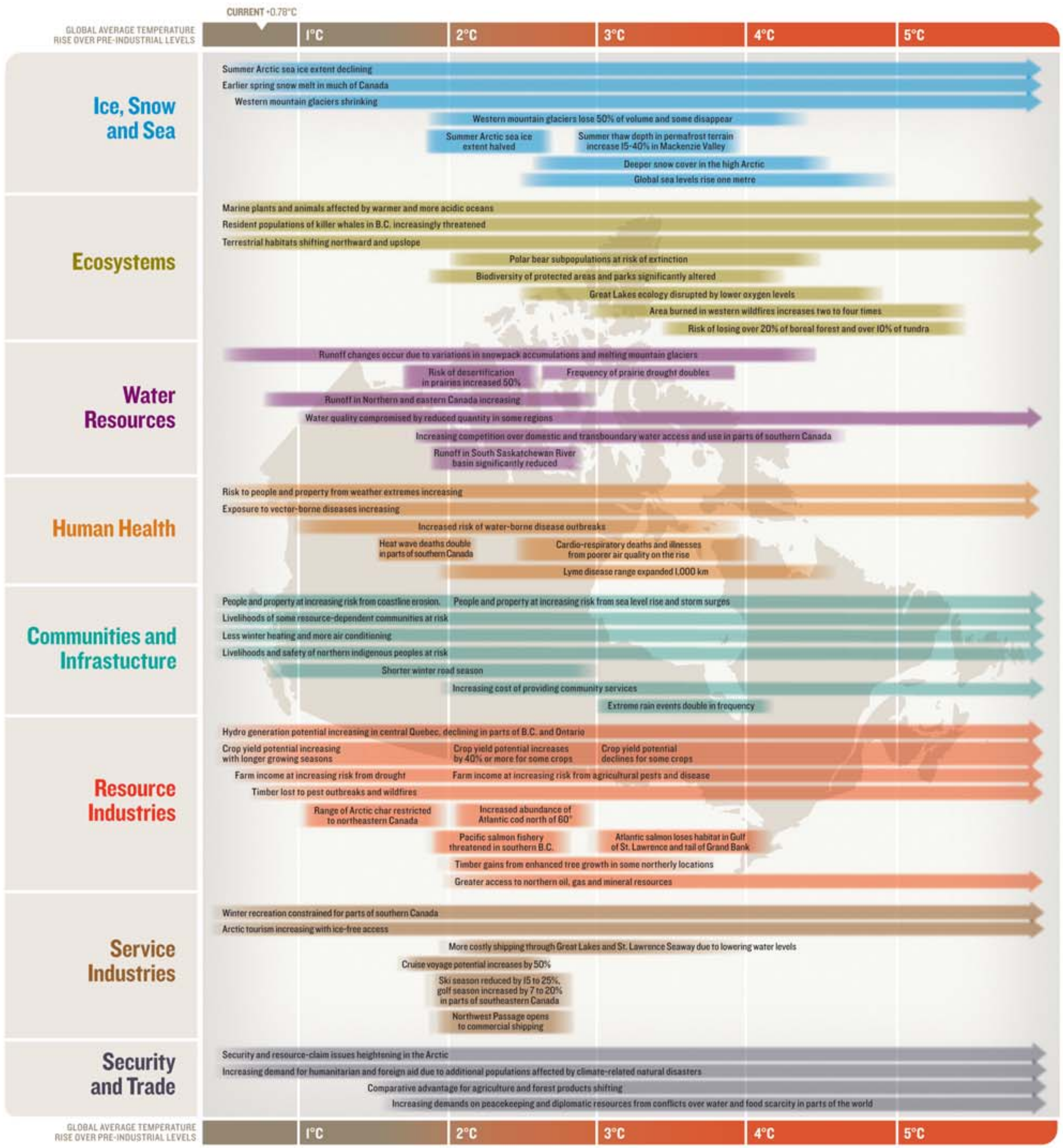
Canada — our people, places, and prosperity — will be affected by climate change. Changes in forest growth, pest outbreaks, and wildfires will impact resource-dependent communities and the livelihoods of workers and families. Tourism operators relying on seasonal patterns for snow and sun may have to plan for different outcomes. Farmers may face more varied drought and rain effects causing new economic impacts on their crop values and farming operations. These are but a few examples of what's at stake and how climate change impacts Canadians where we live and work.

Knowing what climate change could mean allows us to consider how and when to adapt to it. Adapting, so we can prosper through climate change, is essential for Canada's economic and environmental security. Levels of warming in Canada are already higher than the global average. Arresting the growth of greenhouse gas (GHG) emissions — necessary to limit the extent and speed of climate change — does nothing to change the impacts expected from GHG concentrations already in the atmosphere. Inevitably, we must think about how to adapt to the effects already taking place and those sure to come.

With risk comes uncertainty. And climate change offers both. This report helps reinforce the need to improve our understanding of how climate change could affect us and assess the risk of what this means. To date, we as a country have only just begun to consider the implications of future climate change impacts and see that they become factored in major planning decisions by governments, businesses, and communities on a more consistent and coordinated basis. Whether it's reinforcing infrastructure degraded by thawing permafrost in Nunavut or building new seawalls as protection from storm surge flooding in New Brunswick, we need to think differently about the value of taking action to adapt to current and future impacts of climate change. A changing climate makes the very concept of status quo irrelevant. Taking action to adapt now is an opportunity to shape possibilities and secure our prosperity for the future.

DEGREES OF CHANGE:
CLIMATE WARMING AND THE STAKES FOR CANADA

A Summary of the Impacts of Climate Change Expected in Canada Over the 21st Century



CLIMATE PROSPERITY
A CANADIAN INITIATIVE

FORECAST WITHIN INDICATED RANGE

TREND LIKELY TO CONTINUE, POTENTIALLY INTENSIFYING

The NRTEE's *Degrees of Change* diagram (ABOVE) is a summary of the impacts of climate change expected in Canada over the 21st century. It shows both risks and opportunities for Canada from different levels of global warming above pre-industrial levels. Each category in the diagram is an important part of our country's environment and economy, and only contains climate change impacts that we are confident could occur, as documented in scientific literature. Not all expected impacts of climate change are shown here. Nor is the diagram a prediction. It does not account for time lags between global temperature change and the response of our physical environment. Even if actions limit global temperature increases to 2°C by 2050, climate change impacts will continue to build up for decades at a minimum due to the slow response of Earth systems. Adapting to these impacts to reduce or avoid harm would lessen their effect, but this is not shown on the diagram.

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ADAPTING TO RISKS AND OPPORTUNITIES

OF CLIMATE CHANGE

// CHAPTER 01


WATER
OVER ROAD
DANGER
ROUTE
INONDÉE

1.0 // ADAPTING TO RISKS AND OPPORTUNITIES OF CLIMATE CHANGE

1.1 ADAPT AND PROSPER

Climate change is real and happening now.

Mounting scientific evidence indicates that, together with natural drivers of *climate variability**, emissions of carbon dioxide and other greenhouse gases (GHGs) from human activities are acting like a heat-trapping blanket, causing the Earth to warm. Since 1850, the average temperature on the Earth's surface has increased by about 0.78°C.[1]

The physical and biological effects of this warming on indicators such as sea level, extent and thickness of sea ice and glaciers, rain and snowfall patterns, and range and life histories of plants and animals are being felt around the globe. Evidence suggests that the world may well be facing decades, if not centuries, of warming, along with the effects that flow from it if the warming trend is not arrested. At a minimum, the current buildup of GHGs in the atmosphere commits the world to a further 0.6°C of warming over the next three decades.[2] Observed changes in *climate* indicators and related biological and physical impacts across the globe since the mid-20th century match scientific expectations of *global warming* effects.[3] Regardless of uncertainties, it's prudent to take action now to manage the *risks* of a changing climate.

Canada is not immune from the climate change phenomenon. Temperatures in Canada have risen faster than the globe as a whole, with an average 1.3°C rise since the mid-20th century.[4] Effects of this warming are already apparent across the country. The impacts of climate change will touch all regions of Canada, presenting environmental, social, and economic risks and some potential opportunities. Specific vulnerabilities to future climate change on a regional and sectoral basis have increasingly been highlighted by a range of comprehensive scientific assessments.[5]

* Definitions for italicized words appearing in the main text are in 5.1 Glossary of Key Terms.

We are just starting to understand how prepared Canada is to successfully manage the effects of a changing climate. Already in our 2009 report, *True North: Adapting Infrastructure to Climate Change in Northern Canada*, the National Round Table on the Environment and the Economy (NRTEE) concluded that the current patchwork of public and private sector initiatives designed to build capacity to manage the effects of climate change, when added together, ran the risk of being ineffective and expensive. Other advisory bodies have reached similar conclusions for specific regions in Canada.†

The NRTEE is dedicating three reports of its *Climate Prosperity* program to help develop a national roadmap to adapt and prosper through climate change. The NRTEE believes that strategic and concerted action is necessary now to sustain Canada's early *adaptation* efforts, and to promote the efficiency and effectiveness of climate-sensitive policy and investment decisions over the long term. Together, our reports will explain the implications of a warming world for Canada's environment and economy, and recommend adaptation strategies to avoid future costs and position us to gain from potential opportunities.

Climate Prosperity does not assume that climate change is a good news story for Canada. But, how we and the world react to it — both through adaptation and mitigation actions — will have a lot to do with our future prosperity. We see a range of opportunities for Canadian businesses, consumers, and households in the global transition to a low-carbon economy. We also think it's smart policy to encourage action so Canada and Canadians can benefit from adapting to expected and inevitable climate change in the short term while investing to reduce or avoid climate change damage in the long term.

† The Ontario Expert Panel on Climate Change Adaptation concluded that Ontario needed a comprehensive strategy to address current and future changes in climate, and that "piecemeal, uncoordinated actions will be insufficient and costly." (page 28, *Adapting to Climate Change in Ontario*, November 2009). Available at: http://www.ene.gov.on.ca/publications/7300e.pdf

In this report, we set out the problem, explaining how climate change could affect our country. The *Degrees of Change* diagram created for this report is a uniquely Canadian illustration to help visualize key implications for our country of a warming world in a range of areas, from ice, snow and sea to security and trade. We summarize a large body of evidence developed by the federal government, research organizations, and others on the way in which climate change is affecting and could affect Canada in this century and map our findings onto a global temperature scale. In doing so, we show how the effects of climate change could develop and intensify here at home, as the world warms. It represents our contribution to raising awareness and understanding of the many connections between our continued health and well-being and the changing climate.

Governments, businesses, and communities can use the information contained in *Degrees of Change* and contemplate strategic adaptation choices now that minimize the risks and take advantage of potential opportunities that a changing climate may present. Canadians can use the diagram to consider the implications of meeting or failing to meet a commitment reinforced in 2009 by 100 heads of state in Copenhagen of keeping global climate warming below 2°C relative to pre-industrial levels.* Using *Degrees of Change*, we can begin to assess on a broad scale what kind of preparations we, as a society, may need to make to manage the effects of a warming world, while working to prevent undesirable climate futures that loom on the horizon.

Some conclusions are already apparent when it comes to managing the early effects of a changing climate:

1 // **We can cost-effectively reduce, and in some cases avoid, adverse impacts of climate change on the health and safety of Canadians, the economy, and our environment.** In planning our communities, growing our economy, designing and building our *infrastructure,* and managing natural resources we have tended to take the stability of the climate for granted. That is, we assumed past climate — both variability within historical ranges and averages — was a good guide to the future. But, as temperatures increase, as moisture patterns change, as other *weather* and climate conditions that we used to rely on for work, play, or economic gain become less reliable, we will be forced to react to these new and chang-

* The Copenhagen Accord includes an article (Article 12) that states that by 2015 governments will decide whether the 2°C target is good enough or whether the new target should be set at 1.5°C.

ing realities. As a country, we could apply our talents and ingenuity to take steps now to prepare for the future, preventing a domino effect of costs and setbacks in achieving social, environmental, and economic goals we have set for ourselves.

2 // **We can gain economically from developing and providing climate adaptation solutions to domestic and global markets.** Canadian corporations have already started to assess their competitive climate advantage and to identify investment opportunities and technological applications to help address global problems, such as access to water, that climate change accentuates. As awareness of the risks and opportunities posed by climate change continues to grow, so too will the application of market solutions to the climate change challenge.

3 // **We can anticipate and prepare for global security challenges heightened by climate change and shifting trade patterns.** In a globalized economy and an increasingly interconnected world, we cannot ignore the potential ramifications for Canada of the impacts of climate change and actions taken in response to them in other countries. The increased navigability of Arctic waters and related access to energy and mineral resources is one example with the potential to both bring economic opportunities and pose national security and (local and global) environmental risks. The continued effect of a changing climate on patterns of extreme events, water resources, and food and fibre production on a global basis has implications for Canada's policy choices in areas such as immigration, international development, peacekeeping, diplomacy, and international trade.

1.2 OUR CHANGING GLOBAL CLIMATE

The global climate has changed significantly over the Earth's history.[6] In the past two and a half million years, it has swung between ice ages and warmer, interglacial conditions. Changes in climate conditions also take place over shorter time scales, with considerable regional variation.

Climate refers to the prevailing weather patterns of a planet or a region over time. *Weather* is more short lived, referring to air temperature, air pressure, humidity, wind, cloud cover, and precipitation at a specific time and place.

Natural drivers of climate change include variations in the Earth's orbit, solar energy output, sunspot cycles, and volcanic eruptions. Together, these natural causes can explain much of the change in global climate conditions experienced over the past several thousand years. However, natural factors do not fully explain the global temperature record and changes in other climate and weather indicators observed over the late 20th century. Scientists are concluding that much of the changes observed over the 20th century and into the 21st century are linked to the discharge of GHGs into the atmosphere from industrial processes, transportation, and energy use in buildings, and from agricultural and forestry activities. In the process of running our economies and living our lives, we are amplifying the greenhouse effect (see **Box 1**).

BOX 1 THE GREENHOUSE EFFECT

The atmosphere is a 50-km blanket of gas covering the Earth's surface. Its composition is 78% nitrogen (N_2); 21% oxygen (O_2); and 1% of other trace gases, including water vapour (H_2O), carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and ozone (O_3). These trace gases, known collectively as greenhouse gases (GHGs), absorb energy from the sun and, in so doing, are responsible for keeping the Earth's surface warm. If the "greenhouse effect" were not in place, the Earth would be about 30°C cooler, making the planet inhospitable. By burning fossilized carbon and changing land-cover patterns, human activity is adding to the store of GHGs in the atmosphere and amplifying the natural greenhouse effect. In 2008, the atmosphere contained about 40% more carbon dioxide than it did before industrialization. Prior to the industrial revolution, the proportion of carbon dioxide in the atmosphere was 285 parts per million by volume. Today, we are at 387 parts per million and counting. Concentrations of carbon dioxide in the atmosphere are the highest they have been in at least 800,000 years.

SOURCES: KUMP ET AL. (2004); CLIMATE LITERACY, MARCH 2009 EDITION (US CLIMATE CHANGE SCIENCE PROGRAM); NATIONAL ACADEMY OF SCIENCES (2010); CURRENT CARBON LEVELS ARE BASED ON INFORMATION FROM THE CARBON DIOXIDE INFORMATION ANALYSIS CENTER (HTTP://CDIAC.ORNL.GOV/PNS/CURRENT_GHG.HTML). THE BENCHMARK FOR ATMOSPHERIC CONCENTRATIONS IS TYPICALLY PRE-1750

Table 1 summarizes key changes in climate and weather patterns already observed on a global basis:

TABLE 1 OBSERVED CHANGES IN GLOBAL CLIMATE AND WEATHER INDICATORS

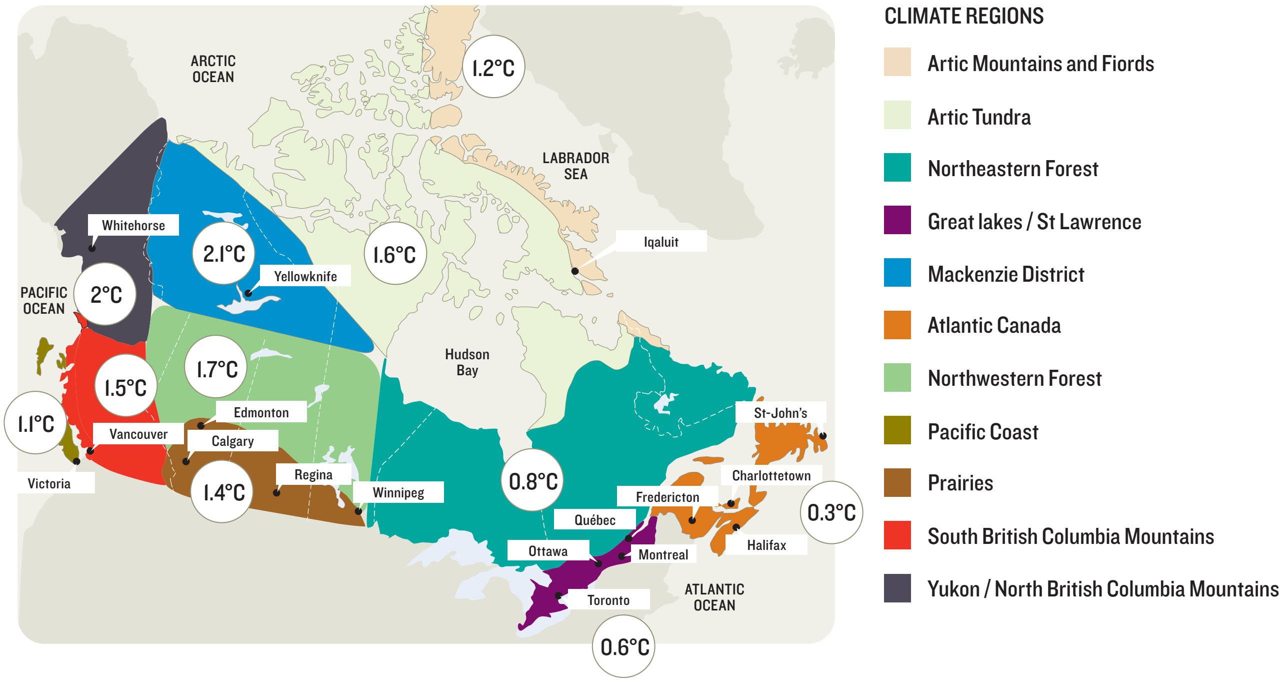
INDICATOR	CHANGE	TIME PERIOD
AIR TEMPERATURE	INCREASED 0.78ºC	1850 - 2009
OCEAN TEMPERATURE	INCREASED TO DEPTHS OF 3000m, WIDESPREAD WARMING IN THE UPPER 700m	1961 - 2003
OCEAN CHEMISTRY	INCREASED 0.1 UNIT ON pH SCALE AT THE SURFACE, REPRESENTING A 30% INCREASE IN OCEAN ACIDITY	DUE TO UPTAKE OF ATMOSPHERIC CARBON SINCE 1750
SEA LEVEL	ROSE 0.17m	1870 - 2000
SNOW COVER	DECLINED	NORTHERN HEMISPHERE, SINCE 1960s
MOUNTAIN GLACIERS	WIDESPREAD RETREAT	SINCE 1900
ARCTIC SEA-ICE EXTENT	DECREASED 2.5% PER DECADE	RATE BETWEEN 1978 AND 2005
EXTENT OF SEASONALLY-FROZEN GROUND	DECREASED BY ABOUT 7%	SINCE 1900
HEAVY PRECIPITATION EVENTS	INCREASED IN FREQUENCY	SINCE 1950
DROUGHTS	INCREASED IN INTENSITY AND DURATION	SINCE 1970s
HEAT WAVES	INCREASED IN FREQUENCY AND DURATION	SINCE 1950s
TROPICAL CYCLONES	INCREASED IN INTENSITY*	SINCE MID - 1970s

SOURCES: INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (2007); WARREN AND EGGLINTON (2008); SECRETARIAT OF THE CONVENTION ON BIOLOGICAL DIVERSITY (2009)

In Canada, we see that average temperatures have increased 1.3˚C since the mid-20th century. This national average masks substantial variability across regions. **Figure 1** shows that the rise in annual temperatures has been more pronounced in northern and western parts of the country compared to the southeast.

* At an October 2010 panel discussion in Halifax hosted by the NRTEE and the Royal Canadian Geographical Society, Environment Canada meteorologist Dr. Gary Lines indicated that it is likely that future tropical cyclones will become more intense, with larger peak wind speeds and more heavy precipitation, but that no scientific consensus existed on whether we can expect an increase in activity.

FIGURE 1 AVERAGE TEMPERATURE CHANGES IN CANADA BY REGION BETWEEN 1948 AND 2008



SOURCES: ANNUAL REGIONAL TEMPERATURE DEPARTURES FROM CLIMATE NORMAL, TRENDS AND EXTREMES,1948 TO 2008, FROM ENVIRONMENT CANADA, SCIENCE AND TECHNOLOGY BRANCH, CLIMATE RESEARCH DIVISION, HTTP://WWW.EC.GC.CA/ADSC-CMDA/DEFAULT.ASP?LANG=EN&N=F3D25729-1

If the world continues emitting GHGs like carbon dioxide at current levels, average global temperatures could rise by up to 6°C by the end of this century.[7] Canada has joined other countries in recognizing that the global temperature rise ought not to exceed 2°C above pre-industrial levels.[*] The policy goal is to halve global emissions by 2050 in order to limit the speed and intensity of climate change and to reduce the odds of triggering serious and irreversible changes to the global climate system that are beyond our collective experience and capacity to adapt.

But, even if we succeeded in drastically cutting GHGs today, the global climate would well be facing several decades, if not centuries, of change from the buildup of emissions and momentum already in the climate system. This is because GHGs stay in the atmosphere for many years, and because the climate and other components of the Earth system, such as the oceans, land-based ice sheets, and major forested landscapes, take time to respond to the effect of greenhouse gases and interact with each other through *feedbacks* and in other complex ways (see **Box 2**).

* This commitment is contained in: Backgrounder: Canada's Action on Climate Change; 17 December 2009; Ottawa, Ontario. Available at: http://www.pm.gc.ca/eng/media.asp?id=3037

BOX 2 CLIMATE LAGS AND FEEDBACKS

The atmosphere interacts with other components of the Earth system through physical, chemical, and biological processes regulating the flux of carbon (among other compounds) and energy on Earth, and shaping the world's climate conditions. Understanding the climate-carbon cycle — the processes and time scales involved — is critical to understanding the long-term prospects of our planet in a changing climate. Scientists are investigating a number of questions: What is the relationship between carbon levels in the atmosphere and global temperature change relative to pre-industrial averages? What happens if we cut global emissions with a view of holding atmospheric carbon levels constant?

Their investigations tell us that global temperatures would continue to rise long after achieving stable carbon levels in the atmosphere. First, it takes time for the global climate to adjust to specific levels of carbon in the atmosphere. Second, major components of the Earth system need time to "equilibrate" to changes in global climate indicators and to the changed chemistry of the atmosphere, in some cases adding to global warming in the process. For example, less ice and snow cover reduces the Earth's ability to reflect the sun's radiation back to the atmosphere; thus an ice-free Arctic traps more heat and further contributes to warming. Warmer temperatures and more frequent and intense forest fires could release GHGs currently stored in peatlands, also amplifying warming. Oceans and ice sheets have a particularly sluggish response time, as they work to absorb and redistribute excess heat (and carbon in the case of oceans).

Because of these lags and feedback mechanisms, for any given level of carbon in the atmosphere, we need to consider both the near-term ("transient") and long-term ("equilibrium") effects of global warming. For example, some scientists estimate that achieving stable carbon levels in the atmosphere of 450 parts per million (ppm) by volume could result in a near-term rise in global average temperatures of just above 1°C over pre-industrial levels, but an eventual rise of 2°C.

SOURCES: SOLOMON ET AL. (2007); NATIONAL ACADEMY OF SCIENCES (2010)

Scientists are generally confident in overall global patterns of warming but cannot predict the exact timing or the very localized effects of climate change. We must therefore adapt to and limit climate change based on risk and precaution, not certainty. Engineers, public health officials, insurers, farmers, and foresters are already accustomed to this way of thinking; they, and others throughout the economy, already make decisions by assessing risk. That is exactly the approach we now need to apply to adapt to a changing climate: assessing and managing the risks — and the opportunities — that result from climate change by combining experience and context-specific knowledge with the best available science.

1.3 THE NRTEE'S *DEGREES OF CHANGE* REPORT

This NRTEE report illustrates the range and detail of scientifically accepted information on the possible effects of climate change in Canada over this century. It points to viable response strategies to begin to manage related risks and opportunities through adaptation.

This report serves two purposes:

FIRST, the NRTEE uses its *Degrees of Change* diagram to explain to Canadians how the effects of climate change could develop and intensify in Canada. A number of international science bodies assess the likely consequences and very long-term risks associated with global warming for the world as a whole or for specific global regions. Our diagram (and this report) is not a scientific assessment. It is a summary of the science literature on the expected effects of climate change in Canada over the 21st century. By illustrating the possible effects of climate change in sectors and systems that are significant to Canada, it helps build understanding of how adapting to these effects now and into the future will be necessary to secure our prosperity in uncertain climate futures. It also sheds light on some of the impacts that may prove challenging, if not impossible, to adapt to.

SECOND, it lays the groundwork for the NRTEE's forthcoming work on climate change impacts and adaptation by outlining the scope and scale of the issue. This report does not include cost estimates of the impacts of climate change or of adaptation strategies to address related risks or opportunities. NRTEE analysis on the possible costs of action or inaction at the national level and costs and benefits of adaptation, and advice on practical pathways to deepen engagement and action on adaptation in Canada will follow in two later reports of the *Climate Prosperity* series.[*]

* Through the Climate Prosperity series, the NRTEE will issue seven reports in total between now and 2012. Three reports highlight risks and opportunities for Canada in a changing climate, provide analysis on the economics of climate change impacts and adaptation, and deliver policy advice to advance adaptation action nationally. Three focus on analysis and advice to help position Canada in the global low-carbon transition. A final report will discuss the role of citizen engagement in shaping and advancing climate policy. For more information see http://www.climateprosperity.ca

Our report follows this structure:

CHAPTER 2 is the core of the report. It describes the NRTEE's *Degrees of Change* diagram, explaining each element of it: the global temperature scale, the eight impact categories, and the expected effects within each category. It starts with guidelines for readers, moves on to highlight the impacts we can expect to see, and includes examples of what households, businesses, communities, and governments can do to manage these impacts.

CHAPTER 3 discusses the implications of the NRTEE's *Degrees of Change* diagram. It summarizes what a warming world could mean for Canadians, the places where we live and that surround us, and how we make our living. It emphasizes the importance of a Canada-wide adaptation response and describes strategies to adapt to uncertain climate futures.

CHAPTER 4 concludes with key messages on the risks of a changing climate for Canada and the importance of adaptation in managing these risks. It also sets out next steps for the NRTEE concerning our work on climate change impacts and adaptation.

Approach to developing the *Degrees of Change* diagram:

What follows is an explanation of the approach we took to developing the core of this report — our *Degrees of Change* diagram. In all, the diagram includes eight categories, covering direct impacts of climate change, and environmental, social, and economic effects flowing from them:

- Ice, snow, and sea
- Ecosystems
- Water resources
- Human health
- Communities and infrastructure
- Resource industries
- Service industries
- Security and trade

As a whole, the diagram highlights 60 specific effects of climate change scientists expect to occur over this century. It relates these effects to increases in global average temperatures above pre-industrial levels. For most categories, we find few studies containing numerical estimates of future effects of climate change for Canada. Where numerical estimates exist, they rarely refer to specific degrees of global temperature change. Furthermore, depending on their scope and assumptions, studies covering the same topic — say the effects of climate change on agriculture production — sometimes disagree on the magnitude of effect expected, with impacts spanning both positive and negative values.*

Summary diagrams such as *Degrees of Change* require making appropriate judgment calls and reasoned inferences. Our aim in developing the diagram was to strike the right balance between presenting complex and comprehensive information in a way that it is accessible to many Canadians and staying true to the underlying scientific evidence, benefiting from the advice of several experts. With this aim in mind, the diagram's development involved the following stages:

1 // A literature review of international diagrams summarizing impacts of climate change as a function of global temperature rise, including the work of the Intergovernmental Panel on Climate Change, and of relevant reports on climate change impacts and adaptation in Canada. The literature review informed our selection of impact categories.

2 // Development of a first draft diagram for Canada and supporting documentation by Dr Barry Smit, Professor, Canada Research Chair in Global and Environmental Change, University of Guelph.

* Estimates of the economic effects of climate change on land values and farm incomes in Canada differ by several orders of magnitude. Reinsborough (2003) calculated an increase in land value of $1.5 million (+/- $40 billion) between 1995 and 2020, whereas Weber and Hauer (2003) found a land value increase of $5.24 billion between 1995 and 2050.

3 // Four waves of review and refinement*:

i. Review of the first draft diagram and supporting documentation by three experts in climate change impacts and adaptation. Their feedback confirmed the relevance of the impact categories selected and the overall exercise. It also revealed the need for a more transparent and systematic approach to justify the position of specific effects of climate change on the global temperature scale.

ii. Review of a refined diagram and justifications for each climate change effect included in it by eight national and regional experts in climate change impacts and adaptation. They helped validate the choice of climate change effects included in the diagram and their position on the global temperature scale, and recommended seeking further feedback from subject-matter experts for impact categories of higher profile.

iii. Review of the climate change effects in the diagram pertaining to sea ice, snow, and permafrost by four Canadian experts in the related disciplines led to further refinements.

iv. A final review by two Canadian experts in climate change impacts and adaptation. This helped us complete the diagram and ensure that the work was a fair and compelling representation of the underlying evidence.

The *Degrees of Change* diagram first appeared in the October 2010 issues of the magazines *Canadian Geographic* and *Géographica*. This was a result of a joint project between the NRTEE and the Royal Canadian Geographical Society.

* See Appendix 5.3 for the list of expert reviewers and their affiliations.

THE NRTEE'S *DEGREES OF CHANGE* DIAGRAM

ILLUSTRATING THE IMPACTS OF CLIMATE CHANGE IN CANADA

// CHAPTER 02

2.0 // THE NRTEE'S *DEGREES OF CHANGE* DIAGRAM: ILLUSTRATING THE IMPACTS OF CLIMATE CHANGE IN CANADA

2.1 // GUIDELINES FOR READERS

2.2 // THE GLOBAL TEMPERATURE SCALE

2.3 // IMPACT CATEGORIES

2.1 GUIDELINES FOR READERS

The *Degrees of Change* diagram summarizes a body of scientific literature on the expected effects of climate change in Canada associated with a rise in global average temperatures over the 21st century.

It is an illustrative and representative depiction of what a changing climate could mean for Canada, citing 60 specific examples of impacts. It is based on existing published research, with examples of impacts selected to highlight direct and indirect effects of global warming. The diagram is a summary of some of the more important impacts, those we know most about, are most confident about, and those expected to occur this century. In doing so, the NRTEE seeks to inform Canadians on just how pervasive the effects of a changing climate will be. And it seeks to inform decision makers on the scope and need for adaptation measures.

INTERPRETING THE *DEGREES OF CHANGE* DIAGRAM

Degrees of Change is a simple diagram that contains abundant information. Here we draw the reader's attention to four key elements: the global temperature scale, the "Current +0.78°C" marker, the eight impact categories and the suite of impacts of climate change represented.

THE "CURRENT +0.78°C" MARKER: INCREASE IN GLOBAL AVERAGE TEMPERATURES ALREADY OBSERVED RELATIVE TO 1850-1899 LEVELS (SINCE INDUSTRIALIZATION)

THE GLOBAL TEMPERATURE SCALE: RANGE OF GLOBAL AVERAGE TEMPERATURE INCREASES RELATIVE TO 1850-1899 LEVELS THAT COULD BE EXPECTED IN THE 21ST CENTURY. GLOBAL TEMPERATURES ARE USED AS A PROXY FOR CLIMATE CHANGE

THE IMPACTS OF CLIMATE CHANGE: ENVIRONMENTAL, SOCIAL, AND ECONOMIC IMPACTS EXPECTED TO OCCUR IN CANADA (UNLESS OTHERWISE NOTED) IN THE 21ST CENTURY LINKED TO A CHANGING CLIMATE. EACH IMPACT COMPRISES OF A STATEMENT ON THE EXPECTED DIRECTION AND QUALITY OF CHANGE AND A GLOBAL TEMPERATURE RANGE WHERE WE CAN EXPECT THE STATEMENT TO BE TRUE

THE EIGHT IMPACT CATEGORIES: SYSTEMS AND SECTORS THAT ARE IMPORTANT TO CANADA AND CANADIANS AND THAT ARE EXPOSED AND SUSCEPTIBLE TO CHANGES IN CLIMATE CONDITIONS AND / OR TO THE IMPACTS THAT FLOW FROM THEM

The NRTEE believes the diagram is a useful tool to communicate the risks and potential opportunities of climate change for our country and to foster a national conversation on strategies that governments, businesses, communities, and households can take to manage them.

HOWEVER, THE DIAGRAM HAS LIMITATIONS. WE SET THEM OUT HERE:

1 // The *Degrees of Change* diagram is not a comprehensive overview of *all* expected impacts for Canada — the effects of climate change are too pervasive, broad and wide-ranging for a comprehensive summary in diagram form to be possible. This means that we may be excluding poorly understood yet extremely relevant and important impacts for Canada. It also means that we exclude reinforcing impacts that could result from sustained warming of several degrees over several centuries, such as the release of large pools of carbon stored in sediments from warming of the deep ocean.

2 // The diagram is not a firm prediction, it is an illustration of what we think is possible and likely based on scientific literature. The impacts of climate change will occur at different times in different places, and result from a combination of changes in climate conditions, not just warmer temperatures. In addition, some of the scientific studies that we used to develop the diagram do not always specify the relationship between local and regional effects of climate change and global temperatures. As a result, we have made some interpretations and inferences of impacts reported in the literature, which can add uncertainty to some aspects of the diagram.

3 // The effects of climate change are not all instantaneous, and long-term impacts from warming are difficult to represent. It's important to recognize that changes in air temperature do not trigger an immediate response in the physical environment. Even if we limit global temperatures to 2°C by 2050, climate change impacts will continue to build up for decades at a minimum, simply due to the inertia of the systems involved. For example, sea levels would continue to rise for hundreds of years because of the long time it takes for surface changes to mix through to the bottom of the ocean and for major masses of ice and snow to react to warmer air temperatures. Although very important, these lags are difficult to represent in a diagram.

4 // A common international view is that Canada is likely to experience both beneficial and adverse impacts from climate change, but much of the literature focuses on quantifying risks, costs, and damages rather than positive changes. The *Degrees of Change* diagram can only represent what exists in the current scientific literature, which mostly highlights the risks from a warming world.

5 // The climate change effects included in the diagram do not account for the potential to reduce or avoid harm through adaptation. Some of the effects of climate change — such as those on industries and communities — will depend on the way in which people respond to the changing climate. By taking proactive action to prepare for expected impacts, Canadians can lessen the blow of climate change and even position ourselves to benefit accordingly in some cases.

2.2 THE GLOBAL TEMPERATURE SCALE

In the diagram, we map climate change effects expected in Canada to a global temperature scale (see **Figure 2**).

We did so because, while Canada as a whole is warming faster than the global average (see **Box 3**), a global temperature scale places expected effects of climate change in Canada within the broader context. This broader context includes international climate change talks currently negotiating country-level commitments to prevent global temperatures from exceeding 2°C above pre-industrial levels (i.e., relative to 1850–1899 averages).

FIGURE 2 DEGREES OF CHANGE DIAGRAM – GLOBAL TEMPERATURE SCALE

The diagram's global temperature scale embodies complex scientific information that merits explanation. The temperature scale starts at 0.5˚C and ends at about 6˚C. The range is significant for two reasons.

FIRST, we can benchmark the rise in global average temperatures relative to pre-industrial times that has already occurred and warming that is in the pipeline. The diagram's "Current +0.78°C" marker captures the observed warming and tells us that the effects of climate change that line up with this marker are already taking place. From the marker at 0.78°C a further rise in global temperatures of 0.6˚C is now unavoidable due to the historic buildup of heat-trapping gases. This means that adapting to the impacts shown to about 1.5˚C is no longer optional.

SECOND, the range reflects current understanding of the possible rise in global average temperatures during this century. The range is so large because of uncertainties in future changes to the chemical makeup of the atmosphere (mainly the proportion of heat-trapping gases), and the reaction of the global climate and other components of the Earth system to these atmospheric changes.

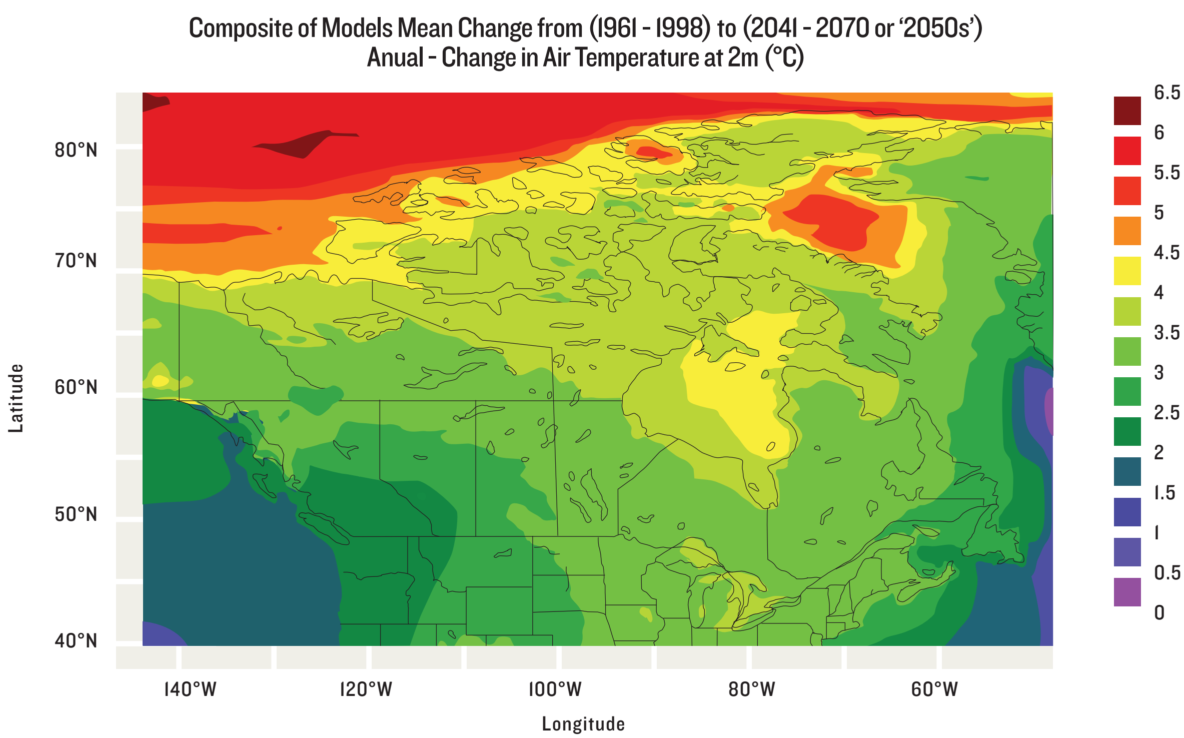
Our focus on the trend in rising global average temperatures does not mean that temperature is the only indicator to worry about. In Canada and elsewhere, global warming affects averages of other climate indicators in addition to climate variability, resulting in changes in the amount and timing of rain and snow, air and soil moisture, wind patterns, and in the frequency, extent, and severity of climate extremes such as droughts, heat waves, and intense storms and rain events. The diagram specifically highlights some of these changes as impacts.

BOX 3 RATE OF WARMING IN CANADA

During the past century, temperature increases in Canada were approximately double the global average. This pattern can be expected to continue, with Canada as a whole warming roughly 1.5 times the global average, and up to 3 times in the case of the Arctic.* Land is expected to warm faster than oceans and high latitude regions faster than those at mid-latitudes.

This means that a rise in global temperatures above pre-industrial levels of about 2°C by the 2050s would likely result in much higher temperatures in some parts of Canada. The figure below, taken from the website of the Canadian Climate Change Scenarios Network, illustrates this regional variability. It shows that, on average, the Mackenzie Valley could warm as much as 3.5 to 4°C and the southern Prairies as much as 2.5 to 3°C by the 2050s.

Temperature changes are relative to a 30-year baseline (1961–1990 in this case), which is a common practice in studies examining future climate change impacts.



SOURCE: IPCC (2007); WARREN AND EGGINTON (2008); CCCSN (2009).

* Indeed, North America is likely to warm more than the global average. Projections from regional climate models indicate that "all of North America is very likely to warm during this century, and the annual mean warming is likely to exceed the global mean warming in most areas", However, "the uncertainty associated with regional climate model projections of climate change over North America remains large" (IPCC AR4 Working Group 1 Chapter 11, p. 889. See http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-chapter11.pdf).

2.3 IMPACT CATEGORIES

The *Degrees of Change* diagram includes the eight impact categories listed below.

- Ice, snow, and sea
- Ecosystems
- Water resources
- Human health
- Communities and infrastructure
- Resource industries
- Service industries
- Security and trade

The NRTEE chose these eight impact categories to illustrate the full chain of effects of climate change, and interconnections among them from a Canadian perspective. Although inspired by formats used by the Intergovernmental Panel on Climate Change, *Degrees of Change* is uniquely Canadian in representing categories and impacts that are significant to our country. Categories include direct and visible impacts on our environment and then progress to indirect impacts on our economy and society. Together, these eight categories represent interconnected systems and sectors but with varying degrees of *adaptive capacity*:

- those incapable of adapting to the effects of higher global temperatures, such as glaciers and sea ice;
- those that can, within limits, adjust spontaneously to change, such as forests; and
- those that are capable of anticipating the effects of climate change and making change to accommodate them, such as service industries.

In several cases, the effects of climate change in one impact category have implications for another category. Among the most obvious examples are the impacts in *Ecosystems* and those in *Resource industries:* shifts in the viability and range of fish species as oceans warm and change chemistry because of higher carbon concentrations in the atmosphere greatly influence the economic sustainability of *capture fisheries*.

Each category includes four or more impacts of climate change. Sixty in total are plotted on the diagram. Every impact has two components: a statement on the expected direction and quality of change and a global temperature range where we can expect the statement to be true.

A rigorous selection and validation process decided what impacts to include in the diagram and how to portray them.

The diagram includes impacts that are already evident and impacts that scientists project for the future. We can expect the former to continue into the future and probably increase (or decrease, depending on the direction) with higher global temperatures. Drawing definitive conclusions on forecasts of climate change impacts is more difficult. Confidence is a function of understanding the direction and magnitude (how much or how little) of change, the global temperature range associated with this change, the lag time between global temperature change and the response of our physical environment, and conditions under which the direction of change may flip, or the speed of change may accelerate. Issues of certainty and confidence are noted in Appendix 5.5, which highlights where and why readers should be cautious about drawing firm and fast conclusions on each and every impact at this time, over and above clear directional changes.

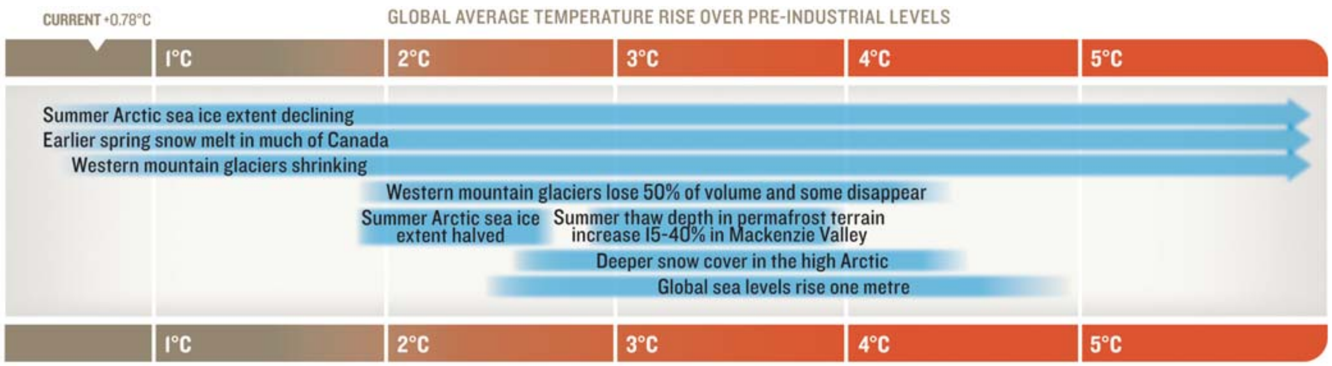
Overall, we have tried to present the potential impacts of climate change in a way that is balanced, informative, and compelling. We have summarized existing evidence. New evidence and more scientific research are always appearing. Having established a framework and means of communicating climate change impacts in Canada, the NRTEE's *Degrees of Change* diagram can be updated to reflect this.

ICE, SNOW AND SEA

This category includes major reservoirs of water, each with different properties and functions for natural processes shaping life on Earth as we know it. On a global level, expanses of snow cover, land ice (including mountain glaciers), and sea ice provide a reflective surface that helps regulate the amount of energy from the sun that reaches the Earth's surface. Oceans perform regulating functions as well, acting as vast reservoirs of heat from the atmosphere, redistributing excess heat toward the poles, and absorbing extra carbon from the atmosphere. Warming of the Earth's surface since pre-industrial times has raised global sea levels, from a combination of the expansion of water in oceans and melting ice caps, mountain glaciers, and blocks of ice from land-based ice sheets (e.g., Antarctica and Greenland). Roughly a third of atmospheric carbon resulting from human activity has ended up in the global ocean. Ice in permafrost terrain locks in methane (a powerful greenhouse gas), serving as a climate regulating function. Thawing of permafrost also releases water and other compounds, influencing natural processes such as river hydrology.

For Canada, the significance of this category is two-fold. First, vast expanses of snow cover, land ice, sea ice, and permafrost within Canada's territory, and our access to three oceans means that it's important for us to understand how changes to our landscape and seascape contribute to global climate change. According to some estimates based on glacier inventories, ice covers just over 200,000 km^2 of Canada's land mass.[8] Permafrost underlies half of Canada's land surface.[9] Second, ice, snow, and our long coastline are also part of our national identity, influencing activities of Canadian households, communities, and businesses. We cover these linkages in impact categories below. Examples include reliance on permafrost stability for the integrity of infrastructure in parts of Canada's North, and on snow conditions for winter recreation in several Canadian regions.

FIGURE 3 ICE, SNOW AND SEA



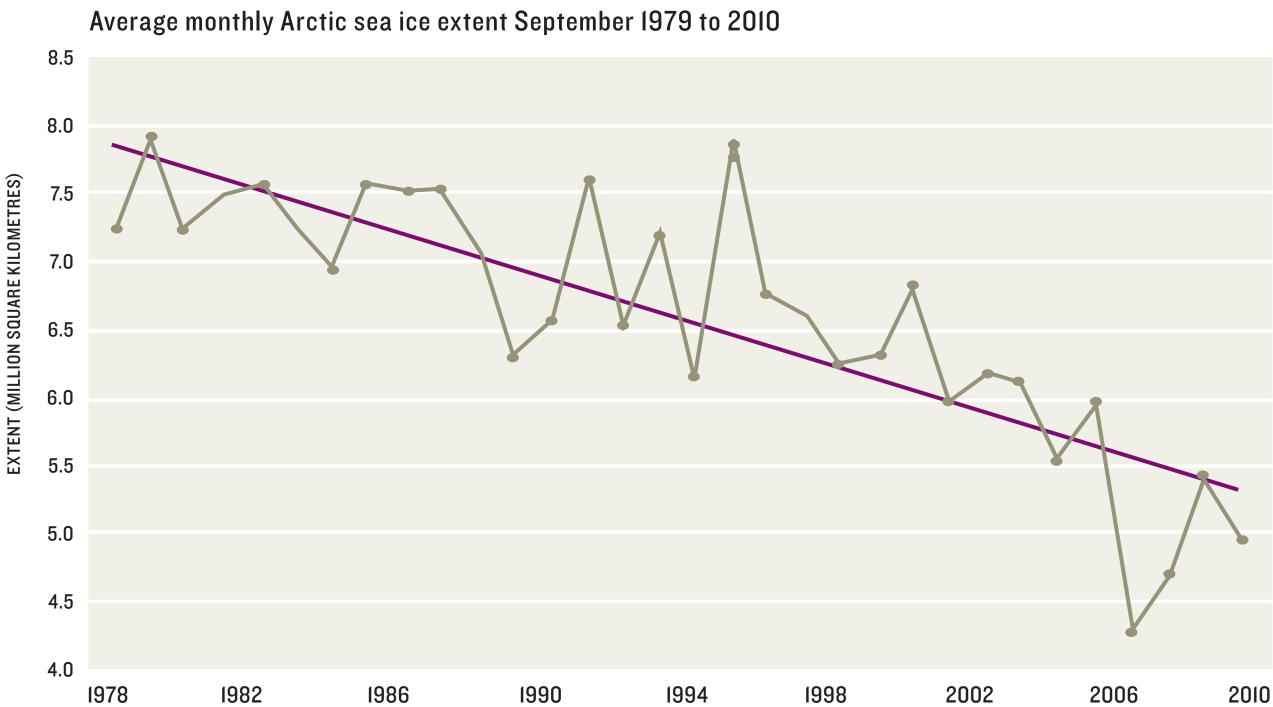
What we can expect

SIGNIFICANT REDUCTIONS IN ARCTIC SEA ICE. The past 30 years saw the extent of summertime sea ice in the Arctic decline by about 10% per decade, compared to the 1979 to 2000 average, and in 2007 it was 30% below average (see **Box 4**).[10] Global climate models project a 50% reduction in the extent of summertime sea ice and in concentrations in the Canadian Arctic at global temperatures between 2 and 3°C above pre-industrial averages,[11] with reductions in sea ice happening at an accelerating rate at global temperatures above 2°C.[12] Other research suggests that a completely ice-free Canadian archipelago is unlikely by 2050[13], with models projecting an ice-free Arctic ocean in late summer by the end of the 21st century (3 to 5°C over pre-industrial levels).[14] However, the observed decreases in summertime sea-ice extent have taken place faster than climate models projected,[15] so the declining trend in Arctic sea ice toward ice-free summer conditions could occur sooner and to a greater extent than either anticipated or presented here.

This transformation of the Arctic has immediate implications for marine and land-based plants and animals, for northern peoples and their livelihoods, and for national security. In addition, disappearing Arctic sea ice means that the Arctic Ocean is absorbing more solar energy, further contributing to global climate warming.

BOX 4 ARCTIC SEA ICE DECLINE

According to satellite data, the past thirty years saw the extent of summertime sea ice in the Arctic decline significantly. Minimum sea-ice extent in 2010 was the third lowest on record. The decline in summertime ice extent in the Beaufort and Chukchi Seas this year was "unusually fast." A combination of factors contributed to the speedy loss in summer ice, including the degraded state of a portion of the ice and winds that carried warm air to the region and pushed ice northward. The Beaufort and Chukchi Seas border the north westernmost corner of Canada and western Alaska, respectively.



SOURCE: NATIONAL SNOW AND ICE DATA CENTER, ARCTIC SEA ICE NEWS 2010. HTTP://NSIDC.ORG/ARCTICSEAICENEWS/

INCREASING DEPTH OF SEASONAL THAW IN PERMAFROST TERRAIN. Over the past 60 years, air temperatures in the Mackenzie Valley region of the Northwest Territories have increased more than any other climate region in Canada, with implications for ground temperatures and the integrity of permafrost. Indeed, in this same region, the depth to which the ground thaws in the summer could increase 15 to 40% over the next century, in response to global climate warming of 3 to 4°C.[16] Permafrost terrain overlain by a thick layer of organic material, such as soil and vegetation, will see smaller changes in thaw depth.

SHRINKING MOUNTAIN GLACIERS. Almost all glaciers in Canada are already retreating. Glaciers in British Columbia and Alberta have shrunk in area by an average of 0.55% per year between 1985 and 2005.[17] This recent shrinkage is not just due to global climate warming but also to natural variability on the scale of decades in the way moisture is distributed across the region.[18] Increases in global temperatures of about 2 to 4°C could reduce the volume of western mountain glaciers by over 50%.[19] Smaller glaciers may well disappear over the next 100 years[20], with summer melting outstripping any modest gains in snow and ice accumulated in winter in some locations.[21]

SHIFTING SNOW PATTERNS. Over much of Canada, warmer average temperatures since the 1980s have prompted snow to melt earlier in the spring and reduced the depth of snow cover.[22] In the Pacific Northwest, a greater proportion of winter precipitation is falling as rain than has been the case in the past, reducing the mountain snowpack.[23] At global temperatures on average about 3°C higher than pre-industrial levels, climate models project an increase in snow accumulation in Canada's high Arctic in response to warmer air and more open water.[24]

RISING SEA LEVELS. Global sea levels have risen an estimated 0.17 m since 1870.[25] Recent estimates suggest that global sea-level rise could reach between 0.50 m and 1 m by the end of the century,[26] corresponding to global temperatures between about 2.5°C and 5°C above pre-industrial levels. Other research shows the possibility of global sea-level rise exceeding 1.5 m also by 2100.[27] The effects of this sea-level rise will vary by location. Actual changes in sea levels depend on local physical properties: whether land is subsiding or facing uplift. Coastlines particularly sensitive to the effects of sea-level rise include those with low relief and low resistance to erosion, those exposed to high-energy waves, and those with large ranges between high and low tides. Projected rates of sea-level rise will have direct impacts on communities and *ecosystems* in low-lying coasts throughout Canada, particularly in the Atlantic coast, the Beaufort Sea coast, and part of the lower mainland of British Columbia. Coastal ecosystems, such as wetlands and marshes, are already facing "coastal squeeze," with human development creating a barrier to natural migration inland.

What we can do about it

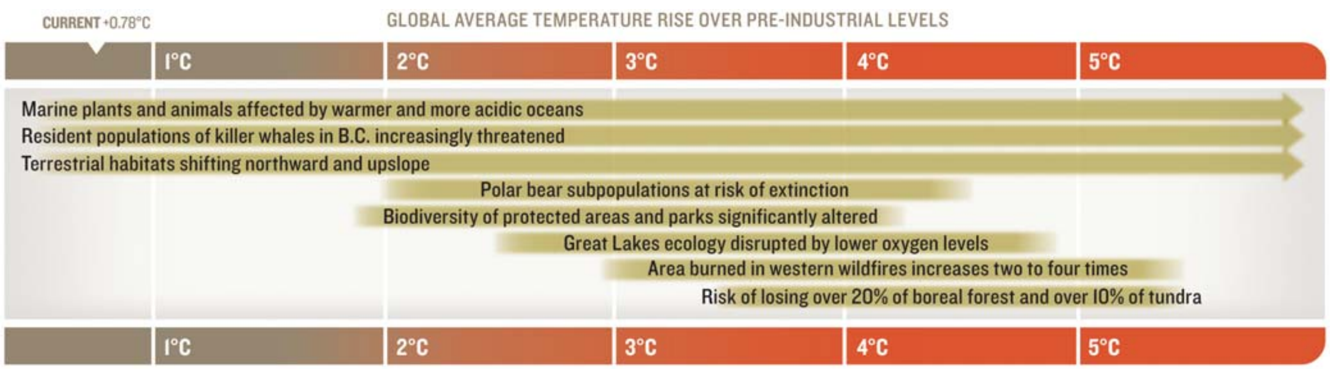
The effects of warmer global temperatures are most observable on our physical environment, including ice, snow, and sea levels. Broadly speaking, we can do little to reduce the effects of a changing climate on these systems in Canada, other than limit global climate change itself. A few examples do exist of technologies developed or practices adopted to resist or adapt to changes in ice systems driven by warmer temperatures. In Canada's North, governments and industry have taken measures to inhibit permafrost warming and minimize ground settlement underlying major infrastructure projects, including the installation of "thermosyphons." Some northern residents reliant on frozen waterways for travelling, fishing and hunting activities have started using maps containing satellite images of up-to-date ice conditions to guide their decisions.[28] The effectiveness of technologies such as these and the feasibility of their continued application will depend on the extent of change in the physical environment and the rate at which change takes place.

ECOSYSTEMS

This category includes communities of biota — plants and animals — that live on land and in water, interacting with each other and their environment. Canada is rich in ecosystem diversity, with 15 distinct ecozones on land and five marine-based ones.[29] Ecosystems perform a range of services that we value greatly, whether we know it or not. They provide water, food, and fibre for our direct consumption or as inputs for industry. They regulate natural processes. The 1.2 million square kilometres of wetlands[30] covering about 14% of Canada's land, for example, help absorb high-energy waves and control coastal erosion.[31] Our expansive forests — representing about 10% of the world's forest cover — and soils absorb and store carbon dioxide, playing a key role in regulating the climate.[32] They are important for recreation and spiritual purposes. They support processes that sustain life, as we know it, such as nutrient cycling and photosynthesis.

A changing climate is already affecting Canada's ecosystems.[33] Combined with pressures from economic development, including pollution, overuse, *habitat* fragmentation, and introduction of invasive species, future climate change has the potential to not only alter the quality and health of our ecosystems but also to set off physical processes that add to global climate warming. We include examples of these instances below (also see **Box 2** on Climate Lags and Feedbacks).

FIGURE 4 ECOSYSTEMS



What we can expect

EFFECTS TO PLANTS, ANIMALS, AND FOOD WEBS FROM CHANGES IN CHEMISTRY AND TEMPERATURE OF OCEANS AND FRESHWATER SYSTEMS. In addition to their role as heat sinks, oceans have 50 times the capacity of the atmosphere to store carbon, providing an important buffer to global climate warming.[34] Increasing levels of carbon in the atmosphere, however, are changing the surface chemistry of the oceans toward an environment that is more acidic.[35] Ocean acidification poses threats to marine life, including reducing the capacity of many organisms to form calcium carbonate shells.[36] In Canadian waters, plankton, pteropods, molluscs, and cold-water corals are particularly at risk,[37] some of which play key roles in the sustainability of marine food webs. One study estimates that by 2100, 70% of known cold-water stony coral ecosystems will no longer be able to maintain their calcified skeletal structures due to the impact of ocean acidification.[38] Waters off Nova Scotia and New Brunswick are currently home to at least 45 of the 500 cold-water coral occurring worldwide.[39]

Warmer temperatures affect the availability of oxygen in marine and freshwater columns. Globally, ocean surface temperatures have increased over the past 40 years,[40] contributing to the spread of "dead zones" or areas depleted in oxygen. In the Saanich Inlet on the coast of British Columbia, for example, the depth of waters depleted in oxygen is now 25 metres higher than 50 years ago, shrinking the habitat for many marine organisms and causing ripple effects on the viability of predators such as seabirds.[41] The ecology of the Great Lakes also stands to be affected by warmer surface temperatures. Projected warming of lake surfaces by 2100 would accelerate plants' and animals' use of dissolved oxygen, resulting in lower overall oxygen levels and limiting the habitat for various species of fish.[42]

SHIFTING GEOGRAPHIC DISTRIBUTION AND COMPOSITION OF ECOSYSTEMS. A changing climate will alter the Canadian landscape and seascape. Ecosystems are expected to change in composition and to gradually move northward (and upslope on land, deeper in water), with some species gaining suitable habitat and others losing it.[43] This shift in habitat suitability has implications for the spread of invasive species. Warmer conditions, for example, are likely to prompt expansion of the introduced Asian shore crab, threatening soft-shell crabs and blue mussel fisheries.[44]

For forests, models forecast a northward expansion of boreal forest cover into what is currently tundra,[45] at the same time forecasting risks of significant loss of boreal forest, in particular at the southern edge of current boreal extent. One study estimates a one-in-three chance of losing 20% of boreal forest at a global temperature increase of 3.5°C over pre-industrial levels.[46] As the boreal forest cover moves north, it will replace tundra areas, with one study projecting 10% loss of tundra area by the end of the century.[47]

On land, the timing of several events in the life histories of plants and animals, like seasonal migrations, egg-laying, and blooming, depend on temperature. In a changing climate, the timing of these seasonal activities is shifting. For example, researchers have documented a 26-day shift in the onset of spring in Alberta over the past century, based on trends in the flowering dates of key perennial plants.[48]

Among other important consequences, shifts in vegetation cover and composition of ecosystems will have significant implications for current land-based parks and protected areas, some specifically established to protect certain ecological features and conserve current biodiversity levels.[49] Canada's National Park system, for example, encompasses areas that are representative of Canada's ecozones as we know them today.

CHANGING PATTERNS OF NATURAL DISTURBANCES. Disturbances such as fires and insect outbreaks are important for natural reproduction and rejuvenation of forests like the boreal. However, climate change is likely to accelerate the intensity and frequency of fires and insect outbreaks, changing the forest landscape and releasing carbon stored in trees and soils as emissions into the atmosphere.[50] The average forest area burned from wildfires in Canada is already on the rise.[51] The average area burned per decade could increase by a factor of 3.5 to 5 by the last decade of this century.[52] The area burned in Canada is projected to increase about 75% to 100% by the end of this century at global temperatures 4°C and above.[53] This aggregate number masks a wide range of regional impacts: the average forest area burned in western wildfires could increase by 200% to 400% by the end of this century. In a warming world, insect attacks are likely to increase in frequency and intensity as established forest stands face stress from warmer, drier conditions, and as population dynamics of forest pests shift.[54]

BOX 5 FOREST FIRES

Several severe fire seasons have occurred in the past decade, most notably the 2003 season in British Columbia, which cost the province $700 million in fire suppression costs. In the 1990s, the average area burned per fire in B.C. was about 125 hectares. In the 2000s, that average climbed to over 400 hectares. The 2004 summer in Yukon was the warmest on record and the area burned in that territory was more than twice the highest previous amount, which occurred in 1958.

Pests and fire can have strong interactions — the dead and dying forests represent highly flammable conditions that could lead to very large areas burned, if hot and windy weather conditions prevail over a region.

SOURCE: SOURCES: ARBORVITAE ENVIRONMENTAL SERVICES LTD. & DR. GARY BULL (2010). THE ECONOMIC IMPLICATIONS OF CLIMATE CHANGE ON NON-TIMBER VALUES OF CANADA'S FORESTS, REPORT COMMISSIONED BY THE NATIONAL ROUND TABLE ON THE ENVIRONMENT AND THE ECONOMY; ESTIMATES ON AVERAGE AREA BURNED IN BRITISH COLUMBIA USE DATA FROM HTTP://CANADAFORESTS.NRCAN.GC.CA/STATSPROFILE/FOREST/BC

THREATS TO BIODIVERSITY. Changes in climate conditions, habitat, and food webs have implications for the viability of specific species of plants and animals. Here we highlight the killer whale and polar bear.[55] Killer whales are losing their traditional food sources as fish and mammalian species migrate northward.[56] Off the coast of British Columbia, reports of killer whales feeding on sea otters instead of sea lions and harbour seals have come in. Because of changes in fish migration patterns, sea lions and harbour seals have moved out of the killer whales' range. The decline in abundance of Chinook salmon from the Fraser River is a major threat to resident killer whales.

Polar bears depend on sea ice as hunting platforms and for transportation; the duration and extent of sea ice influence the viability of polar bear populations. Some polar bear *subpopulations* are already under threat from changes in sea-ice conditions.[57] In Hudson Bay, local air temperatures have increased by 2 to 3°C over the last 50 years. This has led to earlier spring breakup of ice, affecting the success of the Western Hudson Bay polar bears.[58] A continued trend of warming and reduced access to sea ice poses significant extinction risk to this polar bear subpopulation by the end of the century.[59]

What we can do about it

On balance, scientists project losses in biodiversity in a changing climate, especially for ecosystems already under pressure from other causes. This is mainly because climate conditions are likely to change faster than ecosystems and species within them can adapt. Plants and animals naturally adjust to changes in their environment by changing behaviour, shifting timing of events in their life histories like reproduction and, in some cases, migrating to other suitable locations. Collectively, these adjustments represent changes to ecosystems and hence biodiversity, resulting in expansion and contraction of species' ranges and ensembles of species over relatively long timeframes. For example, the shrinkage of glaciers increases the area of land for tundra ecosystems to occupy, but it could take over 300 years to achieve a dense tundra plant cover after the ice melts.[60]

Initiatives that enhance ecosystem *resilience* can help withstand the impacts of climate change (see **Box 6**). These include establishing or expanding networks of protected areas and migration corridors, and applying *adaptive management* and *ecosystem-based approaches* in economic activities like forestry and fisheries.[61] As ecosystems and species shift in response to climate change, national park management and boundaries will also need to adapt to ensure that the targeted ecosystems and species remain protected.[62]

BOX 6 ECOLOGICAL RESILIENCE AND CANADA'S NATIONAL PARKS

Parks Canada — the federal agency overseeing Canada's national parks — is well aware of the threats that climate change poses to park biodiversity and is taking action on a few fronts.

At an agency level, Parks Canada is funding projects that strengthen the ecological integrity of parks and therefore foster resilience in the face of stress. Parks Canada has budgeted $90 million over five years (2009–2014) to undertake restoration projects within the park system. One such project in Gros Morne (Newfoundland and Labrador) aims to limit the establishment of exotic invasive species by reducing the moose population within the park. Moose grazing has eliminated much of the small tree and shrub layer, as well as the herbaceous layer in the park's forests, making these niches available for exotic invasive species.

The agency is also enhancing its knowledge of current and future impacts of climate change on park ecosystems. It has initiated a program to monitor ecosystem health. It is also using modelling tools to examine key ecological relationships and risks within parks, with the goal of projecting climate change impacts at a scale useful for management decisions.

Ecosystem management at the landscape level is key for climate change adaptation. However, few individual parks are large enough to constitute landscapes, meaning that parks by themselves may have limited capabilities to retain especially vulnerable ecosystem types within their boundaries or to facilitate natural adaptation. National parks could well form conservation nodes, in connection with other provincial and territorial parks and areas that are lightly managed — including tracts of private land. Maintaining corridors between the nodes would facilitate the movement of plants and animals.

In Manitoba's Riding Mountain Park staff understand the vulnerabilities of their park to climate change, and that partnerships with stakeholders outside park borders are part of the solution. They anticipate that the boreal forest component of the park is most vulnerable: it is located at the southern edge of its range, separated from other boreal forest by tens of kilometres of agricultural land. The combination of higher temperatures and a greater disturbance frequency puts this forest type at greater risk than the hardwoods or the aspen parkland components of the park, both of which will likely expand at the expense of the boreal forest. Staff at Riding Mountain Park are working with surrounding municipalities on climate change issues. Both the park and these municipalities are part of a World Biosphere Reserve, which provides a forum for the parties to come together on ecosystem management.

SOURCES: ARBORVITAE ENVIRONMENTAL SERVICES LTD. & DR. GARY BULL (2010). THE ECONOMIC IMPLICATIONS OF CLIMATE CHANGE ON NON-TIMBER VALUES OF CANADA'S FORESTS, REPORT COMMISSIONED BY THE NATIONAL ROUND TABLE ON THE ENVIRONMENT AND THE ECONOMY.

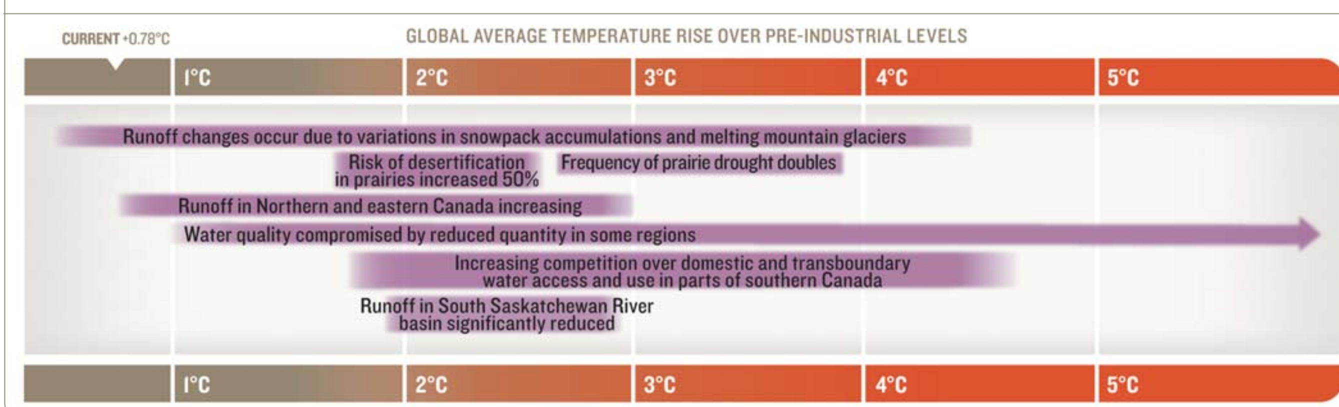
WATER RESOURCES

This category includes freshwater systems (rivers, ponds, lakes, glaciers, snowpack, reservoirs, groundwater aquifers) and sources that replenish them. Although we recognize the important connections between surface and groundwater flows, here we highlight effects on surface waters. With only half of one per cent of the world's population, Canada currently has 20% of the world's stock of surface freshwater, and our average annual renewable freshwater supply or water yield is 3,472 km^2 — the third largest in the world.[63] Within Canada, most people live along the southern border and much of the economic activity occurs there, yet the majority of surface water flows to the north.

Access to clean, sustainable supplies of water is essential for the health of Canadians and for the functioning of economic activities and sectors. Water scarcity is not a national problem in Canada, but seasonal variability and demand from multiple users already present management challenges in important agricultural regions (e.g., south-central Prairies and southwestern British Columbia). In *Changing Currents*, the NRTEE concluded that economic and population growth, coupled with anticipated effects of climate change, will impact Canada's freshwater systems and create new pressures on the long-term sustainability of our water resources.

Warmer average temperatures affect precipitation patterns and evaporation rates, as well as the frequency, intensity, and duration of *extreme weather* and climate events like droughts, heat waves, and storms. A national picture of the potential effects on water is challenging to develop: effects will be highly localized, influenced in part by natural processes that regulate *hydrology*.

FIGURE 5 WATER RESOURCES



What we can expect

BOTH LESS AND MORE WATER SUPPLY. Changes in precipitation patterns are already evident, with, on average, 20 more days with rain in Canada today compared with the 1950s.[64] In a warmer world, we can expect further changes to the amount and timing of precipitation and to regional hydrology. Overall precipitation is expected to increase slightly in the north and east, and decrease slightly in the south and west, with less in summer, and more as intense events.[65] Studies project increasing runoff in Québec, Newfoundland and Labrador, and the Territories as global temperatures rise up to around 3°C above pre-industrial levels.[66]

Freshwater systems reliant on snow and ice accumulations for replenishment are likely to see dwindling supplies, particularly in summer months. Mountain glaciers in Canada are already shrinking. Studies show an increase in runoff associated with melting glaciers,[67] with runoff declining as glaciers disappear. Some western basins may have already experienced an increased flow phase from glacial melt.[68] At global average temperatures about 2 to 4°C above pre-industrial levels western glaciers could shrink significantly, with smaller glaciers at risk of disappearing.[69] Snow accumulations in alpine areas and across the Prairies are also likely to diminish.[70] Parts of British Columbia and the Prairie provinces will likely experience decreasing supplies and shifts in streamflow timing to earlier in the year, facing increasing water shortages as a result.

Changes in seasonal variability and air moisture also affect regional water availability. For example, despite projections of a rise in precipitation in Maritime provinces, seasonal and yearly variations in precipitation will combine with higher *evapotranspiration* rates to induce drier summer conditions.[71] In the Prairies, lower spring and summer stream flows are likely to occur in what is already a dry region, increasing both soil water deficits and surface water deficits.[72] At global temperature rises of about 2°C to 3°C, flows in the South Saskatchewan River basin could see significant declines.[73] Studies project drier conditions in the Prairies, with the area of land at risk of desertification increasing 50% by mid-century,[74] and drought frequency doubling at global average temperatures 3 to 4°C above pre-industrial levels.[75]

WATER STRESS AND COMPETITION OVER ACCESS AND USE OF WATER. Water stress and related restrictions in use are a result of mismatches between available supplies and demands for water. A few locations in Canada are already facing restrictions in water use. For example, in August 2006, the Alberta government stopped accepting applications for new allocations of water in the Oldman, Bow, and South Saskatchewan sub-basins. Climate change affects both the amount of water available for use and the demand for the resource. In the Okanagan region of British Columbia, climate change is expected to both cause changes to runoff and increase irrigation demand, leading to challenges for water managers in maintaining adequate supply[76] while ensuring water quality and ecosystem health. Lower water levels in the Great Lakes, which some climate scenarios project, will likely restrict municipal water use.[77]

Reduced seasonal water supplies and increased demands over the next several decades could enhance competition among water users and lead to conflict in some basins.[78] This has implications for complying with water sharing agreements between Canadian jurisdictions and between Canada and the United States[79], with the potential to increase the level of current conflicts and create new ones heightening at global average temperatures 2°C and above.

BOX 7 WARMER GREAT LAKES WATERS

Covering an area of over 240,000km^2, the Great Lakes system contains one-fifth of the world's stored freshwater, and important coastal wetlands, fish and water fowl populations, while also supporting a variety of activities including shipping and transportation, commercial and recreational fisheries, agriculture, and hydroelectric generation. One in three Canadians and one in eight Americans live in the region surrounding the Great Lakes.

Evidence suggests that warmer air temperatures are changing some physical characteristics of the Great Lakes. Average surface temperatures of all lakes in the system have increased over the past decades. Between 1968 and 2002, Lake Huron warmed 2.9°C, Lake Ontario and Lake Erie warmed 1.6°C and 0.9°C, respectively, over the same timeframe. Since 1980, surface waters of Lake Superior are 2.5°C warmer. The duration of ice cover is also declining, further contributing to the warming of Great Lakes waters. Among other ecological effects, the warming trend will favour production of warm-water fish (such as bigmouth buffalo and flathead catfish) over cool- and cold-water fish (such as lake trout).

GREAT LAKES BASIN

SOURCES: DOBIESZ AND LESTER (2009); AUSTIN AND COLMAN (2007); ASSEL (2005); THE GREAT LAKES: BASIC INFORMATION - HTTP://EPA.GOV/GREATLAKES/BASICINFO.HTML. MAP ADAPTED FROM CHIOTTI AND LAVENDER (2008)

EFFECTS ON WATER QUALITY. Declines in supplies of water — because of increasing evaporation rates, changing precipitation patterns, increasing demand, or all of the above — affect the quality of water. Warmer air temperatures affect the chemistry of water bodies, contributing to thermal layering in the water column, accelerating plant and animal use of dissolved oxygen, and resulting in oxygen depletion.[80] Less water reduces the ability of water bodies to dilute chemical pollutants and nutrients, which among other effects, diminishes the taste and smell of our drinking water.[81] An increase in the frequency of intense rainfall events, as is expected in a changing climate, increases the risk of water contamination carried by runoff from urban and rural waste and nutrients.[82] Water quality would likely suffer in some Canadian regions with warming beyond that experienced over the 20th century.[83]

What we can do about it

Continued access to clean water is important for households, industry, communities, and governments. As managers and stewards of water resources, provincial and territorial governments are already developing or introducing water management programs, mostly to deal with existing issues related to supplies and demands. For example, the *Ontario Clean Water Act* (2006) requires local authorities and *stakeholders* to develop source protection plans for individual *watersheds*, including assessments of how much water is available within each watershed.

Effective water conservation and management strategies will need to incorporate changes in moisture and shifts in demand associated with climate change, including demand for potable consumption, irrigation, hydroelectric generation, and other industrial uses, and consider in-stream ecosystem needs as well. The implications of climate change effects on water resources will also need to factor into renegotiation of water -sharing agreements. Within industry, levels of awareness of and concern about the impacts of climate change on water availability differ across sectors, but incorporating uncertainty of climate change projections into management practices is a common struggle.

Adaptive strategies include developing and applying technologies for efficient water use, and changing water use behaviour. Governments can implement programs and policies to shift water use and consumption patterns, including pricing regimes, updating permitting requirements, and providing information on best practices.

BOX 8 PERCEIVED BUSINESS RISK FROM CHANGING PRECIPITATION PATTERNS

The NRTEE examined perceptions of Canadian businesses to potential risks and opportunities from the impacts of climate change. To do this, we analyzed six years' worth of responses by Canadian businesses to an annual survey administered by the Carbon Disclosure Project (CDP). The CDP targets top global firms, based on market capitalization.

Changing precipitation patterns is the most common gradual, long-term risk from a changing climate identified by Canadian companies. An average of one in five companies over the six-year data set identified potential risks from changing precipitation patterns, and the number of companies aware of these risks remained relatively constant over the past six years. Companies representing a range of business interests, from utilities to agricultural producers, provided their perceptions on the possible implications of changes in precipitation on runoff patterns. Companies in the energy sector with operations in Alberta expressed the highest level of concern. A number of them described potential water shortages due to decreased precipitation and runoff as the most significant risk from physical impacts of climate change that they are likely to face. Thermal electrical and hydroelectric power generation sectors are highly reliant on water availability. Oil and gas operations also use water in several processes including during extraction and separation of hydrocarbon resources.

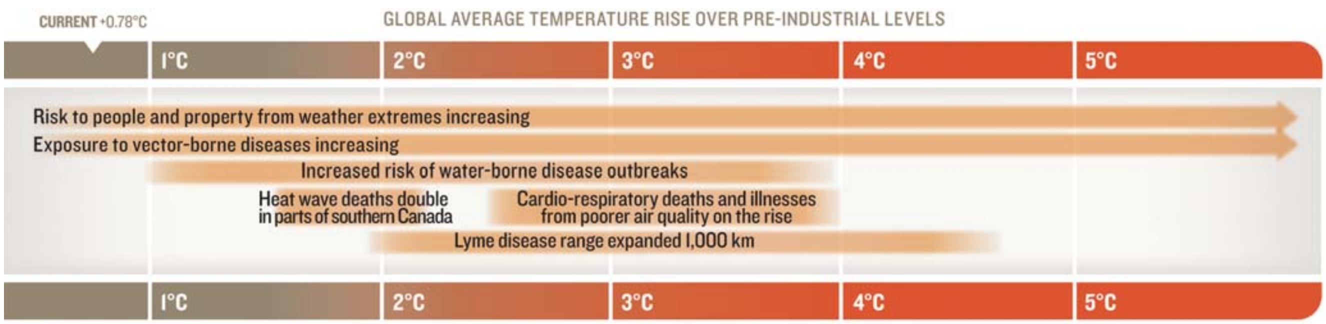
SOURCE: BERRY, R.D. (2009). PREPAREDNESS OF CANADIAN BUSINESSES TO ADAPT TO CLIMATE CHANGE, REPORT COMMISSIONED BY THE NATIONAL ROUND TABLE ON THE ENVIRONMENT AND THE ECONOMY.

HUMAN HEALTH

This category refers to the overall health of Canadians, although the diagram's focus is physical health. Health status is an important indicator of national prosperity. A country's ability to innovate and remain productive depends on the characteristics and quality of its human capital, key elements of which are health, education, and skills. Promotion and enhancement of Canadians' health is a national objective, with significant investment attached to it. Total health spending accounted for about 10% of Canada's gross domestic product in 2008, a slightly higher proportion than the OECD average.[84]

Weather and climate directly and indirectly affect the health status of individuals or groups of individuals within a given community. For example, the 1998 ice storm in eastern Canada resulted in 28 deaths from trauma or hypothermia related to power outages, and a number of illnesses and injuries for which medical treatment was necessary.[85] In addition to direct health impacts, events such as these cause stress and affect mental and physical health. Consider the stress from temporary evacuations, extensive damage to homes and business assets, and subsequent insurance and rebuilding hassles. Lost productivity and the need for *emergency* services, such as medical services, are additional social costs tied to health impacts from the *hazards* of extreme weather.

FIGURE 6 HUMAN HEALTH



What we can expect

HEALTH IMPACTS FROM CHANGES IN WEATHER AND CLIMATE-RELATED EXTREMES.

Extreme weather and climate events such as droughts, storms, heavy rainfall events, and heat waves increased over the last century, as did the number of injuries, the number of Canadians affected, and associated economic costs.[86] In a changing climate, these events will increase in frequency, intensity, and duration,[87] as could the health impacts and financial costs.[88] For example, as temperatures rise, the number of hot days exceeding 30°C is likely to as well. By the end of the century,[89] communities in southern Canada could experience as many as four to six times more hot days during summer months than they did toward the end of the 20th century. Annual heat-wave deaths for parts of southern Canada could double with global average temperatures between about 1.5°C and 2°C.[90]

GREATER EXPOSURE TO POOR AIR QUALITY. Warmer global temperatures could affect air quality in Canada in several ways. Levels of ground-level ozone and particulate matter could increase, as could emissions of noxious chemical compounds from plants (volatile organic compounds) and soils (nitric oxide), production of pollens and other aeroallergens, and the number and duration of wildfires.[91] Studies project the severity and duration of air pollution episodes to increase in some areas of Canada because of a warming climate.[92] Air pollution can adversely affect cardiac and respiratory function, including damage to lung tissue, putting people with asthma or other breathing problems particularly at risk. In 2008, air pollution contributed to the death of more than 21,000 Canadians.[93] A rise in average local temperatures of 4°C could lead to a 5% increase in air pollutant-related health burdens on Canadian society relative to a 2002 baseline.[94]

GREATER EXPOSURE TO INFECTIOUS DISEASES. Climate change is increasing Canadians' exposure to infectious diseases transmitted via insects and mammals.[95] Warmer winters and warmer and more humid summers create conditions favourable for mosquitoes carrying West Nile.[96] The type of West Nile virus that first emerged in North America requires warmer temperatures than other strains; an increase in temperatures could result in higher levels of this type of virus.[97] Cold temperatures currently limit the geographic range of ticks carrying Lyme disease. Global temperatures at least 2°C over pre-industrial levels would accelerate the tick lifecycle and expand the northern limit of its range by 1,000 km, increasing the likelihood of transmitting Lyme disease to Canadians.[98] The introduction of new vector-borne diseases, such as Eastern Equine Encephalitis virus and St. Louis Encephalitis virus is possible. The risk of increased prevalence of tropical diseases such as malaria in Canada remains low in a changing climate.

BOX 9 EXPOSURE TO VECTOR AND WATER-BORNE DISEASE

Carried by ticks, Lyme disease, affects upward of 20,000 people annually in the United States. In a changing climate, warmer temperatures could expand the range of black-legged tick populations (*I. scapularis*) northward, exposing more Canadian to Lyme disease risks. Since 1997, new populations of the black-legged tick have been identified in southern Ontario, Nova Scotia, southeastern Manitoba, and New Brunswick, with data on Lyme disease cases suggesting a recent increase in the number of endemic cases in central and eastern Canada. In the decade prior to 2004, 15 cases were reported annually in these areas, but from 2004 to 2006, 69 cases were reported, with the annual incidence doubling in 2005 and 2006. As of this year, medical professionals must report cases of Lyme disease to the Public Health Agency of Canada by way of their regional public health systems.

Changing precipitation patterns heighten exposure risk to diseases transmitted via water. Prolonged drought followed by excess rainfalls was determined to be one of the factors contributing to the *E. Coli* outbreak in Walkerton, Ontario, in 2000 in which 2,300 people became sick and seven people died. Similar conditions contributed to a toxoplasmosis outbreak in Victoria, British Columbia, in 1994–1995 and a *Cryptosporidium* outbreak (causing gastrointestinal illness) in Milwaukee (United States) in 1993. In 2006, a million people in Vancouver, British Columbia, were subject to boil water advisories for nearly two weeks due to increased turbidity and the unacceptable quality of drinking water following a major rainstorm that affected three reservoirs in the area.

SOURCES: MACKENZIE ET AL. (1994); BOWIE ET AL. (1997); BGOSHU (2000); AULD ET AL, (2001); CENTERS FOR DISEASE CONTROL AND PREVENTION (2003); OGDEN ET AL. (2004); OGDEN ET AL. (2005); BERRANG-FORD (2006); CBC NEWS (2006); AND, OGDEN ET AL. (2008);LYME DISEASE FACT SHEET. HTTP://WWW.PHAC-ASPC.GC.CA/ID-MI/LYME-FS-ENG.PHP#S8

GREATER EXPOSURE TO DISEASES FROM WATER AND FOOD. Higher temperatures and changing patterns of intense rainfall events are associated with higher rates of water-and food-borne disease, particularly during summer months.[99] Higher temperatures increase the abundance of pathogens, such as bacteria, and intense rainfall events increase the odds of well water contamination. Pathogens currently contributing to outbreaks of water-borne diseases in North America include *Escherichia coli, Giardia, Cryptosporidium* and *Toxoplasma*. By crossing key thresholds, climate change may result in conditions favourable to more frequent and intense outbreaks of water-borne diseases. A 5°C increase in maximum daily temperature over a 42-day period quadruples the risk of disease outbreak.[100] Climate change may also allow the re-establishment of diseases previously eradicated in Canada such as leptospirosis and cholera.[101]

Food-borne diseases result from the ingestion of contaminated food, with *Salmonella, Campylobacter,* and *E. coli* being the most common food-borne pathogens in Canada.[102] Canada has an excellent food safety system in place, yet food production chains are sensitive to changes in climate conditions. Within limits, ambient temperatures influence survival rate of bacteria and parasites transmitted via food.[103] Longer summers with hotter temperatures, conditions expected in a changing climate, are likely to increase the number of cases of food-borne disease and lengthen the period over which they take place.

What we can do about it

Canada already has measures in place and the ability to protect the health of its population from hazards linked to environmental conditions. These safeguards include safe water (treatment); air and food regulations; high-quality public infrastructure such as storm sewer, drainage and sanitation systems; health infrastructures and services, including disease surveillance, public health programs, and vaccinations; and adequate income, housing and clothing to handle environmental conditions such as heat, cold, and pests. A changing climate will place increased demands on emergency hospital services and the health care system generally. Attaining public health standards will require adjustments in the health system to take into account future climate change impacts and their effect on vulnerable populations, such as low-income Canadians, Aboriginal Canadians, children, the elderly, and those with heart, breathing, and immunity problems. Understanding the health implications of climate change impacts in other sectors — such as public infrastructure systems — is also important.

Adaptive strategies include preventative and reactive measures. Some preventative strategies have less to do with the health system and more to do with land use, energy planning, and environmental policy. They include increasing albedo and planting trees to counteract the urban heat-island effect, and reducing emission of air pollutants. The first example addresses health impacts from extreme heat and the second from poor air quality. Other preventative strategies generally involve public information, early warning systems, and health services planning, and include heat alert and response systems, infectious disease surveillance and response plans, air quality indices, and smog advisories. Rather than taking action to prevent, avoid, or reduce health impacts, reactive approaches involve treating health impacts such as illness from heat-related events as they arise.

BOX 10 THE AIR QUALITY HEALTH INDEX

Health Canada and Environment Canada have recently developed an Air Quality Health Index (AQHI), a national index that provides information relating air pollution to health risk, disseminated with weather forecasts. A collaborative effort between federal, provincial, and local environmental health authorities, the AQHI is a tool to help Canadians protect their own health by limiting short-term exposure to adverse air quality and adjusting activity levels during air quality episodes. At present, the AQHI is tailored to local conditions in selected communities across all provinces but Alberta, and its reach is expected to expand over time. Measures to reduce chronic or long-term exposure to air pollutants are complementary to initiatives such as the AQHI.

HEALTH MESSAGES			
HEALTH RISK	AIR QUALITY HEALTH INDEX	AT RISK POPULATION (PEOPLE WITH HEART OR BREATHING PROBLEMS)	GENERAL POPULATION
LOW	1 - 3	ENJOY YOUR USUAL OUTDOOR ACTIVITIES	IDEAL AIR QUALITY FOR OUTDOOR ACTIVITIES
MODERATE	4 - 6	CONSIDER REDUCING OR RESCHEDULING STRENUOUS ACTIVITIES OUTDOORS IF YOU ARE EXPERIENCING SYMPTOMS	NO NEED TO MODIFY YOUR USUAL OUTDOOR ACTIVITIES UNLESS YOU EXPERIENCE SYMPTOMS SUSH AS COUGHING AND THROAT IRRITATION
HIGH	7 - 10	REDUCE OR RESCHEDULE STRENUOUS ACTIVITIES OUTDOORS. CHILDREN AND THE ELDERLY SHOULD ALSO TAKE IT EASY	CONSIDER REDUCING OR RESCHEDULING STRENUOUS ACTIVITIES OUTDOORS IF YOU EXPERIENCE SYMPTOMS SUCH AS COUGHING AND THROAT IRRITATION
VERY HIGH	ABOVE 10	AVOID STRENUOUS ACTIVITIES OUTDOORS. CHILDREN AND THE ELDERLY SHOULD ALSO AVOID OUTDOOR PHYSICAL EXERTION	REDUCE OR RESCHEDULE STRENUOUS ACTIVITIES OUTDOORS, ESPECIALLY IF YOU EXPERIENCE SYMPTOMS SUCH AS COUGHING AND THROAT IRRITATION

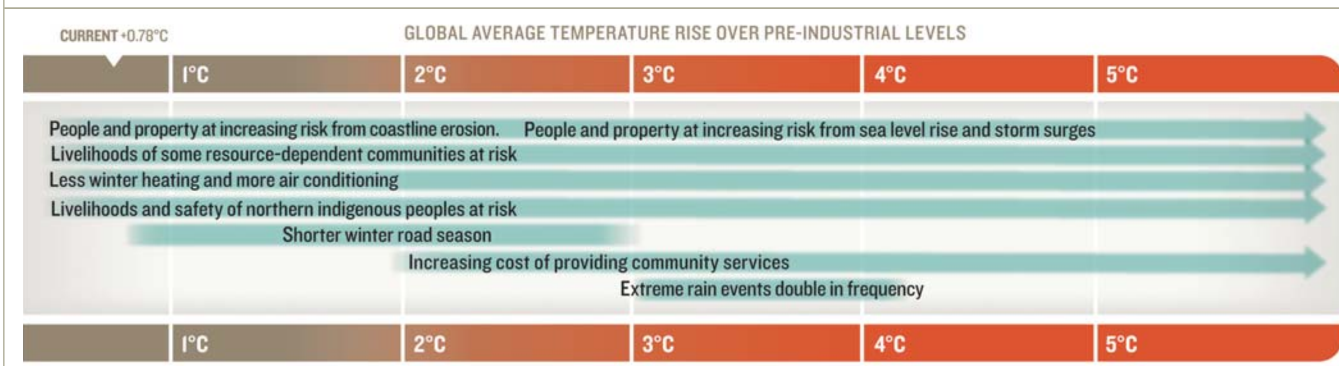
SOURCE: HTTP://WWW.EC.GC.CA/CAS-AQHI/DEFAULT.ASP?LANG=EN&N=065BE995-1#WHAT_IS_AQHI

COMMUNITIES AND INFRASTRUCTURE

This category pays special attention to coastal, resource-reliant, and northern communities in Canada. Each type of community presents characteristics that heighten its *vulnerability* to climate change, including exposure to climate impacts, direct links between climate and their economic base, and limitations in their capacity to adapt. At a length of 243,042 km, Canada's coastline and surrounding areas are home to a significant portion of the population; support substantial economic activity and infrastructure that is essential for trade, transportation, tourism, and culture; and encompass diverse land and aquatic ecosystems whose health is integral to the economy. "Primary" industries — agriculture, forestry, fishing, and hunting — may account for only around 2% of the national economy, but about 1,600 communities across Canada derive at least 30% of their income from one or more of these industries.[104] Communities in northern Canada are unique in their relationship with permafrost and sea ice, in their remoteness, and in the role of natural resources for subsistence and traditional activities.

This category also draws attention to some of the services that affect our quality of life and that we all rely on for our continued safety. Services derived from public and private infrastructure figure prominently here, as does the ability of governments to fund and deliver services that fulfil basic human needs and are essential for business continuity.

FIGURE 7 COMMUNITIES AND INFRASTRUCTURE



What we can expect

PEOPLE AND PROPERTY ON CANADA'S COASTS INCREASINGLY THREATENED. Sea ice protects coastlines from exposure to wave action and tidal surges. A warming climate is causing this ice to retreat earlier, with eastern Canada already experiencing accelerated erosion and degradation of coastlines, resulting in damage and loss of infrastructure such as roads and homes.[105] Portions of the Beaufort Sea coastline, including the community of Tuktoyaktuk, are highly sensitive to sea level change, and are now experiencing high erosion rates, accentuated by degradation of ground ice. Sea-level rise projected to the end of the century, combined with flooding from increasing storm surge risk, has important implications for communities along all three of Canada's marine coasts, including structural damage, disruption of key economic activities, inundation of wetlands and forests, and freshwater salinization.[106] Flooding and dike breaching in the Bay of Fundy and in the highly urbanized Fraser Delta area in greater Vancouver are particular concerns.

A one-metre sea-level rise would inundate more than 15,000 hectares of industrial and residential land, more than 4,600 hectares of farmland, and the Vancouver International Airport, all currently protected by dikes.[107] In Atlantic Canada, a 50-centimetre rise in sea level would inundate causeways, bridges, some marine facilities (e.g., ports, harbours), and municipal infrastructure, with replacement value estimated at hundreds of millions of dollars.[108] Sea-level rise, enhanced coastal erosion, and stronger storms pose risks to many small Canadian coastal settlements, such as the loss of natural and cultural heritage sites on Haida Gwaii (Queen Charlotte Islands).[109]

BOX 11 ATLANTIC SEA LEVELS AND STORM SURGE RISK

In several areas of Canada's coastline, sea levels have been rising and will continue to rise; climate change is now adding to this process. Natural Resources Canada (http://atlas.nrcan.gc.ca/auth/english/maps/climatechange/potentialimpacts/coastalsensitivitysealevelrise) classifies 80% of the Nova Scotia, New Brunswick, and Prince Edward Island coastlines as moderately or highly sensitive to sea-level rise. Rising sea levels in southeastern New Brunswick are already problematic, mostly due to temporary flooding and rapid erosion rates, and in the winter, when the Gulf of St. Lawrence is partially covered by sea ice, high water levels during storms push the ice cover inland, harming houses, roads, and other infrastructure.

A multi-partner study led by Environment Canada examined the risks of higher sea-levels and storm-surge risk in southeastern New Brunswick and options to address these risks. They looked at abandoning property and returning the most vulnerable areas to nature — commonly known as "retreat" — as one of the options. Retreat has not been popular among property owners, for whom protective barriers are often the preferred response. Discussions with local stakeholders repeatedly reveal that risk awareness does not translate well into willingness to relocate inland: people who live and work on the water want to be there and tend to resist leaving. The financial cost of retreat is also a real issue, which is only increasing as the value of coastal land rises, large houses replace smaller old ones, and new subdivisions appear. In Shediac Bay alone, the cost of vacating all properties within an average flood depth of 1.5 metres or more (Flood Classes 4, 5, and 6) as a result of a storm surge with a 3-metre water level amounted to: $2.8 million as compensation to the owners of 42 developed properties; close to $560,000 to the 52 owners of undeveloped properties; $50,400 per year in foregone provincial property taxes; and $49,700 per year in foregone municipal property taxes. However, with rising sea levels and storm surge risk, the cost of maintaining, rebuilding, and replacing protective structures so that they remain effective over the long term could well be much more.

SOURCE: ENVIRONMENT CANADA (2006) AS SUMMARIZED IN STOCKHOLM ENVIRONMENT INSTITUTE – U.S. CENTER (2010). COSTING CLIMATE IMPACTS AND ADAPTATION: A CANADIAN STUDY ON COASTAL ZONES, REPORT COMMISSIONED BY THE NATIONAL ROUND TABLE ON THE ENVIRONMENT AND THE ECONOMY

PEOPLE, PROPERTY, CULTURE, AND ECONOMIES IN NORTHERN COMMUNITIES AT RISK. A changing climate is already affecting livelihoods and the safety of individuals in some northern indigenous communities.[110] With warmer temperatures and other changes in climate indicators, the range and abundance of wildlife species crucial to livelihoods of indigenous peoples is shifting.[111] Less predictable weather, including an increased occurrence of unusual storm events, limits participation in traditional and subsistence activities, and increases the risk of being stranded in remote locations or involved in accidents.[112]

Warmer temperatures present risks to northern infrastructure and access to their services. In *True North: Adapting Infrastructure to Climate Change in Northern Canada*, informed by local northern observations and concerns, the NRTEE drew attention to recent events to highlight the baseline vulnerability of northern infrastructure to today's climate and prospects in a changing climate. Degradation of ice-rich permafrost, partly related to warmer air temperatures, can affect the integrity of northern infrastructure. At risk are building foundations, water and wastewater treatment and distribution facilities, road-beds, and pipelines whose engineering design does not adequately account for potential effects of climate warming on permafrost conditions over the service life of the structure. Northern Manitoba communities have already observed shorter winter road seasons and decreased quality of the winter roads themselves, linked to warmer temperatures.[113] In the Northwest Territories, the Mackenzie River Crossing Ice Road has seen delays in the average opening date of about three weeks since 1996.[114]

UNCERTAIN OUTLOOK FOR RESOURCE-RELIANT COMMUNITIES. Natural resources, such as soil, forests, and fish, are sensitive to changes in weather and climate, as are local economies reliant on the resource base. The mountain pine beetle outbreak in British Columbia already poses challenges to some forestry-dependent communities. The outbreak, combined with structural changes in global markets, significantly affects the long-term viability of the forest industry in this region.[115] Diminished water resources would affect municipal water supplies and challenge a range of sectors, including agriculture, fisheries, and energy.[116]

CHANGING DEMANDS FOR PUBLIC AND PRIVATE SERVICES, FROM ENERGY PROVISION TO ROAD MAINTENANCE. A changing climate adds a new dimension to energy planning. Warmer winters across Canada are expected to reduce demands for winter heating, with fewer *heating-degree days* already apparent in Québec and Ontario.[117] Conversely, higher temperatures are likely to increase demand for air conditioning in many parts of Canada. By the end of the century, Québec demand for residential heating could fall by 10 to 15%, and demand for air conditioning could increase 200 to 400%.[118] In British Columbia, demand for air conditioning could be 60% higher than 2005 levels at a global rise in temperatures of about 1.3°C.[119]

Extreme weather and climate events present real costs to local and regional governments and their residents. Annual damages to private buildings and property from weather extremes already amount to billions of dollars, according to insurance claims data, with claims from water damage as the fastest-growing category of all claims in Canada. Québec insurance payouts for claims mainly related to flash storms, sewer backups, and basement flooding in 2005–2006 represented a 25% jump in water-related payouts as a per cent of overall payouts from 2001-2002 levels.[120] More frequent and severe coastal and riverine flooding will likely place municipal water infrastructure (e.g., treatment and distribution facilities, pumps, and wastewater collection and treatment systems) at greater risk of failure.[121] More frequent and intense wildfires[122] are likely to increase fire-fighting costs in at-risk communities. Extreme rain events could double in frequency at global temperatures 3°C to 4°C higher than pre-industrial levels.[123] Individuals, insurance companies, and governments at all levels bear the costs of extreme weather and climate events.

The cost of maintaining roads and bridges could very well rise with warmer temperatures. In the summer, increased pavement temperatures may damage roadbeds and cause road surfaces to rut or crack, accelerating rehabilitation and reconstruction schedules.[124] Temperatures may hover near freezing more frequently, and the increased frequency of freeze-thaw cycles could exacerbate wear on pavement and bridges.[125]

What we can do about it

Adaptation options for climate-related challenges in coastal zones are well known and fall under three main categories: *protect* (build seawalls or other structural defences, beach nourishment), *accommodate* (build on piles, shift to drought or salt-tolerant crops), and *retreat* (abandon land). Governments play a key role in reducing vulnerability in coastal zones. In Richmond and Delta in Greater Vancouver, 220,000 people live at or below sea level, protected by 127 kilometres of dikes, which did not factor in rising sea levels in their initial design. In 2009, as part of its Climate Change Initiative, Delta adopted a flood management plan that includes upgrades to its sea wall, dikes, and related infrastructure, as well as a floodplain by-law to limit development.[126] New Brunswick implemented a forward-looking *Coastal Areas Protection Policy* in 2002 that addresses ecosystem health and, among other provisions, includes limitations on structural interventions that would affect sediment flows and coastline erosion. In response to coastal erosion and permafrost degradation, some northern communities are reinforcing shorelines and moving buildings inland.[127]

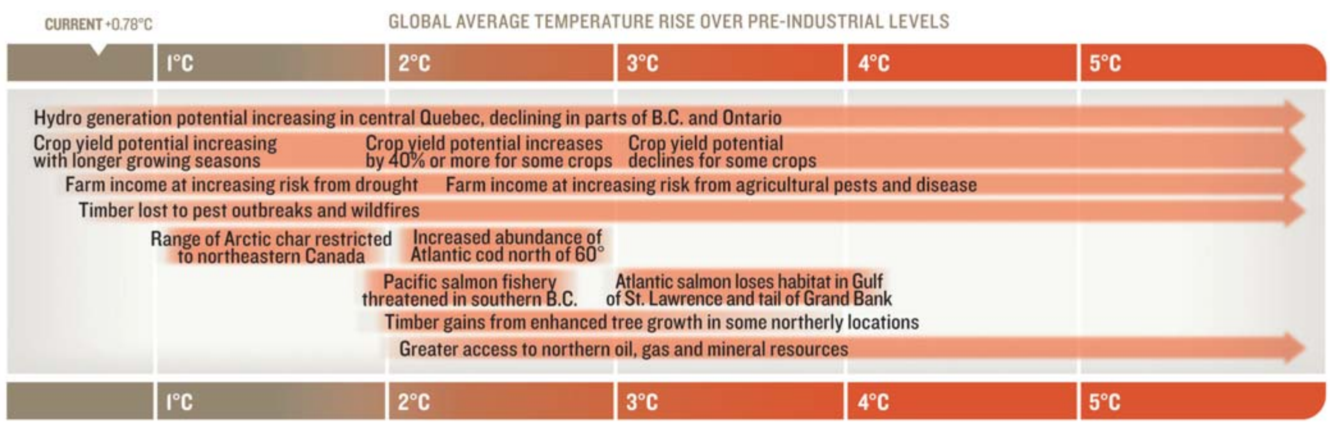
Community and sector planning, codes and standards, and insurance are important vehicles for adaptation to changes in weather and climate conditions. Emergency management plans in remote communities that include risks from climate-related hazards can help reduce vulnerability to these changing conditions. Utilities planning will need to factor in upgrades in water, sewage, and storm water infrastructure to deal with changed likelihoods and quantities of water. Adaptations to degrading permafrost are being introduced in northern Canada, including new engineering guidelines for building on permafrost terrain.[128] Climate change is already a factor considered in the design of major long-lived infrastructure, where the consequences of structural failure would be high. Resource-reliant communities susceptible to "boom and bust" cycles seek to adapt with social programs and economic diversification, assisted by rural development policy. Insurance companies provide *incentives*, including information, to encourage the implementation of loss prevention strategies, such as the installation of backwater valves in homes to avoid basement flooding.

RESOURCE INDUSTRIES

This category includes industry sectors that produce goods from natural resources. We highlight agriculture, forestry, fisheries, energy (electricity, oil and gas), and mining, the primary activities of which together accounted for about 9% of Canada's gross domestic product in 2008.[129] Significant manufacturing activity occurs in Canada with inputs from primary resource industries, including manufacturing and processing of food and beverages, wood products, pulp and paper, fuels, and mineral and metal products. The economic importance of specific resource industries at a regional level varies. Agriculture, forestry and/or fisheries activities are major sources of jobs in Newfoundland and Labrador, Prince Edward Island, Manitoba, and Saskatchewan, employing over 5% of the labour force in each province. Mining and oil and gas extraction is a significant source of jobs in Alberta and the Northwest Territories, also employing over 5% of each jurisdiction's labour force.[130]

Resource industries are sensitive to weather and climate. A changing climate is already affecting these industries, mainly in relation to changes in amount and timing of water availability and more intense and frequent extreme conditions and disturbances. Alongside global market forces, climate change is an important source of risk and opportunity for these industries into the future.

FIGURE 8 RESOURCE INDUSTRIES



What we can expect

POTENTIAL FOR GAINS IN AGRICULTURAL PRODUCTION. A changing climate could potentially benefit agriculture in parts of Canada as a result of longer growing seasons and more available heat, and in some places, more precipitation. Already, growing degree days in southern Québec increased by 20% between 1960 and 2005, improving growing conditions for most crops.[131] Warm-season crops and higher-yielding varieties become viable with increased temperatures, contingent on adequate levels of moisture.[132] Recent projections show increases in crop yield potential in Ontario, Québec, New Brunswick, Nova Scotia, Prince Edward Island, and Newfoundland and Labrador of 40 to 170% with global temperatures about 2°C to 3°C above pre-industrial levels.[133] Carbon levels in the atmosphere also influence crop yields, at least in the short term: additional carbon promotes photosynthesis in some crop types and reduces water stress by shrinking leaf pores.[134]

However, warmer temperatures will also increase crop damage due to heat stress and pest problems, resulting in diminishing returns and declining crop yields. For some crops, such as wheat and potatoes, this threshold may take place once *local* temperatures increase more than 3°C to 4°C above a 1961–1990 baseline.[135]

BOX 12 GROWING CANOLA IN A CHANGING CLIMATE

Common now to most grocery stores across Canada, canola oil came to the market over three decades ago thanks to the Saskatchewan and Manitoba plant breeders who successfully developed rapeseed varieties to yield food-grade oil. Seeded in all provinces but Newfoundland and Labrador, 99% of canola (an abbreviation of "Canadian oil, low acid") production occurs in Alberta, Saskatchewan, Manitoba, and the Peace River region of British Columbia. Canada is the second largest canola producer and fourth largest canola oil producer in the world, with much of our production going to export markets. In 2005, canola surpassed wheat as the country's most valuable field crop.

The outlook for canola production in a changing climate is mixed. In general, agriculture in the Prairies, Ontario, and Québec could benefit from an extension of 3 to 5 weeks of frost-free seasons, and from larger areas suitable for crop production. However, warmer temperatures mean higher rates of evapotranspiration, leading to water deficits. We can also expect more variable precipitation patterns to result in severe seasonal moisture deficits, particularly in Ontario, and southern Saskatchewan and Manitoba. A 2010 study on canola yields in Saskatchewan indicates potential losses of approximately 7% per degree increase in average temperatures over the growing season, 12% for every week (7 days) with maximum temperatures above 30°C, and gains of 2% for every 10mm of rain over the growing season. Some researchers in the Prairies are concerned about the potential for both more severe and frequent drought and unusually wet years, drawing attention to the fact that, between November 2009 and September 2010, much of the southern Prairies went from record dry to record wet conditions.

SOURCES: MOTHA AND BAIER (2005); CANOLA: A CANADIAN SUCCESS STORY, STATISTICS CANADA (2009) HTTP://WWW.STATCAN.GC.CA/PUB/96-325-X/2007000/ARTICLE/10778-ENG.PDF;; ALMARAZ (2009); KUTCHER ET AL. (2010); SAUCHYN, D. CLIMATE CHANGE RISKS TO WATER RESOURCES SOUTH SASKATCHEWAN RIVER BASIN. NRTEE / RCGS PANEL DISCUSSION, SASKATOON, 21 OCTOBER, 2010. PRAIRIE ADAPTATION RESEARCH COLLABORATIVE. UNIVERSITY OF REGINA

STABILITY OF FARM INCOMES AT RISK. A changing climate increases the risk of crop loss associated with weather and climate extremes, including droughts and intense storms. We can look to loss estimates from droughts in the early 21st century to consider potential implications. The droughts of 2001–2002 resulted in $3.6 billion worth of lost agricultural production in the Prairies, and contributed to a zero or negative farm incomes in Prince Edward Island, Saskatchewan, and Alberta.[136] In Ontario, droughts in 2000–2004 caused the Ontario Crop Insurance program to pay out about $600 million.[137] Evidence from studies of expected future runoff trends,[138] agricultural droughts,[139] and crop modelling work[140] indicates that Canadian agricultural producers are likely to face increasing economic risk due to water stress and drought.

Future crop loss from agricultural pests and disease is also a concern. Throughout Canada, warmer winters improve survival rates of insects, including agricultural pests.[141] In some regions, such as Atlantic Canada, wetter and warmer conditions tend to favour a more diverse pest population.[142] One study examining three agricultural pests concluded that their ranges expanded significantly at a 2°C global temperature rise above pre-industrial levels.[143] The net effect of climate change on plant diseases is less clear, with some diseases expected to increase and others decline.[144] Overall, however, the combined effect of changes in pest and disease patterns is likely to adversely affect agricultural production.[145]

UNCERTAIN OUTLOOK FOR FORESTRY, WITH SIGNIFICANT REGIONAL DIFFERENCES. A changing climate affects forestry directly through impacts on tree growth, and indirectly via wildfire, insects, storms, disease, and harvesting conditions. Changing patterns of forest disturbances have already produced visible effects on Canada's forests and related timber supplies.[146] Regional examples include the unprecedented outbreak of the mountain pine beetle in British Columbia and Alberta, the recent spruce bark beetle outbreak in Yukon, aspen dieback in the Prairies, high levels of fire activity in the western boreal forest, and record forest fire seasons in Yukon and British Columbia.[147] Forest stands affected by pests can result in relatively short-term increases in economic activity (salvaging pest-killed timber), followed by a sharp decline.

Warmer temperatures and increased carbon levels in the atmosphere at global temperature increases over 2°C could boost timber supplies by enhancing tree growth. The potential for productivity gains under a changing climate may only apply to easterly and northerly areas with relatively cool and moist climates; productivity could decrease in southern areas that are relatively hot and dry.[148] For example, we may see a decline in productivity of lodgepole pine in the foothills region of Alberta over the next century. Warmer and drier summers in southern British Columbia will likely reduce tree growth rates, regeneration success, and change wood quantity and quality. In addition, management of forest operations could become more challenging, as warmer winters affect access to the forest for logging and exacerbate ground disturbance from logging roads.[149]

GAINS AND LOSSES FOR FISHERIES. Fish species that are already under stress and at or near their southern range limit are likely to be further distressed by changes in ocean temperature and chemistry and by warmer temperatures in spawning habitat.[150] A 1°C to 2°C global temperature increase could contract the range of Arctic char by 40% or more compared to today, with complete extirpation in some areas and local declines in abundance in others.[151] Arctic char could see its range restricted to Nunavut, northern Québec, and Labrador; it is currently present across the Arctic coast, in islands in Hudson Bay, in a few coastal locations as far south as Newfoundland, New Brunswick, and the lakes of southeastern Québec.[152]

Pacific salmon stocks from the Fraser Basin are likely to see significant decline at global temperatures 2°C to 3°C over pre-industrial levels, whereas stocks that are more northerly (Skeena and Nass) could increase in abundance due to greater ocean productivity.[153]

In Atlantic Canada, warmer temperatures projected over the next century are likely to create unfavourable habitat conditions for several commercial fish species.[154] Atlantic salmon is among the species facing greatest habitat losses, with ranges contracted in Cape Cod, the tail of Grand Bank, and the Gulf of St. Lawrence. Atlantic cod could increase in abundance at up to global temperatures 2°C to 3°C over pre-industrial levels, but potentially declining at greater temperatures.[155] One study finds a general increase in catch potential for a range of species in Atlantic Canada at high latitudes.[156]

In the Great Lakes, cold-water fish populations have decreased by 60% in the last 20 years, and warm-water populations have increased by a similar magnitude.[157] Future warming is likely to continue to provide suitable habitats for warm-water fish at the expense of cold-water species.[158]

SHIFTS IN HYDROELECTRIC POTENTIAL. Climate change is likely to alter supply of electricity from hydroelectric systems,[159] mainly related to changes in runoff and competition with other water users. British Columbia is already experiencing constraints on generating capacity related to runoff deficits.[160] Decreased hydroelectric generation due to lower water levels in the Great Lakes could lead to economic losses of up to $660 million per year.[161] Higher annual inflows in central Québec could result in increased hydroelectric production from reservoir and run-of-the river operations and therefore, economic gain.[162]

GREATER ACCESS TO NORTHERN ENERGY AND MINERAL RESOURCES. A changing climate alters accessibility to the oil, gas, and mineral resource potential of Canada's North and to enhanced navigation options through increasingly open Arctic waters. A seasonally ice-free Northwest Passage would help accelerate the development of port and road infrastructure, stimulating additional resource exploration and extraction to meet growing demands from emerging economies.[163] However, increased access to the resource base and to marine distribution channels is one among several considerations in development decisions. Operational costs in a changing climate[164]— such as the need to shut down operations due to more frequent and intense storms — demand from global markets, environmental protection requirements, regulatory barriers, provisions for equitable distribution of resource revenues, among others, also influence the viability of new projects.

What we can do about it

In agriculture, adaptation to realize opportunities from increased heat involves adopting new varieties and new crops, particularly higher-value crops, which may require changes in inputs, resource use and management strategies.[165] Producers in most regions have strong adaptive capacity, because of a tradition of addressing drought and climate variability through short-term coping strategies. In the future, producers will need to adapt to increasing levels of moisture stress and changes in weather extremes. The forestry sector can adapt by planting tree species expected to thrive in the changing conditions for particular locations, and to adopt preventative strategies that attenuate the effects of wildfires, pests, and diseases.[166] Fishery regulators and businesses can adjust management strategies to the likely changes in fish populations. Decreasing fishing pressure, reducing stresses to fish populations unrelated to climate, employing spatial management such as marine protected areas, and changing fisheries targets and locations are all strategies to help promote the long-term viability of the fishing industry.[167] Sectoral planning can help avoid demand-supply mismatches for power, with climate change providing additional impetus to energy managers and regulators to diversify sources and promote energy efficiency. Strategies to promote regional economic development are important entry points for the integration of climate change considerations into plans and investments.

BOX 13 FORESTRY AND CLIMATE CHANGE ADAPTATION

Some forest companies, such as Mistik Management Limited in Saskatchewan, are updating their long-term management plans to reflect a growing exposure to drought, wildfires, and pest outbreaks in a changing climate. Based on recorded cases of drought and damage from natural disturbances, the Mistik Forest Management Area is among the regions in the province most susceptible to climate risk, leading to disruptions in forestry operations (view forest disturbance animation at http://www.mistik.ca/fma.htm#). As a result and as a proactive response, Mistik Management Limited incorporated a 20-year Forest Management Plan for its operations in this area. This plan explicitly includes a manageable planning horizon and takes into account the expected increase in natural hazards under future climate change. The company has also voluntarily become third-party certified in sustainable forest management practices, illustrating the potential of nationally- and internationally-recognized certification standards for influencing corporate operations and practices. Adaptive planning such as this enhances the economic sustainability of the forest industry and the safety and livelihoods of forest-dependent communities.

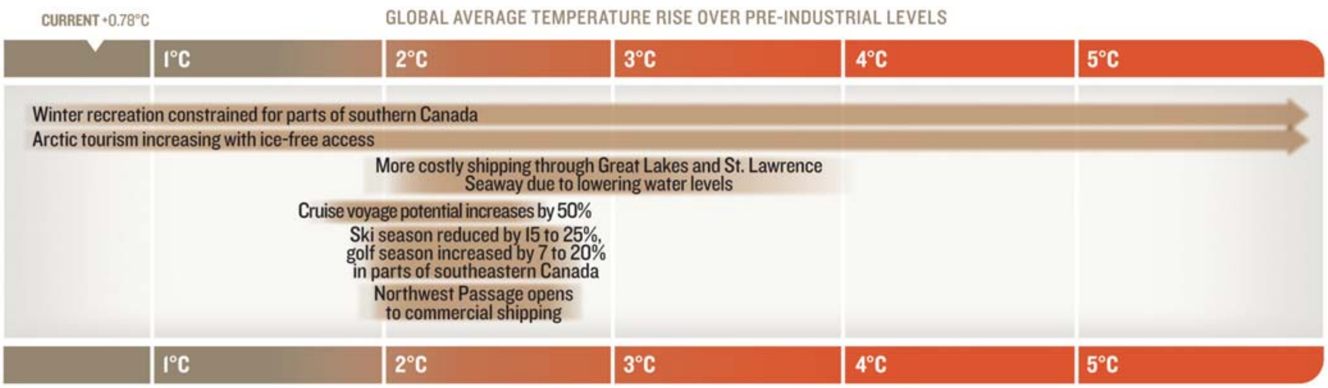
SOURCE: SHAW, A. ON BEHALF OF THE ADAPTATION TO CLIMATE CHANGE TEAM AT SFU (2010). TOWARDS A POLICY PATHWAY FOR AN ADAPTIVE CANADA: AN ANALYTICAL FRAMEWORK, REPORT COMMISSIONED BY THE NATIONAL ROUND TABLE ON THE ENVIRONMENT AND THE ECONOMY.

SERVICE INDUSTRIES

This category includes industry sectors that provide services that are highly valued — movement of goods and people, and access to culture, leisure, and recreation. Here we highlight water transport as a mode for freight activity. Despite the growth in trucking as a mode of transport in recent decades, freight transport via coastal shipping, the Great Lakes, and inland waterways remain an important input into the economy, conveyor of trade, and source of jobs. In 2008, water transport infrastructure handled approximately one in twenty tonnes of domestic freight.[168] Tourism and recreation are major contributors to the Canadian economy,[169] also providing spiritual and cultural value and opportunities for physical exercise. Every year, upward of 20 million foreign travellers come to Canada for leisure, in addition to the millions of trips made by Canadians within the country.[170] In 2008, each Canadian household spent an average of about $4,000 on recreation.[171]

The service industries we highlight here are sensitive to weather and climate in a few dimensions. Weather and climate affect operating costs, including the efficiency of supply chains and logistics. For tourism and recreation, weather conditions and factors such as snow quality influence consumer preferences for particular activities and destinations. As with some resource industries, climate change presents both risks and opportunities, and is one consideration among many in sector and business planning.

FIGURE 9 SERVICE INDUSTRIES



What we can expect

SHIFTS IN WATER-BASED SHIPPING. Increasingly open Arctic waters present opportunities to expand commercial shipping and transportation in general. The Northwest Passage, a series of channels linking the Pacific and Atlantic oceans, could be accessible for commercial shipping at global temperatures about 2°C over pre-industrial levels, with deep routes potentially accessible 30–50% of the time.[172] This major expansion of access could attract vast shipping traffic. The Northwest Passage is about 7,000 kilometres shorter than the shipping route used today through the Panama Canal, which would save about two weeks of travelling time between London and Tokyo.[173]

Projected declines in water levels in a changing climate could affect the long-term viability of shipping through the Great Lakes and St. Lawrence Seaway. Lower water levels would decrease the depth of navigation channels and leave docks and harbours stranded, particularly in shallow connecting channels and ports.[174] Ships would not be able to handle carrying their full capacity, requiring more trips for the same cargo.[175] For example, intra-lake shipping vessels experiencing a reduction in draft of one inch lose 270 tonnes of capacity.[176] Lower water levels expected at a global temperature rise upward of 2°C over pre-industrial levels could increase shipping costs between 5 and 40%.[177]

INCREASING TOURISM POTENTIAL WITH IMPROVED ACCESS TO THE ARCTIC. Already the opening up of southern Arctic waterways to cruise ships has seen the number of voyages to Arctic Canada double in the last five years.[178] Further seasonal ice-free access projected at global temperatures about 2 to 3°C above pre-industrial levels could see a 50% increase in cruise voyage potential.[179] Despite the potential increases in cruise shipping as sea ice retreats in Arctic waters, continued sea-ice hazards, public and commercial infrastructure requirements, and lack of supporting services are factors that could curtail growth.

CHANGES IN SEASONAL RECREATION ACTIVITIES. Shorter and milder winters pose challenges to winter recreational businesses, notably ski resorts. Conversely, some evidence shows that areas like Saguenay, Québec, have benefited from fewer cold waves and could continue to benefit in this way for the next 20 years or so.[180] Although substantial regional variability exists, by 2050 ski season length in parts of southeastern Canada could shorten an average of 20% relative to what it was in the late 1990s.[181] The snowmobile season could decrease by about half over the same period.[182] Despite shorter seasons, ski centres and trails that receive sufficient snow may benefit from reduced competition, and from snow-seeking tourists from northern United States.

Longer and warmer summers could benefit summer recreation.[183] By 2050, the golf season in parts of southeastern Canada could be 7 to 20% longer than what it was in the late 1990s.[184]The number of visitors to National Parks could also increase markedly over the same period.[185] Aside from visitation rates, climate change is likely to affect the timing and seasonality of visits, along with costs associated with ensuring the safety of staff and visitors. [186]

These projections for 2050 assume a global temperature rise of about 2°C to 3°C over pre-industrial levels.

BOX 14 CHANGING RECREATIONAL PATTERNS

Since the 1970s, yearly levels of precipitation in Canada have seen a downward trend, with snow cover also declining in many areas. Year-to-year and longer-term variations in climate conditions affect seasonal recreation, including our ability to enjoy the outdoors, and earn predictable revenues from these activities. In 2001-2002, four cross-country ski clubs (out of 14) of the Ontario Snow Resorts Association were unable to open for the season due to a warmer winter and poor snow conditions. During the same mild winter, the Rideau Canal Skateway in Ottawa opened nearly 6 weeks later than usual. The 2004 spring and summer were particularly cool and wet, affecting campgrounds, golf courses, provincial parks and beaches. For example, the Wasaga Beach area in Ontario saw a 40% drop in summer occupancy rates, hurting beach merchants' bottom line. In 2004–2005, a lack of snow caused by a wet and mild winter resulted in the early closure (pre-March break) of 60% of Whistler-Blackcomb's ski runs and a 14% decrease in skier-visits. However, later and more plentiful snowfalls the following winter season allowed the ski resort to remain open until early June.

SOURCES: TORONTO STAR (SEPTEMBER 7, 2004); GLOBE AND MAIL (MARCH 24, 2005); TORONTO STAR (SEPTEMBER 14, 2005); MONTREAL GAZETTE (APRIL 1, 2006);SCOTT AND JONES (2006A).

What we can do about it

Adaptation planning for enhanced Arctic transportation includes establishing protocols to safeguard Canadian interests, ensure marine transportation safety, and protect the environment and northern peoples in the face of increased shipping traffic.[187] In the Great Lakes and St. Lawrence Seaway, opportunities for engineering to deepen connecting channels are limited and costly, especially given concerns over release of contaminants from sediments.[188] Adaptations sufficient to maintain commercial shipping and transportation activity in the St. Lawrence at current levels range from minimal adjustments, such as changes in schedules, to costly investments in new and upgraded structures.[189]

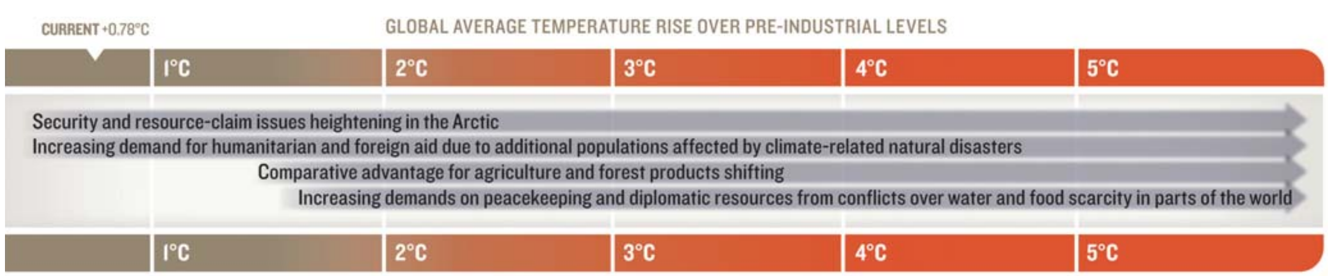
For tourism and recreation, adapting to the impacts of climate change involves adjusting business activities to realize opportunities, monitoring and adjusting activities in those areas where conditions are expected to be less favourable, and diversifying seasonal activities offered. Businesses are already adjusting to changing conditions, with, for example, ski resort operators investing in lifts to reach higher altitudes and in snowmaking equipment.[190] Arctic communities can plan for tourists in order to maximize local benefits and minimize risks from the influx of people from other parts of Canada or elsewhere.

SECURITY AND TRADE

This category focuses on security and trade to explore the implications for Canada of a warming world and responses to it outside our borders. Security is a value shared the world over. National security broadly refers to social, political, and economic stability of a country and its people, whereas human security centres on protection from fear and want, and empowerment for full participation in society. The exchange of goods and services with foreign markets through trade is a major feature of liberalized economies such as Canada's. In 2008 alone, Canadian exports to our top three trading partners — the United States, the United Kingdom, and Japan — amounted to $396 billion.[191]

A changing climate is fast becoming a key lens through which to consider Canada's place in the world, presenting both risks and opportunities. Climate change has risen to the agenda as a security issue in both international and Canadian fora. In 2007, for example, the United Nations Security Council discussed climate change as a potential driver of conflict around the world.[192] To mark its 20th anniversary, the NRTEE held high-level roundtable discussions in 2008 framing climate change as an issue of ecosystem security, energy security, and Arctic security.[193]

FIGURE 10 SECURITY AND TRADE



What we can expect

SECURITY ISSUES HEIGHTENED IN THE ARCTIC. International issues regarding security and resource claims could arise or heighten with improved access to the region via marine routes and to resources underlying it.[194] Canada may well require further investments to protect its national security interests, such as safeguarding the Arctic marine environment, enforcing control and ownership over the Northwest Passage, and asserting our Arctic sovereignty overall with a more visible military and civil defence infrastructure.[195]

SHIFTING COMPARATIVE ADVANTAGE IN TRADE. Canada's comparative advantage in some products and services may improve in a world 1.5°C warmer than pre-industrial levels, as the impacts of climate change constrain other countries' productive capacity.[196] Canada's position in the production and trade of wheat and grains, for example, may improve relative to the rest of the world.[197] In regions where growing conditions become favourable, an increase in domestic production of fruit and vegetables could help satisfy demands and reduce reliance on imports. A changing climate could also contribute to a rise in global timber production (from increased forest growth), affecting global markets in the next few decades.[198] Benefits would likely go to consumers, as producers would see lower world prices and a reduction in Canada's market share.[199]

INCREASING DEMAND FOR ASSISTANCE FOR AND RELIEF FROM CLIMATE-RELATED NATURAL DISASTERS. The number of severe damage-causing storms worldwide has doubled over the last three decades, leading to a rise in property loss and affected populations, and a concurrent rise in Canadian assistance to *disaster* victims.[200] Compounded by a rise in people and property in at-risk locations, more frequent and intense extreme weather and climate events expected in the future are likely to increase global demand for disaster relief and assistance. Increased international assistance will be required, among other reasons, to secure access to safe water and food supplies in order to reduce deaths and illness due to diarrhea and other diseases in post-disaster settings.[201] Canadians with businesses and property abroad could also place demands on disaster response services.[202]

BOX 15 CANADIAN NATURAL DISASTER ASSISTANCE

Canada and Canadians, along with governments and citizens of many other countries, have a history of supporting humanitarian assistance and disaster relief efforts. Highlighting recent disaster statistics and levels of Canadian financial support provides some context for considering future needs in a world with increasingly severe and frequent climate-related natural disasters.

Natural disasters in 2008 (including earthquakes) resulted in 235,000 deaths, 214 million people affected, and upward of $190 billion in economic costs. Droughts affected 12 million people in Asia and 14 million in Africa, and severe weather in May and June in the United States affected 11 million people. A single event in May 2008 -—Cyclone Nargis in Burma (Myanmar) — caused immense human suffering, with nearly 140,000 people found dead or missing. The Government of Canada responded to this disaster by disbursing almost $26 million. The same year, hurricanes, tropical storms, and flooding in Haiti affected more than 800,000 people and resulted in nearly $900 million in economic losses due to the destruction of thousands of homes and businesses. In this case, the Government of Canada responded by providing $10 million in relief aid.

In 2010, Canada contributed $40.5 million in response to Pakistan's worst monsoon flooding in 80 years.

SOURCES: CRED (2009); CIDA (2009); CIDA (2010A, 2010B)

INSTABILITY LINKED TO FOOD AND WATER SCARCITY. More frequent and intense extreme weather and climate events distributed across the world pose risks to the basic elements of life such as food production, water access, and health, acting as threat multipliers in regions of the world already unstable or inducing instability in stable regions. [203] Outcomes of such instability and unrest include migration and conflict, increasing demands on immigration, global peacekeeping and diplomacy as well as Canadian resources to contribute through our armed forces, humanitarian aid and other official development assistance.

What we can do about it

As a rich country with well-developed *governance* structures, *institutions*, and positive global influence, Canada already has many of the mechanisms in place to help mitigate the security issues highlighted here and position itself to take advantage of any potential gains from a changing climate. Strategies to increase awareness, enhance monitoring and intelligence, and promote integration of climate change risks and opportunities into decisions in policies and programs pertaining to international trade, national defence, international assistance, disaster risk reduction, and immigration are all important. Canada's Arctic Foreign Policy recognizes the effects of a changing climate on Arctic ecosystems and echoes the vision for the North as a *"healthy, prosperous and secure region within a strong and sovereign Canada"* previously outlined in Canada's Northern Strategy.[204] Canada played an active role in developing OECD policy guidance on integrating climate change adaptation into development cooperation released in 2009.[205]

PEOPLE, PLACES, AND PROSPERITY

WHAT *DEGREES OF CHANGE* MEANS FOR CANADA

// CHAPTER 03

3.1 PEOPLE, PLACES, AND PROSPERITY

The NRTEE's *Degrees of Change* diagram plainly shows that Canadians, the places where we live and that surround us, and how we make our living — people, places, and prosperity — all stand to be affected to varying degrees by a changing climate.

People

Whether rural or urban, southern or northern, a changing climate has implications for people. Climate change can affect physical and mental health, comfort and safety, and the very livelihoods of communities. Canadians have experience coping with weather hazards and risks from environmental phenomena, and climate change falls within this scope. Some evidence points to adaptation initiatives already undertaken by Canadians in reaction to recent environmental changes. For example, to deal with the rise in insect levels, northerners are installing window screens and using bug nets and insect repellent more frequently. Residents in remote coastal communities are better prepared to cope with temporary shortages in food and other goods and services resulting from inclement weather. Hunters in the Arctic are using global positioning systems to help find their way in unpredictable or adverse weather conditions.[206]

But as the impacts of climate change intensify and possibly accelerate, will Canadians be as well equipped to deal with these changing conditions? Is there a gap between how Canadians perceive risks of changing climate and what scientific assessments say about those risks? Are some groups of Canadians better positioned to deal with the changes ahead than others? Beyond information, what incentives might Canadians need to keep the climate in mind when making major investment decisions, such as the location of their house or expensive home retrofits? If climate change increases the price of goods (such as food and electricity) and services (such as insurance) who will be affected and how?

Governments in Canada and research organizations have started looking into these questions. Much of the effort is going into investigating human health impacts of climate change and public awareness and understanding of possible risks.[207] This research is informing changes to existing public health programs and helping to create new ones.

Others take a more hands-on approach. For example, the Canadian Public Health Association, in partnership with the College of Family Physicians of Canada, the Canadian Nurses Association, the Canadian School Boards' Association, Friends of the Earth, and TransAlta Corporation, has embarked on a two-part project to increase Canadians' knowledge of the health effects of climate change and air pollution issues. Their aim with this initiative is to change attitudes and encourage responsible individual and group action on climate change.[208]

A close look at the *Human health* and *Communities and infrastructure* categories of the *Degrees of Change* diagram leads to a basic conclusion: we need to also consider the social face of climate change adaptation and begin to take stock of the questions we pose here.

Places

Canadians will experience and perceive the impacts of climate change very differently across the country. For example, communities in coastal zones will likely see more and faster erosion, effects of more severe and frequent storm surges, and sea-level rise. Living on the Prairies could mean greater exposure to heat, drought, and precipitation patterns that are much more variable than in the past. The needs of urban life will lead to different approaches than in rural Canada, and the same is true of large cities compared to small towns. Place and the experiences of people within it will determine the degree of support for climate adaptation responses as a result.

Understanding the possible impacts of climate change on communities and economic sectors and adapting to them is a growing priority of provincial, territorial, and municipal governments. Many have either released or are working on climate strategies, frameworks, or policies that outline sectors vulnerable to the impacts of climate change, broad adaptation needs, and priorities in response. Naturally, the economic and environmental makeup of each jurisdiction is a good guide to the issues they profile. Building community and municipal capacity is a common theme for many jurisdictions. Supporting research and providing information, communicating the risks, helping internalize risks in planning, and funding community projects or case studies are approaches provinces and territories are taking to strengthen local capacity. Several jurisdictions are also partners in the federal *Regional Adaptation Collaboratives* program, a multi-million dollar *"cost-shared initiative to support coordinated action towards advancing regional climate change adaptation decision-making."* [209]

TABLE 2 AREAS OF FOCUS OF REGIONAL ADAPTATION COLLABORATIVES

PREPARING FOR CLIMATE CHANGE: SECURING BRITISH COLUMBIA'S WATER FUTURE	// WATER ALLOCATION AND USE
	// FOREST AND FISHERIES MANAGEMENT
	// FLOOD PROTECTION
	// COMMUNITY ADAPTATION

PRAIRIE REGIONAL ADAPTATION COLLABORATIVE	// WATER SUPPLY AND DEMAND
	// DROUGHT AND FLOOD PLANNING
	// FOREST AND GRASSLAND ECOSYSTEMS

ONTARIO REGIONAL ADAPTATION COLLABORATIVE	// EXTREME WEATHER RISK MANAGEMENT
	// WATER MANAGEMENT
	// COMMUNITY DEVELOPMENT PLANNING

REGIONAL ADAPTATION COLLABORATIVE – QUÉBEC	// BUILT ENVIRONMENT AND INFRASTRUCTURE
	// WATER MANAGEMENT
	// FORESTRY, AGRICULTURE, AND TOURISM SECTORS

ATLANTIC CLIMATE ADAPTATION SOLUTIONS	// COMMUNITY PLANNING FOR FLOOD AND COASTAL AREAS
	// GROUNDWATER PROTECTION
	// ENHANCING CAPACITY OF PRACTITIONERS, INCLUDING PLANNERS AND ENGINEERS

SOURCE: HTTP://ADAPTATION.NRCAN.GC.CA/COLLAB/COLCOL_E.PHP

In compiling the *Degrees of Change* diagram, our lens was national. However, it does highlight impacts specific to coastal Canada, the North, mountain regions, the B.C. interior, the Prairies, the Great Lakes region, and Québec, lending support to the conclusion that climate change presents different but real risks and some opportunities to all regions across Canada.

Prosperity

A changing climate will be a fundamental driver of economic change this century. Understanding how Canada can prosper through climate change — by transitioning to a low-carbon economy and by adapting to the risks and opportunities that a changing climate could bring — will help shape our economic future. The ongoing sustainability of Canada's resource industries and of some service industries depends, in part, on strategies taken now to address the risks and opportunities of a changing climate. Adaptation thinking is also critical to ensure the soundness of many public investment and policy choices, whether for upgrading community infrastructure, augmenting networks of protected habitat, reducing human pressures on our ecosystems, realigning trade promotion strategies in light of a shifting comparative trade advantage, or adjusting development assistance envelopes.

Yet it's unclear to what extent industry sectors, governments, and others are taking action to prevent future costs and take advantage of potential economic gains presented by a changing climate (see **Box 16**). Our analysis of Canadian survey responses to the *Carbon Disclosure Project* — an international effort to track corporate progress on managing climate change risks — and input from stakeholders leads us to conclude that corporate Canada's engagement on climate change adaptation is generally low. Awareness of impacts and adaptation lies in environment, health, and safety officers, not fully at senior management levels. In the CDP analysis, very few Canadian firms indicated that they were specifically engaged in risk management activity or business planning focused on examining the risks or opportunities from the impacts of climate change. A possible exception is the financial and insurance sectors. Responses from these sectors indicate that business planning related to climate change impacts may be more common than in other sectors.

BOX 16 BUSINESS OPPORTUNITIES IN A CHANGING CLIMATE

The NRTEE examined perceptions of Canadian businesses to potential risks and opportunities from the impacts of climate change. To do this, we analyzed six years' worth of responses by Canadian businesses to an annual survey administered by the Carbon Disclosure Project (CDP). The CDP administers a voluntary survey and targets top global firms, based on market capitalization.

Here we focus on the perceived opportunities reported. We examined business perceptions of four types of opportunities related to physical impacts of climate change: warmer temperatures and lower heating costs, business opportunities related to existing products and markets, business opportunities related to the development of new products and services, and other opportunities or opportunities related to indirect impacts. Here is what we found:

// One of the most common, specific examples of a business opportunity created by climate change relates to possible energy savings and lower heating costs from warmer winters. In a high-latitude country like Canada, these savings could be significant. Seven per cent of Canadian firms identified a potential benefit to their businesses from savings in warmer temperatures.

// Eighteen per cent of Canadian CDP responses identified potential benefits related to existing business lines. Opportunities in this area can stem from lower production costs, increased demand for goods or services, or reduced competition. Examples of Canadian companies that identified potential benefits of this type include Canadian Tire (increased demand for home repair and weatherization materials), Bombardier (increased demand for aircraft used in fighting forest fires), and several Canadian telecommunication firms that expect their services to be in greater demand due to climate change impacts. In addition, some firms, such as CN, expect they could benefit from reduced competition.

// Three-and-a-half per cent of Canadian business identified business opportunities related to new products and services. Most of those that did were either in financial services (relating to new financial products focused on climate change impacts), or energy, mining and materials firms, which tended to focus on possible opportunities emerging due to changing conditions in the Arctic.

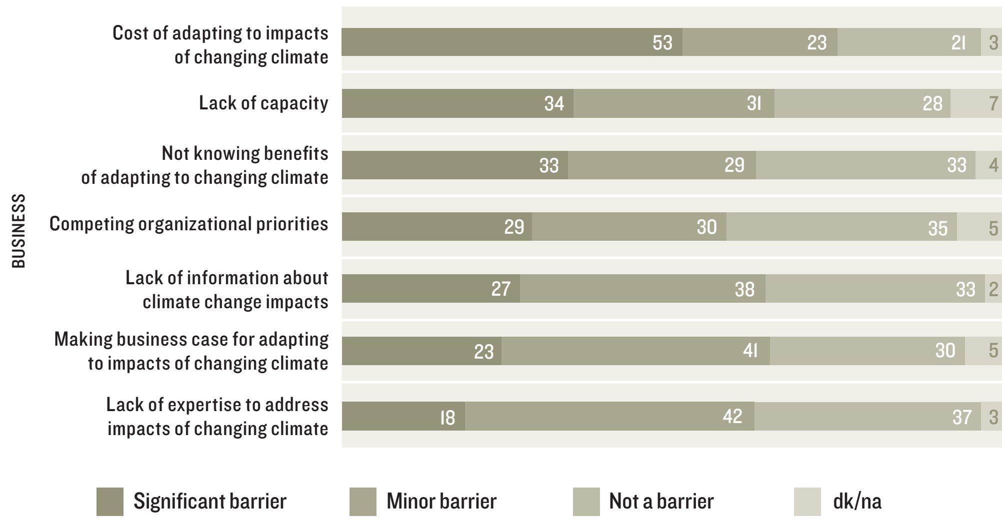
// Canadian firms highlighted a few examples of other/indirect opportunities, the majority of which were associated with the financial sector. Financial service firms stand to potentially benefit indirectly from physical impacts of climate change by an increased demand for infrastructure financing and other financial products motivated by a changing climate.

SOURCE: BERRY, R.D. (2009). *PREPAREDNESS OF CANADIAN BUSINESSES TO ADAPT TO CLIMATE CHANGE*, REPORT COMMISSIONED BY THE NATIONAL ROUND TABLE ON THE ENVIRONMENT AND THE ECONOMY.

Canada has conducted remarkably little economic analysis to date on climate change impacts, and even less so on the costs and benefits of adaptation. More has been done on the economic costs of reducing Canada's GHG emissions, by contrast. This conclusion comes from our review of economic studies costing climate change impacts in Canada or containing results for Canada. The federal government has identified quantitative economic analysis of the effects of climate change — and options for reducing those effects — as a key research need and knowledge gap.[210] Indeed, key decision makers in government and industry see the costs of adapting to a changing climate as the most significant barrier to moving forward (see **Figure 11**).

FIGURE 11 BARRIERS TO ADAPTATION DECISION MAKING

Barriers to taking climate change into account in decision-making



Barriers to taking climate change into account in decision-making

SIGNIFICANT BARRIER – BY TYPE OF GOVERNMENT	MUNICIPAL GOVERNMENT (N=174) %	PROVINCIAL GOVERNMENT (N=27[a]) %
COST OF ADAPTING TO IMPACTS OF CLIMATE CHANGE	60	74
COMPETING ORGANIZATIONAL PRIORITIES	56	67
LACK OF EXPERTISE TO ADDRESS IMPACTS OF CLIMATE CHANGE	43	30
COMPLEXITY OF POLICY CHANGE PROCESSES	39	41
NOT KNOWING BENEFITS OF ADAPTING TO CLIMATE CHANGE	31	22
NEED TO HAVE OTHER DEPARTMENTS/ORGANIZATIONS ACT FIRST	28	30
LACK OF INFORMATION ABOUT CLIMATE CHANGE AND ITS IMPACTS	26	19

[a]Very small base (<50) – extreme caution is advised in interpreting results.
Subsample: Those who either personally think, or whose organizations think, that climate change is happening or will happen in the future

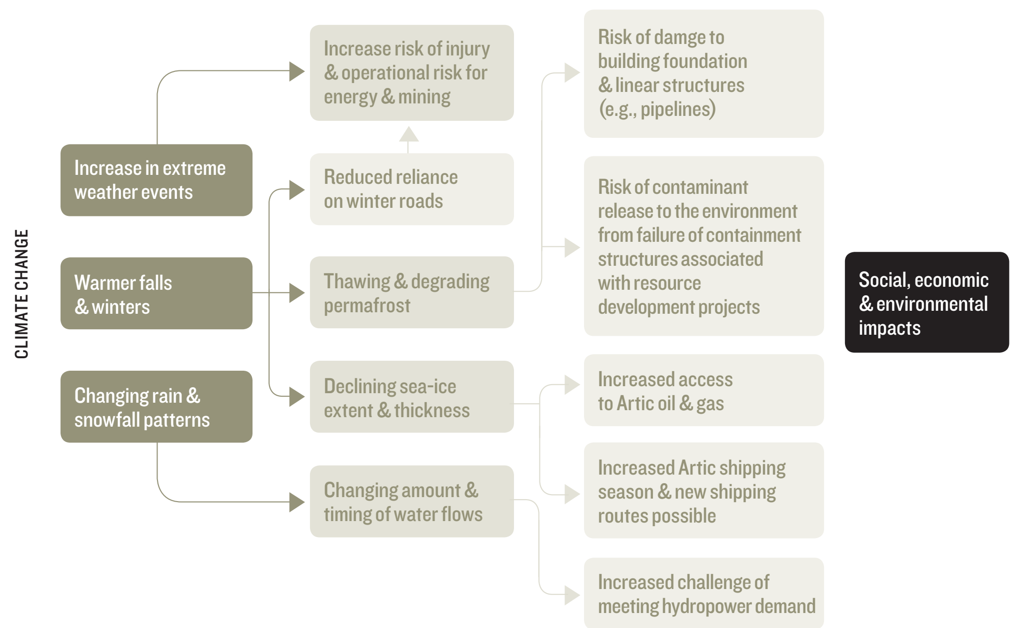
REPRODUCED FROM: NATIONAL CLIMATE CHANGE BENCHMARK SURVEY (APRIL 2010). PREPARED BY ENVIRONICS FOR NATURAL RESOURCES CANADA[211]

3.2 BUILDING A NATIONAL RESPONSE

In the *Degrees of Change* diagram, we use 60 data points to collectively illustrate that the impacts of climate change could be significant for Canada. The NRTEE believes an increased level of national coordination and purpose will be necessary to adapt to climate change for these reasons:

I // A changing climate affects many aspects of daily life, as we know it. The scope and scale of risk and opportunity exceeds the ability or responsibility of any one community, industry sector, or government to respond. Using Canada's North as an example, **Figure 12** illustrates the cascade of effects flowing from selected direct impacts of climate change — warmer temperature and shifting patterns of weather extremes and rain and snow fall. These direct impacts of climate change in turn result in physical impacts, including the depth of summer thaw and extent of permafrost and sea ice, and the flows in rivers. Along with particular regional characteristics, such as demographic and economic makeup, direct and physical impacts of climate cha nge combine to threaten human health and safety, the integrity of buildings, the cost of doing business, local job security, ecosystem health, and the overall well-being of communities. We can expect some of these effects to happen concurrently, alongside other pressures. And, although, households, communities, governments, and businesses will independently taken action to protect themselves if they are able, many problems will exceed the capacity or mandate of individual sectors or decision makers.

FIGURE 12 SOME EXAMPLES OF THE CASCADING EFFECTS OF CLIMATE CHANGE



SOURCE: BASED ON INFORMATION IN FURGAL AND PROWSE (2008)

2 // The diverse effects of climate change on Canadian regions and sectors preclude a "one-size-fits-all" approach, yet several benefits lie in leveraging experiences and resources. If summarizing what we know about how climate change could affect Canada is difficult, mandating adaptation targets that can apply to the entire country is unreasonable. Context matters greatly. The impacts of climate change are regionally variable as are their implications, and, within regions, pockets of demographic groups (Aboriginal peoples, children and the elderly), systems (networks of critical infrastructure), and particular economic activities are more vulnerable than others. Stimulating the sharing of lessons and resources across regions and internationally, minimizing duplication, preventing negative spill-over effects from one region or sector to another, and protecting the most vulnerable are all important functions to strengthen Canada's ability to prosper as a nation in a changing climate.

3 // Climate change presents risks but also opportunities. The possible opportunities created by the effects of a changing climate may require nurturing through the dedication of attention and resources. Too often, news coverage portrays climate change as a doom-and-gloom story of impending disaster.[212] Certainly, many of the possible impacts of climate change are likely to negatively affect us, and we must address them, but we should not ignore the possible opportunities that a changing climate could create in part by proactively adapting to them. Some economic sectors and businesses may do better because of the effects of climate change, and they should seek to identify those new economic opportunities and invest in pursuing them. Turning back to the example in **Figure 12**, reduced reliance on winter roads due to warmer average temperatures disrupts supply chains and increases costs for the mining companies operating in the region. On the flipside, this same impact presents an opportunity for road construction and logistics companies.

At the same time, we need to be realistic about what can be accomplished via adaptation. In previous sections of the report, we raised the speed of climate change as a limiting factor to adaptation of plants, animals, and the ecosystems they form. The potential also exists for Canada and the world to experience major effects of climate change abruptly and without warning, which would make adaptation a challenging prospect. The global climate is enormously complex, and scientists do not expect that the climate will change in a straightforward or "linear" way, with each year being warmer (or wetter, or drier, or windier) than the last. Although some kinds of change will be gradual, others may happen as *"tipping points"* — a phenomenon that is difficult to predict yet common in nature. At a regional level, the case of the mountain pine beetle in British Columbia is a good example of this kind of phenomenon. This beetle has always been a pest in the pine forests of British Columbia. However, several years ago warm winters and dry summers, combined with other factors, allowed the beetle population to cross a tipping point, resulting in an unprecedented outbreak. The implications of the 16.3 million hectares of forest affected by the beetle outbreak since 1999 are both short and long term, with a temporary economic boost from logging and processing the glut of affected trees, and a long-term decline in economic activity, and effects on regional hydrology, tourism, and recreation.[213]

These tipping points can also happen at the global scale, with sudden and large changes in the global climate and other components of the Earth system resulting in widespread effects that exceed the capacity of humans and ecosystems to adapt. Disappearance of Arctic sea ice, rapid melting of the Greenland and West Antarctic ice sheets, large-scale thawing of permafrost, and massive diebacks of major forests such as the boreal are examples of such catastrophic events causing self-reinforcing cycles that further contribute to climate change. Massive melting of ice and snow reduces the Earth's ability to reflect the sun's radiation back to the atmosphere, thus an ice-free Arctic, for example, traps more heat and amplifies warming. Widespread thawing of permafrost in certain types of terrain could potentially release large amounts of methane — a GHG — to the atmosphere, also amplifying warming.[214]

3.3 NAVIGATING UNCERTAIN CLIMATE FUTURES

Confronting the physical, social, and economic effects of climate change is not about adapting from the present climate to a new one, it is a matter of navigating through ongoing change, at least for the next several decades and likely through this century.

We need to adjust our decision-making frameworks to account for the basic reality that we will never have complete information about the precise magnitude and timing of future impacts of climate change at a given location. There are several reasons for this:

1 // There's uncertainty in the scale and speed of future changes in temperature, rain or snowfall, or any other weather or climate indicator.[215] Marked shifts in the chemical makeup of the atmosphere, principally the amount of heat-trapping gases, affect the global climate system. Our failure to predict with confidence the future composition of the atmosphere inhibits our ability to make predictions about the global climate system overall.

2 // We still lack a full understanding of the global climate and how it interacts with other components of the Earth system, like ice sheets and oceans, as the distribution of heat, energy and carbon changes. Our understanding of these relationships has advanced significantly over the past decades, and scientists continue to refine and update global models that forecast future climate conditions based on a combination of theory, climate records, and experiments.

3 // We have incomplete knowledge and understanding of how physical and biological systems at a regional or local level, such as river systems and forests, may respond to changes in climate conditions. With slight adjustments in their inner workings — such as the natural migration of tree species northward — biological systems may prove resilient to a certain level of change. In other cases, sources of stress that are unrelated to the climate, such as pollution or over-harvesting, can exacerbate the effects of climate change.

4 // Predicting human behaviour — the interaction of future economic development, technological progress, evolution in politics and governance, and demographic trends — is itself challenging. We have some idea of how decision makers at the national, regional, local, and household levels could act to limit climate change and manage its effects, but our estimations could turn out to be overly pessimistic or optimistic.

The reality is that we will have to get comfortable with making adaptation decisions under conditions of uncertainty. Uncertainty applies to any future event or phenomenon; it is not unique to climate change. We routinely make decisions under uncertainty, and have developed several approaches to managing and coping with uncertainty, including ignoring it. Engineers make decisions on structural tolerance levels for bridges and overpasses based on good enough, imperfect information. Government decision makers dedicate substantial public resources to addressing national security issues based on incomplete and uncertain information about the future of international terrorism and geopolitical alliances. With climate change, however, we face the prospect of several "unknown unknowns" looming on the horizon.

Guided by the precautionary principle and using approaches that treat risk explicitly provides a useful and manageable means of addressing both risk and uncertainty. The precautionary principle emphasizes that the absence of scientific certainty should not be used as an excuse to delay taking action, especially when faced with the possibility of irreversible damage.[216] Risk management and adaptive management approaches provide structured and consistent means of treating uncertainty and comparing actions against objectives.

That means moving away from trying to find "perfect" solutions and looking to strategies that minimize the costs, financial or otherwise, of being wrong.[217] These strategies include the following:

1 // Promoting long-term planning processes that include monitoring and review functions, and allow for the inclusion of new information as it becomes available. Long-term planning applies to areas such as coastal zone and watershed management, energy planning, and urban design and redevelopment. British Columbia's *Living Water Smart* initiative, for example, is a comprehensive plan to keep the province's water healthy and secure for the future. It comprises innovations to modernize the *Water Act*, including provisions for an efficient and flexible water-allocation scheme that can adapt to changing conditions.

2 // Prioritizing options with the potential to bring benefits even in the absence of climate change. "Win-win" options enhance the capacity of ecosystems, businesses, communities, and households to adapt to the effects of climate change and contribute to the achievement of environment, economic, or social outcomes, such as increased biodiversity, economic competitiveness, and poverty reduction. "No-regret" options reduce risks from current climate conditions, and include strategies to minimize damage from natural hazards. "Low-regret" options have relatively low or negligible costs, so even if it turned out that they were not required to address the future effects of climate change, there is low regret from incurring the (unnecessary) costs.

3 // Prioritizing strategies that are reversible and avoid "lock-in." Because of uncertain climate futures, decisions with long-term implications made today, such as zoning, siting major industrial operations, and building connecting and critical infrastructure, could constrain our options tomorrow and could prove costly over time. For example, building coastal protection structures as an adaptation option to safeguard homes and commercial operations from storms and sea-level change can perform well, provided they are designed to withstand changing climate conditions and are adequately maintained over their service life. If built, little incentive would exist for governments to discourage development along the seafront. However, the

combined effects of sea-level rise and storminess could turn out to be more intense than expected, periodically overtopping the coastal protection structures, flooding homes and businesses, and incurring reconstruction costs. The political benefits of continuing to invest in repairing and reinforcing the coastal protection structure would be high, yet the costs to constituents — including those who do not live on the coast — would accumulate over time.

SECURING CANADA'S PROSPERITY

IN A WARMING WORLD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4.0 SECURING CANADA'S PROSPERITY IN A WARMING WORLD

Canadians face risks and opportunities from a changing climate.

Along with its trading partners, Canada has committed to limiting global warming to 2°C. Even limiting warming to 2°C implies impacts, here and around the world.

An uncertain outlook does not change the need for enhanced adaptation action now. To secure Canada's prosperity through a changing climate, we need to understand that climate change will be a fundamental driver of economic risk and opportunity over the next few decades. The *Degrees of Change* diagram illustrates that climate change is not just an environmental issue, it will affect almost every aspect of life in Canada. Some of the economic effects of climate change will arise because of changes in Canada's climate. Other economic effects will arise because of changes in the climates of other countries and their responses to them.

Understanding the economic effects of climate change helps us to plan better for our future. It helps us figure out where we need to invest to mitigate damage and adapt to effects. If we have a better idea of the likely economic effects of climate change, we can better understand what is at stake if we fail to respond to the changing climate — and we can better understand how to respond in a way that safeguards our prosperity. We need to reframe adaptation as both economic necessity and an economic opportunity to limit future losses and prevent creating a long-term economic burden for Canadians not yet born.

Existing evidence on the costs of climate impacts and the costs and benefits of adaptation is limited. Canada's first national-scale assessment of climate change impacts and adaptation — the Canada Country Study[218] — concluded that the environmental, economic, and social costs in Canada would be large. Other studies since then have produced a varied picture, with some regions and sectors at significant economic risk, and others expected to do better. We do not have a good idea yet of what the overall economic implications could be. We need to develop one. Further evidence will help Canada move forward on cost-effective measures to reduce the economic costs of climate change. The existing evidence on the likely economic effects of climate change in Canada is insufficient to inspire or enable effective planning, either by governments or by businesses.

The NRTEE is moving forward with research on the economic risks and opportunities of a changing climate to help fill this knowledge gap.

The fourth report in our *Climate Prosperity* series will provide estimates of possible costs of climate change impacts over the next century, highlighting the economic risks and opportunities to Canada. It will also illustrate the role of adaptation in cost-effectively managing these risks and opportunities.

Minimizing economic risks and taking advantage of potential opportunities from a changing climate, in many cases, requires coordinated, deliberate, and sustained action across a number of priority areas. Grounded in case studies and experience of early adapters, the fifth report of the *Climate Prosperity* series, will offer advice to governments and others on a policy pathway to catalyze additional action and to sustain adaptation into the future.

Together, we hope these three reports on climate change impacts and adaptation and the knowledge and recommendations they bring will help secure Canada's prosperity in a warming world.

APPENDICES


Is this what the future will look like? – National Post
A rise of 2 degrees poses huge risks for Canada: study –thestar.com

5.1 GLOSSARY OF KEY TERMS

KEY TERMS	DEFINITION
ADAPTATION	Adjustment in natural or human systems in response to actual or expected climate stimuli and their effects, which moderates harm or exploits beneficial opportunities. There are various types of adaptation, including anticipatory, autonomous, and planned adaptation.[1*]
(ADAPTIVE) CAPACITY	The whole of capabilities, resources and institutions of a country, region, community or group to implement effective adaptation measures.[2*]
ADAPTIVE MANAGEMENT	Management that is responsive to, or even anticipatory of, changing functions of natural and human systems, evolving management purposes, and changing contextual conditions. This management approach acknowledges uncertainty, designing and implementing actions that are deliberately experimental and focused on learning from the effects of management. It emphasizes monitoring and participatory approaches as well.
ALBEDO	A value representing a body's ability to reflect solar radiation. It is quantified as the proportion of solar radiation of all wavelengths reflected by a body or surface to the amount directed upon it. Bodies with a high level of albedo, such as fresh snow (~95% albedo) will *reflect*, most solar radiation; whereas darker surfaces, such as dark, wet soil (~5% albedo) will *absorb* most solar radiation.[3*]
CAPTURE FISHERY	Activity involving the capture of wild fish (or other marine species), which leads to harvesting.
CLIMATE	Climate in a narrow sense is usually defined as the average weather or, more rigorously, as the statistical description of mean values and variability of variables such as surface temperature, precipitation, and wind over a period of time ranging from months to thousands or millions of years. Climate in a wider sense describes the state of the climate system.[1*]
CLIMATE CHANGE	Climate change is a significant and persistent change in an area's average climate conditions or their extremes.[4]
CLIMATE VARIABILITY	Seasonal variations and multi-year cycles (for example, El Niño Southern Oscillation) that produce warm, cool, wet, or dry periods across different regions are a natural part of climate variability.[4] Variability may be due to natural internal processes within the climate system (internal variability), or to variations in natural or anthropogenic external forcing (external variability).[5]

KEY TERMS	DEFINITION
DISASTER	Social phenomenon resulting from the intersection of a hazard with a vulnerability that exceeds or overwhelms the ability to cope and may cause harm to the safety, health, welfare, property or environment of people.[6]
ECOSYSTEM	The interactive system formed from all living organisms and their physical and chemical environment within a given area. Ecosystems cover a hierarchy of spatial scales.[1*]
ECOSYSTEM APPROACH (ECOSYSTEM-BASED MANAGEMENT)	A strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way. It applies appropriate scientific methodologies focused on the essential structure, processes, functions and interactions among organisms and their environment, and recognizes that humans, with their cultural diversity, are an integral component of many ecosystems.[1]
ECOZONE	Ecologically-distinct zones with characteristic plant and animal life and physical features.
EMERGENCY	A present or imminent event that requires prompt coordination of actions concerning persons or property to protect the health, safety or welfare of people, or to limit damage to property or the environment.[6]
EVAPOTRANSPIRATION	The combined process of water evaporation from the Earth's surface and transpiration from vegetation.[1]
EXTREME WEATHER EVENT	An event that is rare within its statistical reference distribution at a particular place. Definitions of "rare" vary, but an extreme weather event would normally be as rare as, or rarer than, the 10th or 90th percentile. By definition, the characteristics of what is called 'extreme weather' may vary from place to place.[1*]
FEEDBACK	When the result of an initial process triggers changes in a second process that in turn influences the initial one. A positive feedback intensifies the original process, and a negative feedback reduces it.[1*]
GLOBAL WARMING	The observed increase in average temperature near the Earth's surface and in the lowest layer of the atmosphere. In common usage, "global warming" often refers to the warming that has occurred as a result of increased emissions of greenhouse gases from human activities. Global warming is a type of climate change: it can also lead to other changes in climate conditions, such as changes in precipitation patterns.[4]
GOVERNANCE	The process whereby societies or organizations make important decisions, determine whom they involve, and how they render account.[7]

KEY TERMS	DEFINITION
HABITAT	The locality or natural home in which a particular plant, animal, or group of closely associated organisms lives.[1]
HEATING DEGREE DAY (HDD)	A measure to estimate the amount of energy (oil, natural gas, etc.) required for home and commercial heating or cooling. Taking the mean temperature for a day and comparing the figure to base temperature (usually 18°C), the figure provides a heating requirement estimate based on the difference from the base value.[8*]
HYDROLOGY	The local physical geography that mediates the movement, distribution, and quality of water throughout the earth, including both the hydrologic cycle and water resources.[9*]
INCENTIVES	Incentives broadly refer to mechanisms that encourage or discourage certain types of behaviour. Incentives can include relevant information, price signals, regulations, and financial rewards or penalties. Provision of or access to these incentives can be design or unintentional.
INFRASTRUCTURE	The physical foundation of a society, community or enterprise. Infrastructure comprises assets, installations or systems used to provide goods or services.[10]
INSTITUTIONS	Rules and norms that guide how people within societies live, work, and interact. Formal institutions are codified rules, such as the constitution, organized markets, or property rights. Informal institutions are rules governed by social or behavioural norms of a family, community or society.[11]
LIVELIHOOD	The ways and means of 'making a living', a livelihood comprises the capabilities, assets (including both material and social resources) and activities required for a means of living.[12*]
(NATURAL) HAZARD	An event or physical condition (e.g., floods, forest fires, landslides) that is a potential cause of fatalities, injuries, property damage, infrastructure damage, agricultural loss, environmental damage, business interruption, or other types of harm or loss. The magnitude of the phenomenon, the probability of its occurrence, and the extent and severity of its impact can vary, although in many cases may be anticipated or estimated.[13*]
PERMAFROST	Ground (soil or rock and included ice and organic material) that remains at or below 0°C for at least two consecutive years.[5]
RENEWABLE SUPPLY (OF FRESHWATER)	Water that is fully replaced in any given year through rain and snow that falls on continents and islands and flows through rivers and streams to the sea.[14]
RESILIENCE	The ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the same capacity for self-organization and the same capacity to adapt to stress and change.[1]

KEY TERMS	DEFINITION
RISK	A combination of the likelihood (probability of occurrence) and the consequences of an adverse event (e.g. climate-related hazard).[15] In line with the multi-dimensional character of climate change, the framing of risk considers these three questions: What can happen? How likely is it to happen? If it does happen, what are the consequences? Thus, risk from the impacts of climate change is an expectation that involves a threat or hazard (climate change as a source of or contributor to adverse outcomes), adverse outcomes (losses or harm to conditions that Canadians value such as healthy communities and ecosystems), and uncertainty of occurrence and outcomes (the likelihood of adverse outcome actually materializing).
RISK MANAGEMENT	A systematic approach to setting the best course of action under uncertainty, by applying management policies, procedures and practices to the tasks of analyzing, evaluating, controlling and communicating about risk issues.[16]
STAKEHOLDER	A person or an organization that has a legitimate interest in a project or entity, or would be affected by a particular action or policy.[1]
SUBPOPULATION	A geographically or otherwise distinct group within a wildlife species that has little demographic or genetic exchange with other such groups (COSEWIC refers to it as "population").[17]
THERMOSYPHONS	Self-powered refrigeration devices that are used to help keep permafrost cool and eliminate thaw settlement.[18*]
TIPPING POINT	A critical threshold at which a tiny perturbation can qualitatively alter the state of development of a system, resulting in, for example, dramatically altered ecosystems, financial markets, and widespread disease within a population.[19*]
URBAN HEAT-ISLAND EFFECT	The relative warmth of a city compared with surrounding rural areas, associated with changes in runoff, the concrete jungle effects on heat retention, changes in surface albedo, changes in pollution and aerosols, and so on.[1]
VULNERABILITY	Vulnerability to climate change is the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability to climate change is a function of the character, magnitude and rate of climate variation to which a system is exposed, its sensitivity and its adaptive capacity.[1*]
WATERSHED	An area of land that intercepts and drains precipitation through a particular river system or group of river systems.[20]
WEATHER	State of the atmosphere at a given time and place with regard to temperature, air pressure, humidity, wind, cloudiness and precipitation. The term is mainly used to describe conditions over short periods of time.[21]

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5.3 LIST OF EXPERT REVIEWERS

We asked several individuals for their expert feedback on the degrees of change diagram (and related documentation) as a whole, or parts of it. Reviewers provided many constructive comments and suggestions, but the NRTEE did not ask them to endorse the *Degrees of Change* diagram nor review the final diagram prior to its release.

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5.4 ENDNOTES

1 Estimated from: http://hadobs.metoffice.com/hadcrut3/diagnostics/global/nh+sh/annual. Accessed February 19, 2010.

2 IPCC (2007); Hansen et al. (2004).

3 See Figure TS1 in Parry et al. (2007).

4 Temperature departures from climate normals are from Table 2.7 in Statistics Canada's Human Activity and the Environment: Annual Statistics. See http://www.statcan.gc.ca/pub/16-201-x/2009000/t057-eng.htm Table 2.7 - Annual regional temperature departures from climate normal, trends, and extremes, 1948 to 2008. Accessed June 15, 2010. Environment Canada is the source quoted in Statistics Canada. Environment Canada, Meteorological Service of Canada, Climate Research Branch, 2009, Climate Trends and Variations Bulletin for Canada, Annual 2008, http://www.ec.gc.ca/adsc-cmda/default.asp?lang=En&n=F3D25729-1

5 These studies include the Canada Country Study (Mayor and Avis 1998), the report Climate Change Impacts and Adaptation: A Canadian Perspective (Lemmen and Warren [2004]), Arctic Climate Impact Assessment (2005), From Impacts to Adaptation: Canada in a Changing Climate 2007 (Lemmen et al. [2008]), and Human Health in a Changing Climate (Séguin[2008]).

6 This section draws from several sources, including Lemmen and Warren (2004).

7 Solomon et al. (2007); see likely ranges on Table TS.6, page 70. To express temperature change relative to pre-industrial times add 0.5ºC.

8 Natural Resources Canada, 2004, "Glaciers and Icefields," The Atlas of Canada, http://www.atlas.nrcan.gc.ca/site/english/maps/freshwater/distribution/glaciers/1 as cited in Statistics Canada (2008).

9 Atlas of Canada – Permafrost map (http://atlas.nrcan.gc.ca/site/english/maps/environment/land/permafrost

10 Lawrence et al. (2008); see also trend data from the National Snow and Ice Data Center at http://nsidc.org/arcticseaicenews/

11 Reading Figure 10.13 in Meehl et al. (2007), using an A2 or A1B scenario, we see a projected 50% reduction in summertime (July-August-September) ice extent relative to the period 1980 to 2000 around 2070 (central estimate), which corresponds to a global average temperature increase (from pre-industrial) of about 2.7°C using a central estimate from Figure 10.5 (Meehl et al. [2007]) (Dr. Greg Flato, personal communication, March 24, 2010). Sou and Flato (2009) find ice concentrations in the Canadian Arctic Archipelago to decrease by 45% by 2050 under a SRES A2 scenario, which corresponds to a best estimate of about 2.2°C (likely range 1.8-2.7), according to IPCC AR4 WGII Technical Summary Figure TS4. The NRTEE chose the 50% reduction in sea-ice extent to highlight a threshold that might resonate with readers.

12 National Academy of Sciences (2010), page 27.

13 Sou and Flato (2009).

14 Estimates for ice-free Arctic summers range from 2037 to 2100 (Wang and Overland [2009], Boe et al.[2009], Arzel et al.[2006], as cited in National Academy of Sciences[2010]).

15 Stroeve et al. (2007).

16 Woo et al.(2007). This study used scenarios A2 and B2; ~3.5°C lies between the best estimates of those two scenarios in 2100 (2090s), within a range of 3.1-4.2°C.

17 Bolch et al. (2010). Bolch et al's (2010) inventory of western Canadian glaciers suggests that glaciers in British Columbia and Alberta respectively lost −10.8±3.8% and −25.4%±4.1% of their area over the period 1985–2005. The region-wide annual shrinkage rate of −0.55% per year is comparable to rates reported for other mountain ranges in the late twentieth century. We position this impact statement at 0.6°C due to the difference in the global average temperature between the degrees of change diagram's pre-industrial baseline and 1985–2005, the period of Bolch et al's study.

18 M. Demuth (Natural Resources Canada), personal communication, April 1, 2010.

19 Schneeberger et al.(2003) project an average 60% loss in volume of a sub-set of glaciers in the northern hemisphere by 2050 under a global temperature rise consistent with a transient 2 x CO_2 equivalent corresponding to a IS92a emissions scenario. This subset includes glaciers in Alaska and northwest US. The global temperature rise over pre-industrial levels corresponding to 550 parts per million for the 2050s is a best estimate of about 2.1°C (range of 1.6-2.3°C), reading from Figure TS4, Technical Summary, IPCC (2007) WGII.

20 Walker Sydneysmith(2008); Matulla et al, (2009). Continued shrinkage of smaller glaciers is likely to continue beyond 2050 and may well result in total loss of some glaciers: "Most of BC's glaciers are losing mass and many will disappear in the next 100 years" (Walker and Sydneysmith [2008], page 341 – Box 1).

21 Focusing on the Peyto Glacier in Alberta, Matulla et al. (2009) conclude that moderate increases in winter snow and ice accumulations will not compensate for increased summer melt, leading to net wastage and potential disappearance of the glacier by 2100 (all scenarios range for 2090s is 2.5-4.8°C over pre-industrial levels, reading off Figure TS4, Technical Summary, IPCC (2007) WGII).

22 Zhang et al. (2010). This is a technical report that fed into the Canadian Biodiversity: Ecosystem Status and Trends 2010 report, a collaborative effort of the federal, provincial, and territorial governments of Canada. For further information, see http://www.biodivcanada.ca/default.asp?lang=En&n=E0DDE11F-1#X-201010191259305

23 Mote (2006).

24 Räisänen (2008); Brown and Mote (2009); Dr. Ross Brown, personal communication, March 29, 2010. Räisänen (2008) used an A1B scenario for the 2080s, which is associated with best estimate of 3.3°C in the 2080s (likely range: 2.6-4.3°C).

25 Solomon et al.(2007), TS18 – Bindoff et al. (2007) in Solomon et al.

26 National Academy of Sciences (2010), page 123 indicates an estimated range of global sea-level rise in 2100 of about 0.5 to 1m (using an A1B scenario). For that same scenario, Horton et al. (2008) project a global sea-level rise of 0.62 to 0.88m from 2001–2005 levels by 2100.

27 Vermeer & Rahmstorf (2009) project a sea-level rise of 0.97 to 1.56m above 1990 levels by 2100, based on global warming driven by an A1B scenario of global emissions. Pfeffer et al. (2008) conclude "that sea-level rise in the 21^{st} century is very unlikely to exceed 2m."

28 See http://www.noetix.on.ca/floeedge.htm

29 http://ecozones.ca/english/introduction.html

30 Wetlands include swamps, bogs, marshes, fens,and other areas where the soil is saturated either permanently or for part of the year (Statistics Canada 2010).

31 http://www.ec.gc.ca/default.asp?lang=En&n=540B1882-1 September 14, 2010.

32 Statistics are from http://canadaforests.nrcan.gc.ca/keyfacts. Carlson et al. (2010) describe the role of Canada's forests and peatlands in regulating the global climate and provide recommendations to maintain and enhance the carbon storage potential of these ecosystems.

33 Lemmen et al. (2008).

34 Solomon et al. (2007).

35 Harley et al. (2006).

36 Brierley and Kingsford (2009); Denman (2008); Hoegh-Guldberg (2007).

37 Harley et al.(2006), Herr & Galland (2009).

38 Herr & Galland (2009).

39 Oasis of the Deep: Cold Water Corals of Canada. http://www.science.gc.ca/default.asp?lang=En&n=EE39B64D-1 accessed on October 31, 2010.

40 Pierce et al. (2006).

41 Okey et al. (2010).

42 Lehman (2002) project warming of lake surfaces by 2100 leading to accelerated dissolved oxygen use, and consequent oxygen depletion, which can limit habitat for various species of fish (Mortsch et al. 2003), and have various other negative ecosystem consequences. The all-scenarios range for 2100 (2090s), using best estimates, is 2.3-4.5°C.

43 Lemmen et al. (2008); Soja et al.(2007); Burns et al.(2003); Parmesan & Yohe (2003); Walther et al. (2002).

44 Chmura et al. (2005).

45 Jones et al. (2009).

46 Based on multiple model runs and comparing temperature increases from the 20th century to 2080s, Scholze et al. (2006) estimate a one-in-three chance of losing 20% of boreal forest at a global temperature increase over pre-industrial levels of 3.5°C (see Table 2; note that we added 0.5°C to reflect temperature change in 20th century).

47 Tundra loss could also be significant, as the boreal moves north. A moderate projection for 2100 for the replacement of tundra areas by forest is about 10% (Sitch et al.,[2003]; see Figure 15.3). The year 2100 (2090s) corresponds to a best estimate of 4.2°C above pre-industrial levels in the A2 scenario (likely range 3.3-5.3°C).

48 Beaubien & Freeland (2000), as referenced in Sauchyn & Kulshreshtha (2008).

49 Current land-based protected areas and parks, in Canada and globally, are likely to see significant changes in their biodiversity (Hannah et al. [2002]). Loarie et al. (2009) used B1, A2, and A1B scenarios (2050–2100) to estimate relative speeds required to keep pace with climate change per global ecosystem, taking into account habitat fragmentation. Based on current protected areas, they used the indicator “time for current climate to cross a protected area” to rank ecosystem vulnerability. From least to most changed, the ranking for Canadian ecosystems is tundra (mean 74.6), temperate coniferous forests (12.7), temperate grasslands, savannas and shrubland (1.8), temperate broadleaf and mixed forest (1.7), boreal forests / taiga (1.1). Temperature position on *Degrees of Change* is the range of best estimates for 2050s (low end of range) and 2100 (2090s) (high end of range), using B1 as lower bound and A2 as higher bound of range. Earlier work (Scott and Suffling [2000]) suggests that 75-80% of Canadian National Parks will experience shifts in dominant vegetation for a doubling of CO_2.

50 See, for example, Kurtz et al. (2008) and Flannigan et al. (2005).

51 Amiro et al. (2001) noted that area burned had shown an increasing trend over the 1980–1999 period relative to previous decades.

52 Based on analysis on western North America using the A2 SRES, Balshi et al. (2009) projected an increase in the average area burned per decade on the order of 350 –550% by the last decade of the 21st century.

53 Flannigan et al. (2005) projected ~ 74%–118% increase in area burned by the end of this century compared to a 1961–1990 baseline for a 3 × CO2 scenario for Canada (a high global emissions scenario). In Flannigan et al., forest area burned in the west ranges from 200–400% increase. Temperature position on Degrees of Change is the likely range for 2100 (2090s) using an A2 SRES scenario (high global emissions).

54 Williamson et al. (2009); Fleming et al. (2002).

55 We select these as examples among many. In its 2007 scientific assessment, the Intergovernmental Panel on Climate Change indicated “about 20 to 30% species at increasingly high risk of extinction” at global temperatures 2°C above pre-industrial levels and “major extinctions around the globe” at about 4°C of global warming (Parry et al.[2007], page 67, Table TS.3). Three key factors contribute to extinction risk: (1) a small range size, (2) a small population size, and (3) dependence on habitat or other species that are themselves at risk from a range of factors (e.g., pollution, overuse, poaching, climate change) (Rabinowitz et al., [1986], as cited in National Academy of Sciences [2010]).

56 Moore & Huntington (2008); Johannessen & Macdonald (2008).

57 Moore & Huntington (2008).

58 Stirling & Parkinson (2006).

59 Regehr et al. (2007). On the *Degrees of Change* diagram, this impact is positioned toward the lower end of the global temperature range projected for 2100 (2090s) to account for existing evidence of the threat. Note also that figure TS.6 in IPCC (2007) AR4 Working Group II technical summary indicates “extinction risk for polar species” at 2.5 degrees above pre-industrial levels.

60 Jones & Henry (2003). According to Hudson & Henry (2009), warmer temperatures and longer growing seasons have already started to increase plant productivity in tundra communities of the high Arctic.

61 Jessen & Patton (2008).

62 Scott et al.(2002); Suffling et al.(2002).

63 Statistics Canada (2010).

64 Vincent & Mekis (2006).

65 Bruce et al. (2000).

66 Milly et al. (2005) show increasing run off in the territories, and in Quebec and Newfoundland and Labrador in 2050 based on SRES A1B. Similar results are found in a global assessment by Falloon et al. (2006). There is already some evidence for increasing run-off in the Northwest Territories (St Jacques & Sauchyn 2009), so we place the impact "Run-off in northern and eastern Canada increasing" on the diagram using a range that reflects the current limited observations and the projections for 2050 (upper end of likely range for A1B scenario). Note that there is some contention in the cold region hydrology community that the increases in river flow detected, presumably on account of permafrost degradation in the once instance (St Jaques and Sauchyn), may be because of less water going into storage because river ice formation and growth is retarded under a warming influence (M. Demuth, personal communication, April 1, 2010).

67 Jansson et al. (2003); Pietroniro et al. (2006); Fleming and Clarke (2005).

68 The early increase in glacier run-off may have already occurred in some basins (Demuth and Pietroniro [2003]; Stahl and Moore [2006]; Comeau et al,[2009]). Evidence supporting the past peak decline notwithstanding, a period of flow enhancement may not be out of the question. Rigorous hydrological modelling estimates using best possible estimates of future glacier cover scenarios have yet to be produced (M. Demuth, personal communication, April 1, 2010).

69 The end of temperature range (around 4°C) for this impact on the degrees of change diagram corresponds to the expected decline in glacier volumes (see "What we can expect" in the section under ice, snow and sea).

70 For example, Lapp et al. (2005) project substantial decreases in spring runoff due to a decline in snowpack in watersheds in western Canada. This has significant implications for seasonal flows.

71 Vasseur & Catto (2008).

72 Martz et al. (2007); Bruce et al. (2000),

73 Martz et al. (2007) estimated a 2–36% decrease in surface water availability in a 2 x CO_2 scenario. Pietroniro et al. (2006) estimate an 8.5% decrease in flows in the 2050s. Taking into account both estimates, we position the impact statement on the Degrees of Change diagram between 1.9 and 2.8°C (best estimates for range of SRES scenarios for 2050s, reading off AR4 WGII Figure TS4 and represented relative to pre-industrial levels). These studies are consistent with the findings of Milly et al. (2005) and Falloon et al. (2006).

74 Sauchyn et al. (2005) calculated the aridity index for the Prairies in 2050 under a B2 scenario and projected that the area of land at risk of desertification will increase 50% by mid-century. We used likely range for B2 scenario to plot this impact on the Degrees of Change diagram.

75 Early studies suggested that prairie drought frequency could double with a 2x CO_2 warming scenario (Williams et al. 1988; this corresponds to approximately 550ppm CO_2 at 2080s, which is about 2.6°C according to AR4 WGII Figure TS4 and represented relative to pre-industrial levels). More recent projections (Sheffield and Wood [2007]) show a doubling to quadrupling in the frequency of droughts lasting 4–6 months for Western North America (including the prairies), and a slight increase in drought frequency for Eastern Canada for the A1B and A2 scenarios by the end of the 21st century. They found smaller increases in the frequency of long droughts lasting 12 months or more. Burke et al. (2006) describe similar findings. The temperature range shown in the diagram is based on best estimates from the combination of Williams et al. and Sheffield and Wood, establishing low and high ends of the range (2.6-3.9°C).

76 Merritt et al.(2006).

77 Lemmen & Warren (2004); Moulton & Cuthbert(2000).

78 Lemmen et al. (2008); Bruce et al. (2000).

79 Bruce et al. (2003) project challenges to meeting boundary and transboundary water agreements for several river systems in 2050 under an A2 scenario. Cohen et al. (2000) model the effects of warming on the transboundary Columbia River system, and conclude that "Climate change has the potential to increase the level of current conflicts and to create new ones". By highlighting potential water availability issues in a changing climate in the Okanagan, Poplar, and Red River basins, as well as the Great Lakes basin, Koshida et al. (2005) also suggest that there may be heightened competition for water resources in some basins as a result of warming. Bruce & Haites (2008) also discuss issues meeting transboundary water sharing agreements. In plotting this impact on degrees of change, we use the likely ranges for the A2 scenario for 2050s and 2080s to bookend low and high end of range, but this impact is likely to continue beyond the high end of range.

80 Field et al. (2007).

81 Mortsch et al. (2003); Murdoch et al.(2000).

82 Lemmen & Warren (2004).

83 Murdoch et al.(2000).

84 OECD Health Data 2010 (under "frequently requested data"), retrieved on July 30, 2010 from: http://www.oecd.org/document/30/0,3343,en_2649_34631_12968734_1_1_1_1,00.html

85 Retrieved July 30, 2010 http://www.rms.com/publications/1998_Ice_Storm_Retrospective.pdf

86 See Berry et al. (2008) for a comprehensive assessment of the health impacts of climate change-related natural hazards. Analyzing data the Public Safety disaster database suggests an upward trend in weather and climate-related disasters: we estimated that the ten-year average number of disasters from weather and climate-related hazards increased from about four to fourteen between 1950 and 2001.

87 See Table 6 in Warren & Egginton (2008).

88 Etkin et al. (2004).

89 Hengeveld et al. (2005) reported a four to six-fold increase in number of hot days over 30°C for six Canadian southern cities by the last couple of decades of this century, compared to a 1961–1990 baseline.

90 Cheng et al. (2005) found that heat wave deaths are expected to more than double by the 2050s and triple by the 2080s (based on IS92a and SRES A2 and B2); current annual average heat wave deaths in only four cities are 320, including other cities across Canada, in addition to population growth, results in an estimate of 3000 heat wave deaths per year for 2080s. In the Degrees of Change diagram, we plot this impact along the global temperature scale using best estimates for 2050s for IS92a (low) and A2 (high), two of the scenarios used by Cheng et al.

91 Prather et al. (2003); Hogrefe et al.(2004); Lagner et al.(2005); Seguin (2008); Lamy & Bouchet (2008).

92 Mickley et al. (2004), Leung & Gustafson Jr. (2005)

93 Canadian Medical Association (2008).

94 Lamy & Bouchet (2008) assessed the national health impacts of air quality changes from a 4° C increase in ambient temperatures, considering changes in ground level ozone and particulate matter. Relative to a 2002 baseline incidence, they found a 5% increase in air pollutant-related health burden to Canadian society. In the degrees of change diagram, we plot this impact along the global temperature scale at 2.7°C (which accounts for Lamy and Bouchet's use of local temperatures as bases for scenarios). IPCC (2007) Working Group II technical summary Table TS4 highlights "about 70% increase in hazardous ozone days" for North America between 2.5-4°C above pre-industrial temperatures.

95 For a comprehensive review of the state of knowledge of Canadians' vulnerability to vector, food, and water-borne disease linked to a changing climate, see Charron et al. (2008). Increased exposure to infectious diseases in connection to climate change is not only a concern for humans. Purse et al. (2005) describe a resurgence in bluetongue disease, a devastating illness affecting ruminants (such as cattle) in Europe.

96 Charron et al. (2008)

97 Public Health Agency of Canada (2007)

98 Ogden et al. (2006) project an expansion of the tick's range by 1000km in 2080s, using an A2 scenario (this corresponds to a likely range of 2–4.6°C global temperature rise above pre-industrial levels).

99 Curriero et al. (2002); Charron et al. 2008.

100 See Thomas et al. ((2006) for details on this relationship and its implications. In the degrees of change diagram, we plot the impact related to water-borne diseases along a temperature range that reflects the potential for poorer water quality in some regions and vulnerability due to increased extreme rainfall events (1–3.9°C).

101 Charron et al. (2008).

102 Public Health Agency of Canada (2003).

103 Hall et al. (2002).

104 We estimated the proportion of GDP contribution from primary industries using data from Statistics Canada Catalogue no. 15-001-X; the number of resource-reliant communities is from Natural Resources Canada (2006).

105 Vasseur & Catto (2008); Bourque & Simonet (2008).

106 The Bay of Fundy is susceptible to a combination of sea-level rise, high tides and storm surges (Forbes et al. [1997]; Bruce [2000]); projected for 2050s, which corresponds to about 2°C. Additional work by Ouranos on coastal communities in Quebec confirms these risks (Savard et al. [2009]); and risks to communities in the Fraser Delta are described in Walker & Sydneysmith (2008).

107 Andrey et al.(1999).

108 McCulloch et al. (2002).

109 Walker et al. (2007).

110 Nutall et al. (2005).

111 Ford et al. (2006).

112 Ford et al. (2006); Furgal and Prowse (2008); Furgal et al. (2008).

113 Centre for Indigenous Environmental Resources (2006); Furgal and Prowse (2008). The length of the winter road season is projected to decline by 2 weeks by the 2080s (CIER 2006). Much of the observed change in season duration in Manitoba and Northwest Territories has taken place in the past 10 years or so (CIER 2006). This impact is placed on the Degrees of Change diagram at a temperature range between current observations (~0.8°C) and the projection for 2080s (central value of 3°C across range of SRES scenarios).

114 Furgal and Prowse (2008).

115 Williamson et al. (2008); Walton (2009).

116 Vasseur & Catto(2008).

117 Bhartenu & Cohen (1987); Lafrance & Desjarlais (2006).; Chiotti and Lavender (2008).

118 Ouranos (2004).

119 Walker & Sydneysmith (2008) report an increase in demand for space cooling of 60% over 2005 levels by 2025 in British Columbia, which translates to ~1.3°C increase in global temperatures above pre-industrial levels.

120 The Gazette (Montreal). These are the downpour days, June 30, 2008. Retrieved from http://www.canada.com/montrealgazette/news/story.html?id=175a694f-c132-4cb0-a071-d10993bb4408

121 Bruce et al. (2000).

122 E.g., Balshi et al. (2009).

123 Using IS92, A2 and B2 scenarios, Kharin and Zwiers (2005) assessed global and regional changes in the probability of precipitation events that are considered extreme in the year 2000 (20-yr return values of annual 24-h precipitation extremes) and found that the "associated return periods of year 2000 extreme events are reduced everywhere by a factor of 2" by the end of the 21st century. The temperature range we used to plot this impact on the diagram corresponds to best estimates of these three scenarios in 2100 (2090s).

124 Canadian Council of Professional Engineers (2008).

125 Tighe (2008).

126 Corporation of Delta (2009). Climate Change Initiative: A Corporate Framework for Action 2009. Delta, BC. Available online at http://www.corp.delta.bc.ca/assets/Environment/PDF/climate_change_initiative_report_2009.pdf.

127 Furgal & Prowse (2008).

128 The Canadian Standards Association recently released the guideline: CSA Technical Guide (PLUS 4011-10) “Infrastructure in permafrost: A guideline for climate change adaptation”.

129 NRTEE estimates based on Statistics Canada Catalogue no. 15-001-X and http://www.statcan.gc.ca/pub/57-601-x/2008003/t006-eng.htm Accessed August 1, 2010.

130 NRTEE estimates based on Statistics Canada, 2006 Census of Population.

131 Bourque and Simonet (2008) report this occurrence in southern Quebec, based on work by Yagouti et al. (2008).

132 Qian et al. (2009).

133 Agro-climatic modelling shows increases in yield potential in Eastern Canada (Ontario, Quebec, New Brunswick, Nova Scotia, PEI and Newfoundland and Labrador (Pearson et al. [2008]) of 40–170% by the 2080s under a range of scenarios (B2, A2, A1) — although the study notes that gains in productivity may be countered by moisture deficits. This work is largely consistent with older findings, e.g., de Jong et al. (1999), who reported 18% increase in wheat yields in the 2050s for a 2xCO2 scenario. To map this impact on Degrees of Change, we used the temperature range corresponding to B2, A2, and A1B scenarios for 2080s (likely range is 2.2-4.6°C). Since important thresholds may occur at lower temperatures, we position this impact statement towards the lower end of the scenario-driven temperature range. These studies largely ignore climatic extremes, which may limit production increases; to be conservative, the statement on the diagram is restricted to the lower end of the crop yield range reported in Pearson et al. (i.e., “over 40%” rather than “40–170%”).

134 National Academy of Sciences 2010, page 128.

135 Figure 5.2 in chapter 5 of Parry et al. (2007) presents data suggesting that wheat yields are likely to decline once local temperatures increase more than 3–4°C; a mapping of a 4°C local temperature rise to a global temperature scale gives ~2.7°C global average temperature rise. Potato yields are expected to decline before this, with Hijmans estimating declines in potato yields by the 2050s unless adaptive actions are taken (Hijmans [2003]).

136 Wheaton et al. (2005).

137 Cudmore (2005); Wheaton et al. (2005).

138 e.g., Milly et al. (2005); Falloon et al. (2006); Martz et al. (2007).

139 Sauchyn et al. (2005).

140 Pearson et al. (2008).

141 Boland et al. (2004).

142 Vasseur & Catto (2008).

143 Modelling conducted by Olfert & Weiss (2006) projects significantly expanded ranges of three agricultural pest species at 3°C of local temperature rise over current (1960–1990) climate normals. This can approximately be mapped to a 2°C global average temperature rise.

144 An expert assessment in Ontario (Boland et al. [2004]) found that some plant diseases are expected to increase as a result of climate change, but that more than half of those studied will decline. Chakraborty et al. (2000) suggest that the net effects of climate change on individual plant diseases are uncertain, and may be positive or negative.

145 Chapter 5 in Parry et al. (2007).

146 Williamson et al.(2009).

147 Williamson et al. (2009).

148 Growth prediction models based on 2 x CO_2 scenario (corresponds to approximately 550ppm CO_2 at 2080s, which is about 2.6°C best estimate, 2–3.2°C range according to AR4 WGII Figure TS4 and represented relative to pre-industrial levels) suggest an increase in net primary productivity for forests in Eastern Canada (Price and Scott 2006). Williamson et al. (2009) conclude that the potential for productivity

gains under a changing climate is applicable to northerly areas with relatively cold and moist climates; productivity is expected to decrease in southern areas that are relatively hot and dry. For example, Chhin et al. (2008) project a decline in productivity of lodgepole pine in the foothills region of Alberta over the next century (based on A2 and B2 scenarios). The net effect of tree growth in a changing climate is difficult to ascertain due to the many interacting factors (e.g., soil moisture, natural disturbance patterns, extended growing season); however, continued availability of soil moisture is likely to be the most important influence on growth (Williamson et al. [2009]).

149 Spittlehouse & Stewart 2003.

150 Harley et al.(2006); Beamish et al. (2009).

151 Wrona et al.(2005); Furgal & Prowse (2008); Chu et al. (2005) conclude that a changing climate may lead to a range contraction of Arctic char toward the northeast of the country. They project a 40% loss of their current range by 2020s and another 23% reduction by 2050s, with its range restricted to Nunavut, northern Quebec, and Labrador. They used a IS92a emissions scenario for the analysis, the range of which we use here.

152 Fisheries and Oceans Canada, Underwater world. http://www.dfo-mpo.gc.ca/Science/publications/uww-msm/articles/char-omble-eng.htm

153 Beamish et al. (2009) assessed the potential impacts on the fisheries by 2050 (about 2°C of global warming using a range of SRES scenarios; authors report potential impacts by 2050 without specifying associated changes in mean global temperatures).

154 Based on a study of 33 commercial species, Chmura et al. (2007) find that thermal range conditions decline for most commercial fish species in Atlantic Canada (the study is based on A2 and B2 scenarios over an 80 to 100-year horizon). Atlantic salmon is among the species projected to face greatest habitat losses (range contraction in Cape Cod, tail of Grand Bank, and Gulf of St. Lawrence). We use a temperature range that considers the best estimate of B2 for 2050s and A2 for 2100 (2090s), as low and high end.

155 Drinkwater (2005) finds an increase in abundance of Atlantic cod stocks up to about 3°C of global warming above current levels (i.e., about 0.78 degrees C + 3 degrees C), declining at greater temperatures (see Figure 5). Cheung et al. (2009) find a general increase in catch potential across a range of species in Atlantic Canada at high latitudes (60 degrees latitude and higher) by 2055 based on an IPCC A1B scenario. We use a temperature range based on the likely range for A1B scenario in 2050s (2-3°C).

156 Cheung et al. (2009).

157 Ongoing study by J.M. Casselman and P. Lehman "Water Resources, Fish, and Fisheries: Sensitivities, Impacts, and Adaptation to a Changing Climate". For more information, see http://adaptation.nrcan.gc.ca/speakerseries/index_e.php

158 Field et al. (2007) ; Okey et al. (2010).

159 Field et al. (2007).

160 Payne et al. (2004).

161 Buttle et al. (2004).

162 Bourque & Simonet (2008) summarize potential implications of changing hydrological regimes and other impacts of climate change on hydro-electric production in Quebec.

163 Furgal & Prowse (2008); Prowse et al. (2009); International Energy Agency (2008). http://www.worldenergyoutlook.org/docs/weo2008/fact_sheets_08.pdf. Here we assume a seasonally ice-free Northwest Passage by 2050s (~2°C of global warming above pre-industrial levels).

164 Prowse et al. (2009).

165 Smit & Wall(2003).

166 Spittlehouse & Stewart (2003).

167 Harley et al. (2006).

168 Between 1990 and 2009, the proportion of freight transported by road increased from 25 to 85%. NRTEE estimates based on Table 5 – 1, Domestic Freight Activity by Mode (tons). http://nats.sct.gob.mx/nats/sys/tables.jsp?i=3&id=15. Accessed August 2, 2010.

169 Tourism contributed to Canada's economy an average (2002$) $24.0 billion each year between 1998 and 2008. GDP estimate is from Statistics Canada, CANSIM table 387-0001.

170 Dodds & Graci (2009). For more information on trends in international travel see the 2009 Statistics Canada publication "International Travel," catalogue no. 66-201-X, available at: http://www.statcan.gc.ca/pub/66-201-x/66-201-x2008000-eng.pdf

171 Table 1, Expenditures per household. http://www.statcan.gc.ca/pub/62-202-x/2007000/t001-eng.htm Accessed August 2, 2010.

172 Sou & Flato (2009). 2050s corresponds to about 1.9-2.8°C using best estimates of range of SRES scenarios. Recent trend data suggest this may happen prior to 2050 (D. Lemmen personal communication, February 15, 2010).

173 Furgal & Prowse (2008);CBC News in Review, The Big Melt: Canada's Changing Arctic (September 2006) http://newsinreview.cbclearning.ca/wp-content/uploads/2006/09/arctic.pdf

174 Mortsch et al.(2003). See case study on pg 105; Lemmen and Warren (2004); Field et al. (2007).

175 Kling et al. (2003) ; International Joint Commission (2003); Mortsch et al. (2005).

176 Lindeberg & Albercook (2000).

177 Millerd (1996) reported a 5 to 40% increase in shipping costs for 2 x CO2 (corresponds to approximately 550ppm CO2 at 2080s, which is about 2.6°C best estimate, 2–3.2°C range according to AR4 WGII Figure TS4 and represented relative to pre-industrial levels).

178 Dawson et al. (2007); Stewart et al. (2007).

179 Dawson et al. (2007) report this increased potential for 2040s under B2 scenario, we use the range for 2050s in the degrees of change diagram (1.7–2.6°C).

180 Singh et al. (2006).

181 Singh et al. (2006), who projected a "drastic" reduction in the ski season in Southern Quebec by the 2050s — on average reduced by 23% from the 1961–1990 baseline by 2050s. We used global temperature ranges using best estimates of a range of SRES scenarios at 2050s.

182 McBoyle et al. (2007).

183 Singh et al. (2006); Jones & Scott (2006a); Scott et al. (2008).

184 Scott & Jones (2006) presented results on golf season changes in the Greater Toronto region for 2050s, using low and high global emissions scenarios.

185 Jones & Scott (2006b).

186 Government of Canada (2009), page 167.

187 See Huebert (2003), for example. Recent research suggests that an increase in Artcic shipping activity can accelerate local climate changes through emissions short-lived forcing agents (black carbon). http://www.atmos-chem-phys.net/10/9689/2010/acp-10-9689-2010.pdf Accessed November 8, 2010.

188 Bruce et al. (2000).

189 D'Arcy et al. (2005); Field et al. (2007).

190 Scott & McBoyle (2007).

191 http://www40.statcan.gc.ca/l01/cst01/gblec02a-eng.htm Source: Statistics Canada, CANSIM, table (for fee) 228-0003. Accessed August 2, 2010.

192 Security Council Holds First-Ever Debate on Impact of Climate Change on Peace, Security, Hearing Over 50 Speakers. United Nations (2007, April 17). Retrieved from http://www.un.org/News/Press/docs/2007/sc9000.doc.htm Accessed on November 2, 2010.

193 A summary of NRTEE discussions is available at: http://www.nrtee-trnee.ca/eng/news-media/events/other/20th-anniversary/climate-forward/climate-forward-contents-eng.php

194 See Center for New American Security (2010), for example.

195 Charron (2005); Huebert (2005); Bruce and Haites (2008); Borgerson (2008).

196 Figure 2 (TS2) IPCC Working Group II Technical Summary, shows decreases at low latitudes and increases at mid to high latitudes of some cereal crops at about 1.5°C over pre-industrial levels (Parry et al. [2007]).

197 Bruce & Haites(2008).

198 Given observed and projected range shifts of global terrestrial species and increasing risk from natural disturbances, changes in comparative advantage with respect to forest products could occur at relatively modest levels of global temperature rise relative to pre-industrial times.

199 Sohngen & Sedjo (2005); Perez-Garcia et al. (2002).

200 Bruce & Haites (2008); Mills (2005); Canadian Red Cross (2009).

201 Bruce & Haites (2008).

202 Bruce Haites (2008) ; Mills (2005).

203 Barnett & Adger (2003); Bruce & Haites (2008); Smith et al. (2009). The positioning of this impact on the global temperature scale in the degrees of change diagram is taken from Smith et al.'s (2009) findings on risk of extreme weather events distributed across the world.

204 For more information on Canada's Arctic Foreign Policy, see: http://www.international.gc.ca/polar-polaire/canada_arctic_foreign_policy_booklet-la_politique_etrangere_du_canada_pour_arctique_livret.aspx?lang=eng#environment. The Northern Strategy is available at http://www.northernstrategy.ca/index-eng.asp. The four priorities identified in the strategy are exercising our Arctic sovereignty; protecting our environmental heritage; promoting social and economic development; and, improving and devolving Northern governance.

205 The policy guidance document is available at http://www.oecd.org/dataoecd/0/9/43652123.pdf

206 These three examples are documented in Lemmen et al. (2008a).

207 A recent example is Akerlof et al. (2010).

208 Canadian Public Health Association (2010).

209 http://adaptation.nrcan.gc.ca/collab/colcol_e.php

210 Lemmen et al. (2008a), p. 18.

211 Environics Research Group. National Climate Change Adaptation Benchmark Survey. April 2010, prepared for Natural Resources Canada. Accessed on May 20, 2010 at http://epe.lac-bac.gc.ca/100/200/301/pwgsc-tpsgc/por-ef/natural_resources/2010/075-08/index.html

212 In an analysis for the UK, Boykoff (2008) concludes, "Across all the years of study, apart from the stories with a neutral tone, fear, misery and doom headlines dominated the coverage."

213 Williamson et al. (2009); Walton (2009) estimates that seventy percent of merchantable pine volume could be lost to mountain pine beetle infestations by 2015.

214 See the news article by the American Association of rhe Advancement of Science at http://www.aaas.org/news/releases/2010/0304sp_methane.shtml for further explanation.

215 Lemmen & Warren (2004).

216 As stated in the new Federal Sustainable Development Strategy "Canada's environmental policy is guided by the precautionary principle." The precautionary principle asserts that: "Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation" (United Nations, 1992). http://www.ec.gc.ca/dd-sd/default.asp?lang=En&n=06E31414-1#s2 United Nations (1992). Report of the United Nations Conference on Environment and Development - (Rio de Janeiro, 3-14 June 1992). Retrieved from http://www.un.org/documents/ga/conf151/aconf15126-1annex1.htm on November 2, 2010. Broadly, the approach guides decision-making under uncertainty, emphasizing that a lack of scientific evidence should not preclude action if the potential exists for serious and irreversible damage.

217 Hallegatte (2009).

218 Mayor & Avis (1998).

5.5 COMMUNICATING UNCERTAINTY AND CONFIDENCE IN CLIMATE CHANGE IMPACTS IN *DEGREES OF CHANGE*

The NRTEE's *Degrees of Change* diagram is a summary of some of the more important impacts, those we know most about, are most confident about, and those expected to occur this century. Collectively, these impacts are important because they give a picture of the scope and scale of the issue for Canada. The types of impacts on it are also well researched, although some more than others. Many of the impacts are already occurring and the rest are likely to occur in Canada over this century. The diagram does not present low probability yet catastrophic impacts, although we draw attention to these in several parts of our report.

An important difference exists between our degree of confidence on the collective of climate impacts and their ability to paint a scientifically robust picture, and in certainty and confidence in each of the 60 impacts plotted on the diagram at a specific temperature range, based on the research sources available and utilized for this report.

For impacts already occurring, we can say with more confidence that the trends will continue as the globe warms and can easily envision how these trends would unfold into the future. For example, glaciers will continue to lose ice and snow until conditions are such that ice and snow no longer accumulate. Winter road seasons will continue shortening until they are not a viable transportation option and others become cost-effective, such as all-season roads.

Future impacts are by definition more uncertain, and within these future impacts, statements with numbers attached to them can be even more uncertain in terms of absolute precision, given the state of research at this time. Confidence in these forecasted impacts is a function of understanding and learning more about the direction and magnitude (how much or how little) of change; the global temperature range associated with this change; delays between global temperature change and the response of our physical environment; and conditions under which the direction of change may flip, or the speed of change may actually accelerate, upon crossing a threshold.

The following table provides additional explanation for some of the impacts in the *Degrees of Change* diagram where questions of uncertainty and confidence may appear.

IMPACT	MAGNITUDE OF CHANGE	SPEED OF CHANGE	COMPLEX INTERACTIONS / LAGS	CHALLENGE MAPPING TO SPECIFIC GLOBAL TEMPERATURE	OTHER REASONS / COMMENTS
SUMMER ARCTIC SEA ICE EXTENT HALVED	X	X		X	OBSERVED SEA-ICE DECLINE HAS TAKEN PLACE FASTER THAN PROJECTED BY GLOBAL CLIMATE MODELS.
SUMMER THAW DEPTHS IN PERMAFROST TERRAIN INCREASE 15-40% IN THE MACKENZIE VALLEY			X		THERE'S A LAG BETWEEN AIR TEMPERATURE CHANGE AND GRADUAL RESPONSE OF THE FROZEN GROUND.
WESTERN MOUNTAIN GLACIERS LOSE OVER 50 % OF VOLUME AND SOME DISAPPEAR	X			X	STUDY ON WHICH THE 50% FIGURE IS BASED USES A SMALL SUB-SET OF HIGH-LATITUDE GLACIERS, NOT ALL FROM CANADA.
GLOBAL SEA LEVEL RISES TO 1M		X	X		EVEN AT LOW TEMPERATURE INCREASES, SEA LEVELS WOULD CONTINUE TO RISE BEYOND THE 21ST CENTURY. SEA-LEVELS ARE RISING FASTER THAN EXPECTED.
RISK OF LOSING OVER 20% OF BOREAL FOREST AND OVER 10% OF TUNDRA	X		X		MAGNITUDE OF CHANGE (% LOSSES) COMES FROM TWO STUDIES, ON BOREAL AND TUNDRA LOSSES RESPECTIVELY.
AREA BURNED IN WESTERN WILDFIRES INCREASES TWO TO FOUR TIMES	X		X		SIGNIFICANT REGIONAL VARIABILITY, SITE SPECIFIC CONDITIONS.
FREQUENCY OF PRAIRIE DROUGHT DOUBLES	X			X	
RISK OF DESERTIFICATION IN PRAIRIES INCREASED 50%	X				LIMITED NUMBER OF STUDIES AVAILABLE.
HEAT WAVE DEATHS DOUBLE IN PARTS OF SOUTHERN CANADA	X		X		NUMBER OF EXTREME HEAT DAYS WILL INCREASE AND THIS WILL LIKELY RESULT IN ADDITIONAL DEATHS AMONG VULNERABLE POPULATIONS, BUT DOSE RESPONSE RELATIONSHIP INCLUDES IMPORTANT ASSUMPTIONS ABOUT ACCLIMATIZATION AND ADAPTATION THAT MAY CHANGE.

IMPACT	MAGNITUDE OF CHANGE	SPEED OF CHANGE	COMPLEX INTERACTIONS / LAGS	CHALLENGE MAPPING TO SPECIFIC GLOBAL TEMPERATURE	OTHER REASONS / COMMENTS
EXTREME RAIN EVENTS DOUBLE IN FREQUENCY	X			X	SIGNIFICANT REGIONAL VARIABILITY LIKELY. LIMITED NUMBER OF STUDIES AVAILABLE.
TIMBER GAINS FROM ENHANCED TREE GROWTH IN SOME NORTHERLY LOCATIONS			X	X	COMPLEX ECOSYSTEM DYNAMICS INVOLVED. ENHANCED PRODUCTIVITY STRONGLY A FUNCTION OF ADEQUATE MOISTURE AVAILABILITY, AS WELL AS CAPACITY OF TREE SPECIES TO THRIVE UNDER DIFFERENT CLIMATE ENVELOPES. ENHANCED CARBON FERTILIZATION LIKELY SHORT-LIVED.
RANGE OF ARCTIC CHAR RESTRICTED TO NORTHEASTERN CANADA			X	X	LIMITED NUMBER OF STUDIES AVAILABLE.
ATLANTIC SALMON LOSES HABITAT IN GULF OF ST. LAWRENCE AND TAIL OF GRAND BANK			X	X	LIMITED NUMBER OF STUDIES AVAILABLE.
INCREASED ABUNDANCE OF ATLANTIC COD NORTH OF 60			X		COMPLEX INTERACTIONS AND BASELINE VULNERABILITY OF SPECIES MAKE PRECISE FORECASTS CHALLENGING.
NORTHWEST PASSAGE OPENS TO COMMERCIAL SHIPPING			X	X	TEMPERATURE AT WHICH THE NWP IS EXPECTED TO OPEN WITHOUT HAZARDS OF ICE CHUNKS LEFT BEHIND IS UNCERTAIN, AND CONTINGENT ON COMPLEX ICE DYNAMICS NOT FULLY UNDERSTOOD YET.
CRUISE VOYAGE POTENTIAL INCREASES BY 50%	X				LIMITED NUMBER OF STUDIES AVAILABLE.
SKI SEASON REDUCED 15-25%, GOLF SEASON INCREASED 7-20% IN PARTS OF SOUTHEASTERN CANADA	X				PERCENTAGE INCREASE / DECREASE SEASON LENGTHS EMBED SEVERAL MARKET ASSUMPTIONS AND ASSUMPTIONS ABOUT ADAPTATION THAT MAY CHANGE.

OUR ENVIRONMENTAL COMMITMENT

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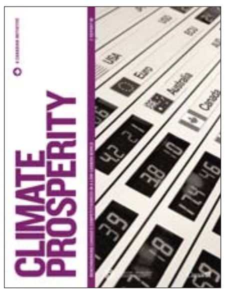

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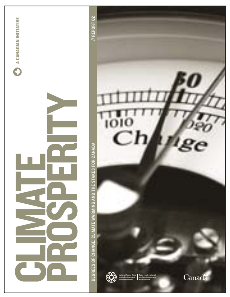

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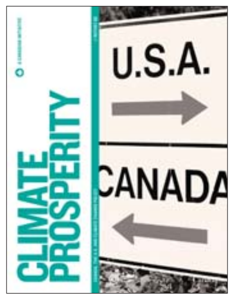

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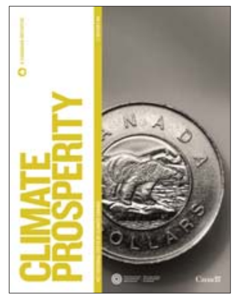

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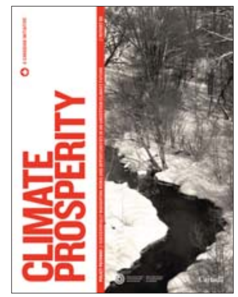
This report will provide, for the first time, national economic costings of the impact of climate change on Canada, together with a detailed look at four key sectors: coastal zones, human health, public infrastructure and forests.



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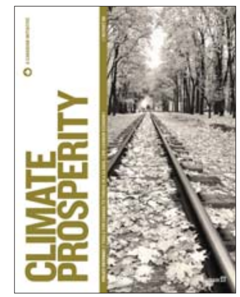

REPORT 06 //
POLICY PATHWAY REPORT FOR GLOBAL LOW-CARBON TRANSITION

Building on previous reports in the series, this advisory report will provide policy pathways and actions necessary for Canada to thrive in a global low-carbon economy in areas such as energy, innovation, skills, investment and governance.

REPORT 07 //
CITIZEN ENGAGEMENT

This report will highlight input from Canadian citizens sought during the course of the program to ensure action on climate change is underpinned by abroad social consensus informed by democratic dialogue and debate.

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