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Building Climate Resilient Communities: Living Within the Earth's Carrying Capacity

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Institute for Catastrophic
Loss Reduction

Institut de Prévention des
Sinistres Catastrophiques

Building Climate Resilient Communities: Living Within the Earth's Carrying Capacity

SSHRC Knowledge Synthesis Grant

April 2021

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This report was prepared by the Knowledge Synthesis Team of 22 experts from across disciplines and institutions.

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Executive summary

1. Background: Climate Change is Impacting Canadians

Communities across Canada are presently experiencing about \$2B per year in damages from severe weather and residents continue to experience adverse health outcomes from climate change. There is evidence that this is related to insufficient efforts towards adapting to a warming climate.

As warming is projected to continue at the same rate for at least another 3 decades with increases in the frequency and severity of extreme events, there is an increased need for communities to build resilience to reduce impacts from disasters related to climate change. Some provinces and communities have begun planning for adaptation to climate change, but there is need for more action. Most adaptive actions take place during recovery from large loss events. It is important that actions to improve climate resilience become a higher priority for governments and society. Efforts must move beyond high level planning to proactive risk reduction actions, across Canadian communities.

Our knowledge synthesis is based on the expertise of a strong, multidisciplinary team of scientists who came together to review the academic literature, government documents and policies and undertake discussions with individuals across sectors, including Indigenous voices.

2. Objective: *How can communities across Canada proactively advance climate resilience to effectively reduce the risk of adverse climate impacts, loss, and damage?*

3. Findings

Climate change is impacting communities, human health, health systems and society. Risks will continue to grow with the increasing frequency and severity of climate hazards.

The *Pan-Canadian Framework on Clean Growth and Climate Change 2016* places a major focus on reducing greenhouse gas emissions, while identifying adaptation and resilience as policy priorities. The *Healthy Environment and Healthy Economy Plan* (December 2020) also includes actions for promoting collaborations to make Canada more resilient to a changing climate. The *Global Commission on Adaptation* is leading in international actions and it is important that Canada plays a leadership role. The Canadian 2021 federal Budget, entitled: *A Recovery Plan for Jobs, Growth, and Resilience*, addresses the COVID-19 situation and recovery from its impacts. The Budget addresses the *Healthy Environment for a Healthy Economy Plan*, with the prime focus to reduce emissions.

Our synthesis reveals that some communities in Canada have prepared high level adaptation plans, but very few have a detailed implementation strategy with established funding frameworks. Most actions to build community resilience in Canada are unplanned and take place in recovery following an extreme loss event.

Indigenous communities in Canada are at the forefront of climate change adaptation in Canada. Self-determination and adaptive capacity building through community-led risk assessments, planning, and disaster recovery organizations, while addressing the broader context of reconciliation gaps and opportunities for integration are important for climate resiliency. Combining western and Indigenous ways of knowing (two-eyed seeing) for effective knowledge translation is necessary for adaptation and Indigenous collaborations geared towards promoting nature-based solutions and conservation are critical to global GHG sequestration and resilience.

Local scale warming experienced by Canadian communities due to urbanization adds to the heat burden in the warm season and further exacerbates social, health and economic impacts. More research is needed to document and predict the occurrence of heatwaves and to develop heat adaptation strategies attuned to Canadian cities. There are physical (dehydration, heat stroke) and mental health impacts of heatwaves and climate change. Mental health impacts can occur when large scale events are witnessed directly or remotely.

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The Task Force for a Resilient Recovery’s Report – A Bridge to the Future, recommends investing in Climate-Resilient and Energy Efficient Buildings, as key opportunities to achieve climate adaptation and mitigation progress and promote equity and inclusion in the recovery from the Pandemic.

4. Key Messages

Equity, diversity and inclusion are essential principles for health authorities as they work with partners to tackle climate change in a manner that brings benefits to all segments of the population.

Reducing disaster risk of adverse impacts from severe wind, wildland-urban interface fires, basement flooding, hail and other risks requires methods for site-by-site vulnerability analysis and quantification of risk reduction addressing various building characteristics and disaster risk affects. More research and data are required to know the impacts of a warming climate on certain types of severe weather (e.g., tornadoes, hail) and the economics of climate change adaptation needs to be further developed in terms of decision frameworks for selecting which adaptation measures should be implemented. Cost-benefit assessment and alternative decision frameworks exist which can better address concerns around non-monetary impacts and values.

In the recovery from the Pandemic, it is important to rebuild by addressing both the green energy and climate resilience issues together so there is a green climate-resilient Canada that reduces future climate change for the global benefits and the impacts of climate change on Canadian communities.

There is also need to strengthen collaboration between governments, Indigenous communities and all people to promote reconciliation, opportunities for inclusion in adaptation capacity building, and risk reduction actions. Alongside this, there is a need to recognize the importance of Traditional Knowledge and a collaborative and science-based approach in ways that are ethical, equitable and just.

The hazards and actions to reduce impacts cross multi-level governance levels and sectors of society. One example is the occurrence of flooding due to heavy precipitation and disproportionate impacts dependent on context, risk exposure and sensitivity. The enablers for adaptation need to work together to address the barriers, including: multilevel institutional co-ordination as well as the horizontal interplay; and the coordination between formal governmental, administrative agencies and private sectors and stakeholders to increase efficiency, representation, and support for climate adaptation measures. There is need for integrated early warning systems and better prevention strategies across the appropriate range of hazards and governance.

To address the climate crisis, a more ambitious, strategic and collaborative approach to adaptation is required. The 2021 Budget includes *Adapting to Climate Change for a More Resilient Future*. Funding is proposed for better understanding and preparation for climate-related disasters, specifically flooding and wildfires, an also *to help small, rural, remote, northern, and Indigenous communities adapt to climate change impacts*. Canada’s National Adaptation Strategy needs to address these and related issues and work with all levels of governance, Indigenous peoples, the scientific community and other key partners, to build climate resilient communities with key priorities and a monitoring framework for measuring progress. Our analysis has shown that the expert community has developed proven tools, based on best practices, to proactively improve climate resilience with a major issue being lack of funding and direction for governments and indigenous communities to address climate resilience.

5. Knowledge Mobilization Activities

There will be virtual informal discussion workshops during the April-May period to further assess the synthesis. At the CMOS National Congress, June 2021, the Team will make presentations in the Session “*Building Climate Resilient Communities*”. The ICLR holds regular “Friday Forums” for professional and across-sector participants and presentations are being planned. To inform the broad Canadians Risks and Hazards Network, an article will appear in their HazNet Magazine and a session is proposed for the fall 2021 national conference on this Synthesis.

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Chapter 5. Climate Change: Impacts and Adaptation-Resilience Strategies has 6 sections which were prepared by and are primarily the responsibility of the Section Authors. The authors who contributed to one section have not formally approved the full report. Chapter 5 Section Authors:

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REPORT

1. The Issue - Climate Change and Impacts on Communities

A. Changing Climate and Impacts - Global to Canada

“Climate change is the defining issue of our time” with profound implications for international peace and stability (UN Security Council Press Statement, 2021) and the health and well being of societies. There is now clear evidence of a changing climate at global, Canadian and community scales. The years 2016-2020 are set to be the warmest five-year period on record (Figure 1a) for the global mean temperature. Warming in Canada (Fig. 1B) is about twice the global average and the Canadian Arctic is warming about three times faster (Bush and Lemmen, 2019). Current projections show the global average temperature continuing to warm until past 2050 (Fig. 1C). Additional local warming occurs in urban areas arising from processes associated with urbanization (Rosenzweig et al. 2018). Furthermore, the risks associated with hazardous events such as heatwaves and intense rainfall events linked to climate change are magnified by urbanization. With Canadian and global populations increasingly concentrated in community settings, this makes communities a critical focus for building resilience to climate change.”

Climate change as a security issue for Canada was examined and McBean *et al.* (2010) identified the need for an *integrated energy-climate policy*. UN SG A. Guterres (UN Secretary General, 2021), stated: *As we rebuild, we cannot revert to the old normal. Pandemic recovery is our chance to change course.*

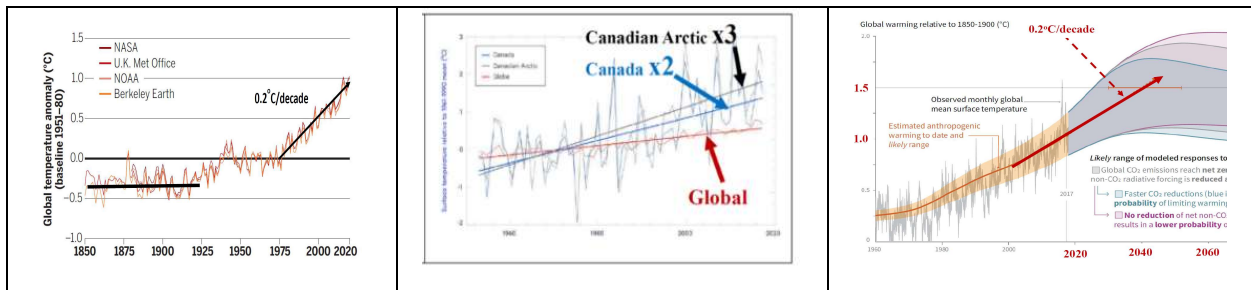


Fig. 1: A. Global temperature anomaly, relevant to 1951-80 (WMO, 2020). B. Observed warming in Canada and northern Canada compared to global warming (Bush and Lemmen, 2019). C. IPCC projections of global average temperature change (IPCC, 2018a)

The importance of and calls for action on climate change are based on highly credible science assessments including the: United In Science High-level synthesis report (WMO, 2020) and Canada’s Changing Climate Report (Bush and Lemmen, 2019). The global economic costs from weather-related disasters are increasing (Fig. 2A) (Aon Weather, Climate and Catastrophe Insight, 2020) and they contribute about 85% of the total of all “natural” disasters economic losses, averaged over the past 20 years. The total economic loss due to weather-related and all other natural hazards in 2020 was \$US 258B. Their report states: *This will require new climate resilience and mitigation strategies.*

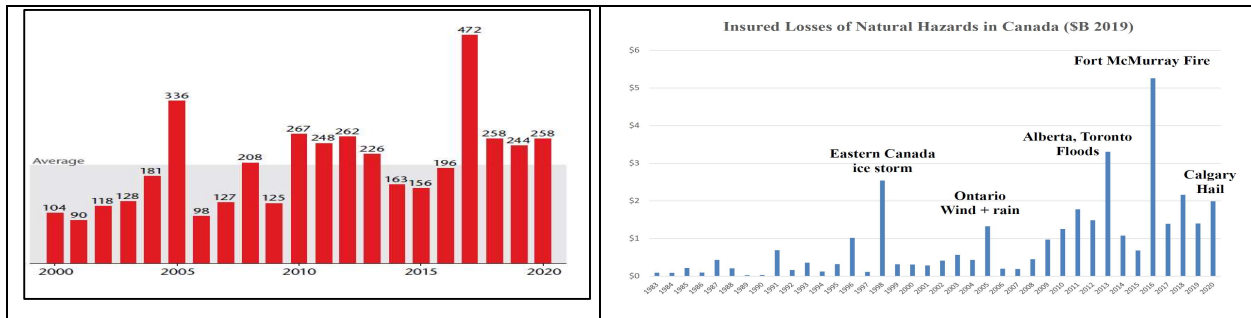


Figure 2: A. Global Economic Losses from weather-related hazards. (\$B US adjusted to 2020); B. Insured Losses due to “Natural” hazards in Canada. (\$B 2019) (CatIQ, 2021; IBC, 2020.)

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The risk of natural hazards in Canada is high and average annual insured losses to natural hazards in Canada have grown from \$815 million in the 1987-2009 period to \$2B in the 2010-2019 period (CatIQ). These figures do not include uninsured direct economic losses, indirect economic losses, or environmental, social, and cultural losses. Major Canadian events have been the Fort McMurray fire, Alberta and Toronto area floods, eastern Canada ice storm and the Calgary hailstorm (Fig. 2B).

B. Climate and Risk Projections for the Coming Decades

The IPCC (2018a) Special Report states that: *Warming ... will continue to cause further long-term changes in the climate system, such as sea level rise, with associated impacts (high confidence). The warming rate of 0.2°C/decade is projected to continue for at least the next several decades (Figure 1C). Adaptation and mitigation are already occurring (high confidence). Future climate-related risks would be reduced by the upscaling and acceleration of far-reaching, multilevel and cross-sectoral climate mitigation and by both incremental and transformational adaptation (high confidence).* To reduce the impacts of a changing climate, there is need to advance adaptation and make communities more resilient. Resilience, being strong, irrepressible, and quick to recover/bouncing forward, is defined as (IPCC Glossary, 2018b): *Resilience: the capacity of social, economic and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity and structure, while also maintaining the capacity for adaptation, learning and transformation; and: Adaptation: within human systems, adaptation is the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities. In natural systems, it is the process of adjustment to actual climate and its effects; human intervention may facilitate adjustment to expected climate and its effects.*

Adaptation is a fundamental requirement of resilience and there is need for strategic methods to bring the approaches together (Mechler *et al.*, 2020). Effective adaptation actions in Canada that build resilience require that decision makers have access to comprehensive information about current and future climate change risks and the tools to apply this information in the development of policies and programs.

The World Economic Forum Annual Global Risk Reports (WEF GRR, 2021) rank global risks (significant negative impacts for several countries or industries within the next 10 years) across all sectors by impacts and likelihood for the next 10 years. The 2021 Report Executive Summary states that: *Climate continues to be a looming risk as global cooperation weakens*". Climate action failure, defined as: *Failure of governments and businesses to enforce, enact or invest in effective climate-change adaptation and mitigation measures, preserve ecosystems, protect populations and transition to a carbon-neutral economy* (underlining added), was ranked as the second most impactful and second most likely risk. The top global risks by likelihood are extreme weather (including storms, fires, floods), climate action failure and human environmental change and by impact, infectious diseases (the Pandemic), climate action failure, weapons of mass destruction, biodiversity loss and natural resources (water, food, ...) crises. Extreme weather is the 8th highest in impact. Over the past 5 years, the climate action failure and extreme weather events, risks which are addressed in this report and are clearly linked, have been at the top in likelihood and near the top in terms of impacts.

Risks (Cardona *et al.*, 2012), the potential for a hazardous event, now and in future with adverse consequences, result from the vulnerability of the affected system and its exposure over time, to the hazard, as well as characteristics and likelihood of the climate-related hazards. To address risks, there is need for risk assessment followed by the preparation and implementation of risk management plans to address increases in the value of assets exposed in light of climate change. Storms and heat spells are expected to become more frequent and intense, increasing the risk of floods, wildfires, and droughts. Sea level rise threatens coastal infrastructure (Bush and Lemmen, 2019). Climate-related disaster losses are likely to increase in the absence of climate adaptation actions.

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2. Project Objective - Building Climate Resilient Communities

- *How can communities across Canada proactively advance climate-resilience to effectively reduce the risk of adverse climate impacts, loss and damage?*

3. International Climate Resilience Agenda

A. Global Agenda 2030 and the Global Science Programs

In 2015, the Sustainable Development Goals (2015), the Paris Agreement (2015) of the UN Framework Convention on Climate Change, and the Sendai Framework on Disaster Risk Reduction 2015-2030 (2015) were created and endorsed by Canada and almost all other countries. To address Global Agenda 2030 with its complexities and challenges, it is important that the global science community comes together (McBean, 2018). Sustainable development (WCED, 1987), defined as: *Humanity has the ability to make development sustainable - to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs*, links social, economic, technology, science and environmental issues and calls on these communities to work together to meet present and future needs.

The 17 Sustainable Development Goals include: #3 – Good Health and Wellbeing; #9 - Industry, Innovation and Infrastructure; #11 – Sustainable Cities and Communities; and #13 – Climate Action. With strong interactions across the Goals (ISC, 2017), understanding and bringing science together to address them is key to unlocking their full potential and ensuring that overall progress is made.

The 2015 Paris Agreement focussed on strengthening the global response to the threat of climate change, through mitigation (emissions reduction) and *(b) increasing the ability to adapt to the adverse impacts of climate change and foster climate resilience...* Article 7 states that: *Parties hereby establish the global goal on adaptation of enhancing adaptive capacity, strengthening resilience and reducing vulnerability, strengthening scientific knowledge on climate, including research, ... early warning systems, ... The process to formulate and implement national adaptation plans, which are key.*

The World Climate Research Programme (WCRP) was established in 1980 to address: 1) *to what extent can the global climate be predicted*; and 2) *how have humans influenced the climate?* and provides major input to the IPCC and the Paris Agreement. The Integrated Research on Disaster Risk Program (IRDR), created in 2008, has the objectives of: 1) *characterization of hazards, vulnerability and risk*; 2) *understanding decision-making in complex and changing risk contexts*; and 3) *reducing risk and curbing losses through knowledge-based actions*. The IRDR provides scientific input to the Sendai Framework and has established 16 International Centers of Excellence, geographically spread around the world, including the Institute for Catastrophic Loss Reduction as the Center for Disaster Resilient Homes, Buildings and Public Infrastructure. The Urban Health and Wellbeing in the Changing Urban Environment (UHW) program focuses on systems analyses towards understanding health and wellbeing in urban settings.

The Future Earth Programme (FE) brings science together across disciplines and the issues of sustainable development. Future Earth plays a significant role at the interface between science and international policy through the SDGs and Paris Agreement, and partners with IRDR, with respect to the Sendai Framework. Future Earth Knowledge-Action Networks (KANs) are collaborative frameworks to facilitate highly integrative sustainability research to inform solutions for complex societal issues. The Emergent Risks and Extreme Events KAN leads research on systemic risk, including the interaction of climate-change induced extreme events and other disasters, transformations to sustainability and resilience through systematic scientific synthesis and research in collaboration with societal actors.

B. United Nations Climate Action Summit 2019

As input to the UN Climate Action Summit (UNFCCC, 2019), assessments showed that *countries are stepping up institutional arrangements for planning, funding, implementing, monitoring and evaluating climate action, and that the portfolio of actions to reduce emissions and adapt to climate change is*

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expanding. Important for this Report are themes: #5. Towards a resilient future - Climate risks cannot be ignored and must be integrated very early on in decision making systems, long-term planning and into investment decision making and business planning; and #9. Adapting now: making people safer - the Summit proposed solutions to act now to respond to immediate climate impacts and to support the most vulnerable members of society and to advance initiatives that will make people safer.

C. Enhancing climate change adaptation/resilience in Covid-19 recovery (IIASA-ISC)

Recovery from the Covid-19 pandemic provides an opportunity for nations to work together to do this effectively while addressing Global Agenda 2030. The International Institute for Applied Systems Analysis (IIASA) and the International Science Council (ISC) have created the Consultative Science Platform: Bouncing Forward Sustainably Post COVID-19 (IIASA-ISC, 2021) to bring together global experts to define and design sustainability pathways, with four themes: Governance for Sustainability; Strengthening Science Systems; Sustainable Energy; and Resilient Food Systems. For governance for sustainability, a systemic and compound risk perspective for addressing risks is recommended and risk governance is fundamental for achieving sustainability amid multiple crises and uncertain events. With systemic risks, failure in one part of the system can lead to triggering cascading events in other system units leading to major disturbances or even complete failure of the whole system. For national-local governance, it is important to make systemic resilience a focus. Increased awareness of compound and systemic risks would benefit multi-level governance and having a joint vision for a more sustainable, resilient post-pandemic economy and society is important (Mechler *et al.*, 2021).

In terms of Rethinking Energy Solutions (Zakeri *et al.*, 2021), cities and urban spaces are key focus areas for sustainable, resilient, people-centered, equitable, and climate-friendly futures. Science systems (Rovenskaya *et al.*, 2021) need to respond more effectively to future global crises. Resilient Food Systems (Sperling *et al.*, 2021) need to address the issues of resilience and equity concerns, including strengthening endogenous research capacities. An extended phase 2 is planned (IIASA, 2021).

D. Global Commission on Adaptation and Climate Adaptation Summit (CAS2021)

The Global Commission on Adaptation (GCA) was created in 2018 and hosted by the Global Center on Adaptation in the Netherlands. Its mandate is to accelerate adaptation by elevating the *political visibility of adaptation* and focusing on *concrete solutions* and accelerate, innovate, and scale adaptation action for a climate resilient world. The Global Commission on Adaptation (2019) report: *Adapt Now: A Global Call for Leadership on Climate Resilience*, states: *Adaptation is not an alternative to a redoubled effort to stop climate change, but an essential complement to it. Failing to lead and act on adaptation will result in a huge economic and human toll, causing widespread increases in poverty and severely undermining long-term global economic prospects. The good news is that adaptation, done right, will lead to better growth and development. It will also save lives, protect nature, reduce inequalities, and create opportunities.* Adapting now has strong economic self-interest with the overall rate of return on investments in improved resilience benefit-cost ratios ranging from 2 to 10, and in some cases even higher. The highest benefit-cost ratio is for strengthening early warning systems. The Global Commission on Adaptation (2020) State and Trends in Adaptation Report notes that Canada's unique geography creates challenges and that *Canada can deepen the coordination across different levels of government and all stakeholders to accelerate climate adaptation of its economy and infrastructure.* The Climate Adaptation Summit (2021), held January 25, 2021, called for action to accelerate adaptation globally for a climate resilient world, with a focus on cities as key to accelerating adaptation action globally, noting that by 2050, 70% of the world's population will live in urban areas (Global Commission on Adaptation, 2021).

E. International Actions - Examples

Bangladesh and the World Meteorological Organization (WMO, 2017) improved the coastal flooding forecasting program for coastal Bangladesh, with assistance of Australian, Canadian, and Japanese

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meteorological agencies, and, as demonstrated with the 2017 cyclones, the *loss of life in the densely populated South Asian nation has been greatly reduced by disaster risk reduction measures and early warning systems.*

In 2001, tropical storm Allison struck Houston, Texas killing 22 people and causing almost \$5B US in damages. The Texas Medical Center (TMC) (Health Care Without Harm, 2018), the largest aggregated medical complex in the US, was greatly impacted, with more than 1,000 patients evacuated and great impacts on research labs. The TMC institutions then worked together to upgrade infrastructure with resilient and sustainable design features. The TMC has since been through Hurricanes Rita, in 2005, Ike in 2008 and Harvey in 2017, and all their hospitals and emergency rooms stayed operational.

In 2003, France was impacted by extreme temperatures and between 15,000 and 19,000 people died: many being isolated elderly citizens (France24, 2015). In response, France has adopted strict heat wave guidelines and provides heat alerts, which have proven effective in preventing health complications, especially among vulnerable members of the population. Heat is a global problem and will impact Canada more as the climate warms and is addressed in Section 5 of this report.

Adaptation Without Borders is a new global partnership working to strengthen systemic resilience to the cross-border impacts of climate change. Their analyses have shown that current approaches to adaptation fall far short of what is needed to effectively manage climate risk in an interconnected world. There is need for more investment and multilateral cooperation on systemic risk reduction.

4. Canadian Climate Resilience Agenda

A. Federal Adaptation Policy

Although there had been actions in Canada on climate change for a few decades, the Canadian Commissioner of the Environment and Sustainable Development (CESD, 2010) reported that: *There is still no federal strategy and action plan for adaptation.* The Federal Adaptation Policy Framework (Government of Canada, 2011) was created in 2011 and the Climate Change Adaptation Platform was launched in 2012, establishing Working Groups to address shared priorities (Canada's Climate Change Adaptation Platform, 2013-17).

The 2014 Canada in a Changing Climate national assessment (Warren and Lemmen, 2014) provided perspectives on impacts and adaptation, including updating the 2008 Assessment (Lemmen *et al.*, 2008):

- *Adaptation is accepted as a necessary response to climate change, complementing global measures to reduce greenhouse gas emissions. Adaptation enhances the social and economic resilience of Canadians to climate change impacts.*
- *Adaptation is occurring with increasing frequency and enhanced engagement. Continued action will help to build capacity, address information needs and overcome challenges.*
- *Adaptation can sometimes turn risks into opportunities, and opportunities into benefits.*
- *Collaboration and adaptive management are approaches that governments and industry are increasingly pursuing to advance adaptation*

The barriers and challenges to adaptation were summarized in Chapter 9 (Eyzaguirre and Warren, 2014) as: *Information and communications; Resources (economic, skills, technology); Governance and norms; Psychology and values; and Leadership.*

The CESD (2016) report stated that: *Overall, we concluded that the federal government has not made it a priority to help decision makers mitigate the anticipated impacts of severe weather.*

B. Pan-Canadian Framework on Clean Growth and Climate Change (2016)

Pan-Canadian Framework on Clean Growth and Climate Change: Canada's Plan to Address Climate Change and Grow the Economy (2016) was agreed to in 2016 by the Federal, provincial and territorial governments, except Saskatchewan, as a *collective plan to grow our economy while reducing emissions*

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and building resilience to adapt to a changing climate. The Framework's primary focus is reducing emissions to meet the commitments of the Paris Agreement but also included are: *measures to adapt to the impacts of climate change and build resilience; and actions to accelerate innovation, support clean technology, and create jobs.* It is stated that *Canada is experiencing the impacts of climate change, so there is also a need to adapt and build resilience. This means making sure that our infrastructure and communities are adequately prepared for climate risks like floods, wildfires, droughts, and extreme weather events, including in particularly vulnerable regions like Indigenous, northern, coastal, and remote communities.*

The ten elements of collaboration included: 7. *strengthening the collaboration between our governments and Indigenous Peoples on mitigation and adaptation actions, based on recognition of rights, respect, cooperation, and partnership;* 8. *recognizing the importance of Traditional Knowledge in regard to understanding climate impacts and adaptation measures;* 9. *recognizing that comprehensive adaptation efforts must complement ambitious mitigation measures to address unavoidable climate change impacts;* and 10. *implementing a collaborative, science-based approach to inform Canada's future targets that will increase in stringency as required by the Paris Agreement.* New actions to build climate resilience were identified in translating scientific information and Traditional knowledge into action; building climate resilience through infrastructure; protecting and improving human health and well-being; supporting particularly vulnerable regions; and reducing climate-related hazards and disaster risks. The Federal Government launched in 2018 the Disaster Mitigation and Adaptation Fund (2018) to invest \$2B over 10 years to reduce the socio-economic, environmental, and cultural impacts of current and potential future climate change events.

The Council of Canadian Academies (2019) Panel on Canada's top climate change risks identified the top 6 to be: *Physical Infrastructure; Coastal Communities; Northern Communities; Human Health and Wellness; Ecosystems; and Fisheries* and summarized key issues as:

- *Climate change risks are complex and interconnected, and impacts can propagate through natural and human systems in ways difficult to anticipate.*
- *All 12 areas of risk ... can be meaningfully reduced through adaptation measures that lessen vulnerability or exposure.*
- *Understanding the climate change risks facing Indigenous Peoples in Canada requires a deeper exploration of these risks and associated adaptation potential, consistent with the spirit of reconciliation.*
- *Federal responses ... can be informed by prioritizing actions within and across three main categories: coordination and collaboration, capacity building, and assets and operations.*

The Treasury Board of Canada is leading Greening Government Strategy (2020) with actions to: *reduce greenhouse gas (GHG) emissions to the atmosphere; and increase the resilience of assets, services and operations by adapting to the changing climate – with the key theme: climate-resilient services and operations: Goals: anticipating future climate related hazards, risk planning, and minimizing disruptions to our operations; using nature-based solutions to protect physical assets from threats, such as flooding.*

C. A Healthy Environment and Healthy Economy Plan (2020)

On Dec 11, 2020, the Prime Minister announced Canada's strengthened climate plan *Healthy Environment and Healthy Economy (2020)* to protect the environment, create jobs, and support communities. The Plan, to work with provinces and territories through the Pan-Canadian Framework, sets out five pillars for the path forward, including: *Embracing the Power of Nature to Support Healthier Families and More Resilient Communities.* The Plan focuses on reducing GHG emissions and stresses nature-based solutions. One section is on *Working together to make Canada more resilient to a changing climate* and notes how the COVID-19 pandemic has underlined the importance of building resilience to risks across Canada and that there is need to be better prepared for the climate risks. *Building*

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resilience will not only help Canadian communities adapt to the current realities of a changing climate, it reduces lost productivity and economic losses from climate-related disasters, as well as enhances the health, well-being, and safety of Canadians and communities.

Other strategies within the Plan include *Canada playing a leadership role as part of the Global Commission on Adaptation* and to address the climate crisis, a *more ambitious, strategic and collaborative approach to adaptation* is required and the plan for moving forward is:

- *Develop Canada’s first-ever National Adaptation Strategy, working with provincial, territorial and municipal governments, Indigenous peoples, and other key partners. The strategy would establish a shared vision for climate resilience in Canada, identify key priorities for increased collaboration and establish a framework for measuring progress at the national level. This work will help inform where the Government of Canada should best target its policies programs and investments going forward.*
- *Co-develop, on a distinction basis, an Indigenous Climate Leadership agenda which builds regional and national capacity and progressively vests authorities and resources for climate action in the hands of First Nations, Inuit, and Métis and representative organizations.*
- *Continue to provide support to Canadians and communities to respond to accelerating climate change impacts, taking into account the major areas of risk*

With the announcement of the Plan, the Hon. Catherine McKenna, Minister of Infrastructure and Communities stated: *“Climate action is about good jobs, Canadian innovation, clean air and water, more inclusive communities and, most of all, a better future for our kids. If we take the same approach to the climate crisis as we are to the COVID-19 pandemic – urgency, science-based decisions, working together across borders and focusing on the planet we want for everyone – we will win the race against climate too.”* Infrastructure Canada will be providing up to \$1.5B in federal funding for community buildings that will support retrofits, repairs or upgrades of existing public buildings and the construction of new public buildings that serve communities across Canada. The Minister’s Mandate Letter of December 13, 2019 included: *Launch a new call for proposals under the Disaster Mitigation and Adaptation Fund to address the impacts of climate change, adjusting the program as required to ensure that the most impactful projects are supported, including those related to natural infrastructure, whether they are from small, rural and Indigenous communities or large urban centres; and Work with the Federation of Canadian Municipalities through the Green Municipal Fund, the Municipalities for Climate Innovation Program and the Municipal Asset Management Program to build climate resilience, reduce greenhouse gas emissions, make better decisions, and monitor investments and ensure they reduce emissions from residential, commercial and multi-unit buildings.*

A supplementary Minister’s Mandate letter (15/01/2021) notes, in the context of the devastating impacts of the pandemic, that *we are at a crossroads and must keep moving Canada forward to become stronger, more inclusive, and more resilient. It is part of your job to look out for Canadians, with particular attention to our most vulnerable.* It also states: *While fighting the pandemic must be our top priority, climate change still threatens our health, economy, way of life and planet.*

D. Canadian Institute for Climate Choices

In December 2020, the new Canadian Institute for Climate Choices (2020) released the report *Tip of the Iceberg*. Its president K. Bardswick states: *One lesson Canada must learn from the global pandemic is that we need to get much better at foreseeing and acting on risk. As climate change accelerates, no individual, province or sector will be immune. Now more than ever, we cannot afford to ignore massive future costs—especially those that we have the power to manage. We can limit our risk exposure and make better decisions by investing in resilience and mandating climate risk disclosure.*

The Report makes the following Recommendations:

- a) *All orders of government should significantly scale up public funding for implementing adaptation.*

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- b) *The federal government should convene provincial, territorial, Indigenous and municipal governments to co-develop a more coordinated approach to governing adaptation.*
- c) *Governments and financial regulators should systematically enhance public disclosure and transparency of the economic and social implications of climate change risks across both the public and private sectors.*

E. Municipal Adaptation - Plans and Implementation

i. Federation of Canadian Municipalities - Municipalities for Climate Innovation Program

Cities and communities across Canada have been actively pursuing and implementing plans and projects geared towards reducing their vulnerability to climate change impacts and bolstering resilience and adaptive capacity. The Federation of Canadian Municipalities (FCM) launched in 2016, with \$75M federal support, the Municipalities for Climate Innovation Program (MCIP) to help Canadian municipalities take action in three key program areas: climate change adaptation; greenhouse gas reductions; and climate and asset management. Of the 322 MCIP projects, 110 can be linked specifically to a climate adaptation plan or project (climate and asset management was categorized as adaptation action) of which only 28 actually implemented an adaptation project which directly improves resilience or reduces exposure to physical climate risks with all but one of them dealing wholly or partially with water management or flood resilience. (Sixty-four grants awarded for hiring staff to support mitigation and adaptation plans were not included.) The other 82 adaptation grants were mostly towards broad municipal climate adaptation plans (28 plans). One example is the Southwestern New Brunswick Regional Adaptation Plan, which considers the risks of coastal flooding, wildfires, flash-freeze cycles, inland flooding, increased temperatures, and ocean biodiversity. Toronto’s MCIP resilience strategy document encompasses multiple areas of resilience beyond climate change, including resilience in equity, civic engagement, communities and neighborhoods, housing, and mobility.

Grants for adaptation plans for a specific hazard such as flood or heat were almost as common, with 27 such grants. For example, the Town of Stony Plain, Alberta, completed in 2019 using an MCIP grant, an in-depth stormwater management plan reviewing existing drainage infrastructure using a computer hydraulic model and provides recommendations for improvements and future development.

ii. ICLR Cities Adapt Book Series and ECCC Adaptation Case Studies

To encourage and support municipal disaster reduction projects, the Institute for Catastrophic Loss Reduction has done research and published books in the “Cities Adapt” series: *Extreme Rainfall* (Kovacs et al, 2014); *Extreme Weather* (Kovacs et al, 2018); and *Wildfire* (Kovacs et al, 2020). Each book highlights twenty case studies of municipalities conducting disaster risk reduction projects along with lessons learned and best practices. These books did not exclusively focus on climate change adaptation, although many of these hazards are exacerbated by climate change. Additionally, there is an opportunity to examine barriers to climate adaptation specifically, and how these were overcome. The case studies provide additional useful information on the status of climate adaptation in cities in Canada, on specific hazard type and case studies of successful implementation adaptation actions and those with achievement of tangible results.

Environment and Climate Change Canada (2021) funded a national climate change adaptation study, on which ICLR consulted, examining 215 climate change adaptation case studies across many sectors. ‘Community’ was the most prevalent sector with 86 entries, ‘infrastructure’ was next with 40 entries, and ‘industry’ and ‘energy,’ were the least common sectors with only six entries apiece. These last two are also the sectors most dominated by private interests. In terms of impacts being addressed by the case studies, there was substantial diversity with all impacts being mentioned multiple times. The most addressed impacts related to ‘Water Resources and Conditions,’ with that category being noted in 116 entries. The least mentioned impact category was ‘Ocean and Marine Ecosystems,’ with only 18 of the cases addressing that issue. Infrastructure appeared to be the issue of greatest concern overall, with the

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sub-entries 'infrastructure resilience' and 'damage to infrastructure' being mentioned 40 and 32 times, respectively.

Overall, flooding is the most common hazard being addressed across Canada. The general topic 'water resources and conditions', which includes flooding, was identified in 116 of 215 total case studies in the ECCC case studies and in 29 out of 74 Cities Adapt studies. There are strong geographic trends with Ontario being the most common location for adaptation measures. In Ontario and Quebec, flooding and extreme heat tend to be the focus. In British Columbia, Alberta, and Saskatchewan, by far the issue of most concern was wildfire. Metro Vancouver is one of the few places to have multiple programs targeting many hazards at once. Coastal provinces are most concerned about flooding and, for obvious reasons, sea level rise. Northern and Indigenous communities tend to incorporate mental health concerns more readily than Southern communities.

Most projects aimed at reducing fire impacts were undertaken by relatively small communities seeking to integrate FireSmart practices into their disaster planning and preparation. Conversely, many of the flooding projects entailed costly infrastructure upgrades, coastal and riverine engineering projects, and widespread economic incentives for improving individual home resilience.

Most adaptation actions are being undertaken on a municipal level. Operational, planning, and legal interventions were usually funded at the municipal level while infrastructure renovations and refits usually had provincial or federal funding. Even small communities are shown to be capable of making substantial improvements, often with relatively little funding. The biggest obstacle for these communities is the lack of specialized knowledge.

There was little to no interest in ecosystem problems like loss of biodiversity and endangered species, shown across the case studies. The general topic of 'Human Health' was frequently addressed, most commonly in direct reference to extreme heat and its deleterious effects on health. When 'Human Health' was referenced in other hazards, it was in a very general sense. Livelihoods and economic viability were often considered but tended to be addressed indirectly and without substantive evidence. For example, a report would indicate that warming oceans waters might harm fisheries but did not provide specific evidence for that claim or indicate the magnitude of expected harms.

iii. Illustrative Municipal Adaptation Examples – Extreme Rainfall/Urban Flooding

Urban and basement flooding caused by short-duration high-intensity (SDHI) rainfall events is one of the most significant drivers of disaster loss in Canada. The July 8, 2013 SDHI flood event in the Greater Toronto Area of Ontario highlights the potential for significant damage from urban and basement flooding with total costs of \$1.02B (IBC, 2020).

The City of Windsor has been exposed to repeated, severe extreme rainfall related flood events -- notably, September 2016 (195 mm of rain, \$165M in insured losses), and August 2017 (>220 mm, \$177M in insured loss). Insured losses are largely due to residential flooding/sewer backup (CatIQ, cited in Robinson, and Sandink, 2021). The City of Windsor's approach to flood management is summarized on their Sewer and Coastal Flood Protection Master Plan (Windsor, 2021). Windsor has a long-running residential subsidy program, extensive inflow/infiltration management programs and promotes innovative approaches to managing urban flood risks. For example, the City is promoting use of available regulation to apply very progressive programs (e.g., mandatory sewage ejector pumps for new construction with below-grade living space and development of a stormwater surcharge program). Further, the City operates a mandatory downspout disconnection program, requires flood protection measures in new construction, and is promoting progressive lot grading and drainage requirements. The City further undertakes aggressive subsidization of lot-level flood protection measures, including 100% subsidies for private-side flood mitigation measures. Most other local jurisdictions provide only partial subsidies.

A further example of progressive basement flood adaptation planning at the municipal level is the City of London's foundation drain disconnection/private-side risk reduction program (Kovacs *et al.*, 2014).

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Similar to Windsor and many other southern Ontario municipalities, the City of London has experienced a number of extreme rain events that resulted in extensive basement flood damage to homes. Connection of weeping tiles – underground drainage pipes that serve to direct below-ground water away from building foundations – to the sanitary system has been identified as a major driver of flood risk in many jurisdictions (Canadian Standards Association, 2018).

In the City of London, connection of weeping tiles to sanitary sewers was common for homes built prior to 1985. Subdivisions that were developed in the late 1970s and early 1980s have experienced recurring basement flooding because sanitary sewers become overwhelmed with foundation drainage water during heavy rainfall events. The City of London assessed source control and infrastructure alternatives to reduce the risk of damage from basement flooding in a target subdivision. Responding to evidence that a \$2M investment in source control (including weeping tile disconnection) would achieve greater protection than a \$10M investment in municipal-side infrastructure designed to store excess flow during extreme rainfall events, the City launched an innovative source control pilot project to disconnect weeping tiles from the municipal sanitary sewer system. The program included comprehensive subsidies for weeping tile disconnection and working directly with households to schedule installation. The program also included provision of additional incentives to offset long-term maintenance and inconvenience associated with installation of pumps in basements to discharge foundation drainage water. The program resulted in achieving the targeted uptake rate, significantly reducing excess water entering the sanitary sewer and helping to protect the target subdivision from future flood events (Chambers, 2013; Kovacs *et al.*, 2014).

In April 2019, the City of London declared a climate emergency and joined with other Canadian cities, including Halifax, Kingston, and Vancouver in making similar declarations. The City is now developing its Climate Emergency Action Plan and inviting inputs from across the community (London Climate Emergency Action Plan, 2021).

5. Canadian Climate Change Impacts -Adaptation-Resilience Response Strategies

In this Chapter, the objective is to provide detailed knowledge synthesis of issues related to major climate change impacts in the Canadian context of Canadian communities. **Focus A** is on communities where there are the most impactful changes in temperatures and the creation of heat environments. **B** is on severe weather-related events of wind and hail and the impacts of wildfire and flooding on community infrastructure and the need for construction codes and enhanced resilience of infrastructure. The impacts of a changing climate vary across different communities and Indigenous communities are certainly among the most impacted, so **C** is on building climate resilience in indigenous communities. **D** addresses the climate impacts on human health and health systems across all sectors in society. A factor across all these issues is economics and **E** deals with economics and climate adaptation. A related issue to all these sectors is the barriers to adaptation, addressed in section **F**. It is recognized that there are other major sectors, such as agriculture and food (McBean, 2021), transportation systems, natural ecosystems and others but, in view of limits on time and scope, these are not explicitly examined.

A. Heat Environments of Canadian Communities - (I.D. Stewart, J.A. Voogt)

i. Background

In Canadian cities, the effects of global warming are worsened by a local climate phenomenon called the urban heat island (UHI) wherein near-surface air and surface temperatures are generally higher over city surfaces than over the surrounding countryside, particularly at night. Heat islands are caused by the conversion of natural ecosystems (meadows, forests, fields) into manufactured landscapes of buildings, paved ground, and fuel-based human activities, all of which alter the natural energy and water balances of the surface (Oke, 1982). The combined effects of local- and global-scale warming have serious implications for heat-resilient cities. Extreme temperatures will become more frequent and more intense, increasing the severity of heatwaves and contributing to increased drought. Under heatwave conditions, urban air temperatures are increased, and the associated heat island effect evolves from a higher baseline

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temperature than would otherwise be the case. Rates of heat morbidity and mortality in cities will also worsen with urban warming, as will the costs of building ventilation and cooling. From a socio-economic perspective, the distribution of extreme heat in cities is not equitable: in densely populated and lower-income communities, public parks and green spaces are often non-existent or inaccessible. This puts marginalised communities (e.g., immigrants, older adults, poor or homeless people) at greater risk of heat-related illnesses. Also, the accumulation of surface and atmospheric heat in cities further degrades local air, soil, and water quality.

With these observed impacts of urban heat, strategies for heat adaptation are critically important for planning of resilient communities. The strategies are numerous and vary in their scales of implementation, but generally include use of: (i) public parks and green spaces; (ii) passive cooling systems in buildings; (iii) cooling shelters and heat warning systems; (iv) community programming for heat health; and (v) public education of heat-health risks. In Canada, there are challenges and trade-offs with implementing these strategies because the warm season is short and the cool season long. During the latter, urban heat is beneficial, e.g., lowering the costs of building energy use, while in the former it is mostly detrimental.

ii. Research Review

a) Urban heat island effects

Measurement studies of the urban heat island have been carried out in many Canadian cities using automobile surveys and networks of climate stations and meteorological sensors. These include the cities of Vancouver (Oke and Maxwell, 1975; Runnalls and Oke, 2000), Calgary (Nkemdirim and Truch, 1978), Edmonton (Hage, 1972), Regina (Stewart, 2000), Saskatoon (Ripley et al., 1996), Brandon (Suckling, 1981), Toronto (Munn et al., 1969; Mohsin, and Gough, 2012), Windsor (Sanderson *et al.*, 1973), Ottawa (Adamowski and Prokoph, 2013), Montreal (Oke and Maxwell, 1975) and communities on the St Lawrence Lowland (Oke, 1973). Among all studies of UHI in Canadian cities, maximum urban-rural air temperature differences are reported to reach (or exceed) 8–10 °C during clear, calm nights.

The *surface* urban heat island (SUHI) has received much less attention in Canada, with most of the work focusing on Toronto, Montreal, and Vancouver. Studies by Roth *et al.* (1989) and Bechtel *et al.* (2019) show that warmest pixels in a daytime satellite image are reliably found in compact residential and industrial/commercial neighbourhoods where there are high amounts of impervious surfaces and few trees, while coolest pixels are found in forests, parks, and water bodies. Similar patterns are reported for Montreal (Martin *et al.*, 2015) and Toronto (Rinner and Hussain, 2011; Ye *et al.*, 2017). In the much smaller city of Saskatoon, Shen *et al.* (2015) found that the Saskatchewan River and urban green spaces generate statistically significant cooling effects on the surrounding surface temperatures within 500 m and 200 m, respectively.

Leroyer *et al.* (2011) used a numerical model to assess the Montreal surface urban heat island. Combining observations with numerical modelling approaches, Gaur *et al.* (2018) examined the SUHI in 20 Canadian cities and its response to future changes to climate, land use, and land cover. They indicate that 15 of the 20 cities will experience increases in SUHI magnitudes under RCP 2.6. Surface and atmospheric heat islands in Montreal were similarly studied for their projected responses to climate change (Roberge and Sushama, 2018) using high-resolution simulations with the Canadian Land Surface Scheme (with and without urban representation) for RCP 8.5. Results show significant increases to land and air temperatures for both urban and nonurban regions, and slight increases to UHI magnitudes. Also shown is a projected increase in the number of “hot days”—i.e., those with temperatures above the 90th percentile—in urban areas (5–8 days in summer; 2–5 days in fall).

b) Urban meteorological networks and heat monitoring

Few studies in Canada report the use of permanent meteorological networks to monitor heat conditions in cities. One exception is Victoria, where a dense network of climate stations has been operating in the

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metropolitan region since 2005 (Weaver and Wiebe, 2006). The network consists of 41 automated weather stations installed on school rooftops. However, these instruments are not sited in accordance with WMO guidelines for “urban” observations (WMO, 2018). In the Greater Toronto Area, a 55-station mesoscale meteorological network was temporarily installed for the 2015 Pan American Games (Joe *et al.*, 2018) to measure the environmental conditions at the sport venues (e.g., heat stress; Herdt *et al.*, 2018). Tsin *et al.* (2016) used microscale mobile surveys of urban air temperature in Vancouver to show that fixed weather stations cannot characterise the variability of thermal conditions in the microenvironments of nearby streets, nor can they indicate the heat exposure of Vancouver's residents in individual neighbourhoods.

c) Heatwaves, urban climate prediction, and community adaptation

Smoyer-Tomic *et al.* (2003) give a spatial and historical overview of heatwaves in Canada, along with an assessment of heatwave adaptation potential in select cities. For the years 1961–90, cities in the Prairies, Southern Ontario, and St. Lawrence River Valley (Ontario and Quebec) experienced the highest temperatures and most frequent occurrences of heatwaves (defined as 2-day consecutive episodes of maximum temperature ≥ 30 °C). Montreal is shown to frequently experience extreme heat events; however, based on its old and compact housing stock (without air conditioning), the potential for heat adaptation in the city is limited. In contrast, Winnipeg and Toronto have the highest frequency of air-conditioned dwellings in Canada (meaning window openings and central-air systems), and thus comparatively good potential for heat adaptation. An important caveat is that the heatwave calculations are based on historical temperatures from Canadian airports, whose temperatures are known to be considerably cooler than downtown locations and thus less prone to heatwave events. This is especially true for Pearson International Airport versus downtown Toronto (Bellisario *et al.*, 2001).

The use of numerical models to investigate and predict urban effects on weather and climate in Canadian cities has been the focus of several publications. Ren *et al.* (2020) investigated the sensitivities of these predictions to urban effects in four major North American cities, including Toronto. A high-resolution (2.5-km) air quality model developed by Environment and Climate Change Canada (Talbot *et al.*, 2008) was coupled with the microscale Town Energy Balance (TEB) scheme. They showed that urbanisation greatly modifies humidity, air temperature, surface heat flux, and land-lake circulations. Tsin *et al.* (2020) used a statistical land-use regression model to predict air temperatures in neighbourhoods of Vancouver. The most predictive variables were shown to be “distance to large water body,” “distance to major road,” “Normalized Difference Water Index (NDWI),” and “sky view factor.” Also in Vancouver, Leroyer *et al.* (2014) conducted local-scale numerical simulations with the Canadian urban modeling system that showed the urban-induced wind circulation slowed the propagation of sea-breeze fronts to the south. To study the effects of climate change and future emission scenarios (RCP 4.5 and 8.5) on human thermal comfort in Vancouver (2070–2100), Aminipouri *et al.* (2019) employed a numerical radiation model that projected days with mean radiant temperature exceeding 65 °C will increase three- to five-fold under RCP 4.5 and 8.5, respectively.

Several studies have examined heat adaptation plans to cope with existing (or expected) heat conditions in Canadian cities. In Montreal, Richardson *et al.* (2009) developed an evaluative tool for communities adapting to urban heat. Residential areas of highest heat-risk ratings were identified with a GIS tool for integrating layers of spatial data on environmental and demographic conditions in the city (e.g., air temperature, percentage of population living in poverty). According to these criteria, the Montreal neighbourhood of Saint Michael was identified as “high heat-risk”. In Toronto, Rinner *et al.* (2010) suggested that heat vulnerability is potentially a valuable addition to the City's hot-weather planning toolkits and in Windsor, Carolis (2012), used satellite thermal imagery to derive a base-map for heat-adaptation analyses and recommendations. The maps provide decision-making support for temperature alerts and response planning in the city.

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A comprehensive report by the Institute for Catastrophic Loss Reduction states that local and regional governments are well-positioned to implement critical actions for helping Canadians cope with extreme heat (Guilbault et al., 2016). These include heat-warning systems, cooling centres, public swimming pools, public education campaigns, and tree planting programs, among others. Twenty case studies in Canada are presented, each providing an illustrative example of how local and regional governments are adapting to extreme heat, and which might inform comparable efforts in other communities. One-half of the 20 communities highlighted in the report have developed “Heat Alert and Response Systems” to protect people during extremely hot days, while the other communities highlight preventative actions that reduce exposure to urban heat (e.g., risk assessments, forest management practices). However, a recent report by Health Canada (2020b), identifies a lack of guidance for local governments and public health professionals to reduce extreme heat in Canadian cities. The report explains that under future emissions scenarios, the number of “warm nights” (minimum temperature ≥ 20 °C) and “very hot days” (maximum temperature ≥ 30 °C) will increase in all major cities across Canada, with greatest increases in Toronto, Montreal, Winnipeg, and Saskatoon. However, these (and many other) climate change projections do not include urban heat island effects, which further increase the number of hot days and nights, as shown for Toronto in a climate modelling study with urban representation (Oleson *et al.*, 2015). Nine instructional case-studies are highlighted in the Health Canada report, each describing actions taken to reduce (and adapt to) extreme heat in Canadian communities.

iii. Research Synthesis

The body of work on urban heat islands in Canada confirms that its cities are warmer, on average, than their surrounding country sides, and that this climatic “anomaly” implicates a range of issues related to public health (e.g., air quality, human thermal comfort), weather forecasting (heat alerts), building energy use (air conditioning), and settlement design (public parks, green spaces). One can estimate from this work the nightly magnitude of the urban-rural air temperature difference for any Canadian city based on general knowledge of its urban form, geographic setting, and weather conditions. Similar estimates for surface temperature differences are much less certain because the body of literature is smaller and restricted to only a few Canadian cities. Also lacking are detailed studies of the physical and spatial relations between surface and air temperatures. This is owed partly to the fact that very few Canadian cities have a sufficiently dense network of meteorological sensors to collect air temperatures from individual neighbourhoods, and to elucidate intra-urban thermal conditions that are comparable in spatial resolution to a satellite thermal image (100 m to 1 km). Most cities have only one or a few “official” climate observatories, meaning the local temperature conditions inside individual communities are rarely studied or monitored. Temporary networks for special events or short-term projects have been employed in some Canadian cities, but continuous, long-term monitoring at spatial scales that are relevant to community-level climate adaptation is almost non-existent in Canada.

The need for heat adaptation in Canada is underpinned by the observed (historical) increase in heatwaves and extreme hot days in all cities, as well as the expected increases shown by numerical climate and weather forecasting models. Some of these models are providing a platform for national-scale assessments and evaluations of urban climates (e.g., Ren *et al.*, 2020). However, despite the far-reaching impacts of heatwaves, they are often not viewed as a national threat because Canada's climate is temperate with long, cold winters (Smoyer-Tomic *et al.*, 2003). Changes in current and future heat conditions are underscored for all major cities of Canada, but Toronto and Montreal are the focus for research on heat adaptation. Whilst these cities are known to experience the greatest number of extreme hot days in Canada (a trend that will continue with climate change), other cities and communities in Canada are poorly represented in the heat adaptation literature. This is not to suggest that heat adaptation actions are not taking place in these communities—indeed many actions are described in two lengthy institutional reports on the subject. Guilbault *et al.* (2016) provide a positive outlook, suggesting that “local and regional governments have begun to take action to prepare for the threat of extreme heat”.

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However, Health Canada (2020b) cites a lack of guidance for collaborative work between local governments and professional workers to advance heat reduction and adaptation measures.

iv. Recommendations and Conclusions

Based on existing gaps in the literature, several areas for future research are recommended. Considerable resources at the national scale have been invested into the development of high-resolution numerical climate models (Talbot *et al.*, 2008, Leroyer *et al.* 2011) that incorporate urban canopy/surface models to improve weather forecasts and heat warning systems in Canada. The models also provide a standardised approach to assess urban-scale heat for present, past, and future climates. However, their application by a broad range of end-users in Canada has been limited. Further research to engage end-users in Canada is needed, and this can be helped by having access to standardised model-input data for urban surface parameters (e.g., vegetation cover, impervious area). A useful framework to use this research is the Local Climate Zone (LCZ) scheme of Stewart and Oke (2012), which classifies urban neighbourhoods according to their surface geometry, land cover, and human activity. Values for these parameters can be retrieved from LCZ maps that are generated manually or with automated methodologies. Although very few such maps exist for Canadian cities, work is underway to make them available to the CANUE (Canadian Urban Environmental Health Research Consortium) (Demuzere *et al.*, 2020). The maps can also be incorporated into the WUDAPT project (World Urban Database and Access Portal Tools, www.wudapt.org) for a range of uses, including urban heat and heat-health assessments (Ching *et al.*, 2018). Currently, very few Canadian cities are represented in the WUDAPT database.

There are notable shortfalls in the literature on the subject of heatwaves and heat adaptation in Canada. More research is needed to document the occurrence of heatwaves and to investigate their impacts in diverse sectors and geographic regions of the country (Smoyer-Tomic *et al.*, 2003). Use of urban climate models in this work is important because they represent the scales, surfaces, and locations of most relevance to urban health. For example, in the international literature, results from numerical modeling studies demonstrate that even widespread implementation of adaptation measures such as cool roofs and urban greening do not overcome the effects of climate warming in U.S. and European cities with climates similar to those of some Canadian cities (e.g., Krayenhoff *et al.*, 2018; Vigié *et al.*, 2020). We recommend similar modelling approaches be used in Canada to address the efficacy of climate adaptation strategies at the community level. Satellite remote sensing is an important source of input data for these studies (Masson *et al.*, 2020). At the policy level, additional work is required on climate adaptation measures for municipal governments. This work must take into account the issues of social equity, social connectedness, community resilience, and community participation. Existing research in Montreal provides an exemplar for how this can be accomplished (e.g., Chan *et al.*, 2007; Suh, 2019). Finally, more policy-related studies are needed to ensure that future heat-adaptation programs are centred on vulnerability assessments and adaptation strategies that protect populations at most risk to extreme heat. Approaches that have successfully correlated urban heat with the locations of vulnerable communities in the United States can provide insights for similar work in Canadian cities (e.g., Harlan *et al.*, 2007).

Relating to heat observations in cities, further work is needed in smaller urban centres to complement the body of work on much larger cities, concentrated entirely in the south. Of particular importance are Northern and Indigenous communities where people and built infrastructure are vulnerable to the expected impacts of global warming. In places where further study is justified for guiding heat resilience and adaptation strategies, communities might consider the use of automated meteorological networks to record basic weather elements (air temperature, wind, humidity, precipitation, radiation). In these cases, the sensors should be deployed in multiple neighbourhoods across the city, especially those that are most vulnerable to urban heat. This approach allows for continuous monitoring of heat where it may be dangerous, while gathering data for mapping heat-health risks, issuing heat warnings, and informing adaptation policies at local and city scales. In this effort, one might be tempted to use volunteer or citizen-based networks of low-cost temperature sensors (e.g., Netatmo weather stations), but lack of siting

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and metadata protocols for these instruments renders the data of poor or unknown quality. Satellite thermal imagery is readily available but should not be used without full recognition that it contains surface not air temperatures (mainly of building rooftops in urban areas), which are minimally related to human interactions at street level.

Critically important to any future studies of heat environments is adherence to international guidelines for siting meteorological instruments in urban areas, and for standardising metadata about the measurement environments of the sites (Oke, 2006; WMO, 2018; Stewart, 2011). The guidelines require placement of temperature sensors at pedestrian level (not rooftops), and ideally in locations where people interact with the outdoor environment (streets, parks, public spaces). LCZs can guide the experimental design of local temperature studies in urban areas, while providing a climate-based perspective for understanding the spatial distribution of air and surface temperatures in cities. Furthermore, LCZ maps can help to identify neighbourhoods where surface and air temperature are likely to be high (or low) based on urban characteristics such as pervious land cover and building height/spacing. Finally, further research in heat monitoring, modelling, and adaptation in Canadian cities must consider the changing seasons. Urban climate design-guidelines, for example, should accommodate both warm and cool seasons, aiming to provide a diversity of microclimates to protect citizens from extreme heat and cold year-round (e.g., Lenzholzer, 2015). The *Winter Design Guidelines* for the City of Edmonton (2016) are exemplary of this all-season approach to urban-climate adaptation in Canada.

B. Construction Codes - Disaster Risk Reduction for Severe Wind, Hail, Wildfire, and Urban Flooding - (G.A. Kopp, D. Sandink, D. Sills)

i. Construction Codes

Construction codes are developed to meet particular societal objectives, which have historically been to achieve fire and structural protection of buildings, health, accessibility for persons with disabilities, and, more recently, energy conservation. Disaster risk reduction measures, which emphasize reduction of property damage, have been considered to be outside of the National Building Code of Canada (NBCC) objectives. Regardless of the above-stated objectives, the role of construction codes in increasing disaster resilience has been highlighted in federal and provincial climate change adaptation strategies (Expert Panel on Climate Change Adaptation, 2009; Government of Canada, 2016; Government of British Columbia, 2010; Government of Quebec, 2012; Ontario Ministry of Environment, 2014). An assessment of the impact of climate change on climatic design was undertaken by Environment and Climate Change Canada (2020).

All levels of government are involved in development and implementation of construction codes in Canada. At the federal level, the Canadian Commission on Building and Fire Codes (CCFBC), situated in Codes Canada and part of the National Research Council, oversees production of Canada’s National Model Codes (National Research Council, 2020). Provincial and Territorial input on Model Code development occurs through the Provincial/Territorial Policy Advisory Committee (PTPAC) (National Research Council, 2020). Standing committees advise CCBFC on technical issues and changes to codes: Earthquake Design, Energy Efficiency, Environmental Separation, Fire Protection, Hazardous Materials and Activities, HVAC and Plumbing, Housing and Small Buildings, Structural Design, and Use and Egress (National Research Council, 2020). National Model Codes include: National Building, Fire, Plumbing, Farm Building Codes of Canada, as well as the National Energy Code of Canada for Buildings. National Model Codes requirements “*can be considered as the minimum acceptable measures required to adequately achieve*” stated code objectives (National Research Council, 2015).

The NRC Climate-Resilient Buildings and Core Public Infrastructure Project (2016-2021) is developing codes, guides, and models with the aim of addressing risk associated with climate change and extreme weather events. These will apply to both new and existing construction (Infrastructure Canada, 2020), with code change requests to be developed and submitted for the 2025 National Model Construction

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Codes. The particular project include (i) assessment of climatic data and climatic loads, (ii) standards and guides concerning flooding, including community, building guidance (guidelines for flood-resistant buildings), guidance concerning bioretention systems, covering urban, coastal and river flooding, and (iii) building durability. Projects specifically focussed on, or offering detailed guidance on, Part 9 buildings include CSA Z800-18: Basement Flood Protection and Risk reduction, a report entitled Practical Guidance for Private-Side Drainage Systems to Reduce Basement Flood Risk, and the NRC Wildland-Urban Interface (WUI) Fire Guide for Canada.

While NRC oversees development of technical content and publishes the National Model Codes, legislative authority for construction codes rests at the provincial/territorial level. To date, provincial authorities have not made significant progress on enhancing local code requirements to accommodate disaster risk reduction, though there are some examples of progress. For example: (i) 2017 Ontario Building Code public consultations - identified a need to incorporate climate resilience measures, including increased adoption of sewer backflow protection and measures to reduce high wind risk (Ontario Ministry of Municipal Affairs, 2017); (ii) BC Housing - Mobilizing Building Adaptation and Resilience, with an emphasis on multi-unit residential buildings and heat-health risk, and capacity building for building designers (BC Housing, 2020). BC Housing is not a code authority -- they are responsible for public housing, but they do serve as a resource to the home building industry and can help “set the tone”.

Municipalities and local authorities have a degree of discretion to adopt provisions in construction codes to increase resilience in their communities. Because municipalities lack authority for codes in Canada, these provisions are largely voluntary. Examples include: (i) City of Victoriaville, QC- Habitation Durable program, which has been adopted by seven additional QC municipalities; (ii) Dufferin County Hurricane Clip Subsidy Rebate Program. In some instances, building code officials may exercise a certain degree of discretion with respect to code interpretations, which may result in mandatory application of disaster resilience measures. For example: (i) most municipalities in Alberta, Saskatchewan, and major cities such as Toronto, Ottawa, Windsor, Mississauga and Hamilton, have adopted interpretation of provincial codes that require additional flood protection measures (specifically, sewer backflow protection) (Sandink, 2013); (ii) interpretation of the BCBC has been in a manner that requires cleanouts to be installed on foundation drainage systems, allowing building owners to access and maintain these systems, thereby reducing basement flood risk (Horizon Engineering, 2020). Where there are gaps in provincial codes, local jurisdictions have governed aspects of building design using the regulatory tools at their disposal. For example: (i) municipalities in the GTA have enacted restrictions on installation of reverse slope driveways through lot grading and drainage requirements and zoning by-laws; (ii) local storm and wastewater design guidelines have regulated building design details including restricting drainage of window wells to foundation drainage systems, various aspects of sump pump system design and location of foundations/basement floors relative to groundwater tables; (iii) following the devastating hail event in Calgary in June 2020, the City is moving toward developing new recommendations concerning disaster risk reduction, with a priority on hail risk reduction. This latter project respects that local jurisdictions do not have construction regulation authority, and will focus on multiple strategies, including education, incentives and code change requests made to provincial code authorities.

ii. Recommendations and Future Actions

There remain several immediate needs for disaster risk reduction of severe wind, wildland-urban interface (WUI) fires, and basement flooding:

- Site-by-site vulnerability analysis methods. Something similar to the energy modelling software/resources that are readily applied by architects, engineers and building designers in Canada is needed.
- Methods to quantify risk reduction on a site-by-site basis. In particular, understanding how various building characteristics affect disaster risk.

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- Improved understanding of efficacy of specific site scale interventions.
- Full cost/benefit assessments. Analyses exceeding the current requirements of only direct costs and benefits, which are required to support code change requests at the provincial and federal level, including consideration of:
 - reductions in: direct damage; additional living expenses associated with displacement; business interruption, avoided disruption in supply chains, indirect business interruption, loss of revenue due to damaged facilities, etc.; emergency response costs; reduced loss of services (fire, hospitals, police, etc.); maintenance costs, improved performance, durability of buildings associated with resilience interventions; mortality, morbidity and mental health impacts; loss of jobs; environmental impacts; and
 - lower insurance costs associated with overhead and profit (pure premium covered under direct damage to buildings job creation; and benefits with respect to reducing loss of tax revenue.

The current Impact Analysis conducted by SPA Risk LLC and ICLR for the NRC WUI Guide serves as an example of how to conduct this type of analysis.

iii. Disaster Risk Reduction Addressing Severe Wind and Hail

The National Building Code of Canada (NBCC) only considers synoptic storms for design, whereas, in many regions, thunderstorm-based winds would govern design. Methods to separate the data are well established but have not been applied in Canada. Additionally, there are a number of gaps in our climatological and meteorological understanding of thunderstorm-related wind gusts, tornadoes and hail in Canada. While there is a wind gust climatology, it is based on widely spaced surface station observations and is unlikely to represent the actual climatology, particularly for maximum speed. A climatology of damaging winds associated with downbursts or derechos has not been attempted. Real-time downburst detection, nowcasting and forecasting is in its infancy in Canada (in the US, major airports have wind shear detection systems). While there is some evidence that wind gusts will increase in parts of Canada with climate change, the same cannot be said for gusts strong enough to potentially cause damage, i.e., those associated with severe thunderstorms (Cheng et al., 2012).

The detection of tornadoes has improved with the creation of the Northern Tornadoes Project (Sills *et al.*, 2020) though far more events need to be documented to significantly improve Canada's tornado climatology. Real-time detection, nowcasting and forecasting of tornadoes is well behind that in the United States. The impact of climate change on tornadoes in Canada has not been investigated to any serious extent.

The implications of code philosophies on building performance in severe windstorms is significant. Post-event damage surveys have indicated that the primary issues for severe windstorms (as well as hail) are cladding, fasteners, and small building components. These are the building systems that protect the contents of the building. In fact, such failures can lead to the write-off of the structure, total loss can occur because of a handful of inadequate fasteners (e.g., nails). This greatly increases societal impacts through the disruption caused by displacement of people during re-building. Resilience to severe wind storms is directly related to the performance of cladding systems and fasteners. The changing climate and increasing losses indicate that resilience and loss reduction need to be considered in building codes, prescriptive requirements, and design practice. Engineering research has identified the solutions to many of these issues, with many being relatively low cost. However, there are still many knowledge gaps, particularly with respect to thunderstorms including downbursts and tornadoes with respect to both meteorological and loading issues.

The hail climatology for Canada is based on records from widely spaced surface stations (Etkin *et al.*, 2018) and is unlikely to represent the actual climatology, particularly for hail size. Tools for real-time hail and hail impact detection and nowcasting lags well behind the United States and there is need for significant improvement and development.

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iv. Summary

To address all hazards, there is need for methods to increase uptake of: new, voluntary standards - user guides, engagement sessions, industry support, etc.; and public users of the guidelines. Methods are also needed to motivate owners of existing buildings, considering the application of behavioural economics and developing easy-to-use resources for the public and those involved in implementation.

C. Building Climate Resilience in Indigenous Communities – (L. Yumagulova, B. Vogel, D. Yellow Old Woman-Munro, A. MacLean-Hawes, D. Naveau)

i. Background

Non-climatic factors including social, economic, cultural, political and institutional inequities produced as a result of uneven development, create social and climate vulnerabilities that result in the marginalization of specific populations (IPCC, 2014). Climate change impacts affect Indigenous peoples in Canada differentially, depending on geographic contexts of exposure and sensitivity to risk of climate impacts (IPCC, 2007; IPCC, 2019; Salick & Byg, 2007). Structural inequalities and inequitable social vulnerabilities impact Indigenous peoples' capacities to adapt (ICE, 2018; Ford et al., 2016). In this section, we critically examine the climatic and non-climatic factors that contribute to climate risk creation processes within Indigenous communities, to contribute to better understanding the significance of Indigenous capacity building efforts to address both climate adaptation gaps and location vulnerabilities.

Across Turtle Island, since time immemorial, Indigenous peoples have had Traditional Knowledge to adapt to changing environmental conditions on the land. There are 1.7 million Indigenous people in Canada accounting for 4.9% of the total population, speaking more than 70 Indigenous languages (Statistics Canada, 2017 & 2018). Rich in distinct and diverse cultures, histories, and traditions, Indigenous communities in Canada are growing at a population growth rate four times faster than the national average (Statistics Canada, 2016a).

Currently, Indigenous peoples are potentially amongst the most vulnerable population groups in Canada to the risks of climate change impacts (Desmarais, 2018). Indigenous communities in Canada are particularly vulnerable to the impacts of climate change, due to: peoples' intrinsic connection and socio-cultural reliance on their traditional territories; remoteness in relation to access to essential services; as well as infrastructure gaps and deficits that compound exposure and sensitivity to climate risks (CIER, 2009).

In the Arctic, rapid climate change, sea level rise, the loss of sea-ice and carbon dioxide and methane release associated with permafrost melt are long-term adaptation challenges to global climate stability (Larsen and Anisimov 2014). The Auditor General of Canada (2018a) reported that average temperatures have increased by up to 2.7°C (compared to 1.7°C in Canada as a whole) in Nunavut between 1948 and 2016. On the Arctic coast, the vulnerabilities of traditional livelihoods, community infrastructure and transportation to climate impacts remains high, necessitating human and financial resources to support the development and implementation of adaptation measures, as well as appropriately scaled policy leadership to prioritize and mainstream adaptation policy efforts, support coordination between stakeholders and promote access to scientific data to support adaptive capacity (Ford, et al., 2017). In 2011, a Nunavut governance framework for climate change adaptation initiatives (Nunavut, 2011) was developed to provide strategic direction for partnership building, research and monitoring, education and outreach and government policy and planning to enable the Nunavummiut to better adapt to climate impacts. Subsequently, the Auditor General of Canada (2018a) found that the Government of Nunavut was not yet adequately prepared to respond to climate change, as regional climate change strategies lacked implementation plans, public reporting and comprehensive climate risk assessments.

The disproportionate exposure and sensitivity to climate risks facing Indigenous people are the result of layered, historical inequities rooted in colonialism and institutional racism (e.g., the Indian Act,

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unhonoured or contested treaty rights, resource exploitation and residential school systems). Historically, colonial, racist policies forced the internal displacement of Indigenous peoples. These policies were enacted by the state through land dispossession, cultural assimilation and reserve systems that assured continued Indigenous oppression and social marginalization, often denying Indigenous peoples their livelihoods and rights to traditional adaptive strategies (e.g., seasonal migration to procure food resources and avoid hazards (Dicken, 2017; Yumagulova, 2020; Yellow-Old Woman Munro et al, 2021; Lewis et al, 2021). These historical, socio-political, and targeted risk creation processes place Indigenous communities in Canada at a disproportionately higher disaster risk to climate impacts, despite their small proportion of the overall Canadian population. Thus, non-climatic social inequities, combined with climatic factors such as disproportionate vulnerability to environmental risks, create unparalleled structural inequality and a higher sensitivity to climate impacts and disasters (Yellow Old Woman-Munro et al., 2021; Karetak et al., 2017; Adger et al., 2009; Smit et al., 2000): such as flooding and fire.

For example, First Nation communities are 18 times more likely to be evacuated as a result of disasters than people living off-reserve, while fire-related fatalities are more than 10 times higher (Government of Canada, 2019). Indigenous reserves are disproportionately exposed to flooding, with more than a fifth of residential properties exposed to risks of 1 in 100-year flooding (Thistlethwaite et al, 2020), and, the impacts of disaster displacement are further compounded by gaps in Indigenous communities' emergency management practices (e.g., lack of emergency hazard evacuation preparedness - Asfaw et al., 2020). Externally imposed emergency management practices can further deepen marginalization, trauma, and conflict within communities; exacerbating disaster impacts and pre-existing vulnerabilities while reinforcing the inequitable status quo of power relations that remove Indigenous participation and self-determination in disaster response (Yumagulova et al, 2019a).

Community infrastructure insecurities (e.g., inadequate, crowded housing, lack of reliable, safe and clean water; remote geography and transportation access to affordable and sustainable food, basic supplies and sustainable energy) further compound social vulnerabilities (Baird and Podlasly, 2020). In 2011, 292 off-grid remote communities (including 170 First Nations, Innu, Inuit or Métis communities) were reliant on diesel fuel for heat and power (Royer, 2011). Inadequate, crowded housing is a major contributor to social vulnerability. In 2016, the proportion of First Nations people with registered or treaty Indian status who lived in a dwelling that needed major repairs was more than three times higher on reserve (44.2%) than off reserve (14.2%) (Statistics Canada, 2016b). The combined impacts of these insecurities result in a 3.8 times higher prevalence of poverty among status First Nations children than non-racialized, non-Indigenous children (Beedie et al, 2019).

The non-climatic factors described above can undermine capacities to adapt in Indigenous communities. A failure to consider how diverse, social factors are experienced across a range of intersectionalities (e.g., historical and political contexts, diverse cultural identities, economic capacities, skills and knowledge, gender, age) results in critical gaps in governmental and researcher efforts to support Indigenous adaptation policy and practice; while running the risk of reinforcing existing social inequalities and the status quo of systemic racism (Walker et al., 2021). Adaptation to climate impacts (e.g., loss of winter roads, increasing wildfire, inland flooding and coastal erosion) requires addressing the social, political, economic, and legal contexts constraining Indigenous adaptive capacities. It also requires intentional efforts to reclaim Indigenous community resilience by recovering of cultural identities, ancestral knowledge, skills, spaces, and languages (Yumagulova et al, 2020; Gabriel et al., 2019).

Building resilience in Indigenous communities in the face of climate change is fundamentally about creating opportunities for self-determination and self-sufficiency. Bottom-up approaches for building Indigenous resilience offers co-benefits and collaborative opportunities for reconciliation, by enshrining social justice and equity in areas of nutrition, food security and Indigenous foodways, and resilient, sustainable livelihoods possibilities for resource diversification and adaptive co-management on Indigenous lands (Galappaththi et al., 2021; Richmond et al., 2021). Government institutions and research

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policy can support Indigenous-led adaptation. Integrated approaches to policy and governance to support much needed basic infrastructure in Indigenous communities, can help to systematically reconcile the challenges and harness the opportunities associated with building adaptive capacities in Indigenous communities (CIER, 2009). Interdisciplinary approaches that provide research support for Indigenous collaborations through co-designed, decision-oriented research can help to promote knowledge mobilization and Indigenous capacity building opportunities for resilience and adaptation by communities and Indigenous-led organizations (Vogel and Bullock, 2020; Ford et al., 2017).

ii. Frameworks, Programs, and Tools Supporting Indigenous Community Resilience

The adoption of the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP) as a national policy framework for reconciliation may provide a critical influence on existing policies and processes. UNDRIP recognizes the requirement for governments and corporations to obtain the free, prior, and informed consent of Indigenous people in any decision-making processes that impact Indigenous land, livelihoods, traditional food security and natural resource-based economic activities. In December 2020, the Canadian government introduced legislation to implement UNDRIP as a roadmap and building block for working together with Indigenous peoples to fully recognize, respect, protect and fulfill the rights of Indigenous peoples, including promoting economic participation, through the creation of opportunities for social and economic equality (Government of Canada, 2020).

Calls for action for climate adaptation and resilience can be achieved through the protection of Indigenous governance laws values, cultures and languages and addressing Truth and Reconciliation Commission (2015) recommendations, including the federal ratification of UNDRIP (Government of Canada, 2020; Townsend et al., 2020). Recognition of the importance of Traditional Knowledge for understanding climate impacts and adaptation measures is identified in Pan-Canadian Framework on Climate Change (Government of Canada, 2016). The Pan-Canadian Framework calls for recognizing and translating information and knowledge into action by integrating Indigenous community-level climate change data collection, risk assessment planning and flood plain mapping with traditional Indigenous practices. The Government of Canada (2020, pp.67-71) has also identified opportunities to co-develop a shared policy-making agenda to build regional and national capacity for climate action in First Nations, Inuit, and Métis communities and representative organizations.

iii. Indigenous-led Adaptation Through Nature-Based Solutions

Indigenous communities have been at the forefront of incorporating nature-based solutions in adapting to environmental change since time immemorial. A tenth of the Canadian land area is currently protected, with a conservation aim to preserve an addition 7% in the next 9 years to support global climate resiliency through GHG sequestration and biodiversity protection using nature-based solutions (Townsend et al., 2020; ICE, 2018). Indigenous organizations have been leading initiatives that connect climate action and land-based adaptations, including the Indigenous Circle of Experts (ICE), the Indigenous Leadership Initiative and Indigenous Climate Action. Some of the barriers to enacting nature-based solutions include climate-change politics, policy gaps and lack of legal recognition in Canada that limits Indigenous autonomy over traditional lands (Scott and Cutfeet, 2020). The Centre for Indigenous Environmental Resources (2009) offers a suite of capacity-building resources and tools to support Indigenous adaptation and resiliency through culturally appropriate planning, mapping and management approaches (See also: Tobias et.al., 2009). At the community level, some examples of Indigenous-led nature-based solutions include: land management for carbon offsetting and nature-based conservation (Great Bear Rainforest, BC); ecosystem service accounting in land use decisions (Poplar River, Manitoba), and an emerging climate-action strategy for Indigenous sustainable forestry management planning (Wahkohtowin, Ontario) (Townsend, Moola & Craig, 2020).

In the next section we list examples from First Nation communities that participated in the [Preparing Our Home program](#) that enables the next generation of Indigenous community resilience leaders.

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a) East Coast: Community-led risk assessment in the Confederacy of Mainland Mi'kmaq (NS)

The [Confederacy of Mainland Mi'kmaq](#), Nova Scotia is a Tribal Council incorporated in 1986 as a not-for-profit organization that serves eight member communities: Annapolis Valley, Bear River, Glooscap, Millbrook, Paqtnekek, Pictou Landing, Sipekne'katik and Acadia First Nation. The organization's mission is: *"To proactively promote and assist Mi'kmaw communities' initiatives toward self-determination and enhancement of community."* In 2014, the Confederacy of Mainland Mi'kmaq's Mi'kmaw Conservation Group started an adaptation and resiliency project through the Climate Change Adaptation Program at Aboriginal Affairs and Northern Development Canada. Recognizing the importance of climate action across multiple areas, which supported the development of the Mi'kmaw Climate Action Program. In 2017 the program evolved to include a project through the Climate Change and Health Adaptation Program for First Nations South of 60N at Indigenous Services Canada First Nation and Inuit Health Branch with the objective of understanding and navigating the relationship between climate change, emergency management, and health within Mi'kmaw communities, by determining community strengths, weaknesses, and gaps.

Through community-led research, needs assessments, and workshops, the project has examined physical, mental, emotional and spiritual impacts of climate change, emergencies, and emergency management on the health of community members. This intergenerational planning project included youth and combining Indigenous and Western worldviews was achieved by using a combination of the "Medicine Wheel" (mind, spirit, body, and emotion metaphors for holistic teaching) with the "Emergency Management Cycle" (prevention, mitigation, preparedness, response, and recovery). A community-led climate risk assessment was conducted across seven communities with over 200 participants. Key findings included finding that more than three quarters (80%) of community members have a health concern and over 60% of participants think that climate change will impact health outcomes (Yumagulova, MacLean-Hawes, Naveau, Sperry, forthcoming). A project advisory committee comprised of emergency preparedness members from each member community (e.g., councillors, band staff, community members, etc.) provides project oversight and structure. This community-led approach ensures long-term ownership of data and solutions that are developed for and by the communities.

b) Central Canada: Planning for Seven Generations in Mattagami First Nation (ON)

Mattagami First Nation is situated on ancient Native land that has long been home to the Ojibway and OjiCree people that lived a nomadic life on the land from the Mattagami River and Mattagami Lake areas, and as far as the Moose River head waters on the James Bay coast. On July 7th, 1906 Treaty #9 was signed which reduced the traditional lands of the First Nation people living in the Mattagami Lake area to an official land base. In 1921, a power company built a holding dam on the Mattagami River flooding parts of the original community's land base. In 1952, as a compensation for the flooding, an additional 200 acres was given back to Mattagami for the purpose of constructing a new community site that is now home to roughly 600 members. The community is faced with fluctuating water levels, land erosion, and is nearing maximum population capacity. The Nation recognizes the widespread impacts of climate change on its ways of life, culture, self-determination, and economy. The Mattagami First Nation Harmony Movement led by Executive Director, Juanita Luke is a strategic planning process that prioritizes seven areas including: tradition and culture, economic development, capacity development, land and infrastructure, inclusivity and advisory services, financial excellence, and policies and codes to ensure that the Nation can continuously adapt in the face of change. By focusing on these seven aspects, Mattagami First Nation aims to build a fair, healthy, competent, and prosperous community for today and future generations through a collaborative community effort. In addition to long-term planning, Mattagami has implemented of a community Master Emergency Response Plan, led by Health Director/Emergency Management Systems Coordinator, Eileen Boissoneau. This plan builds on and expands on the disaster management cycle model involving hazard identification and risk assessments, training and education, response, recovery, and re-entry. This comprehensive process ensures that

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Mattagami plans for and develops emergency procedures for pandemics, environmental contamination, forest fires, rainfall/flooding, major highway road incidents, major windstorms, major blizzards/ice storms, dangerous gasses, and requests for assistance. The Plan has proven its effectiveness over the years, and the Nation has become known leaders in emergency response planning within the Tribal Council (Yumagulova et al, forthcoming).

c) Western Canada: Siksika Nation (AB) - Dancing Deer Disaster Recovery Centre (DDDRC)

The Siksika Nation is a part of the Blackfoot Confederacy and is the second-largest First Nation reserve in Canada, located 87 kilometres southeast of Calgary with a total population of over 7500 members. In June 2013, eight Siksika communities along the Bow River were devastated by a flooding disaster that destroyed two main bridges and affected 171 homes displacing over 1,000 people (Yumagulova et al., 2019b). The evacuees have been moved up to five times: from teepees, tents and trailers to hotels and motels; to first round of temporary relief shelters (ATCO trailers) then to new temporary neighbourhoods and finally to permanent new neighbourhoods (Yellow Old Woman-Munro et al., 2021; Patrick, 2017). Six and half years later, some community members still have not returned to their homes (Yumagulova, et al., 2019b).

In the chaos, loss, and trauma that this long-term displacement of this disaster, a unique community organization, Dancing Deer Disaster Recovery Centre was created to support self-determination in disaster recovery by rebuilding families through “*hope and healing*”. The Centre consisted of a multi-disciplinary group of Siksika professionals, youth and a Siksika traditional Elder. The team was guided by the Medicine Wheel by providing culturally safe supports for spiritual, emotional, physical, and mental needs of evacuees. These services were provided through one centralized centre (instead of having to visit multiple departments); and services were delivered in the temporary housing of the evacuees, thus serving as a critical link for cultural continuity across phases of displacement. An Indigenous service provider stressed the importance of this ability to meet people where they were at in a culturally safe way: “*Meeting the people in their temporary situations, temporary housing, hotel, or trailers...it allowed for a lot more trust building that people would be willing to open their doors to you, to be able to be seen in that situation rather than them seeing you as a psychologist coming to do counselling, they saw me more as somebody coming in to visit and checking in on them in a much safer, non-intrusive way...*” (Yumagulova et al., 2019b). This ability to deliver culturally safe services in Blackfoot languages in however or temporary the ‘home’, was particularly important for the most vulnerable members of community such as elderly, chronically ill, and single parents with special needs children.

iv. Synthesis

Indigenous communities in Canada are faced with diverse social contexts and non-climatic factors that influence collective abilities to adapt to climate impacts. Our synthesis reveals that Indigenous communities in Canada are at the forefront of climate change adaptation in Canada. The evidence presented suggest that:

- Indigenous Knowledge, intergenerational learning, land-based learning, participatory methodologies, and the role of traditional language for community resilience are important social factors that support adaptation at the community scale (Yumagulova et al., 2020).
- Examples of self-determination for building climate resilience include: community led risk assessments, intergenerational planning, and community-led disaster recovery organizations.
- Combining western and Indigenous ways of knowing, provides innovation in techniques for holistic knowledge translation in support of adaptive capacity building in communities.
- Differences in adaptive capacities affect Indigenous communities’ ways and means of organizing to plan and assess current climate impacts and future hazards, with community health overlaps.

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- Building Indigenous community resilience requires addressing the impacts of colonial land dispossession and disaster and climate displacements and the gaps in social service support for providing for the mental, cultural, spiritual health needs of displaced Indigenous peoples.
- Indigenous communities and organizations are leading the way in nature-based solutions, with long-range importance for the global climate, as well as opportunities for reconciliation.
- A path forward on meeting Indigenous socio-economic, cultural, and basic needs recognizes Indigenous rights for the co-management of environmental resources, achieved through reconciliation of the governance and territorial management of Indigenously held land, driven by pivotal opportunities for global biodiversity protection, carbon sequestration, and Indigenous conservation collaborations in Canada (Whitney et al., 2020; ICE, 2018; Hawken, 2017).

We synthesize that transforming top-down governance to advance climate resilience across scales requires support for Indigenous-led environmental co-management and conservation efforts. There is a lacuna of knowledge sharing opportunities or research platforms for community-led Indigenous resilience and adaptation in Canada, necessitating the creation of intentional research space and collaborative opportunities for Indigenous-led, place-based, culture-based adaptation and resilience planning strategies to be supported by public policy, research partnerships as well as collaborative funding opportunities.

D. Climate Change Impacts on Human Health - (A. Gunz, P. Berry, K. Clemens, P. Wilk, B. McKelvie, I. Luginaah)

i. Introduction

Climate change is impacting the health of Canadians, their communities and our health systems. Risks will continue to grow with the increasing frequency and severity of climate hazards. Health is differentially impacted by climate events and this effect is modified by vulnerabilities at the individual, community and health system levels (Figure 3).

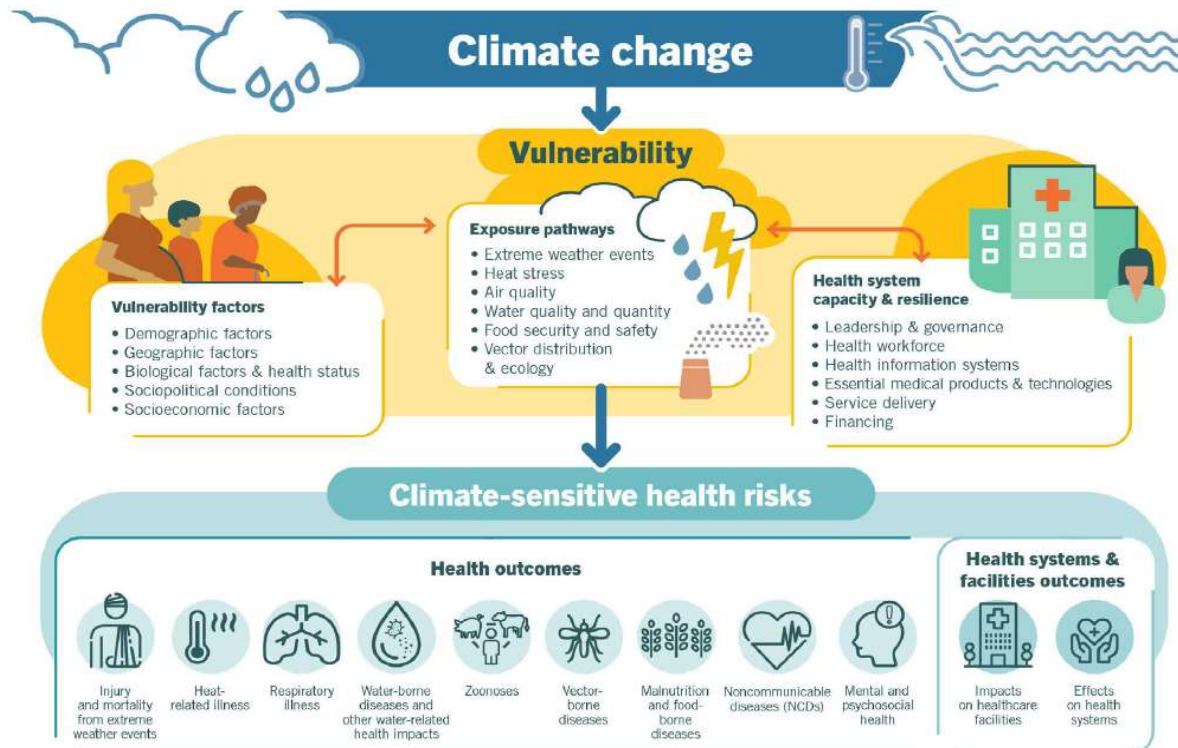


Figure 3: Vulnerabilities and health risks related to climate change (World Health Organization, 2021)

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Health sector decision makers need information, tools and capacity to protect the health of individuals from current climate hazards and withstand more severe and frequent extreme weather events associated with continued global warming.

This chapter provides an overview of the health impacts of climate change at the individual and community levels, with special attention to its inequitable effects on disease burdens among the most vulnerable members of our communities. Growing risks to health care systems in Canada are highlighted along with potential adaptation strategies to improve the resilience of our systems.

ii. Heat, Aeroallergens, Air Pollution & Health

Extreme heat poses significant risks to health. Canadians are at risk of heat stress and heat stroke, worsening of underlying respiratory, cardiovascular and neurological conditions, and increased use of emergency department services (Berry *et al.*, 2014; Wilk *et al.*, 2020). Moreover, periods of extreme heat are associated with increased mortality in Canada and globally (Watts *et al.*, 2019). One study projected an increase in excess mortality due to extreme heat in Canadian cities of 400% - 525% by 2031-2080 from a 1971–2020 baseline under an RCP8.5 and high population growth scenario in the absence of further adaptation (Guo *et al.*, 2018).

Children are at particular risk of adverse effects with exposure to high temperature; renal disease, fever, electrolyte imbalance, and respiratory conditions have all been identified as adverse health outcomes in this population (Xu *et al.*, 2012).

Aeroallergens are airborne organic particulates, including pollen, fungal spores and dust mites that trigger allergic reactions (e.g., allergic rhinitis, atopic dermatitis, and allergic asthma) in susceptible individuals. The ragweed season has already become longer in North America; between 1995 and 2009, the ragweed season increased by 25 days in Winnipeg and 27 days in Saskatoon (Ziska *et al.*, 2011). As Canada's climate changes, the length of the pollen-producing season will continue to increase, the patterns of pollen dispersion will change, and other less common allergens may be amplified and cause new sensitization (Reid & Gamble, 2009; Sierra-Heredia *et al.*, 2018). Allergic symptoms will increase among members of our communities with underlying conditions, and new allergies might affect susceptible individuals (Sierra-Heredia *et al.*, 2018).

Air pollution is also expected to increase with climate change and increased ambient temperatures (Berry *et al.*, 2014). Health Canada estimated that in 2019, 14,600 Canadians died of anthropogenic sources of air pollution – a 1.4% increase from 2017 estimates (Health Canada, 2019). Simulating the effects of climate change on future air quality in 2045, Kelly *et al.* (2012) projected that ground-level ozone (O₃) and fine particulate matter (PM_{2.5}) would increase in many regions of Canada in the absence of future reductions in anthropogenic emissions. Air pollution has been associated with adverse cardiac outcomes, poor lung function, worsening of asthma and chronic obstructive pulmonary disease, as well as an increased risk of lung cancer (Anderson *et al.*, 2012). Children may experience poor lung development and potentially the development of asthma (Radhakrishnan, Bota, Price *et al.*, 2021). In addition, air pollution is linked to poor prenatal outcomes (e.g. preterm birth, low birth weight and intrauterine growth restriction) and cardiovascular mortality and morbidity from ischemic heart disease and stroke (Anderson *et al.*, 2012; Anderson, Favarato & Atkison 2013).

iii. Vector Borne Diseases

The risk of vector-borne infectious diseases will continue to increase as Canada's climate changes (Berry *et al.*, 2014; Ogden & Gachon, 2019). Surveillance of Lyme disease in Canada for example, has demonstrated a continual increase in annual reported cases. With the northward geographic expansion of the tick vector *Ixodes Scapularis*, human cases have increased from 144 cases in 2009 to 992 cases in 2016, and 2,636 cases in 2019 (Ogden & Gachon, 2019; Ogden *et al.*, 2008; PHAC, 2021). The annual incidence of West Nile Virus, currently concentrated in the prairie region of Canada (Chen *et al.*, 2013;

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Ogden & Gachon, 2019), may also increase. Moreover, other exotic diseases could be introduced and sustained in regions of Canada if conditions become hospitable to them (Ogden & Gachon, 2019).

iv. Extreme Weather Events and Related Hazards

Extreme weather events can also lead to significant morbidity and mortality. Direct catastrophic impacts on communities can occur during extreme weather events and indirect effects are also observed. For example, extreme weather events can limit access to lifesaving treatments and medications for pre-morbid health conditions; cause health infrastructure disruption; promote waterborne disease secondary to water shortages; contaminate the water system and disrupt of water-treatment services; and lead to hypothermia and carbon-monoxide poisoning from energy infrastructure failures and use of indoor generators (Berry et al., 2014; Sahni et al., 2016).

Wildfires, which are projected to become more frequent in Canada as the climate continues to warm (Flannigan *et al.*, 2013; Wang *et al.*, 2017), are associated with increased respiratory illness; in 2003 one community in British Columbia reported an increase in emergency department visits for respiratory disease by 46%-78% (Yusa *et al.*, 2015). In addition, between 2013-2018, wildfires may have caused 54 to 240 deaths annually from short-term exposure to smoke and 570 to 2,500 deaths due to long-term exposure (Matz et al., 2020). Large rainstorms can lead to electrical injury with lightning strikes. Rainstorms can also exacerbate allergic disease from associated aeroallergens and can propagate an allergen-burst phenomenon triggering thunderstorm-induced asthma (Reid & Gamble, 2009).

Flooding is associated with a range of direct and indirect health impacts, including increased respiratory and allergic diseases from the propagation of mold spores (Reid & Gamble, 2009). Drought can lead to water scarcity and contamination with organic and waterborne pathogens, and proliferation of foodborne pathogens (Yusa *et al.*, 2015).

v. Mental Health

Climate change has a significant impact on the mental health of Canadians. Exposure to extreme heat is associated with fatigue, anxiety, mood disorders, hostility, and violence. Individuals with pre-existing mental illness are at increased risk of death during heat waves (Cianconi *et al.*, 2020). Extreme weather events have been directly linked to depression, anxiety, post-traumatic stress disorder (PTSD), suicidal ideation, substance abuse and feelings of hopelessness (Cianconi *et al.*, 2020; Hayes *et al.*, 2019; Hayes & Poland, 2018).

The mental health impacts of climate change may also occur when individuals witness large-scale events remotely (e.g. on the news). In addition, awareness of the global loss of biodiversity can be associated with feelings of hopelessness and depression (Cianconi *et al.*, 2020). Awareness of the climate crisis can also lead to distress, anxiety and feelings of impending doom (Hayes *et al.*, 2019; Hayes & Poland, 2018). On the other hand, there have been reports of positive psychological wellbeing or "post-traumatic growth", which leads to feelings of altruism, purpose and optimism (Cianconi *et al.*, 2020; Hayes *et al.*, 2019).

vi. The Disproportionate Burden of Climate Change

Climate change has inequitable health effects on our population. Globally, children are disproportionately affected due to their developing physiology and greater lifespan that increases overall time of exposure (Watts *et al.*, 2019). Older adults and those with medical comorbidities (e.g., diabetes) have susceptible physiology and use prescription medications that place them at risk of heat-related illness (e.g., medications that predispose to dehydration). Women are also disproportionately affected by climate change across different social and cultural contexts (Watts *et al.*, 2019; Williams, 2018). People at risk of homelessness are particularly vulnerable to heat-related illness due to lack of shelter and cooling options, as are outdoor workers (Kiefer *et al.*, 2016).

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Pervasive health inequalities, including those related to historic and ongoing colonial oppression, create barriers to building climate resilient and healthy communities particularly for racialized and Indigenous communities. Poor housing conditions (e.g., overcrowding, homes requiring repair, poor ventilation, mold) in many communities, increases exposure to indoor air pollutants for First Nations, Inuit and Métis peoples, compounded during outdoor air quality threats (e.g., during forest fires) (Carrière *et al.*, 2017; Dodd *et al.*, 2018). There is a complex relationship between climate change, food insecurity and health (Schnitter & Berry 2019); for indigenous communities, interventions should consider culturally specific approaches (Richmond *et al.*, 2021). Indigenous-led health organizations have a role to support their communities, that cultivate a safe-, client-centered space and provide advocacy for community members (Nelson & Wilson 2021). Public health policies and interventions should be decolonized and integrate indigenous knowledge (Lewis *et al.* 2020; Masuda *et al.* 2020).

vii. Climate Resilient Health Systems

Climate resilient communities require health systems that are effective in protecting people from climate variability and are resilient to more severe and frequent climate change hazards. Recent experience in Canada demonstrates that health systems, including critical components like health facilities (e.g., hospitals, medical clinics, community care centres, long-term care homes), can be highly vulnerable. For example, the severe forest fire season in British Columbia in 2017 impacted 19 health facilities or sites within Interior Health Authority; facilities were closed, 880 patients were evacuated, more than 700 health services staff were displaced. Costs to the health authority was approximately \$2.7M (Interior Health, 2017). Climate change is projected to increase the severity, frequency and spatial extent of environmental hazards (e.g., heatwaves, droughts, floods, wildfires, ice storms) and combined events could push health systems beyond tipping points, threatening their ability to maintain operations and protect the health of patients, visitors and staff.

A health system is climate resilient if it can anticipate, respond to, cope with and recover from climate change impacts (WHO, 2015). To build climate resilient communities, health system planners and professionals should take proactive efforts to increase knowledge of climate change threats and use this information to guide policy and program development.

Major categories of health adaptations to prepare for climate change include the following (WHO, 2015; Ebi *et al.*, 2019; Health Canada, 2020a, HealthADAPT):

- Equipping the health care workforce with needed information and tools to protect their own health when disasters occur, and help their clients prevent health impacts, or treat them when they occur;
- Improving the effectiveness of service delivery, for example, during and after climate-related hazards like severe storms;
- Providing adequate financing to support adaptation efforts;
- Integrating considerations of impacts from current climate variability and future climate change into the actions to maintain, upgrade or build new health infrastructure, like hospitals and clinics (e.g., medical clinics in areas of permafrost melt or flood risk);
- Developing health information systems (e.g., monitoring and surveillance systems/syndromic surveillance systems) linked to other sources of information (e.g., meteorological information) to aid in preparation efforts; and
- Evaluating the effectiveness of adaptation options (e.g., heat alert and response systems, emergency management plans) to support iterative improvements to actions to protect health.

New assessment tools and methods are available to health authorities in Canada to acquire the information needed to assess their climate resilience and developed needed adaptations. The Health Care Facility Climate Change Resiliency Toolkit developed by the Canadian Coalition for Green Health Care (CCGHC, 2021) includes a checklist with questions to measure preparedness for emergencies, and in

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critical functional areas, including facilities management, health care services and supply chain management. By applying the checklist regularly, facility managers can monitor progress towards climate resilience over time. The Toolkit also provides a list of resources that can be used to plan risk management measures, for example, efforts to harden infrastructures from more extreme weather events and disasters (CCGHC, 2021). In addition, the next national climate change and health assessment will be released in 2021 and will help inform development of new policies and programs to combat climate change.

viii. Adaptation to Climate Change Risks by Health Authorities in Canada

Many actions are being taken by health authorities across Canada to prepare for climate change. A survey of 80 health sector officials from all regions of Canada in 2019 revealed that the majority (80%) are taking some kind of action to address the risks of climate change to health. For example, 56% of respondents indicated they are undertaking surveillance and monitoring of the health impacts from climate change. In addition, over half (53%) reported engaging in climate change and health education and outreach activities with stakeholders, while 47% have done so with the general public. Fewer officials however, have taken efforts to systematically identify climate change risks to health and adaptation options through science assessments (35%), and just 20% have developed a health adaptation strategy. In addition, only 31% are taking measures to improve emergency plans and programs to increase the climate resilience of the health system and only 23% reported providing climate-informed training for public health professionals (University of Waterloo Survey Research Centre, 2019). It was also identified that we require more efforts to address climate change related inequities through well designed adaptation and greenhouse gas mitigation measures.

ix. Summary

Addressing the health impacts of climate change requires proactive measures to develop climate resilient Canadians, communities and health systems. Evidence suggests that risks to health and well-being are increasing with continued warming. Some populations are bearing disproportionate impacts of climate change. Adaptation at the community and health systems level can reduce future risks through multi-sector, interdisciplinary strategies that improve community health and health system resilience and focus on supporting at-risk groups, while addressing key health inequities. Health sector officials should utilize the growing number of tools and increased knowledge of the pathways through which climate change affects health to chart future progress in protecting Canadians. Equity, diversity and inclusion are essential principles for health authorities as they work with partners to tackle climate change in a manner that brings benefits to all segments of the population.

E. Economics and Climate Adaptation - (B. Li, P. Kovacs)

i. Introduction

There is widespread agreement that investments in climate change adaptation, in addition to mitigation, are required to reduce losses from climate change, since climate change is already occurring and will continue even with successful mitigation efforts. Various decision frameworks exist for selecting which adaptation measures should be implemented. The most common of these is the cost-benefit assessment (CBA). A CBA consolidates the projected costs and benefits of a project into a single monetary value, which allows for simple comparisons across projects. However, there are several limitations of CBA and the use of other decision frameworks like multi-criteria analysis and cost-effectiveness analysis may be appropriate if important impacts can't be valued in monetary terms.

Overall, there is a relatively small amount of investment in climate adaptation. A variety of market and behavioral imperfections can prevent the implementation of adaptation measures with benefits greater than costs. Prominent among these are imperfect information, myopia, borrowing constraints, externalities, and potentially moral hazard. Institutional failures can also create barriers to adaptation.

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Various market-based incentives exist or are emerging which can encourage climate adaptation. Property insurance improves recovery following a disaster and, with industry engagement, can encourage investments in resilience. Investors are requesting that companies increase and improve disclosure of climate change-related performance. Financial instruments where the funding must be exclusively directed towards climate change-related projects, such as green bonds, are currently relatively small but are growing rapidly in use. However, the impacts of these incentives are unclear.

ii. Decision Frameworks

Given a set of normative values, decision frameworks can be used to evaluate and rank different options. However, these frameworks require making assumptions which can have significant effects on the final results. The CBA decision framework is commonly used to evaluate existing climate adaptation projects or appraise potential projects. A CBA compares the costs and benefits of a policy using the present monetary value of impacts and recommends a project if its benefits exceed the costs or, when comparing multiple projects, if it has the greatest benefits over costs of all the options. In Canada, cost-benefit assessments are required for Federal regulatory proposals (Government of Canada, 2018).

Many studies of climate resilience projects using CBA exist (e.g., Vicarelli, *et al.*, 2016; Mechler, 2016) and the general methodology for cost-benefit assessments are similar. The scope of the assessments must be determined, including the types of impacts considered and the baseline scenario. The projects were identified and their impacts are calculated. Finally, the costs and benefits of the various options are compared. Cost-benefit assessments can be performed for a specific historical event, for a hypothetical future event of a certain severity or likelihood, or across the probability distribution of future risk.

Despite being similar in their general methodology, cost-benefit assessments often differ in their choices of specific procedures and assumptions including the types of costs and benefits considered, how to value benefits with no direct market values, and how to compare impacts on different time scales. Differences in these assumptions can have significant effects that change the outcome of an assessment. Guidance on choosing these procedures and assumptions exists in many jurisdictions including Canada (Treasury Board Secretariat of Canada, 2007), United States (National Center for Environmental Economics, 2014), United Kingdom (HM Treasury, 2018), European Union (European Commission, 2014), and Australia (Office of Best Practice Regulation, 2020).

Alternative decision frameworks exist which can better address concerns around non-monetary impacts and values. In scenarios where an outcome or goal is considered mandatory, cost-effectiveness analysis (CEA) can be more appropriate. A CEA considers proposals that can achieve a given outcome and recommends the lowest-cost option.

The use of multi-criteria analysis (MCA) is recommended when the non-monetary costs and benefits of impacts are especially important (Webster *et al.* 2007). In an MCA, options are evaluated on separate categories such as economic, environmental, social, and cultural impacts. For example, the PIEVC protocol assesses options using a triple bottom line approach which considers social, environmental, and economic costs and benefits (Engineers Canada, 2016). Social and cultural impact assessments are often conducted through community consultations (Esteves, et al, 2012). Projects can be compared by scoring each category for each project numerically, then calculating an aggregate score for each project by assigning weights to the categories (Webster *et al.*, 2007; Nodelman *et al.*, 2015).

iii. Factors Limiting Adaptation

Despite the significant benefits of investments in resilience, the overall level of investments in resilience is low. A 2019 report found adapting to climate change in Canada requires an estimated \$5.3B of additional annual investments (IBC, 2019). Internationally, a report by Zurich Insurance (2018) finds *there is little evidence that disaster risk is considered in most investment decision-making and land-use planning.*

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Market failures, behavioral biases, and institutional barriers can prevent adaptation even when the benefits exceed the costs (Boyd *et al.*, 2015). Lack of information and myopia is a prominent obstacle. Asset owners and other decision-makers may not be aware of disaster risk or how to reduce them (Martin & McTarnaghan, 2018; Rakobowchuk, 2018; Moorcraft, 2019) and the perception of disaster risk fades in the years following a disaster (Morgan, 2007; Zhang & Leonard, 2019; Bin & Polasky, 2004). The myopic bias for near-term costs and benefits also leads to underinvestment in resilience (Bonfiglioli & Gancia, 2013; Jackson & Petraki, 2011; Healy & Malhotra, 2009; Kunreuther, 2006).

The market failures of imperfect capital markets, externalities, and moral hazard can impede adaptation. Borrowing and financing constraints are an important factor that can lead households (Zeldes, 1989) and businesses (Buera, 2009) to underinvest. Asset owners may also underinvest in resilience due to the presence of positive externalities. Resilience can directly reduce risk for neighboring structures for wildfire (Westhaver, 2017; Shafran, 2008; Butry & Donovan, 2008) and extreme wind (Golden & Snow, 1991). Disasters can also impact neighborhoods more generally by destroying amenities (Fu & Gregory, 2008) or through economic spillovers (Rose & Liao, 2005; West & Lenze, 1994). Finally, government and insurance assistance can reduce adaptation through moral hazard (Baylis & Boomhower, 2019), although this may not occur if asset owners are highly risk averse (Hudson *et al.*, 2017).

A growing body of studies document institutional and governance failures which present barriers to adaptation, many of which are reviewed in Biesbroek *et al.* (2013) and Oberlack (2017). Overall, studies find many barriers to adaptation exist in the institutional, social, informational, financial, and cognitive areas. The IPCC 5th Assessment Report (IPCC, 2014, p. 107) broadly classifies barriers to and enablers for adaptation into: *1) multilevel institutional co-ordination between different political and administrative levels in society, 2) key actors, advocates, and champions initiating, mainstreaming and sustaining momentum for climate adaptation, 3) horizontal interplay between sectors, actors and policies operating at similar administrative levels, 4) political dimensions in planning and implementation; and 5) coordination between formal governmental, administrative agencies and private sectors and stakeholders to increase efficiency, representation, and support for climate adaptation measures.*

Moser and Ekstrom (2010) find common barriers to climate adaptation include ones around detecting and defining the problem, gathering and use of information, developing, assessing, and selecting options, implementation of options, and monitoring and evaluating outcomes. These barriers will be further discussed in Section f, Barriers to Adaptation.

iv. Market Incentives for Adaptation

Outside of government regulations, subsidies, and direct investment for adaptation, market incentives for adaptation also exist and are emerging. Property insurance is one such instrument. Studies show greater property insurance take-up improves recovery times and reduces declines in economic output following a disaster (von Peter *et al.*, 2013; Wolfram & Yokoi-Arai, 2016), and fully-insured economies generally experience no significant loss in output after a disaster (von Peter *et al.*, 2013). In Canada, take-up rates for insurance across climate-related hazards are generally high, with the exception of overland flood whose take-up rates were roughly half that of fire insurance in 2019 (CatIQ).

The effects of insurance on investments in resilience is less known. As discussed above, insurance may or may not discourage investment in adaptation through moral hazard (Hudson *et al.*, 2017). Insurance companies have incentives to encourage adaptation as it can reduce losses. The Canadian insurance industry funds various groups which support disaster risk reduction such as ICLR and the National Working Group on Financial Risk of Flooding. Insurance premium discounts can also provide an incentive for adaptation, but their effectiveness is unclear (Kousky, 2019).

Stronger investor expectations around the management and disclosure of climate-related risks are emerging. The Task Force for Climate-Related Financial Disclosures (TCFD) released a framework for climate risk disclosure in 2017 (TCFD, 2017), and many publicly traded Canadian companies are making

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TCFD disclosures. Still, many investors believe the current state of climate risk disclosure to be insufficient for their needs (Canadian Securities Administrators, 2019; Ilhan, et al., 2020).

There is some evidence that institutional investors value the management and disclosure of climate risk (Ilhan *et al.*, 2020; Plumlee, *et al.*, 2015), and there is broader evidence that the cost of raising funds for firms can be affected by disclosure of greenhouse gas emission (Dhaliwal *et al.*, 2011; Griffin, Lont & Sun, 2017) and by their environmental, social, and governance (ESG) performance (El Ghouli, et al., 2011; Cheng *et al.*, 2013). There is further evidence that pollution disclosure requirements can encourage firms to reduce pollution, especially for the largest polluters (Konar & Cohen, 1997; Powers *et al.*, 2011). It's unclear whether ESG performance affects the cost of capital for governments (Cappelle-Blancard, *et al.*, 2019; Rashidi *et al.*, 2019), and the effects of disclosure of climate risk specifically are also unclear.

The use of green bonds and related financial instruments (e.g., sustainability bonds) are rapidly growing in Canada and globally, although they are still a small fraction of the overall bond market (Flammer, 2021; Climate Bonds Initiative, 2020). Green bonds are similar to normal bonds except the proceeds from the bonds must be used exclusively for activities classified as green, which include climate mitigation and/or adaptation activities. While green bonds are not necessary to conduct adaptation projects (which can be funded through general revenues or normal bonds), they can be used to raise additional funds for such projects.

The effects of issuing green bonds are still unclear. There are few studies of the effects of green bonds issued by local governments. Partridge and Medda (2020) found U.S. municipal green bonds issued in 2018 carried a premium of 0.05%, which represents a slightly lower cost of capital. However, they found no evidence for a premium at issuance, so it's unclear if the issuing governments benefited. There is evidence that corporate green bonds also trade at a small premium compared to normal bonds (Zerbib, 2019). Flammer (2021) examined stock price reactions to issuances of green bonds and finds the stock market responded positively to these issuances. The effect was strongest for green bonds certified by third-party agencies and for first-time issuers of green bonds. Still, these benefits must be weighed with the additional administrative costs of issuing green bonds compared to normal bonds.

F. Barriers to Adaptation - (G. McBean, B. Li)

The IPCC (2014) assessed the state of adaptation in North America and found “*Governments are engaging in incremental adaptation assessment and planning, particularly at the municipal level. Some proactive adaptation is occurring to protect longer-term investments in energy and public infrastructure.*” In 2018, the Auditor General of Canada (2018b, p.5) found “*most governments had not fully assessed climate change risks and had not developed detailed adaptation plans*”. Other recent assessments (e.g., Bednar *et al.*, 2019; Oulahen *et al.*, 2018) also found many jurisdictions face difficulties with choosing and implementing adaptation measures. Raikes and McBean (2017) found major differences in capacity between a large city (Vancouver) and smaller nearby town (Maple Ridge). The issues of responsibility and liability in emergency management of potential hazards in the Canadian legal context, also matter in terms of implementation (Raikes and McBean, 2016).

Most peer-reviewed studies of barriers to adaptation in Canada focus on British Columbia. Recent examples include Oulahen *et al.* (2018), which examines barriers to adaptation in Surrey and Vancouver during the 2015-2016 period through a review of policy documents and interviews with practitioners and subject matter experts. They classified barriers identified as inadequate collaboration within and across levels of government and the private sector, absence of senior-level political leader, lack of public awareness, insufficient financial and staff capacity, and misalignment of policies. Picketts, Déry, & Curry (2014) participated in the creation of a sustainability and land use policy plan for the City of Prince George. They found factors which enabled the successful inclusion of adaptation into the planning process included availability of existing research on climate impacts, a high level of local climate change awareness, availability of funding, and cooperation between policymakers and the scientific community.

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Burch (2009; 2010) examined barriers to climate mitigation and adaptation in three municipalities and strategies for overcoming them in the Metro Vancouver region. The main barriers identified included structural (e.g., structure of budgetary system, party rivalry), regulatory (e.g., lack of long-range sustainability plan, inconsistency between levels of government), cultural (e.g., lack of leadership, lack of coordination between policy and operations), and contextual (e.g., competing priorities, resistance to change) barriers. Enablers to overcome these barriers include a culture of collaboration and respect between operations and policy staff, strong and informed leadership, regional planning, and mainstreaming climate change into government operations. Crucially, Burch found that a lack of capacity was not frequently mentioned as a key barrier, but barriers instead limited the application of existing capacity to climate adaptation.

The Nova Scotia government took initiatives to promote Municipal Climate Change Action Plans (MCCAPs) in Nova Scotia communities. Analyses (Vogel *et al.*, 2018) showed that the gas tax, a historical focusing event of Hurricane Juan, and provision of adaptation resources were the key for spurring municipal climate adaptation efforts. Later studies (Righter, 2021) evaluated the implementation of coastal adaptation actions that were identified as priorities in the plans of 20 these communities and found that the MCCAP mandate has been highly effective in stimulating coastal adaptation in the province. Cost-benefit analysis for adaptation options in Quebec’s coastal areas has been done (Circé, *et al.*, 2016).

Expert workshops held in Ontario (Bednar *et al.*, 2018a) and BC (Bednar *et al.*, 2018b) examined the federal-provincial governance of climate adaptation (Bednar *et al.*, 2019). The researchers found conceptual (e.g., terminology, temporal scale), knowledge-based (e.g., lack of local expertise, uncertainty of impacts or benefits), and socio-political (e.g., jurisdictional boundaries, political disagreement) barriers to effective governance on adaptation. Strategies to overcome these barriers included improving communications strategies around climate adaptation, effective investments of resources, using legal responsibilities, liabilities, and mandates to incentivize adaptation, and mainstreaming climate adaptation. Climate adaptation by twelve Canadian municipalities across four provinces with a focus on energy infrastructure and utilities (Oldfield & Nciri, 2020) showed that opportunities exist to improve resilience in water infrastructure, energy infrastructure, back-up energy supply, emergency management and communication, planning, food and medicine, and transportation.

More case studies of climate adaptation or resilience to extreme weather exist in the grey literature. To support climate adaptation projects, ICLEI has developed an Adaptation Library which provides resources for climate adaptation including case studies on adaptation projects: the geographic context; climate change context; issue; process; financing; partners; challenges, and lessons learned.

A recent report by QUEST examined climate adaptation by twelve Canadian municipalities across four provinces with a focus on energy infrastructure and utilities (Oldfield & Nciri, 2020). The study found that opportunities exist to improve resilience in water infrastructure, energy infrastructure, back-up energy supply, emergency management and communication, planning, food and medicine, and transportation.

Beyond the Adaptation Library, ICLEI (2016) surveyed Canadian municipalities on common barriers to implementing climate adaptation. They found the most common barriers included “lack of human and financial resources, lack of political buy-in, and difficulty accessing relevant resources and best practice documentation” (ICLEI, 2016, p.3). To support the implementation of climate adaptation projects, ICLEI developed a guide and workbook on implementing climate adaptation projects at the municipal level (ICLEI, 2017). To achieve success in the implementation process, the ICLEI recommends training staff, government officials, and community stakeholders, starting with pilot programs, and prioritizing internal and external communication on the project.

The Commissioner of the Environment and Sustainable Development and provincial and territorial auditors general, in 2018, prepared a report: Perspectives on Climate Change Action in Canada—A

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Collaborative Report from Auditors General—March 2018 (CESD, 2018). A general conclusion was: *Most Canadian governments have not assessed and, therefore, do not fully understand what risks they face and what actions they should take to adapt to a changing climate.* Progress varies widely across Canada and between communities and the data analysis suggests that both the characteristics of the communities and the characteristics of their planned actions are significant determinants of success. There was a need for leadership to prioritize and mainstream adaptation. Other barriers to adaptation included the low priority placed on climate adaptation, limited human and financial resources, lack of coordination between participants and stakeholders, and access to scientific data.

6. Synthesis and Assessment of Climate Resilience in Canadian Communities

A. Context

Climate change is impacting communities, human health and health systems, all society as well as ecosystems and beyond. Risks will continue to grow with the increasing frequency and severity of climate hazards. As noted in Chapter 1, the World Economic Forum’s 2021 Global Risk Report (released in January 2021) stated that: *Climate continues to be a looming risk as global cooperation weakens*”. Their assessment is, that, over the next 10 years, the top global risks by likelihood are: extreme weather (including fires, floods), climate action failure and human environmental damage. The top global risks by their impacts are: infectious diseases (the Pandemic), climate action failure, weapons of mass destruction, biodiversity loss and natural resources (water, food, ...) crises. Climate action failure - *Failure of governments and businesses to enforce, enact or invest in effective climate-change adaptation and mitigation measures ...* is ranked as the second most impactful and second most likely risk.

The *Pan-Canadian Framework on Clean Growth and Climate Change 2016* had its major focus on reducing greenhouse gas emissions, but some actions were taken to address adaptation and building resilience. The *Healthy Environment and Healthy Economy Plan* (December 2020) included *Working together to make Canada more resilient to a changing climate* and notes how the COVID-19 pandemic has underlined the importance of building resilience to risks across Canada and that there is need to be better prepared for the climate risks. The Prime Minister stated that Canada would develop Canada’s first-ever National Adaptation Strategy. This plan would involve work with all levels of governance, indigenous people and other partners for a *shared vision for climate resilience in Canada, a framework for measuring progress at the national level and which areas would be best target its policies programs and investments going forward.* Support to Canadians and communities, to respond to accelerating climate change impacts, would be provided.

On 25 March 2021, a report from the Auditor General of Canada (2021), reviewing the response to COVID-19, noted that *Decision makers need credible and timely risk assessments to guide effective responses. Also important is an effective national surveillance framework ...* and that early warning of public health threats are important. When addressing climate change, similar issues are important in that responding to climate change requires risk assessments and a surveillance framework and addressing extreme weather events needs effective early warnings.

On 25 March 2021, the Supreme Court of Canada (2021) ruled the federal carbon pricing law is constitutional based in the statement, *global warming causes harm beyond provincial boundaries.* The Auditor General also noted that in *Canada, public health is a shared responsibility between the federal government, the 10 provinces, and the 3 territories.* A consistent approach to planning requires the federal, provincial, and territorial governments to work together. The Supreme Court’s statement, *global warming - beyond provincial boundaries,* although written in the context of greenhouse gas emissions, is also relevant for adaptation and building climate resilient communities. There are the “physical” issues of rivers that cross provincial boundaries, making importance issues of water supplies and the threats of flood interprovincial and international, in that rivers cross provincial boundaries within Canada and

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between Canada and the United States. As the Budget 2021 (Government of Canada, 2021) stated: *floods are Canada's most costly natural disaster, causing over \$1 billion in direct damage.* Based on constitutional interpretations, flood forecasting is a provincial responsibility, which in some provinces is delegated to local authorities, such as the regional conservation authorities in Ontario. The occurrence of most floods is related to the weather, for which forecasting is done by a federal agency, the Meteorological Service of Canada.

There is need for multi-level governance arrangements to work together to ensure that communities are informed, and, when appropriate, warned of the flooding threats and provided advice and guidance for appropriate community actions. Budget 2021 proposes to provide \$63.8M over three years to Natural Resources Canada, Environment and Climate Change Canada, and Public Safety Canada to work with provinces and territories to complete flood maps for higher-risk areas.

B. Assessments - Climate Change Resilience

Infrastructure Canada-Climate Lens provides a Climate Lens for assessments related to the infrastructure investments that include: *requirements for conducting the climate change resilience assessment component of the Climate Lens.* The principles are derived from international agreements such as the Sendai Framework for Disaster Risk Reduction and Canada's National Strategy for Critical Infrastructure, which both emphasize resilience as a way to mitigate disasters and natural hazards. They are also informed by the national climate knowledge assessments produced by Natural Resources Canada.

Some communities in Canada have prepared high level adaptation plans, but fewer have a detailed implementation strategy with established funding. Most action to build community resilience in Canada was largely unplanned and took place in recovery following an extreme loss event. Indigenous communities in Canada are at the forefront of climate change adaptation in Canada. Self-determination through community-led risk assessments, planning, and disaster recovery organizations and addressing in the broader context of reconciliation gaps and opportunities for integration will be valued for climate resiliency actions. Combining western and Indigenous ways of knowing for most effective knowledge translation for resiliency and adaptation will also be valued.

C. Canada's Budget 2021

On April 19th, 2021, the Canadian Federal Budget, entitled: *A Recovery Plan for Jobs, Growth, and Resilience*, was tabled (Government of Canada, 2021). The Budget addresses the COVID-19 situation and recovery from its impacts. The Budget Chapter 5- A Healthy Environment for a Healthy Economy, opens with: *Climate change is real. Wildfires, floods, droughts, and powerful storms are becoming more frequent, more costly, and more dangerous. COVID-19 has shown us how Canadians have what it takes to come together, to mobilize, and to take action in the face of a crisis. The climate crisis is just as great a challenge.* The prime focus is to *reduce emissions by about 36 per cent below 2005 levels by 2030.* And actions to *net-zero emissions by 2050* are discussed. There is also a section on Strengthening Public Climate-related Disclosures, with reference to the Task Force on Climate-related Financial Disclosures (TCFD, 2017).

On April 22, 2021, the Prime Minister (2021), speaking at the Leaders' Summit on Climate (2021), announced that *Canada will enhance our emissions reduction target under the Paris Agreement ... by 40-45% below 2005 levels, by 2030.*

Budget Section 5.5 is on *Adapting to Climate Change for a More Resilient Future* and notes that *climate-related disasters are becoming more frequent and severe and having significant negative impacts on public safety, human health, and the economy and also resulting in costly damage to our communities.* Measures to better understand and prepare for climate-related disasters and to mitigate their impact and that would make communities safer and more resilient to a changing climate are presented. For Canada's infrastructure, to ensure Canada's resilience in the face of climate change, Budget 2021 proposes to provide \$1.4B over 12 years, starting in 2021-22, to Infrastructure Canada to top up the Disaster

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Mitigation and Adaptation Fund, to support projects such as wildfire mitigation activities, rehabilitation of storm water systems, and restoration of wetlands and shorelines. Specific funds will be *dedicated to help small, rural, remote, northern, and Indigenous communities adapt to climate change impacts*.

Budget 2021 proposes investments: to renew the *Standards to Support Resilience in Infrastructure Program*; for *Keeping Canadians Safer from Floods*, to work with provinces and territories to complete flood maps for higher-risk areas; *Improving Wildfire Resilience and Preparedness* to improve resilience to wildfires, make communities safer, and adapting to climate change, through mapping and the Canadian Interagency Forest Fire Centre. To support Provincial and Territorial disaster response and recovery, the federal Disaster Financial Assistance Arrangements will provide provinces and territories with additional financial assistance. Funding will also be provided for *Addressing climate change in Yukon*.

D. The Path Forward for Resilient Canadian Communities

As the climate changes over the next few decades, there will be significant impacts on Canadian communities. Actions on climate change, as stated in the Paris Agreement, Article 2: *(b) Increasing the ability to adapt to the adverse impacts of climate change and foster climate resilience and low greenhouse gas emissions development, in a manner that does not threaten food production*, must include adaptation for climate resilience as well as emissions reductions.

The Sendai Framework on Disaster Risk Reduction has four Priorities: *1: Understanding disaster risk. 2: Strengthening disaster risk governance to manage disaster risk. 3: Investing in disaster risk reduction for resilience. 4: Enhancing disaster preparedness for effective response and to “Build Back Better” in recovery, rehabilitation and reconstruction.*

In the recovery from the pandemic, and continuing as a leading priority, investment in resilience for climate-related (and other) disaster risk, and strengthening multi-level governance, to include Indigenous communities, are very important, noting the concept of the Adaptation without Borders as important. It is proposed that the 4th priority be modified to “Build Ahead Better” or better “*Bouncing Forward Sustainably Post COVID-19*” as IIASA-ISC are proposing.

The Task Force for a Resilient Recovery (TFRR, 2020) Report – A Bridge to the Future, provided independent and important advice on how government can build this kind of recovery through actions and investments over the next five years. It calls for *5 bold moves* and the first bold move is to: *Invest in Climate-Resilient and Energy Efficient Buildings*. The Report presents information on Canada’s buildings, as one of Canada’s largest sources of carbon pollution. It also emphasizes that *Canada’s buildings are also increasingly vulnerable to the impacts of climate change, with extreme weather events like flooding and wildfires leading to a steady rise in insured catastrophic losses over the past three decades. ... Climate-resilient building retrofits are a cost-effective way to future-proof existing buildings and to save Canadians costs on disaster recovery. Studies calculate that every dollar invested in resilience averts as much as \$6 in future costs.* The Task Force recommends that in economic recovery and long-term growth, investments in energy efficient and climate resilient upgrades and new buildings be done.

Health sector officials should utilize the growing number of tools and increased knowledge of the pathways through which climate change affects health to chart future progress in protecting Canadians. Equity, diversity and inclusion are essential principles for health authorities as they work with partners to tackle climate change in a manner that brings benefits to all segments of the population.

Local scale warming due to urbanization adds to the heat burden in the warm season for Canadian communities, worsening social, health and economic impacts. More research is needed to document and predict the occurrence of heatwaves and to develop heat adaptation strategies attuned to Canadian cities. There are physical (dehydration, heat stroke) and mental health impacts of climate change; mental health impacts can occur when large scale events are witnessed directly or remotely.

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Reducing disaster risk of adverse impacts from severe wind, wildland-urban interface fires, basement flooding and other risks requires methods for site-by-site vulnerability analysis and quantification of risk reduction addressing various building characteristics and disaster risk affects. More research and data are required to know the impacts of a warming climate on certain types of severe weather (e.g. tornadoes) and the economics of climate change adaptation needs to be further developed in terms of decision frameworks for selecting which adaptation measures should be implemented. Cost-benefit assessment and alternative decision frameworks exist which can better address concerns around non-monetary impacts and values.

The hazards and actions to reduce impacts cross multi-level governance and interplay within levels as well as across many sectors of society. One example is the occurrence of flooding due to heavy precipitation. The enablers for adaptation need to work together to address the barriers, including: multilevel institutional co-ordination as well as the horizontal interplay; and the coordination between formal governmental, administrative agencies and private sectors and stakeholders to increase efficiency, representation, and support for climate adaptation measures. There is need for integrated early warning systems and better prevention strategies across the appropriate range of hazards and governance.

Budget 2021 is to fund the development of flood risk maps and these need to be connected with early warning systems, bringing together federal, provincial and community agencies, need to provide information and warnings both for an imminent event, but also over weeks, months, years to decades, to enable communities to take actions to reduce the impacts and gain benefits of a changing climate (McBean, 2000). The full climate system and many ecosystems are all inextricably linked, so there must be collaborative work together, addressing and predicting the Earth System (Uccellini, 2021) (Shapiro *et al.*, 2010). Projections or predictions of future states, as needed for adaptation and building resilient communities, require understanding and incorporating the implications of science and technology and society in iterative ways, recognizing that changes in technology result in changes in society and vice versa. Further, as the future state becomes clearer for a specific projection based on the *best* estimates of technological and societal changes, these may feedback into the societal response, resulting in the modifications to the prediction of the future state. The fully-integrated science, including social and health sciences, and technology communities need to work closely together with communities, at all level of governance, to enable the prediction of future states through an integrated, continuously iterative process of refinement to reduce uncertainty, with there being clarification of the assumptions inherent in the prediction such that the societal processes can, when possible and appropriate, modify societal changes (McBean, 2016).

7. Conclusions

These conclusions are based on reviews of literature and reports and through communications with a very broad sector of Canadian and international scientists and community leaders by the 20+ members of the Building Climate Resilient Communities Knowledge Synthesis Grant team, who wrote this report.

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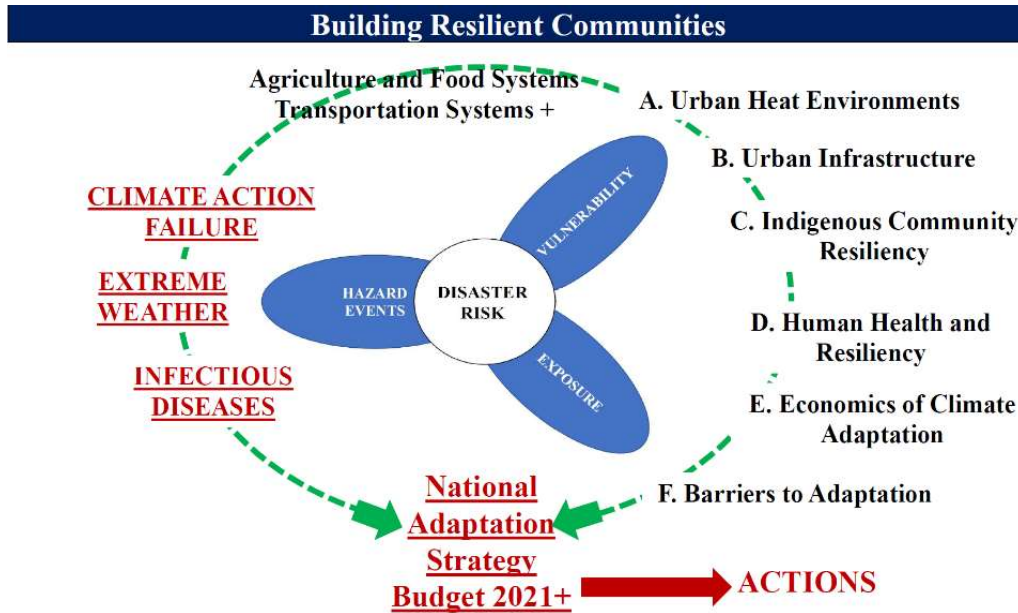


Figure 4: Building Resilient Communities: Addressing the hazards (left) through knowledge (right), leading the plans and actions.

Figure 4 shows schematically the process of building resilient communities, addressing the major risks as identified by the World Economic Forum's Global Risk Report as: climate action failure and extreme weather events and infectious diseases (e.g., COVID-19). Addressing these hazards needs to be based on enhanced knowledge of the community environment, including weather-climate related hazards (heat, tornadoes, floods, etc.). These lead to actions to reduce exposure and vulnerability so that the communities become more resilient and have reduced impacts caused by the hazards. This Report specifically reviewed: urban heat environments; urban infrastructure; indigenous communities; human health; economics; and barriers to adaptation actions. To address the climate crisis, an ambitious, strategic and collaborative approach to adaptation is required. Canada's National Adaptation Strategy, working with all levels of governance, Indigenous peoples, the scientific community and other key partners, and building on Budget 2021 and further initiatives, should have a common vision for building climate resilient communities with key priorities and a framework for measuring progress.

The expert community has developed proven tools for actions to have climate resilient communities develop and implement best plans and best practices to proactively improve climate resilience. There is need to strengthen collaboration between governments and Indigenous and all people for adaptation actions, recognizing the importance of Traditional Knowledge and implementing a collaborative, science-based approach to inform Canada's future. Working across sectors and with international programs, there are plans and actions to build climate resilient communities but the funding and direction from senior governments for local communities needs to be enhanced. In the recovery from the Pandemic, it is important to rebuild by addressing both the green energy and climate resilience issues together so there is a green climate-resilient Canada that reduces future climate change for the global benefits and reduces the impacts now and in the future of climate change and its events on Canadian communities.

Budget 2021 addresses funding and priority issues and the proposed National Adaptation Strategy should lead to actions and implementations addressing these issues, with ongoing support for the significant financial and other challenges, while gaining the benefits.

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8. Knowledge Mobilization Activities

The major benefits of this Report will be the mobilization and enhanced development of knowledge in order to build climate resilient communities. The Knowledge will be conveyed through virtual informal discussion workshops during the April-May period to confirm and expand the synthesis and the transfer of knowledge. The Canadian Meteorological and Oceanographic Society (CMOS) Annual Congress with the theme *Climate Change - Risk Resilience Response* will be held virtually 31 May - 11 June 2021 and the co-PIs of this KSG project will chair a Session “*Building Climate Resilient Communities*” with presentations by co-authors of this report. These Sessions are expected to be attended by 100-150 online attendees and discussants and recordings for broader distribution. The ICLR “Friday Forums” for professional and across-sector participants and presentations are being planned. Several scientific papers, building on the issues drawn from the Synthesis will be prepared. To inform the broad Canadians Risks and Hazards Network (CRHNet), an article will appear in their Magazine, HazNet, and a session is proposed for the fall 2021 national conference on this Synthesis.

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