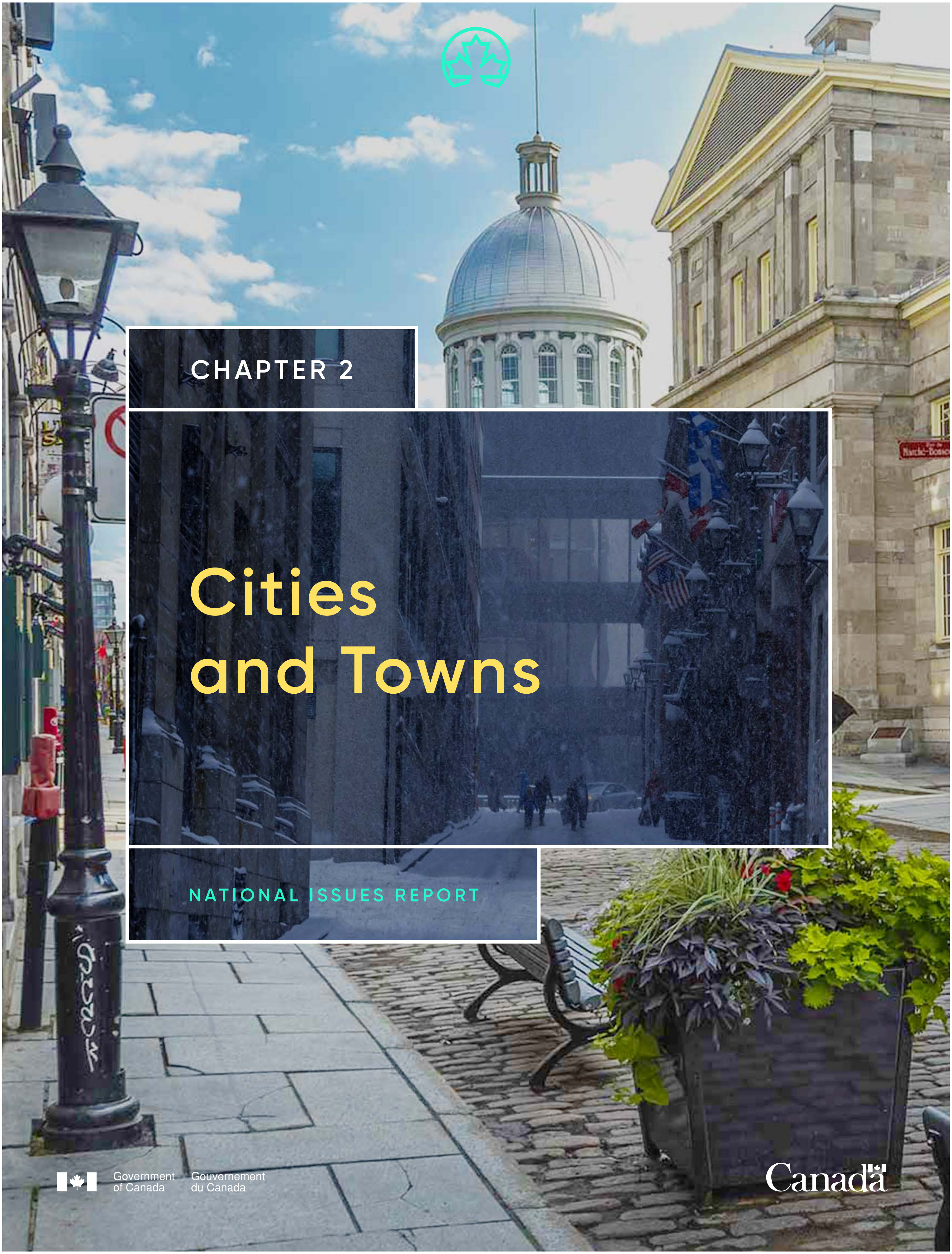

CHAPTER 2

Cities and Towns

NATIONAL ISSUES REPORT

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Canada

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Key messages

Climate change is threatening Canada's ageing infrastructure (*see* Section 2.2)

Safe and reliable infrastructure and resilient buildings are essential to life in cities and towns. The projected changes in climate will increase risk for Canada's ageing infrastructure, causing structural damage, compromising system reliability and threatening health and safety. Integrating climate change information into the design, operation and management of infrastructure projects will help minimize risk.

Enhancing green spaces helps cities and towns adapt to climate change (*see* Section 2.3)

Green infrastructure, such as parks, wetlands and green roofs, in Canada's cities and towns increase the quality of life for residents and improve climate resilience. Recognizing the value of the benefits associated with green infrastructure and nature-based adaptation solutions will be useful in advancing their use to reduce impacts from climate change and other stressors.

Climate change will hit those already struggling in cities and towns the hardest (*see* Section 2.4)

Climate change will impact individual and community health and well-being in cities and towns. However, the negative impacts from climate change will not affect all members of society equally. Considering social equity in adaptation decisions will help reduce the vulnerability of those at highest risk and will ensure that benefits are distributed fairly.

Working together yields the most successful outcomes (*see* Section 2.5)

Effective adaptation approaches to climate change consider diverse perspectives and priorities. Local governments are increasingly playing a strong role in driving meaningful collaboration with different groups when it comes to designing, planning and implementing adaptation in their communities.

Indigenous peoples in cities and towns are often affected in unique ways by climate change (*see* Section 2.6)

Canada's cities and towns are home to large populations of Indigenous peoples, who are often affected in unique ways by a changing climate. Attention is being given to Indigenous issues, and the inclusion of Indigenous perspectives and expertise in municipal adaptation planning processes is occurring, but this is not widespread. Strengthening collaboration with Indigenous peoples will require increased capacity and additional research.

Cities and towns are moving from adaptation planning to implementation (*see* Section 2.7)

Implementation of adaptation initiatives by cities and towns is not keeping pace with the risks posed by current weather extremes and future climate changes. However, examples of implementation are becoming more common, and the barriers to action are being reduced. Promising practices like mainstreaming and innovative funding arrangements offer opportunities to scale up and accelerate implementation.

Monitoring and evaluation of adaptation is an important and often overlooked step (*see* Section 2.8)

Monitoring and evaluation methods are required to track adaptation progress, and measure whether adaptation efforts are resulting in their desired outcomes. While promising approaches exist, monitoring and evaluation of adaptation projects and outcomes are still rare, and there is value in helping cities and towns to develop approaches that are effective and comprehensive.

2.1 Introduction

2.1.1 Cities and towns

Over 80% of Canadians live in urban areas (*see* Box 2.1; Statistics Canada, 2017a), and more than half (51.8%) of Canada's Indigenous population lives in a metropolitan area of at least 30,000 people (Statistics Canada, 2017b). Our cities and towns help drive the national economy, and provide resources and opportunities that contribute to individual and community health and well-being. Although cities and towns have many attributes that increase their adaptive capacity (Natural Resources Canada, 2016); concentrated populations, exposure of economically-valuable assets, ageing infrastructure, degraded ecosystems and social inequality can make urban areas and their residents highly vulnerable to climate change (*see* Figure 2.1; Maxwell et al., 2018).

Figure 2.1: Assets and challenges that influence adaptive capacity in cities and towns.

Changes in Canada's climate are already evident and projected to continue. For example, parts of the country have experienced higher temperatures, more extreme heat, less extreme cold, shorter snow and ice cover seasons, earlier spring peak streamflow, and rising sea level (Bush and Lemmen, 2019). In addition, increased precipitation is projected for most of Canada, on average, although summer rainfall may decrease in some areas. More intense rainfalls will increase urban flood risks, while in coastal regions, sea-level rise and more extreme high-water events will increase the risk of coastal flooding in some communities (Bush and Lemmen, 2019). These changes will result in greater impacts on cities in the future, unless appropriate adaptation and risk management are implemented (*see* Table 2.1).

Managing climate risks is essential, and can provide a range of direct and indirect economic, individual, social and environmental benefits. Cities and towns can also adapt to take advantage of opportunities that a changing climate will bring, such as decreased heating demand in buildings (Amec Foster Wheeler and Credit Valley Conservation, 2017). Reducing net greenhouse gas emissions (mitigation) is essential to managing future risks (Bush and Lemmen, 2019), although a discussion of mitigation efforts is largely outside of the scope of this report, which focuses on climate change impacts and adaptation.

Population growth, urbanization, densification and increased resource consumption in the coming decades will amplify the sensitivity of cities and towns to climate-sensitive hazards (Webb et al., 2018). For example, the population in Ontario's Greater Golden Horseshoe is expected to grow by 50%, reaching 13.5 million people by 2041 (Government of Ontario, 2017), and that of Metro Vancouver is expected to increase by 25% to 3.2 million people over the same time period (Metro Vancouver, 2014, 2018). This population growth will mean higher exposure to impacts (as more people would be affected), along with greater demand on critical systems like energy, water and health care. The composition of Canada's population can also affect vulnerability; for instance, newcomers to Canada and the elderly can have higher vulnerability to extreme weather events (Chang et al., 2015).

This chapter assesses climate change impacts and adaptation in cities and towns across Canada and acknowledges that each location experiences and adapts to climate change differently (Hunt and Watkiss, 2011). This chapter references Canadian and international literature, and includes case stories that provide practical examples of adaptation in action. The content has been structured using key messages that reflect the current state of research and practice on issues of priority to cities and towns. The volume in which this chapter appears is part of a suite of complementary products that are contributions to the national assessment process Canada in a Changing Climate: Advancing our Knowledge for Action.

Box 2.1: Urban areas

Although the term "urban area" is often used interchangeably with cities and towns, Statistics Canada has replaced the term "urban area" with "population centre" and uses the following discrete categories: small (populations between 1,000 and 29,999), medium (populations between 30,000 and 99,999), and large (populations of 100,000 or more) (Statistics Canada, 2017e). As in previous assessments (e.g., Palko and Lemmen, 2016), this chapter focuses primarily on medium and large population centres, with some consideration of small centres that have more than 10,000 people. It is estimated that 500 of Canada's 3,650 cities and towns have populations over 10,000. For discussion on climate change impacts and adaptation in communities smaller than 10,000 people, see the Rural and Remote Communities chapter.

2.1.2 Climate change impacts in cities and towns

As the global mean temperature continues to increase, cities and towns across Canada will experience warmer temperatures, shifting precipitation patterns (e.g., less snow and more rain, sustained periods of drought), increased frequency and intensity of some extreme weather events, and—for most coastal cities—sea-level rise (Bush and Lemmen, 2019). Under all emissions scenarios of the Intergovernmental Panel on Climate Change (IPCC), these changes will result in an increased incidence of acute and chronic biophysical impacts, including more frequent and intense heat events (*see* Figure 2.2), increased incidences of poor air quality (e.g., from ground-level ozone, particulate matter), short-duration, high-intensity rainfall events, wind storms, wildland-urban interface fires, increased coastal erosion, storm surge flooding and decreased water quality (Bush and Lemmen, 2019; Field, 2018; BC Ministry of Environment and Climate Change Strategy, 2017; Government of Canada, 2016; Gasper et al., 2011). These biophysical impacts will affect built infrastructure, natural environments, individuals and communities (*see* Table 2.1). Such impacts are accentuated in developed areas because many impact-reducing natural surfaces have been replaced by water-shedding, heat-absorbing and re-radiating surfaces, and the population density is higher (Seto and Shepherd, 2009; Venema and Temmer, 2017). Many of the high costs associated with these impacts (*see* Costs and Benefits of Climate Change Impacts and Adaptation chapter) will be borne by local governments.

Table 2.1: Common climate change impacts facing cities and towns

CATEGORY	COMMON CLIMATE CHANGE IMPACTS
Infrastructure and buildings	• Damage to infrastructure and buildings from storms • Increased cooling demand and decreased heating demand in buildings • Potential increase in disruption to and failure of electrical systems from heat and storms • Increased winter maintenance costs and higher public safety risks • Damage to coastal infrastructure due to sea-level rise
Natural systems	• Shifts in distributions of plant and animal species, including beneficial and invasive species • Degradation of urban ecosystems and those in the outskirts • Increase in environmental pollution (e.g., rainfall events transporting contaminants into waterways) • Saltwater intrusion into water supply aquifers
Individuals and communities	• Increased social inequity • Business disruptions • Mental and physical health impacts • Loss of cultural landmarks, heritage and traditional practices • Changes to recreation and tourism opportunities

Sources: Abbott and Chapman, 2018; Cedeño Laurent et al., 2018; Field, 2018; Diamond Head Consulting Inc., 2017a; Public Health Agency of Canada, 2017; Government of Canada, 2016; Giordano et al., 2014; Revi et al., 2014; Solecki and Marcotullio, 2013; Gasper et al., 2011.

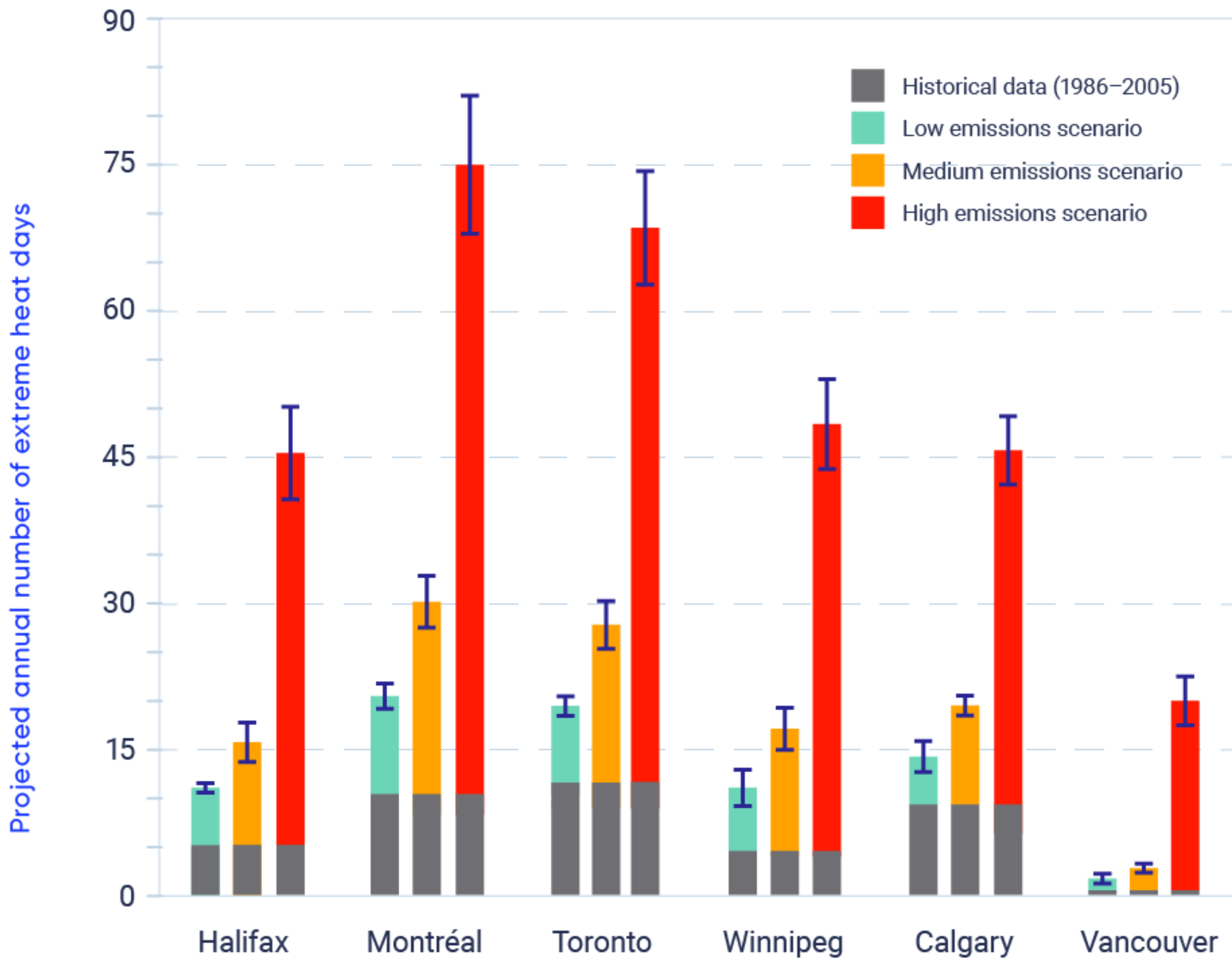


Figure 2.2: The annual number of extreme heat days projected for six Canadian cities under three warming scenarios: global mean surface temperature of 1.5°C, 2°C, and 4°C above pre-industrial levels. The values are based on statistically downscaled simulations by 24 climate models participating in CMIP5, with the error bars representing the 25th and 75th percentiles, and the grey section showing the number of historical extreme heat days (1986–2005). The threshold for extreme heat differs by city (e.g., Toronto = 31°C, Vancouver = 29°C). Data source: Environment and Climate Change Canada.

2.2 Climate change is threatening Canada's ageing infrastructure

Safe and reliable infrastructure and resilient buildings are essential to life in cities and towns. The projected changes in climate will increase risk for Canada's ageing infrastructure, causing structural damage, compromising system reliability and threatening health and safety. Integrating climate change information into the design, operation and management of infrastructure projects will help minimize risk.

Historical and recent exposures to weather extremes have shown that urban infrastructure is vulnerable to these types of events. Climate change will increase the risk of overheated buildings, damaged infrastructure (e.g., bridges during flooding) and power outages across Canada. Increasing the resiliency of Canada's ageing infrastructure is challenging due to factors such as higher levels of use beyond initial design, the large investments required, and performance under uncertain future climate conditions. In addition, infrastructure design to date reflects an assumption of a steady-state climate, whereas we now must design for "non-stationarity" in order to minimize disturbance and damage as the climate continues to change dynamically. Infrastructure was identified as the top sector at risk to climate impacts, but also has the greatest "adaptation potential" to avoid and reduce negative consequences, as long as careful planning is undertaken (Council of Canadian Academies, 2019). The state of research and practice in Canada is advancing, as are the resources available to cities to towns.

2.2.1 Introduction

The infrastructure in cities and towns includes water systems (e.g., stormwater, wastewater, drinking water), transportation systems, public and private buildings, sport and recreation facilities, utilities (e.g., electricity and gas), telecommunications and industrial sites (*see* Box 2.2 for more details). Nearly two thirds of core public infrastructure is owned and maintained by municipal governments, and over one third is in need of retrofit or replacement due to being in a relatively poor condition (Project Steering Committee, 2016). Rising temperatures, changing hydrological conditions and more frequent extreme weather events will increase the risk of failure and make it more difficult to deliver optimal levels of service across the entire lifespan of existing and new infrastructure assets (Asset Management BC, 2018; Amec Foster Wheeler and Credit Valley Conservation, 2017).

Box 2.2: Infrastructure

The term “infrastructure” can mean many different things. Public Safety Canada provides a list of ten sectors that are termed critical infrastructure: health, food, finance, water, information and communication technology (ICT), safety, energy and utilities, manufacturing, government, and transportation (of all types—ground, air and water) (Public Safety Canada, 2020). The emphasis of this chapter is on the physical assets that underpin the functioning of these and other sectors within cities and towns, including buildings. Much of the infrastructure in population centres is publicly owned, such as roads, water mains and public buildings. Other infrastructure, such as most buildings, and ICT, natural gas and power distribution can be privately owned (in some cases depending on the regulatory structure). Infrastructure assets are dependent on other assets and services from other infrastructure. The term “interdependent” is used to describe cases where assets or systems are dependent on each other.

2.2.2 Approaches and mechanisms to reduce risks

The Climate-Safe Infrastructure Working Group—a panel of scientists, registered engineers and architects in California—defines climate-safe infrastructure as “infrastructure that is sustainable, adaptive and that meets design criteria that aim for resilience in the face of shocks and stresses caused by the current and future climate” (Climate-Safe Infrastructure Working Group, 2018, p. 5). Although this goal is conceptually straightforward, there are many challenges in achieving it (e.g., Climate-Safe Infrastructure Working Group, 2018; Amec Foster Wheeler and Credit Valley Conservation, 2017). As the field of climate change adaptation matures, approaches are emerging to assist infrastructure designers and operators as they modify their planning and design approaches. The Infrastructure and Buildings Working Group—a multi-stakeholder working group under Canada’s Climate Change Adaptation Platform—outlines the key areas that must be addressed, several of which are presented below:

- Development of guidelines, codes, standards and specifications that take into consideration the expected climate change impacts;
- Development of critical infrastructure inventories, including the evaluation of vulnerabilities and identification of priority at-risk areas, based on the projected impact of climate change;
- Identification of high-risk areas based on recent events (e.g., new flood zone mapping);
- Completion of risk assessments and cost benefit analyses of alternatives to support decision-making on priority adaptation actions; and
- Integration of planning and decision-making between departments within an organization or between stakeholders (Amec Foster Wheeler and Credit Valley Conservation, 2017).

Although it is difficult to precisely track progress in each of these areas, there is evidence of advances. For example, asset management is a relatively widespread practice that seeks to inventory and manage existing and new infrastructure across municipal corporations, in a way that maximizes benefits and reduces risks, while reflecting the context and priorities of the community (Federation of Canadian Municipalities, 2018). Over the last few years, the asset management community has been encouraged to incorporate climate change into its practices (Asset Management BC, 2018). While the inclusion of climate change is not yet well established, it involves considering how a range of potential climate impacts may affect levels of service, and building these considerations into asset management activities (*see* Case Story 2.1; Federation of Canadian Municipalities, 2018). This process can also be used to manage natural assets (e.g., wetlands), although this practice is still very new (Municipal Natural Assets Initiative, 2017). Incorporating climate change into asset management represents a significant opportunity to accelerate adaptation through mainstreaming, and to pursue low-carbon options during infrastructure renewal (Adaptation to Climate Change Team, 2019).

Codes, standards and guidelines are essential drivers of climate-safe infrastructure that are largely determined by various levels of government (Amec Foster Wheeler and Credit Valley Conservation, 2017). For example, in Quebec, standard BNQ 3019-190 provides information, guidelines and recommendations to improve the thermal performance of parking areas (e.g., reduced surface area, increased greenspace, permeable pavement) with the goal of reducing the urban heat island effect (Bureau de normalisation du Québec, 2013). The Borough of Rosemont–La Petite-Patrie, Quebec, has used this standard to require that "paving material in all new parking, loading and storage areas must meet a minimum solar reflectivity index rating of 29" (Government of Canada, 2011, p. 2). The Standards Council of Canada (2019) is also advancing work in this area , including a new national guideline on basement flood protection (Canadian Standards Association, 2018) and support for a Canadian standard for flood-resilient communities (Moudrak and Feltmate, 2019). Additional information on buildings is provided in Box 2.3.

2.2.3 Decision-support tools

Despite promising examples, designing for an increasingly non-stationary climate remains a challenge with evolving solutions. Designers are encouraged to incorporate flexibility to allow for uncertainty (Field, 2018; Milly et al., 2008), and to use safe-to-fail approaches that minimize consequences instead of the probability of failure (Climate-Safe Infrastructure Working Group, 2018). Traditionally, infrastructure parameters and thresholds have relied on historical weather data (Amec Foster Wheeler and Credit Valley Conservation, 2017). Given the long lifespans of most infrastructure, future climate projections will be needed to establish parameters and thresholds for infrastructure. Intensity Duration Frequency (IDF) curves relate rainfall intensity with its duration and frequency of occurrence, and are often used to inform infrastructure decisions. Tools such as the IDF CC Tool 4.0 (Simonovic et al., 2018) can be used to develop IDF curves based on historical data, as well as under future climate conditions, thereby helping to incorporate climate considerations into infrastructure decisions. For instance, IDF curves were used in a study of Saskatoon residential retention ponds under future climate scenarios (Elshorbagy et al., 2018).

The Climate Lens from Infrastructure Canada represents an effort to embed the consideration of climate risk in professional practice. It requires analysis of climate change resilience during the planning and design phases of a project, as a prerequisite to funding for projects over $10 million, and also requires consideration of how the emissions from all projects will be managed and minimized (Infrastructure Canada, 2019). The guide contains a collection of supporting resources, including regional climate resources, engineering data sets (e.g., IDF files), provincial and territorial flood maps, risk assessment methodologies, previous federal assessment reports, and adaptation resources (Infrastructure Canada, 2019).

Professional associations across Canada are increasingly providing voluntary training to their members on the planning and management of climate-safe infrastructure. For example, Engineers and Geoscientists British Columbia has an extensive climate change information portal that aims to support its members as they incorporate climate risk management into their practices (Engineers and Geoscientists British Columbia, 2020). Similarly, the Canadian Society of Landscape Architects has produced a set of adaptation primers to guide its members' practice (Canadian Society of Landscape Architects, 2018), and the Canadian Institute of Planners has a climate change portal with resources to inform planning and design for climate change adaptation, and a new policy for climate change planning that guides professional practice (Canadian Institute of Planners, 2018).

In addition to these decision-support tools, there is also an expanding body of examples and design strategies in the following areas: storm and sanitary sewer design (Moudrak and Feltmate, 2017; Crowe, 2014), transportation infrastructure (Temmer and Venema, 2018; Simonovic et al., 2016; Dennis Consultants, 2008), energy distribution (Gomez and Anjos, 2017; AECOM and Risk Sciences International, 2015; Boggess et al., 2014), water systems (United States Environmental Protection Agency, 2014; Loftus, 2011), and information and communications technology (Kwasinski, 2016).

2.2.4 Funding

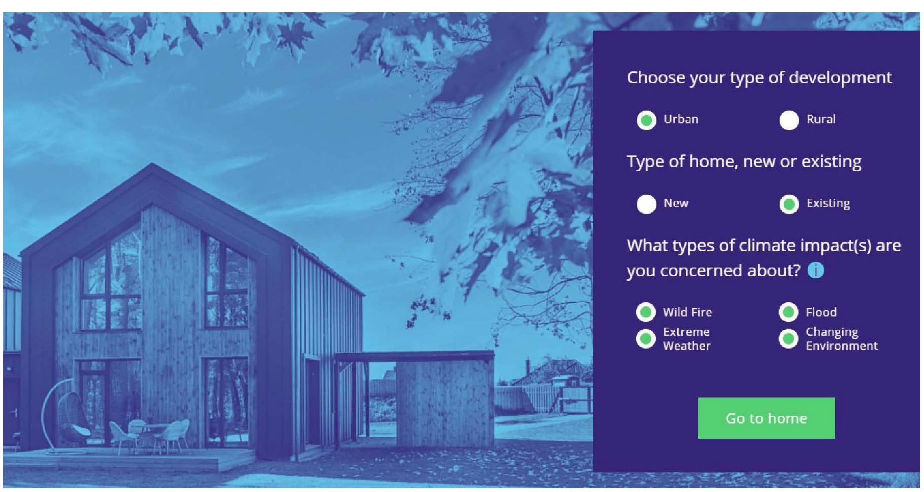
Although there are many barriers relating to financing of climate-safe infrastructure in Canada's cities and towns (Amec Foster Wheeler and Credit Valley Conservation, 2017), there are innovative paths forward that are currently available to infrastructure owners and operators. These include incentive-based tools such as local improvement charges (LICs), density for benefit agreements, development costs charges and natural area tax exemptions (Zerbe, 2019; Adaptation to Climate Change Team, 2015). Funding options have also been assessed for natural assets initiatives (Cairns et al., 2019), and municipalities have received funding for adaptation through federally funded programs, such as the Municipalities for Climate Innovation Program (delivered by the Federation of Canadian Municipalities) and the Natural Disaster Mitigation Program (delivered by Public Safety Canada). However, most of these funding opportunities are time-bound, and the amount of funding available generally falls short in comparison to the scale of adaptation responses that are needed. Since public funding sources represent only one quarter of capital expenditures in Canada, it will also be essential to mobilize private investment from businesses, homeowners and public-private partnerships in order to implement adequate infrastructure adaptation (Adaptation to Climate Change Team, 2015).

Box 2.3: Buildings

In the past five years, there has been an increased effort to design for climate resilience at the building level (e.g., BC Housing, 2019). For each building type, there are a number of structural and operational adaptation options available depending on the hazard faced (*see* Figure 2.3). These include general guidance for designers and operators (e.g., BOMA Canada, 2019; Kesik and O'Brien, 2017; City of Toronto, 2016) and also certification systems like BOMA BEST 3.0 (BOMA Canada, 2020) for existing buildings, and the pilot credits in the RELi project rating system for new buildings (Pierce, 2017). There are also a number of pilot projects. For example, the City of Windsor, Ontario, retrofitted a 100-year-old home in the city's core to reduce the risk of flooding by using a variety of property-level flood protection measures, including a backwater valve, sump pump with overflow, and regrading (City of Windsor, 2019).

Enhancing climate resilience through building codes is another approach being used in cities and towns. Many local jurisdictions in Canada have adopted measures to reduce disaster risk through building design, despite limited authority to regulate construction beyond provincial code requirements (City of Barrie, 2017; Town of Wasaga Beach, 2015; City of Cambridge, 2011). For example, most municipalities in Alberta and major cities in Ontario such as Toronto, Ottawa, Windsor, Mississauga and Hamilton have adopted building code interpretations that have resulted in the installation of sewer backflow protection in most new homes to reduce sewer backup risk (Sandink, 2013a). In the City of Victoriaville, QC, the voluntary, incentive-based Habitation Durable [sustainable housing] program includes disaster risk reduction measures, such as improved roof-to-wall connections to reduce wind risk and measures to decrease heat-health risks. Seven additional municipalities in the province of Quebec have adopted Habitation Durable (City of Victoriaville, 2018). Halifax enforces a vertical setback for residential ground floors of all new buildings along its coastline to accommodate sea-level rise, based on predictions and modelling out to the year 2100 (Halifax Regional Municipality, 2014).

For many building-level adaptation measures, there are associated co-benefits. For example, passive solar design in buildings can help maintain comfort, including during power outages, while reducing heating and cooling loads (e.g., via optimized shading). Similarly, foliage and green roofs reduce urban heat, while also retaining stormwater and decreasing cooling demand. These and other building-level resilience measures deliver co-benefits relating to livability and property values as well (Urban Land Institute, 2015).



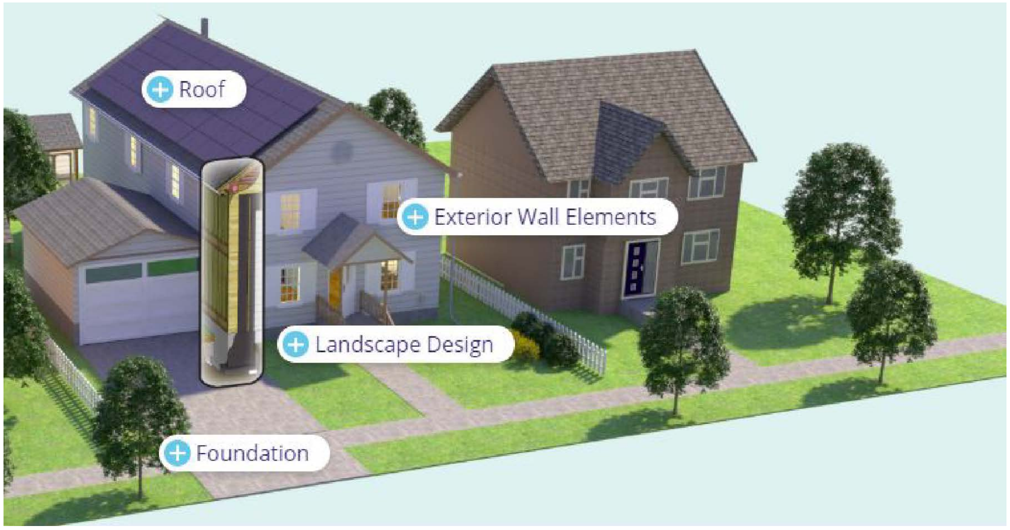


Figure 2.3: A series of screenshots from the website www.climateresilienthome.ca, developed by the City of Edmonton and Ask for a Better World. This interactive tool provides information about modifications for making new and existing homes more climate resilient.

2.2.5 Interdependencies

Creating climate-safe infrastructure requires an operationalized understanding of the interconnected and interdependent nature of urban infrastructure, where interdependency refers to a relationship between two or more infrastructure systems (e.g., electricity distribution and water treatment) (*see* Figure 2.4; Zimmerman and Faris, 2010). Interdependencies can be physical, cyber-based, geographic or operational in nature (C40 Cities and AECOM, 2017), and can lead to cascading impacts across infrastructure systems, involving multiple infrastructure owners (Asset Management BC, 2018). Identifying interdependencies is increasingly considered to be a first step in reducing climate risk (C40 Cities and AECOM, 2017). Pilot projects related to specific assets, including the General Hospital in Nanaimo, BC, are being initiated to explore how interdependencies translate into climate risks (Cross Dependency Initiative, 2019).

Discussions about interdependencies and cascading impacts often highlight the centrality of electricity to urban life. As Figure 2.4 shows, when the electricity supply is disrupted, many negative impacts occur across other infrastructure systems—as well as in natural and social systems (C40 Cities and AECOM, 2017). For example, high-rise buildings may experience disruptions in essential services like water supply and elevator service, and may lose their ability to maintain safe thermal conditions during power outages (Kesik et al., 2019). Buildings tend to be highly interdependent, in that they rely on most other infrastructure types and are designed with minimal ability to function without these infrastructure elements. Utilities across Canada are striving to manage the risks to their distribution networks (e.g., BC Hydro, 2019; Canadian Electricity Association, 2019).

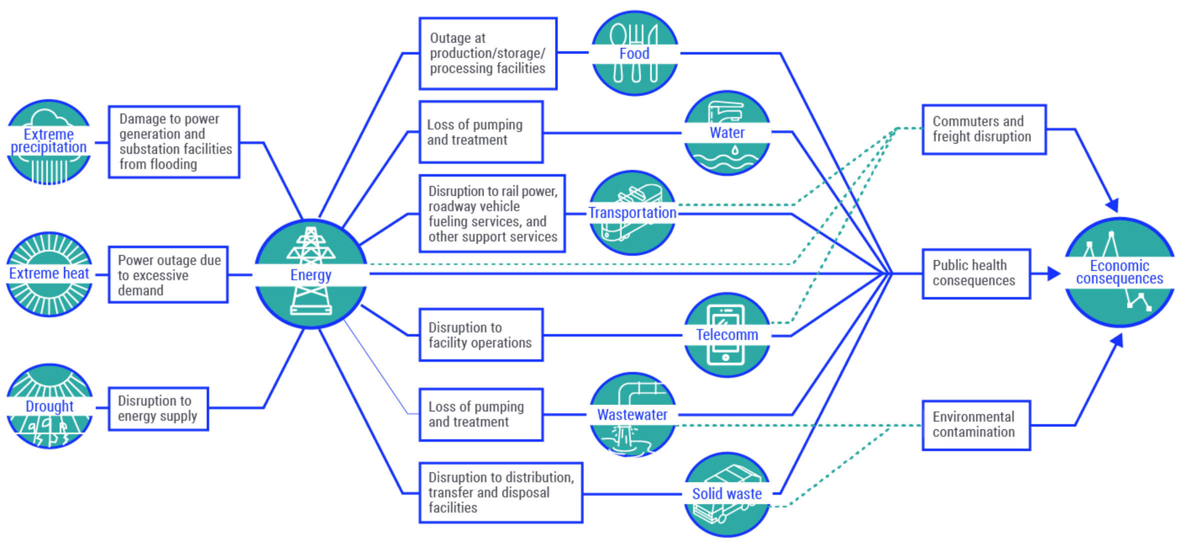


Figure 2.4: A graphical representation of an example of interdependencies between infrastructure systems. Source: Adapted from C40 Cities and AECOM, 2017.

Case Story 2.1: Enhancing infrastructure resilience in Fredericton, NB to reduce flood risk

Located on the Saint John River, the City of Fredericton is the capital of New Brunswick and is home to nearly 60,000 people. The primary climate risk for Fredericton is spring flooding of the Saint John River—a hazard so prominent that a public art piece was commissioned to contextualize the height of floodwaters (*see* Figure 2.5).

Fredericton experienced back-to-back spring floods in 2018 and 2019, both lasting for over a week. For each flood, a significant portion of the arterial transportation network was disrupted, and commuters struggled to travel from one side of the river to the other for work, hospital visits and other activities that are often taken for granted. During this time, the City encouraged using active transportation, free transit, park-and-ride options and telecommuting to ensure business continuity, as well as altering the flow of traffic on the major bridge to permit improved access to and from downtown. Business continuity is one way that City staff have framed adaptation efforts, accepting that eliminating flood risk is not possible.

Persistent flood risk has resulted in over two decades of efforts to ensure that the City's infrastructure is more resilient. Fredericton has relied on a commitment to asset management planning and a long-term vision to guide this work. This has led to changes, such as culverts that are sized 20% above a 1:100 return period; the use of active transportation (e.g., cycling); and rail-corridor trails that have been used as sites for water mains to increase redundancy, and also to act as alternative transportation routes when flooding disrupts vehicle traffic. The City has relied on diverse funding mechanisms to complete this work and will receive support from the National Disaster Mitigation Program to make Fredericton more resilient.

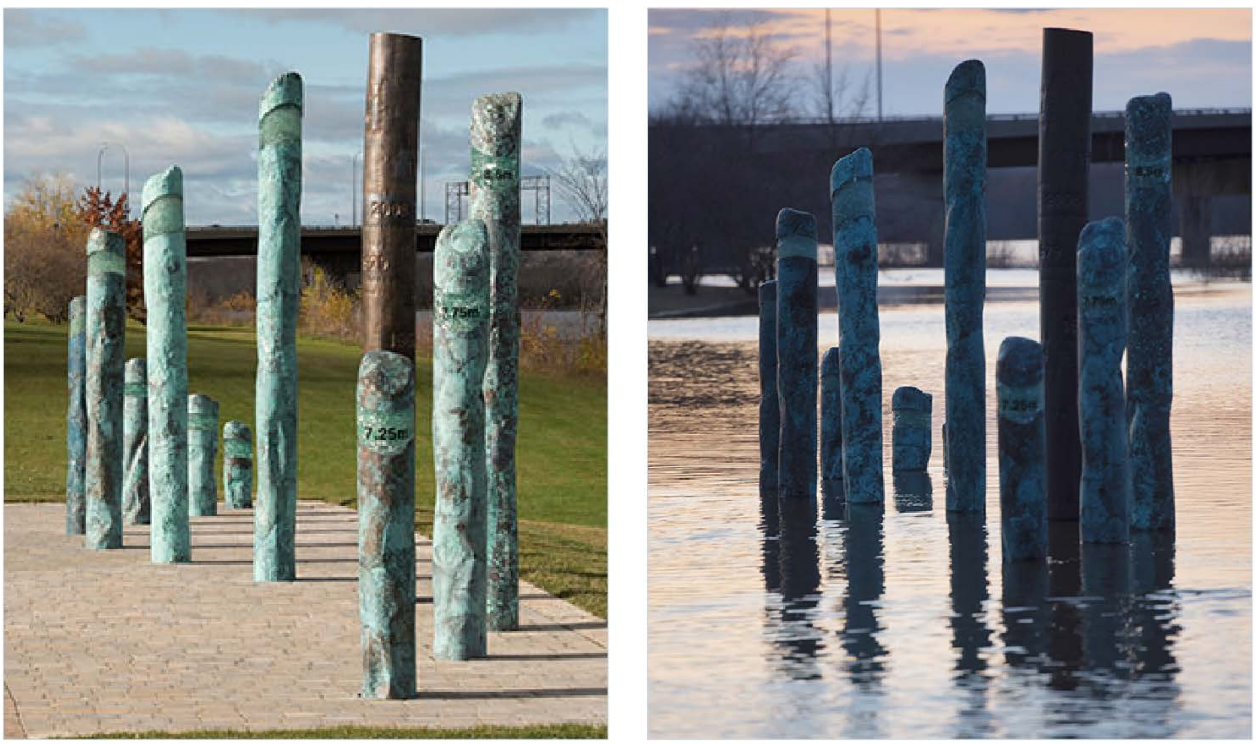


Figure 2.5: Gerald Beaulieu's public art installation "Watermark", consisting of a series of 11 wooden posts of different heights along a riverside walking path in Fredericton, NB. The tallest post—the "memory pole"—is encased in copper sheets that mark the year and peak water level of the Saint John River during the annual freshet. This project is a great example of municipal Public Works collaborating with the Culture Office. Photos courtesy of the City of Fredericton.

2.3 Enhancing green spaces helps cities and towns adapt to climate change

Green infrastructure, such as parks, wetlands and green roofs, in Canada's cities and towns increase the quality of life for residents and improve climate resilience. Recognizing the value of the benefits associated with green infrastructure and nature-based adaptation solutions will be useful in advancing their use to reduce impacts from climate change and other stressors.

The natural environment influences quality of life in Canada's cities and towns, and supports food and water security, as well as providing significant benefits in terms of air quality, water filtration and biodiversity. The ability of green infrastructure to increase resilience to climate change is well understood. Green infrastructure is beginning to be used more widely in Canada's cities and towns, as are innovative approaches to design and governance relating to the natural environment. As the climate changes, protecting and enhancing green infrastructure (see Figure 2.6) will contribute to its resilience and its ability to continue to provide ecosystem services and co-benefits. This requires integration with complementary planning processes (e.g., built infrastructure decisions), as well as consideration of other factors relating to land-use planning and development.

2.3.1 Introduction

Cities and towns incorporate natural systems that include waterways, coastlines, wetlands, urban forests, parks, and remnant ecosystems, as well as built assets such as green roofs, bioswales and rain gardens (*see* Figure 2.6). These natural and engineered assets provide valuable goods and services that can increase adaptive capacity (*see* Ecosystem Services chapter; Frantzeskaki et al., 2019; Adaptation to Climate Change Team, 2017; Kabisch et al., 2017; Terton, 2017) and are often flexible, cost-effective, and broadly applicable in reducing the impacts of climate change (Emilsson and Sang, 2017). Green infrastructure can reduce impacts associated with extreme heat, drought, flooding and sea-level rise, while delivering multiple co-benefits (*see* Table 2.2). For example, there is increasing understanding of the effects that green infrastructure can have on heat and air pollution at the site, neighbourhood and city levels (Zupancic et al., 2015). However, the ability to provide these benefits is threatened by rapid urban growth and development, destructive land and water use practices, and the temperature and precipitation changes and extreme events associated with climate change (The Nature Conservancy, 2018; Emilsson and Sang, 2017; Terton, 2017).

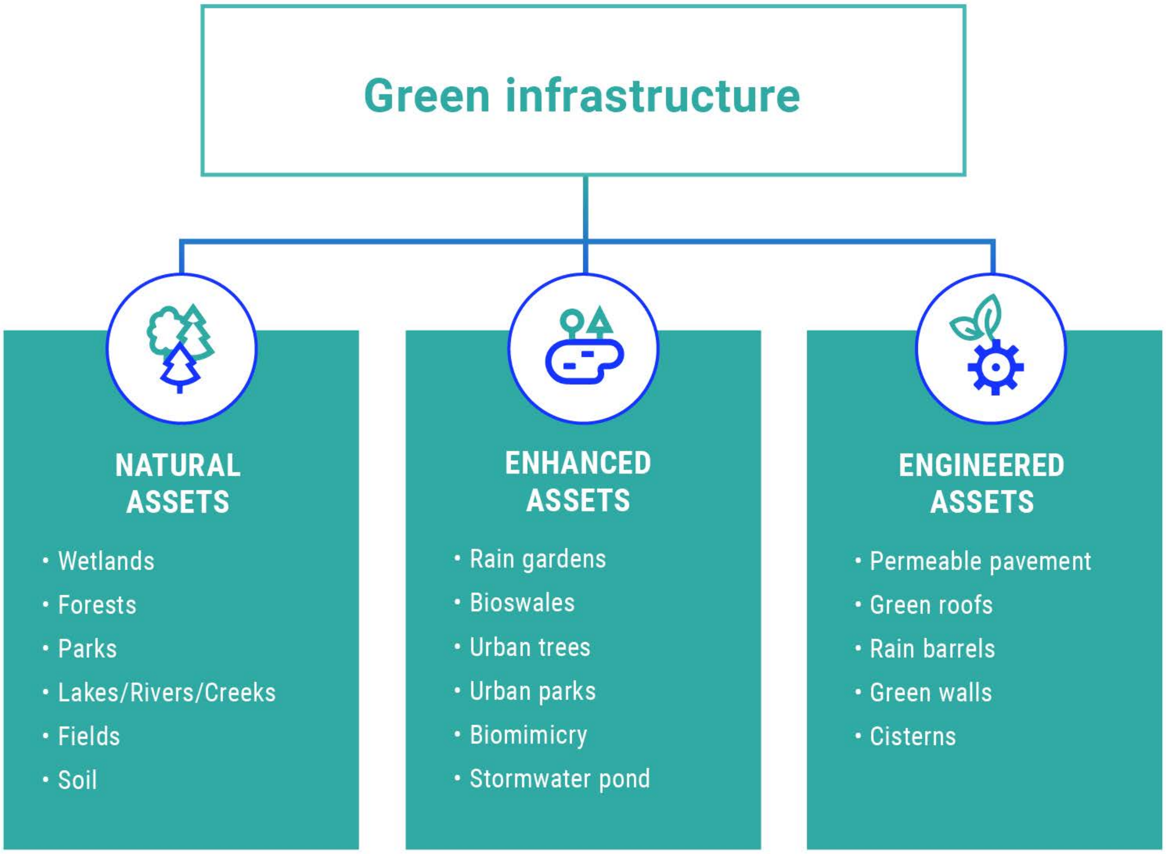


Figure 2.6: Definition of green infrastructure. Source: Adapted from Brooke et. al, 2017.

There is an increasing amount of guidance available for those seeking to use green infrastructure for adaptation (e.g., *see* Case Story 2.2; Terton, 2017). Vulnerability and risk assessment tools also exist. For example, the PIEVC (Public Infrastructure Engineering Vulnerability Committee) protocol was applied to three parks in Mississauga to assess their vulnerability to twelve climate parameters (e.g., flooding, freeze-thaw cycles, drought and air quality). A number of risks were identified that could be managed by construction, operations and management, and/or additional research (Risk Sciences International, 2018).

Table 2.2: Co-benefits of green infrastructure

CATEGORY	CO-BENEFITS
Environmental	• Improved air quality • Improved water availability and quality • Increased habitat and connectivity for biodiversity • Reduced urban temperatures • Erosion prevention • Carbon sequestration and reduced emissions
Social	• Opportunities for recreation and physical activity • Improved mental health • Increased social cohesion (e.g., parks, community gardens, beaches) • Potential for urban agriculture and local food security • Reduced mortality • Educational opportunities • Spiritual value and sense of place
Economic	• Cost effectiveness compared to grey infrastructure • Flood protection • Reduced energy consumption in buildings • Reduced energy required for pumps, etc. • Pollution removal • Improved power transformer capacity and electrical transmission efficiency • Increased property values and property tax revenue

Sources: Arsenijevich, 2018; EPCCARR, 2018; Kabisch et al., 2017; Terton, 2017; Berry, 2016; McDonald et al., 2016; Sörensen et al., 2016; AECOM and Risk Sciences International, 2015; Kardan et al., 2015; Alexander and McDonald, 2014; ARUP, 2014; Beatley and Newman, 2013; Summers et al., 2012; Foster et al., 2011.

2.3.2 Low impact development

Low impact development (LID) aims to return the hydrology of a site as closely as possible to its pre-development conditions (Ahiablame et al., 2013) and is widely recognized as an important strategy for stormwater management in urban areas (Berry, 2016; Dagenais et al., 2014). Examples of LID include green roofs, permeable pavement, rain gardens, bioswales, infiltration planters, vegetated swales, flow-through planters, drywells and retention ponds. These natural assets retain and filter a portion of stormwater, help to recharge water supplies, avoid costly upgrades to hard infrastructure, provide habitat and recreation opportunities, and are viewed as vital components of municipal infrastructure systems (*see* Figure 2.7; Kabisch et al., 2017,). For example, in Washington State's Puget Sound, there is an initiative to install 12,000 rain gardens, which would defer 160 million gallons of water from entering the stormwater system (Stewardship Partners and Washington State University Extension, 2019). Planning is underway for a similar project in North Vancouver (Pacific Water Research Centre, 2020). The City of Niagara Falls now offers a rebate program that will cover 50% of the cost of one rain barrel for its residents (City of Niagara Falls, 2019).

Regulatory approaches have also been effective at increasing LID. For example, Toronto's Green Roof bylaw requires developments with a roof space larger than 2,000 square meters to have green roofs. The City estimates that these green roofing initiatives have alleviated over 9 million litres of stormwater from their drainage systems and mitigated 120 tonnes of greenhouse gas emissions by reducing annual energy usage by 1,000 megawatt hours (Guilbault et al., 2016). LID has been embraced variably, but generally favourably across Canada (Ishaq et al., 2019). Current concerns about LID include lifecycle operational and maintenance requirements, including considerations of maintenance processes and costs, and the impact of freezing rain and winter rain events on the efficiency and survival of roof gardens.

Figure 2.7: Photos of existing conditions at the often-flooded mouth of the Don River in Toronto, ON, and a rendering of a design to better accommodate floodwaters while improving amenities. Source: Waterfront Toronto, 2020.

2.3.3 Urban biodiversity

The protection of urban biodiversity (i.e., the variety of life in the urban context) is a priority for many Canadian cities. Tools exist to support cities and towns in urban biodiversity planning (e.g., ICLEI Canada, 2014) and in creating urban biodiversity strategies (e.g., City of Vancouver, 2016); these tools can help address issues such as the arrival of invasive species, which is increasingly likely to occur in a changing climate (Smith et al., 2012). Efforts to preserve green space and biodiversity outside of a city can complement initiatives occurring within municipal boundaries (e.g., Parks Canada, 2014). However, coordinating transboundary and trans-sectoral planning for ecosystem connectivity is becoming increasingly urgent in the face of habitat loss and climate change. Some degree of connectivity is important for the health and survival of almost all species, and local and regional approaches to green infrastructure are likely to provide larger-scale benefits for flood and heat reduction (Satzewich and Straker, 2019).

2.3.4 Urban forests

Urban forests are useful in retaining stormwater, improving air quality, and reducing urban heat (*see* Figure 2.8). To maintain these benefits, it is essential that municipalities manage urban forests in ways that ensure their adaptability to climate change (Diamond Head Consulting Inc., 2017b; Brandt et al., 2017; McDonald et al., 2016). For example, the City of Kitchener is preparing its urban forest for more winter ice storms (City of Kitchener, 2019). For many cities, increasing heat and drought mean that cities need to actively plan to introduce tree species that will not only reduce various climate risks, but will also be resilient themselves to changing climate conditions (Brandt et al., 2016). Cities and towns across Canada are acknowledging this dimension of climate risk, and are developing a deeper understanding of the climate vulnerability of trees (e.g., City of Montréal, 2017). Cities and towns are also prioritizing the health of their urban forests. For example, the urban forest in Kingston, Ontario, provides $1.87 million in environmental benefits annually, and is being actively managed via the city's Urban Forest Management Plan and Drought Protection Strategy (Guilbault et al., 2016). In some neighbourhoods—particularly in dense cities like Montréal and Toronto—the cost of tree planting for particulate matter (PM) reduction is as low as US$840/ton, and rivals commonly used strategies to reduce PM (e.g., point source control) (McDonald et al., 2016). Similarly, the shade provided by trees reduces temperature in the area, with associated reductions in cooling costs (McDonald et al., 2016).

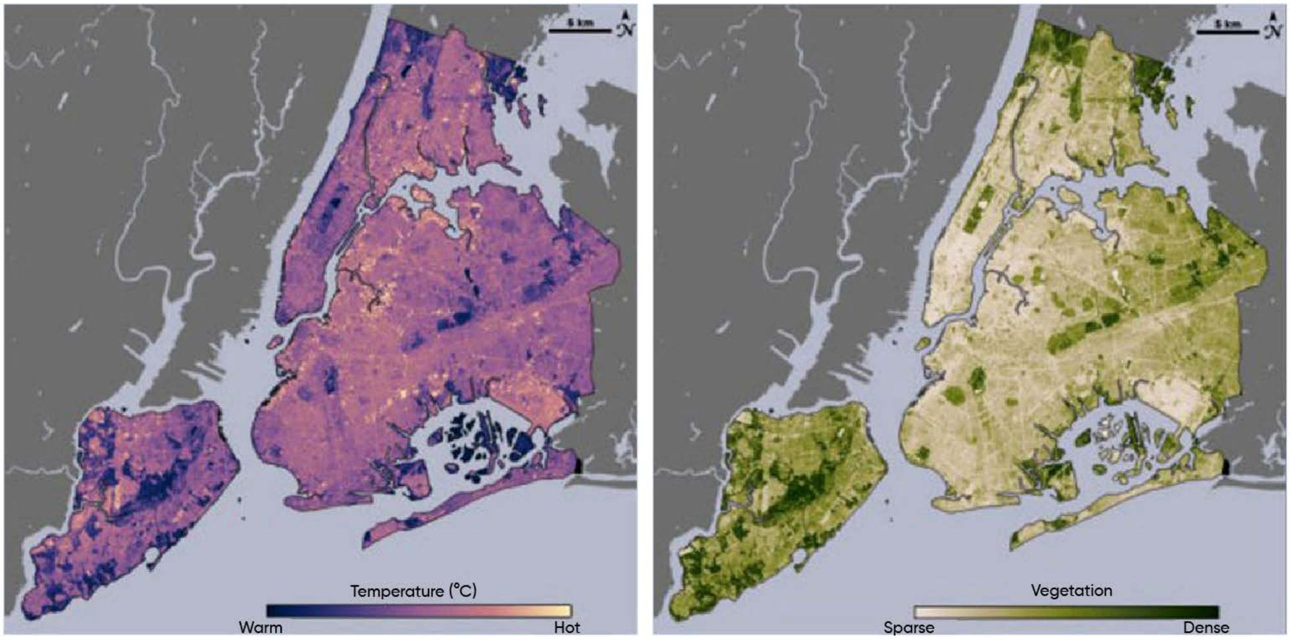


Figure 2.8: A graphical representation of the correlation between urban trees and temperature. Source: NASA Earth Observatory, 2006.

2.3.5 Water supply

Water is an essential resource for cities and towns, and degraded water quality is commonly identified as a potential impact of a changing climate (*see* Water Resources chapter). The provision of clean drinking water is contingent on supply, treatment and delivery, with supply being the primary climate-related challenge. Local governments have always managed variability in supply; however, this occurred within the context of relatively predictable climatic variability (de Loe and Plummer, 2010). The causes of water shortages vary depending on the hydrology within a given region, and vary widely across Canada (de Loe and Plummer, 2010). For example, in rainfall-dominated regions, a water shortage is often caused by decreased summer precipitation, while in snowmelt-dominated regions, earlier or more rapid snowmelt, or a reduced snowpack could be the cause (BC Ministry of Environment and Climate Change Strategy, 2019). Additional factors, such as stormwater management decisions that impact groundwater recharge, also affect municipal drinking water supply and quality (Amec Foster Wheeler and Credit Valley Conservation, 2017).

There have been some assessments of the resilience of water supply treatment and distribution infrastructure. For example, an assessment of Calgary's water supply system found that the system was generally resilient due to robust treatment processes, two raw water sources, and redundancy within the distribution system (Associated Engineering, 2011). Tools also exist to guide the planning process. These often point to the importance of collaborative governance when managing watersheds (e.g., POLIS Project on

Ecological Governance and Centre for Indigneous Environmental Resources, 2019), including the inclusion of Indigenous Knowledge Systems (Porten et al., 2016). An example of this type of governance can be seen in the Cowichan Valley Regional District (CVRD) water use planning process that involved the CVRD, Cowichan Tribes, the Cowichan Watershed Board and Catalyst Paper (Cowichan Valley Regional District, 2018). This process was created in response to significant pressure being placed on the drinking water supply system by factors relating to water demand, land use and a shifting hydrological cycle from climate change (Compass Resource Management Ltd., 2018).

2.3.6 Multifunctional landscape planning

Multifunctional landscape planning offers an emerging alternative to urban development frameworks that utilize built infrastructure, such as buildings, streets or districts, as the central organizing element of the urban fabric (e.g., smart growth and new urbanism). Multifunctional landscapes are explicitly designed to provide synergistic functions (e.g., environmental, social, economic and cultural) that support ecological health and co-benefits at and across the site, neighbourhood, city and regional scales (Kabisch et al., 2017; Sörensen et al., 2016). Ecosystem services are reintroduced or reinforced within the urban fabric by coordinating development around "spatially and functionally integrated systems and networks of protected landscapes" that may be supported with additional complementary built infrastructure (Ahern et al., 2014, p. 255). The approach suggests a greater need for involvement of landscape architects throughout the planning and design process (Canadian Society of Landscape Architects, n.d.; Lovell and Johnston, 2009). Although effective applications of multifunctional landscape approaches are still limited in an urban context (Meerow and Newell, 2017; Lovell and Taylor, 2013), Toronto's Don Mouth Naturalization and Port Lands Flood Protection project, with its series of proposed terrestrial, wetland and aquatic ecosystems, illustrates a multifunctional space in which ecological function is restored to the benefit of human health, recreation, restoration and built asset protection (*see* Figure 2.7). Since green infrastructure measures often require significant space that developers and others may desire, it is important to take climate change into consideration when contemplating urban growth (Geneletti and Zardo, 2016).

Case Story 2.2: Piloting natural asset valuation in Nanaimo, BC

Cities and towns face the dual challenges of upgrading ageing infrastructure and increasing the resilience of their natural environment. The Municipal Natural Assets Initiative (MNAI) aims to address these challenges by helping municipalities identify, value and account for natural assets in their financial planning and asset management programs (O'Neil and Cairns, 2017), and to consider future climate conditions (Municipal Natural Assets Initiative, 2017). By identifying natural assets—such as wetlands, forests and parks—cities and towns can work to protect them, and can rely on ecosystem services to reduce the load on conventional infrastructure, like underground drainage.

Guided by the MNAI, the City of Nanaimo, BC, sought to assign a financial value to its natural assets, using the Buttertubs Marsh Conservation Area (BMCA) as part of a pilot study. When the opportunity came to participate in the MNAI, the City had just completed a Management Plan update with the Nature Trust of British Columbia and Ducks Unlimited for the BMCA. There was interest in exploring how the City could work more effectively to help implement the conservation plan, while also recognizing its value in mitigating the flows of the Millstone River. The BMCA comprises 55 hectares of reclaimed wetland and floodplain within Nanaimo (*see* Figure 2.9; Molnar et al., 2018). The project found that the BMCA helps moderate the rivers downstream during extreme precipitation events, and therefore reduces flood risk in the floodplain. Building an engineered system that could do what the BMCA does naturally would cost the City between $6.6 and $8.5 million, a figure that would rise with more extreme events. The results of this pilot study will guide the City in identifying other key natural assets to be recognized and integrated into the City's infrastructure (Molnar et al., 2018). Water levels throughout the BMCA have been tracked for the last two years in an ongoing effort to monitor and evaluate the project.

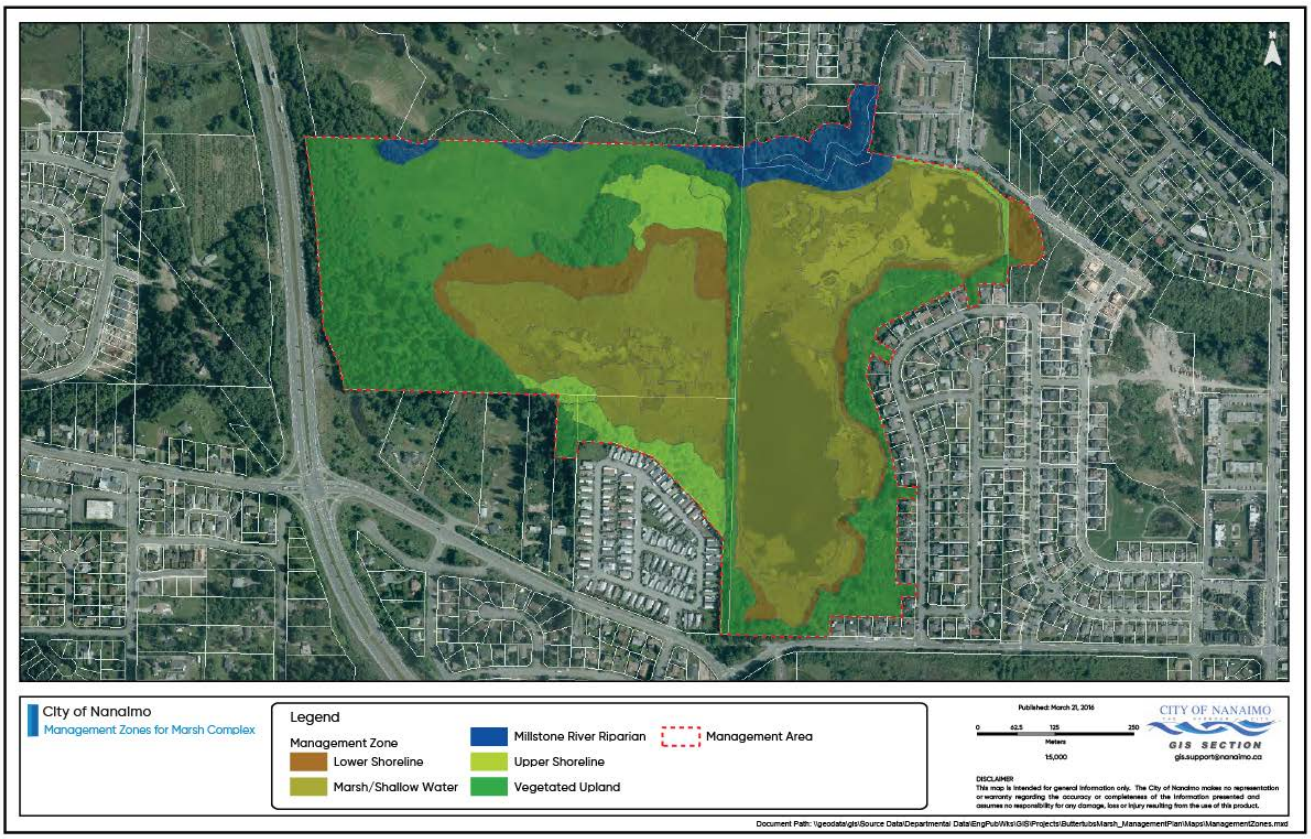


Figure 2.9: The Buttertubs Marsh Conservation Area, which comprises 55 hectares of reclaimed wetland and floodplain, appears in the center (the "management area") of this aerial photo of Nanaimo, BC. Source: City of Nanaimo.

2.4 Climate change will hit those already struggling in cities and towns the hardest

Climate change will impact individual and community health and well-being in cities and towns. However, the negative impacts from climate change will not affect all members of society equally. Considering social equity in adaptation decisions will help reduce the vulnerability of those at highest risk and will ensure that benefits are distributed fairly.

Many of the impacts of climate change on health and well-being—especially those relating to individual physical health—are increasingly well understood (see Health of Canadians in a Changing Climate Report). Adapting to these impacts requires continued collaborations across sectors and consideration of the many non-climate factors that influence health. Understanding and addressing the vulnerability of various urban populations to climate change is essential for increasing both individual adaptive capacity and the overall resilience of urban communities. It continues to be an important area of practice to establish practical linkages between community development, social resilience interventions, initiatives that increase equity, reconciliation and climate change adaptation.

2.4.1 Impacts on individuals and communities

There is strong understanding of the impacts that climate change has on the physical health of individuals (*see* Table 2.2; EPCCARR, 2018; Berry et al., 2014). This understanding is becoming more nuanced and is beginning to include mental health impacts, such as despair and anxiety, as well as post-traumatic stress disorders for those affected by, and responding to, extreme events (Decent and Feltmate, 2018; Gifford and Gifford, 2016). Negative impacts can also result from individuals and communities experiencing grief or loss regarding some aspect of their surroundings that has been altered by climate change (e.g., the loss of cedar trees on Vancouver Island) (Cunsolo and Ellis, 2018). Framing climate adaptation as a public health issue is likely to garner public support for adaptation (Araos et al., 2017; Cheng and Berry, 2013) and is increasingly commonplace in adaptation practice in Canada's cities and towns. Climate change is also affecting the delivery of services by health agencies across Canada (e.g., disease surveillance, air quality monitoring and emergency preparedness) (Buse, 2018).

Negative impacts of extreme weather events and climate change on cultural practices include the loss of landmarks and a reduced ability to engage in recreational and cultural activities, such as bird watching, using public playgrounds and harvesting traditional foods (*see* Figure 2.10; Government of Canada, 2016; Ford, 2012). In Ottawa, for example, Canada Day festivities have been reduced due to extreme heat (Dunham, 2018), and it is likely that skating on the Rideau Canal will decrease in the future (Spears, 2017).

Figure 2.10: Thermal imaging of Windsor's Captain John Wilson park shows that the temperature of the dark rubber mat under the play structure (yellow area) is 69.0°C. Photos courtesy of the City of Windsor.

2.4.2 Social determinants

Climate change can exacerbate existing socioeconomic vulnerabilities (EPCCARR, 2018). Social vulnerability refers to a set of social characteristics (e.g., socioeconomic status, age, ethnicity, housing status) that affect adaptive capacity and that increase the sensitivity of certain populations to climate impacts (EPCCARR, 2018; Cutter et al., 2010). Considering socioeconomic vulnerabilities, including their history and dynamics, helps to ensure that adaptation initiatives do not exacerbate existing inequities and that they are better positioned to maximize benefits for marginalized groups (Shi et al., 2016). The relationship between social vulnerability and climate change is often evident during extreme weather events. For example, Superstorm Sandy "exposed the role that chronic societal stressors—such as poverty, lack of mobility and lack of social cohesion—can play in both increasing community vulnerability and hindering a region's ability to recover from a disaster" (Grannis, 2016, p. 1). Some adaptation plans acknowledge the effects that climate-sensitive hazards can have on homeless populations (e.g., City of Toronto, 2019), and climate change is increasingly being viewed as a risk multiplier for the affordable housing crisis many cities are facing (Ortiz et al., 2019).

Adaptation planning across Canada often takes into consideration those who are vulnerable, including low-income and equity-seeking groups (i.e., groups facing an unequal distribution of opportunities and resources)

(City of Toronto, 2019). For example, the City of Montréal considered social susceptibility by assessing the vulnerability of the following groups to different climate hazards: children aged 0 to 15, seniors aged 65 and up, people living alone, underprivileged people, recent immigrants and people who speak neither French nor English (City of Montréal, 2017). Indeed, the majority of the 53 heat-related deaths in Montréal's 2018 heat wave were men older than 50 years of age who lived alone (Santé Montréal, 2018). Box 2.4 describes impacts and adaptation relating to extreme heat events in cities and towns in more detail. Ideally, climate adaptation and resilience efforts would complement existing social vulnerability reduction efforts, including by mainstreaming.

Wildland-urban interface fires are projected to increase in frequency and will continue to cost more than fires that threaten only forest resources (Mahmoud and Chulahwat, 2018; Canadian Council of Forest Ministers, 2013). The impacts of these fires include mortality, negative mental health effects (e.g., generalized anxiety disorder), displacement and respiratory illness. Particulates from wildfire smoke can affect air quality and health across great distances. These impacts are often most pronounced for vulnerable populations, including children, the elderly, pregnant women, people of low socioeconomic status, as well as first responders (National Collaborating Centre for Environmental Health, 2019b; Abbott and Chapman, 2018; Agyapong et al., 2018; Ford, 2012).

Box 2.4: Extreme heat

The urban heat island effect results from the prevalence of hard surfaces in cities that store heat, often leading to higher daytime and nighttime temperatures (McDonald et al., 2016). This rise in temperature amplifies the risks that cities face during extreme heat events, which are expected to increase in frequency and intensity as the climate changes (*see* Figure 2.11; Zhang et al., 2019), along with the number of heat-related mortalities (Guo et al., 2018). The negative health impacts associated with extreme heat events are well understood (*see* Video 2.1; National Collaborating Centre for Environmental Health, 2019a; Lebel et al., 2017). Multiple organizations, including local and provincial governments, health authorities and the federal government, often lead heat response efforts in Canada. Montréal's heatwave plan involves "monitoring signs of heat-related illness, frequent visits to home-care patients, opening air-conditioned shelters, extending pool hours and mass media communication campaigns" (Araos et al., 2017, para 9). These efforts are estimated to have reduced heat wave-related mortalities by 1.52 deaths per day during heat events in Montréal (Benmarhnia et al., 2016).

In Toronto, only 128 of the 583 schools in the Toronto District School Board have air conditioning, which exposes students and workers to significant heat stress, and can prompt parents to keep children home from school (Flanagan, 2018). Retrofitting the schools with air conditioners would cost roughly $750 million, and so temporary cooling centres are set up in libraries and gyms (Flanagan, 2018). Many high-rise residential buildings also lack air conditioning, and some local governments have implemented adaptation initiatives to address this problem. For example, the City of Hamilton trained landlords to deal with extreme heat by providing common rooms with air conditioning, and having superintendents identify heat-related health symptoms, and check in on vulnerable residents (Guilbault et al., 2016). Health authorities in British Columbia are exploring the role that passive cooling strategies can play in maintaining safe operating conditions in buildings, in order to avoid increasing greenhouse gas emissions through mechanical cooling (Lower Mainland Facilities Management, 2018).

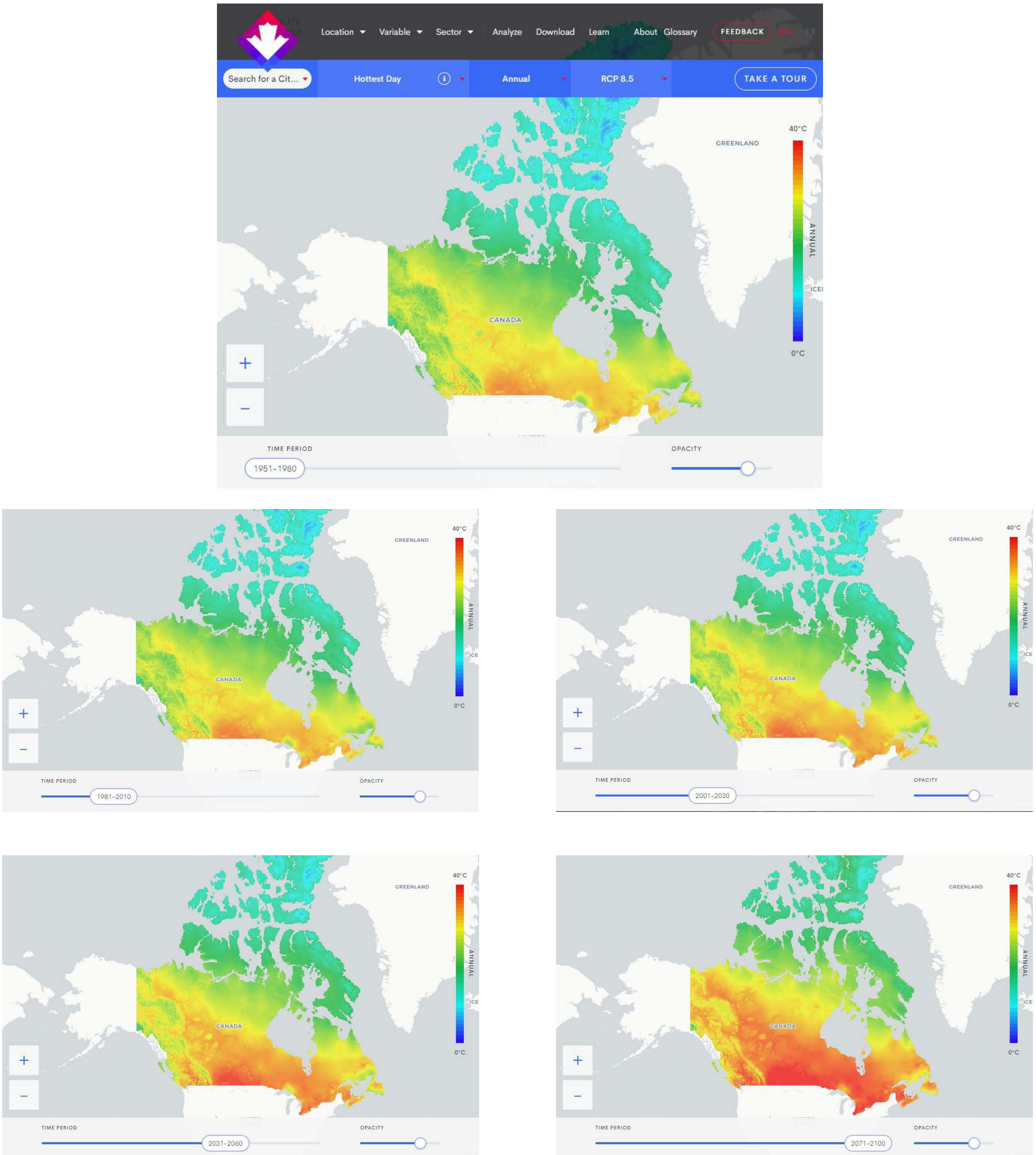
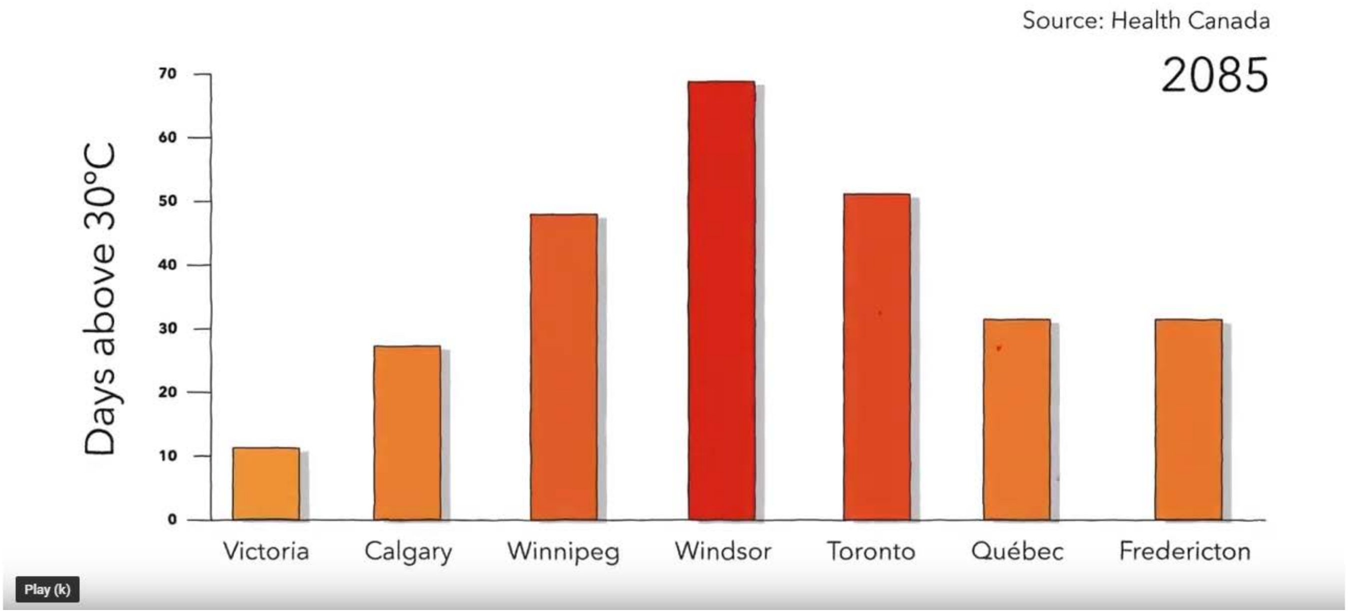


Figure 2.11: This map is from climatedata.ca and displays the "hottest day" variable across multiple timescales.



Video 2.1: The National Collaborating Centre for Environmental Health has produced a video about the impacts of and adaptations to urban heat. Source: National Collaborating Centre for Environmental Health, 2018. <https://youtu.be/RBwgS_1D5FM

2.4.3 Strong social systems

In addition to built infrastructure, cities and towns also have social infrastructure, complete with assets that include community centres, trust and social cohesion (Carter et al., 2015; Kenton, 2014). Social resilience is a necessary, but insufficient condition of climate resilience (Kwok et al., 2016). It encompasses a number of factors, including social capital, innovation, a strong economy and inclusivity (Gibberd, 2015). For example, social capital—which is a measure of social cohesion, agency, trust and social learning (Walker et al., 2014)—helped reduce the number of injuries and fatalities in the 2013 floods in Calgary (Haney, 2018). Similarly, during the agenda-setting workshop for Calgary's 100 Resilient Cities initiative, "participants noted that successful responses to shocks are frequently driven by grassroots efforts and rely on cohesive and connected communities that can assemble quickly" (City of Calgary, 2017, p. 10). Interestingly, participants also pointed out that social media—primarily Twitter—enabled rapid community mobilization.

There are many examples of social resilience building exercises in Canada, several of which are motivated by an emergency management imperative, or by health and well-being agendas. For example, the City of Vancouver's Healthy City Strategy sets the following target: "all Vancouverites report that they have at least 4 people in their network they can rely on for support in times of need" (City of Vancouver, 2015, p. 26). Vancouver's "Hey Neighbour!" program is a resident-led initiative aimed at increasing social connectedness, neighbourliness and resilience in multi-unit buildings (City of Vancouver, 2019a).

2.4.4 Increasing equity

Equitable climate change adaptation involves understanding the inequitable nature of climate impacts, and ensuring broad representation in the planning, implementation and delivery of adaptation initiatives. Creating equity is understood to increase adaptive capacity and well-being in cities (Rosenzweig and Solecki, 2018), and can also increase the likelihood of climate resilience measures being implemented (Gonzalez et al., 2017), though this has not been explored empirically in Canada. In order to achieve this, equity must be present in both the processes and outcomes of climate adaptation activities (Doorn, 2017). This issue is sometimes characterized as the "resilience for whom" question (Meerow et al., 2016). For example, Video 2.2 demonstrates the importance of involving youth in climate action.

Equitable climate adaptation is an emerging trend in Canada, and an increasing body of international best practices inspire and direct action here in Canada. For example, infrastructure designers in the United States are being urged to consider the extent to which their designs prioritize equity and inclusion (Climate-Safe Infrastructure Working Group, 2018, p. xi). Similarly, the City of Portland, Oregon has incorporated equity into its climate preparedness plan (City of Portland, 2014). These sentiments were echoed in the October 2019 Victoria Call to Action (*see* Case Story 2.3).

Video 2.2: This video describes the importance of youth perspectives. Source: ResiliencebyDesign Research Innovation Lab, 2017. <https://youtu.be/bQg42VCZegk

2.4.5 Place-based adaptation

Place-based approaches to adaptation recognize the importance of social resilience by organizing adaptation efforts around community spaces that support social bonding and elicit a strong sense of place attachment (Adger et al., 2011). For example, the City of Toronto created ten resilience hubs across the city that engaged diverse local residents to design resilience projects in their communities (City of Toronto, 2019). When knowledge pertaining to community spaces and their value to communities is overlaid with scientific knowledge about impacts, new opportunities for participatory dialogue between stakeholders and local citizens can emerge (Amundsen, 2015). The spatial structure of place attachments can be examined through engagement techniques like participatory GIS mapping (Brown and Raymond, 2014), while more experiential approaches like collaborative citizen science projects can foster scientific learning about climate change while simultaneously enabling a deeper sense of place (Groulx et al., 2017; Newman et al., 2016). When adaptation planning focuses on the place-based values that are unique to different communities, citizens gain greater access to, and influence over, defining what is important to protect through adaptation (Amundsen, 2015). At the same time, technical experts gain a local framework for discussing climate change that may reveal potentially overlooked impacts and sources of vulnerability (De Dominicis et al., 2015; Marshall et al., 2012). Orienting resilience-building towards places that foster our traditions and livelihoods, house individual and shared histories, and impart a sense of our identity can also support implementation by garnering public support to protect places from climate-driven environmental change (Nicolosi and Corbett, 2018; Masterson et al., 2017; Adger et al., 2013; Devine-Wright, 2013).

Case Story 2.3: Victoria Call to Action: Building resilience through thriving and inclusive communities

In October 2019, more than 50 mayors and councillors from across Canada gathered in Victoria, BC as part of the Livable Cities Forum to discuss and share ideas on building social resilience, community belonging and inclusion as a key resilience strategy (ICLEI Canada, 2018b). The session culminated with elected officials finalizing a collective Call to Action for local leaders to advance work on the health, well-being and social cohesion aspects of resilience. The Victoria Call to Action was endorsed by those locally elected officials present as a call to themselves and other locally elected officials to take action and commit to the following six points of action:

1. Ensure that all actions we take are done through a lens of decolonization, health and well-being, equity and inclusion, racial and social justice, and ecological integrity.
2. Empower and resource our communities and use our role as leaders to create opportunities for education, connection, belonging and community building.
3. Enrich the fabric of our communities by building towns and cities that create a sense of place and a strong connection to neighbourhoods.

4. Leverage the interconnection of issues and look for opportunities to solve complex challenges that generate multiple benefits and solutions.
5. Seize the pockets of brilliance in our communities coming from youth and residents as bottom-up solutions to our collective challenges.
6. Invest our collective resources to deliver short- and long-term solutions that will have the greatest impact and help us go further, faster together.

2.5 Working together yields the most successful outcomes

Effective adaptation approaches to climate change consider diverse perspectives and priorities. Local governments are increasingly playing a strong role in driving meaningful collaboration with different groups when it comes to designing, planning and implementing adaptation in their communities.

Initiatives that help make Canada's cities and towns more resilient to a changing climate are more effective when they are collaborative. Collaboration that is inclusive, transparent, and incorporates diverse perspectives, from the initial planning phases right through to adaptation implementation, enhances outcomes for all. Local governments are well-placed to bring groups together to share their unique perspectives and priorities, create solutions, and implement action. As such, strengthening local government capacity to plan and implement adaptation would help build adaptation momentum in cities and towns.

2.5.1 Introduction

Climate change adaptation in Canada's cities and towns is motivated by local governments' need to ensure levels of service for their communities, as well as by policies and resources at the federal (Henstra, 2017) and the provincial levels. For example, Nova Scotia required its municipalities to create climate action plans (Climate Change Nova Scotia, 2014), and other provinces have developed planning tools and resources to help cities incorporate adaptation into land-use planning (Government of Ontario, 2017; Legislative Assembly of Ontario, 2017).

Cities and towns operate within a governance context that includes provincial and federal entities, alongside their own staff, councils, residents and businesses (*see* Box 2.5 and Case Story 2.4). Although complex, this context presents an opportunity for effective action on adaptation (Paterson et al., 2017; Graham and Mitchell, 2016; Revi et al., 2014).

2.5.2 Co-production

Participatory, collaborative planning approaches embracing and leveraging the viewpoints of multiple actors are viewed as essential for successful adaptation in cities (Archer et al., 2014; e.g., Auditor General of Canada, 2018; Wamsler, 2017; Revi et al., 2014; Burch et al., 2010). Such approaches are usually described as “inclusive, transparent, participatory, multi-sectoral, multi-jurisdictional and interdisciplinary” (Rosenzweig and Solecki, 2018, p. 757). Co-production allows multiple parties to find ways to combine their efforts and capacities towards achievement of a common goal (Wamsler, 2017). Co-production can occur at all points in the adaptation process, including risk assessment, setting objectives, implementation activities, and monitoring and evaluation. This is an equitable approach that also increases the likelihood of implementation, which is partially contingent on those impacted by a changing climate being aware, empowered to act and capable of creating change (Birkholz et al., 2014).

2.5.3 Municipal governments

Municipal governments help drive climate adaptation in Canada, as they are motivated by impacts in their jurisdictions affecting levels of service and budgets (Dale et al., 2013). While Video 2.3 demonstrates the important role that municipal planners play in climate change adaptation, adaptation also includes staff from across municipal departments (e.g., parks, engineering). Municipal governments can use numerous regulatory tools to drive land-use planning decisions that consider climate change impacts. For example, development limitations can increase the resilience of natural systems (Terton, 2017) and help cities to mitigate risks relating to wildland-urban interface fires (Kovacs, 2018).

Local governments are increasingly encouraged—in the literature and through policies—to create more meaningful engagement with multiple actors (Canadian Institute of Planners, 2018; Mees, 2017). For example, in the collaborative work in the Bras d’Or watershed on Cape Breton Island, municipalities are working with First Nations, provincial governments, federal agencies and citizens to ensure the health of the watershed into the future (Bras d’Or Lakes Collaborative Environmental Planning Initiative, 2018). Similarly, the Fraser Basin Council Lower Mainland Flood Management Strategy is a collective approach to coastal and river flooding resilience that involves 23 municipalities and numerous community organizations (Fraser Basin Council, 2018).

Video 2.3: This video highlights the role of planners in the adaptation process. Source: Climate Atlas of Canada, 2018. <https://climateatlas.ca/video/planning-climate-resilience

2.5.4 Private and public sectors

Cities and towns are sites of concentrated economic activity. Climate change can undermine community resilience by affecting physical assets, disrupting supply chains and business networks, and affecting workers (Decent and Feltmate, 2018; Hunt and Watkiss, 2011). The connection between economic resilience and climate resilience is increasingly being recognized. For example, as part of its involvement in the "100 Resilient Cities" international network, the City of Calgary (along with Toronto, Montréal and Vancouver) connects the health of its economy to its ability to remain resilient in the face of extreme weather events (Nenshi, 2018). Effective adaptation enables cities and towns to maintain favourable credit ratings and property values in the face of a changing climate, thus positioning cities as favourable sites for investment and in-migration (McCullough, 2018). This has led to cities like Toronto and Vancouver participating in the Task Force for Climate-related Financial Disclosure (*see* Climate Disclosure, Litigation and Finance chapter). Similarly, ensuring business continuity is essential to a city's ability to function during and after an extreme event.

Private sector businesses, and public sector organizations like universities, health authorities/organizations, and provincial/federal governments, are also important partners for municipal governments. These actors often own significant assets in cities and towns, and provide essential services. Health authorities and municipal governments, for example, are interdependent in that health authorities depend on municipal infrastructure to deliver health services that are essential to cities and towns. Creating meaningful partnerships early in the adaptation planning process will help create the relationships that are essential in the implementation phase, where multiple actors are responsible for implementation actions within their mandate (*see* ICLEI Canada, 2020 for examples of this approach).

2.5.5 Citizens

Citizens are central to co-production of adaptation approaches in cities and towns (Cloutier et al., 2018; Wamsler, 2016). Individuals drive political will, participate in citizen-science monitoring programs (e.g., City of Vancouver, 2019b), and create and implement adaptation initiatives. For example, homeowners are increasingly responsible for protecting themselves from flooding and other extreme weather, and for financing their own recovery through private insurance (Henstra et al., 2018; Kovacs et al., 2018). Local governments can encourage residents to take property-level actions by offering direct incentives for the purchase, installation, or construction of certain adaptive measures. Incentives and rebates can be coupled with policy initiatives to encourage property owners to take adaptive measures beyond those mandated by a local bylaw or regulation (Zerbe, 2019). There are also a number of programs that target building owners (e.g., Victoria's Stormwater Utility), encouraging them to effectively manage stormwater, but uptake has been sporadic (Canadian Standards Association, 2018; Thistlethwaite et al., 2018; Kovacs et al., 2014; Chambers, 2013; Sandink, 2013b).

Effectively encouraging individuals to take action on climate adaptation involves engagement in co-production of risk perception, action planning, and implementation. This involvement can be achieved through community-based organizations (Gonzalez et al., 2017). For example:

- West Vancouver's urban shoreline rehabilitation was spurred by the West Vancouver Shoreline Preservation Society (Centre for Civic Governance, 2018);
- The use of sand dunes in Hamilton involved experiential learning for students that was spurred by Environment Hamilton and the Hamilton Naturalists' Club, with the help of the City of Hamilton; and
- Green Communities Canada's RAIN Community Solutions program works with homeowners to implement low impact development initiatives (RAIN Community Solutions, 2020).

2.5.6 Boundary organizations

Boundary organizations help to translate science and Indigenous Knowledge Systems into practice, build capacity, contribute analysis, and convene co-production processes (Bauer and Steurer, 2014). Boundary organizations can include not-for-profit organizations, private consultants, researchers or even government agencies (Graham and Mitchell, 2016). Effective boundary organizations provide credible, legitimate and salient information and action to cities, and help with implementation (Graham and Mitchell, 2016). As described in Section 2.4, health organizations are increasingly developing programming that explicitly builds adaptive capacity.

Box 2.5: Urban flooding

Urban flooding associated with impervious surfaces, inadequate drainage infrastructure, and short-duration, high-intensity rainfall events is one of the most significant drivers of disaster loss in Canada (Insurance Bureau of Canada, 2018; Friedland et al., 2014) and is expected to become more common in a changing climate (Gaur et al., 2019; Canadian Standards Association, 2018; Amec Foster Wheeler and Credit Valley Conservation, 2017). During these events, local governments face decreased capacity to act, increased operational and repair costs, and can also be exposed to the risk of legal liability (Zizzo et al., 2014; City of Stratford, 2010; Campbell et al., 2007). Additionally, the flooded basements that are a hallmark of these events cause property damage, displacement, loss of irreplaceable and sentimental items, and negative physical and mental health impacts (Decent and Feltmate, 2018; Feltmate et al., 2017), as well as reduced insurance coverage for future events (Sandink, 2016).

Managing these risks requires structural and non-structural responses (e.g., improved land-use planning). An important non-structural approach is insurance coverage for overland flooding. This type of coverage is improving in Canada (Meckbach, 2018), but its success requires a high degree of capacity to act on the part of homeowners, insurers and all levels of government (Henstra et al., 2018). Cities and towns, for example, need to improve risk planning and mitigation in order to increase the commercial viability of residential flood insurance (Insurance Bureau of Canada, 2015). Additional barriers include lack of flood hazard awareness (Thistlethwaite, et al., 2018; Sandink, 2016), limited understanding of the specifics of home insurance coverage (Oulahen, 2015; Sandink et al., 2010), an inaccurate understanding of the level of post-disaster assistance available from provincial and federal governments (Henstra et al., 2018), and a host of socio-psychological factors (McDonald et al., 2015; van der Linden et al., 2015).

Awareness of flood hazards through updated flood mapping (*see* Figure 2.12 as an example) has been associated with increased uptake of voluntary insurance coverage for floods (Shao et al., 2017), and also as important enabling evidence for the development of flood control bylaws (e.g., Prince George's floodplain bylaw). The need for such mapping is increasingly being met by a variety of government programs (e.g., Public Safety Canada's National Disaster Mitigation Program) as well as by academics (Thistlethwaite et al., 2018). In 2018, Natural Resources Canada released additional guidance on floodplain mapping, as well as a series of case studies (Natural Resources Canada, 2018). However, flood mapping is most effective if it makes its way into regulation. The town of Paradise, Newfoundland, for example, has plans to update its bylaws to reflect the flood risk mapping shown in Figure 2.12 (Town of Paradise, 2016).

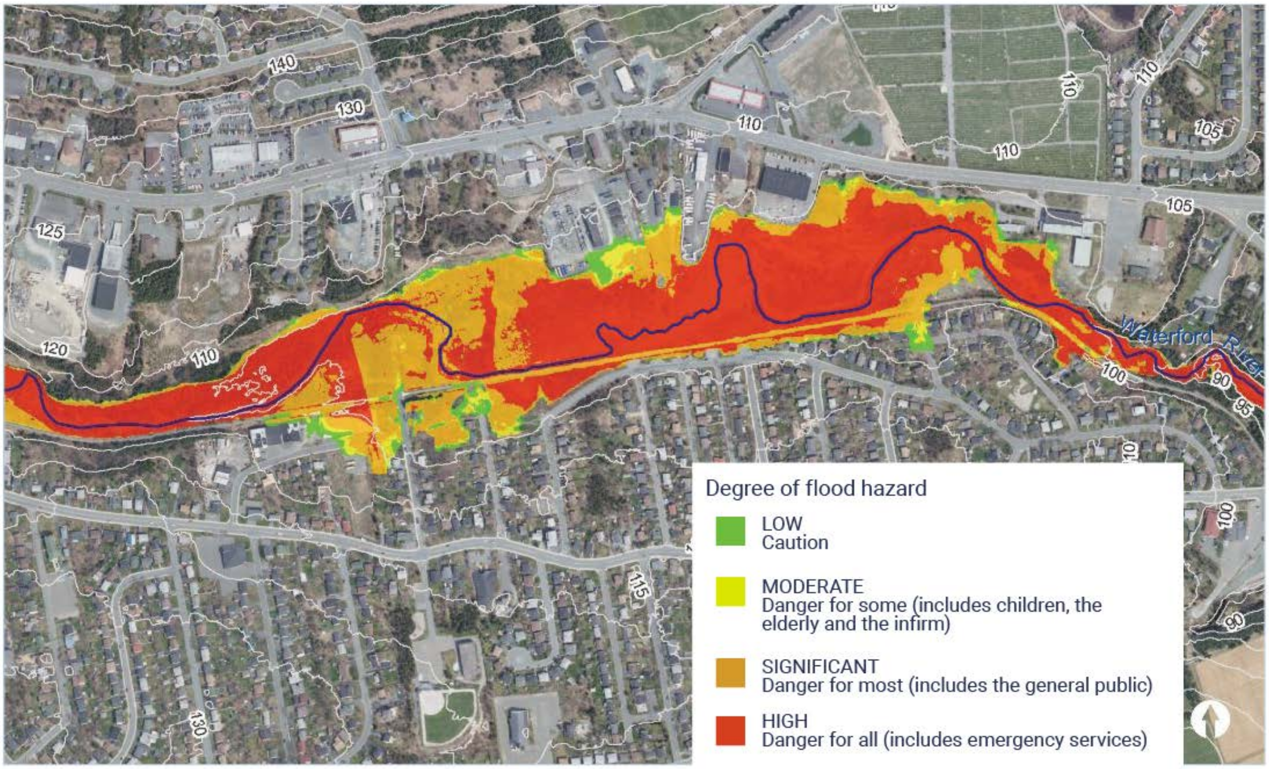


Figure 2.12: An example of a flood hazard map for the municipalities of St. John's Mount Pearl and Paradise in Newfoundland and Labrador. Source: Natural Resources Canada, 2018.

Case Story 2.4: Brampton Lighthouse Project: Supporting vulnerable populations during extreme weather events

The City of Brampton's Lighthouse Project is a collaboration between the City and 20 of its faith-based organizations (FBOs) (Keam and Murray, 2018). This collaboration allows FBOs to provide support to vulnerable populations during extreme weather events and non-climate-related emergencies. FBOs provide pre-screened volunteers, places of refuge, wellness checks on members, emotional counselling and donation management (Cummings, 2017). The City provides resources, including training, identification cards and signage, promotional material, some equipment, support for community grants, and liability and Workplace Safety and Insurance Board insurance coverage during emergencies (Cummings, 2017). Extensive work was required to structure these partnerships.

Faith and the Common Good, a national, non-sectarian charitable network, provided evidence in support of this concept with a preliminary study that explored how FBOs could be better utilized to provide local service centres during extreme weather emergencies (Cummings, 2016). The study found that, in addition to owning a large number of physical assets (e.g., buildings, parking lots), FBOs also have a history of serving vulnerable populations. A mapping exercise identified the locations of FBOs in relation to known vulnerable populations (*see* Figure 2.13). This mapping revealed favourable conditions in Brampton, and thus the project was pursued. A crucial element of the project was the inclusion of Brampton's legal and risk division, which was able to create a capacity-building agreement that enabled and formalized the partnership. A "Champions Kit" was also produced to encourage new FBOs to join the program. Numerous metrics are used to gauge the effectiveness of the program, including the level of participation in FBO training workshops, follow-up interviews with FBOs after the workshops, and expressions of interest from other community groups and municipalities to participate (ICLEI Canada, 2018a).

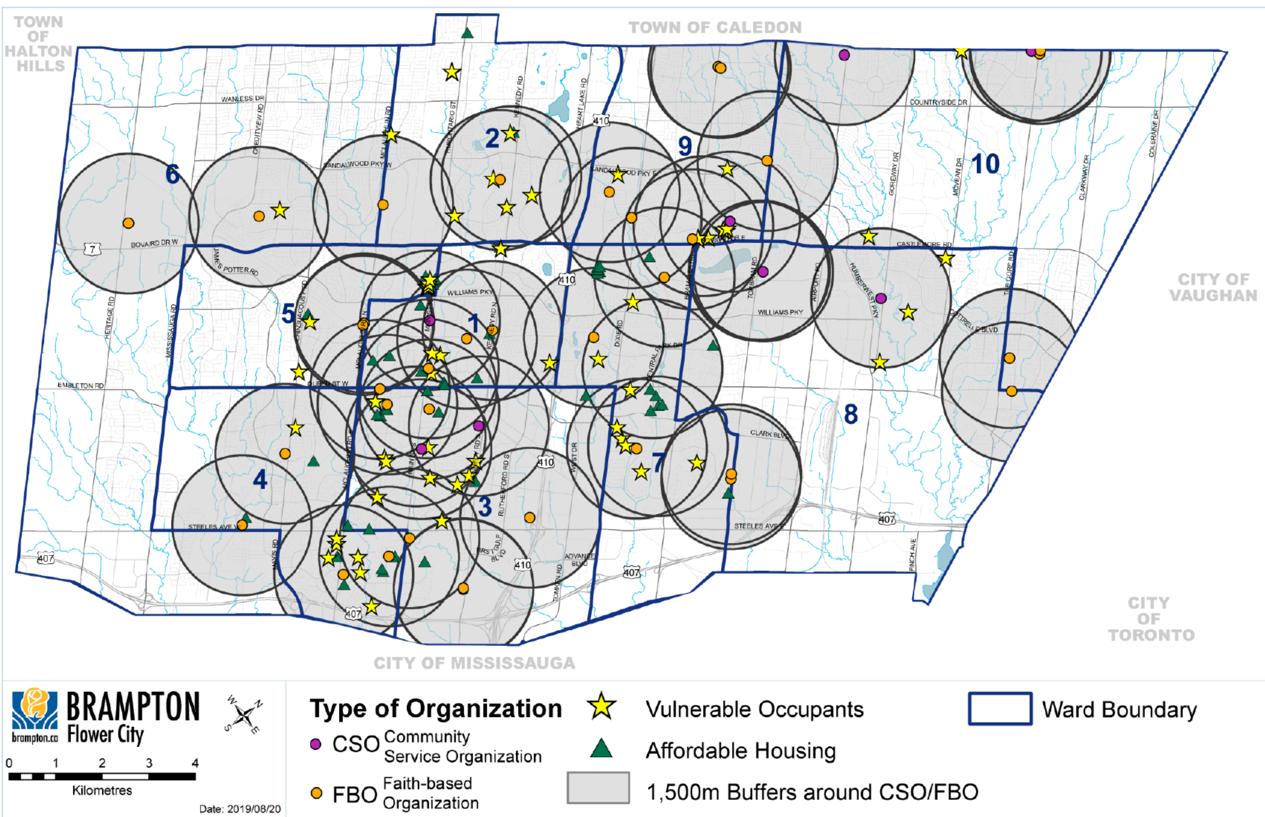


Figure 2.13: A map showing the location of Faith-Based Organizations, affordable housing and vulnerable occupants. Source: Courtesy of the City of Brampton, 2019.

2.6 Indigenous peoples in cities and towns are often affected in unique ways by climate change

Canada's cities and towns are home to large populations of Indigenous peoples, who are often affected in unique ways by a changing climate. Attention is being given to Indigenous issues, and the inclusion of Indigenous perspectives and expertise in municipal adaptation planning processes is occurring, but this is not widespread. Strengthening collaboration with Indigenous peoples will require increased capacity and additional research.

Indigenous people living in Canada's cities and towns will face all of the climate change impacts described throughout this chapter, as well as unique impacts that Indigenous communities have long experienced and understood, (Whyte, 2017). These impacts are related to land and territory, community well-being and culture. Efforts to address the impacts of climate change on Indigenous people and communities in cities and towns should be informed by the broader context of colonialization and should involve Indigenous-led organizations. Creating meaningful collaborations with Indigenous organizations will enhance the inclusiveness of adaptation approaches in cities and towns. Best practices are starting to emerge in Canada, although more research and practice are needed.

2.6.1 Introduction

All cities in Canada are built on the traditional territories of First Nations, Métis or Inuit peoples. As Canadian cities were founded and settled, First Nations peoples were often purposefully relocated from cities to reserves (Peters et al., 2018). Nevertheless, Canada's cities and towns are home to large populations of First Nations, Métis and Inuit peoples.

Many First Nations, Métis and Inuit peoples living in urban areas are either living in their traditional territory, or continue to have strong ties to their home territories (Snyder and Wilson, 2012; Peters and Robillard, 2009; Peters, 2004). Thus, while some First Nations, Métis and Inuit people are disconnected from their communities of origin, many continue to be connected and to engage in traditional land-based activities such as hunting and fishing (Wilt, 2016). When considering how climate change affects urban Indigenous peoples and resilience, it is important to think beyond the city limits, and to understand the broader relationships that mediate both climate change impacts and adaptation strategies (*see* Case Story 2.5).

The population of urban First Nations, Métis and Inuit peoples is growing across Canada (Statistics Canada, 2017b). According to the 2016 Census, Winnipeg, Edmonton, Vancouver, Toronto and Calgary are the cities with the largest population of First Nations people, followed by Calgary, Ottawa-Gatineau, Montréal, Saskatoon and Regina (*see* Figure 2.14; Statistics Canada, 2017c). Trends are similar for Métis and Inuit. One quarter of Métis people in Canada live in cities (Statistics Canada, 2018). Although three-quarters of Inuit live in Inuit Nunangat, four out of ten of the Inuit people living elsewhere reside in large cities. Edmonton, Montréal, Ottawa-Gatineau, Yellowknife and St. John's have the largest populations of Inuit (Statistics Canada, 2018). First Nations, Métis and Inuit urban communities are diverse and often made up of people from many different nations. In many cities, First Nations, Métis and Inuit are dispersed throughout the city, and do not live in concentrated neighbourhoods (Howard and Proulx, 2011; Environics Institute, 2010). Cities are important sites of Indigenous governance. Many cities are home to vibrant organizations representing the interests of First Nations, Métis and Inuit. Friendship Centres, social service organizations, such as child and family service agencies or housing co-operatives, as well as health care agencies, are important sites for Indigenous governance in cities (Tomiak 2010; Peters, 2004). These organizations are important interlocutors for municipal governments. At the same time, the creation of urban reserves in some cities and urban expansion into First Nations communities invite collaboration between First Nations and municipal governments. Many Indigenous communities and governments are developing their own climate change strategies of relevance to neighbouring municipalities.

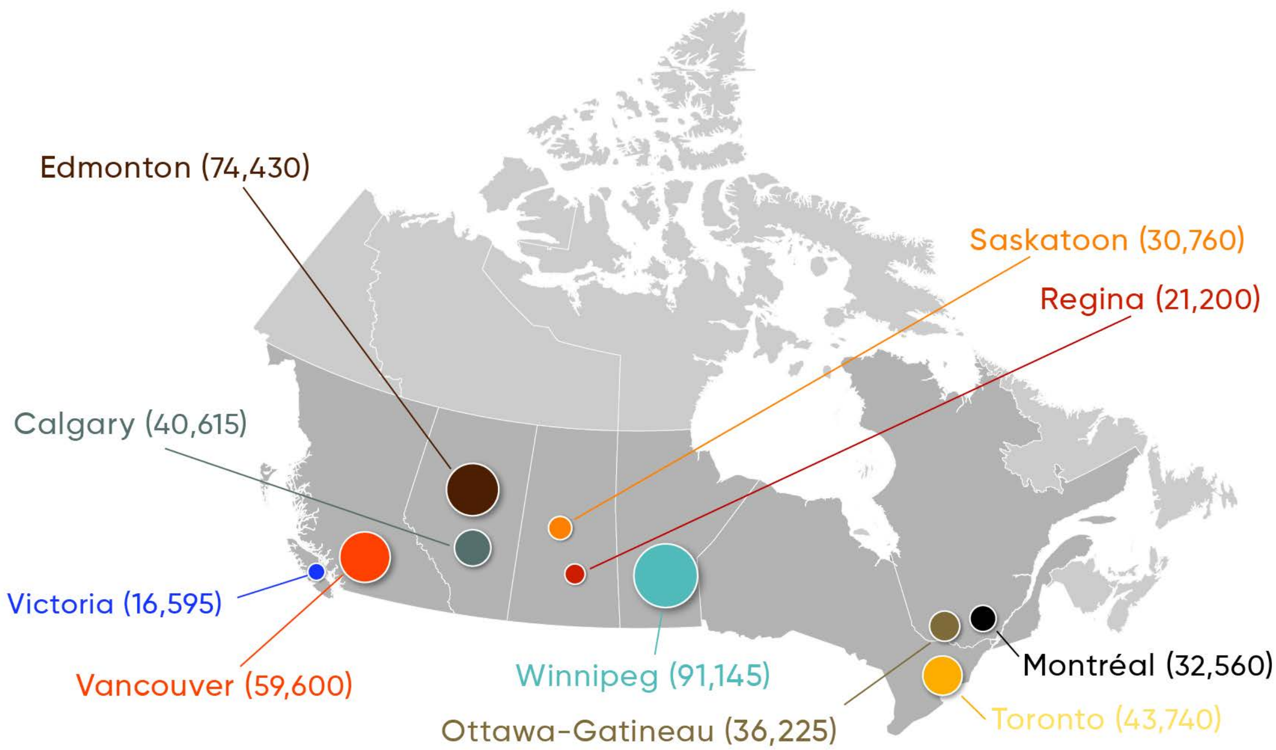


Figure 2.14: Map illustrating the Canadian cities with the largest Indigenous populations. Data source: Indigenous and Northern Affairs Canada, 2016.

2.6.2 Climate change impacts for First Nations, Métis and Inuit peoples

Literature that directly addresses specific impacts of climate change on First Nations Métis and Inuit in cities and towns is relatively scarce. However, there is a large body of literature that examines the effects of climate change on Indigenous peoples in Canada in general, and internationally. This literature demonstrates that, globally, Indigenous peoples have already been significantly affected by climate change, with effects including displacement from traditional territories, and impacts on food security and health, as well as sovereignty and self-government (Whyte, 2016; Ford, 2012, 2009; Turner and Clifton, 2009).

Some climate change adaptation measures can negatively impact Indigenous peoples living within cities, as well as those living a considerable distance away. For example, the operation of aspects of Winnipeg's floodwater infrastructure during the 2011 Manitoba floods caused the flooding of four First Nations communities, resulting in multi-year displacement (Blais et al., 2016) and a class action lawsuit (The Globe and Mail, 2017). The flooding destroyed roads and housing as well as wild rice beds, which are a source of sustenance and economic activity for First Nations. The psycho-social effects of the lengthy displacement were acute (Thompson et al, 2014; Ballard and Thompson, 2013). According to community leadership, at least five of the evacuees died by suicide during the period of extended displacement (CBC News, 2016), reflecting the degree of hardship such displacement causes.

Cities thinking about climate change adaptation must consider how related initiatives could impact Indigenous peoples within and beyond urban boundaries, as well as how Indigenous peoples bring indispensable knowledge, perspectives, and expertise to help identify and develop adaptation solutions. This kind of collaboration requires capacity building on the part of non-Indigenous governments, which must work to understand these important perspectives and to work with Indigenous peoples and governments in order to build upon this knowledge in a respectful and impactful way.

2.6.3 Indigenous Knowledge and climate change

First Nations, Métis and Inuit communities and scholars have stressed the importance of using Indigenous Knowledge Systems in addition to Western science when addressing climate change (EPCCARR, 2018). A growing body of research explores the sources and content of Indigenous Knowledge Systems, as well as the ethical and practical considerations related to the incorporation of Indigenous Knowledge into environmental governance regimes (McGregor, 2014, 2013; Patrick, 2013; Whyte, 2012). Many authors stress that the core of Indigenous environmental knowledge is fundamentally about creating the kinds of relationships that sustain life (Whyte, 2018; Kimmerer, 2011; McGregor, 2005). Thus, rather than taking knowledge about the environment as its object, Indigenous environmental knowledge systems emphasize environmental relations, and the actions that create these relations. As McGregor (2005, p. 104) writes, “It is not just about understanding the relationship with Mother Earth, it is the relationship itself.” Many authors have stressed the significance of Indigenous Knowledge Systems for sustaining Indigenous sovereignty (Whyte, 2017). Indigenous Knowledge Systems invite a holistic approach to climate change that addresses not only environmental outcomes, but also political and social factors. For Indigenous peoples, this means that addressing the restoration of Indigenous political and territorial authority and advancing reconciliation are fundamental steps to mitigating and adapting to climate change.

2.6.4 Adaptation and reconciliation

Indigenous environmental knowledge has often been used to inform environmental planning and resource management in rural and remote areas. However, this knowledge has rarely been applied within urban contexts (Porter, 2013). Yet, it is clear that First Nations, Métis and Inuit peoples must be involved in the design and implementation of climate change adaptation initiatives (Government of Canada, 2016). This position is becoming increasingly recognized in Canada. For example, in its policy on climate change planning, the Canadian Institute of Planners (2018, p. 5) supports that "local Indigenous Knowledge and planning traditions are integrated into planning processes, respecting the rights of Indigenous peoples."

Although little research currently exists discussing how this might be accomplished in urban contexts, some Canadian cities are beginning to explore the possibilities, and are engaging Indigenous peoples in the development of climate change resilience strategies. For example, participants in the creation of a resilience strategy for the City of Toronto found that "building bridges between First Nations, Indigenous, Métis and Inuit peoples, and industry and resilience infrastructure projects is a foundational part of the resilience building process" (City of Toronto, 2018). This process was facilitated by the Indigenous Climate Action Network.

Similar initiatives are occurring elsewhere. For example, Calgary's Indigenous relations efforts are viewed as integral to the city's social resilience (City of Calgary, 2017). Similarly, the City of Surrey, British Columbia, is engaging the Semiahmoo First Nation in the development of its Coastal Flood Adaptation Strategy (City of Surrey, 2018).

Case Story 2.5: Community climate change resilience planning in the Tsleil-Waututh Nation

Tsleil-Waututh are the People of the Inlet and have used, occupied and governed the lands and waters of Burrard Inlet and surrounding watersheds since time immemorial. It is the birthright, obligation and sacred trust of the Tsleil-Waututh to care for and restore this environment to a state of health and balance. The Tsleil-Waututh people have noticed the complex impacts of climate change in their territory for decades. With an inherent understanding of how climate change is affecting the environmental and its cultural values, the Nation has passed down stories, traditions and knowledge-sharing that are the living record of this information. The Tsleil-Waututh Nation has continuously adapted and enhanced community resilience throughout time.

The Tsleil-Waututh are particularly concerned about the acceleration of harm to the environmental, cultural, spiritual and economic values of the Nation. Waterflow regime changes to local creeks, rising sea levels, and increased bank and coastal erosion are affecting the reserve land area, associated economic opportunities and real estate developments, while hotter and drier summers are threatening forest-based habitat, biodiversity, and cultural and recreational use areas. The Tsleil-Waututh worry about the spread of invasive species, soil degradation and landslides in the Indian River Watershed—the heart of the Nation. The health and abundance of salmon, forage foods, wildlife and cultural use areas are at risk.

Acknowledging the immediacy and intensity of climate change, Tsleil-Waututh members are developing a Community Climate Change Resiliency Planning Process (CCCRP). The CCCRP aims to build understanding of the impact of climate change hazards on the Tsleil-Waututh community, to institutionalize climate resiliency planning through Tsleil-Waututh's government, and to develop adaptation strategies for future prioritization and implementation to ensure that current and future generations of Tsleil-Waututh people can continue to thrive in a changing climate.

As a multi-year undertaking, the CCCRP assesses Tsleil-Waututh climate vulnerabilities, develops an action plan with prioritized adaptation strategies, and supports implementing these adaptation strategies while monitoring their effectiveness. At the beginning of this work, the Tsleil-Waututh undertook an extensive hazard mapping and exposure sensitivity analysis, assessing the associated vulnerabilities on the lands, people, and culture of the Tsleil-Waututh Nation on and near the lands of Tsleil-Waututh Reserve IR#3.

The Tsleil-Waututh's unique eco-cultural and archeological approach to hazard mapping has revealed previously unknown climate information. Subsurface testing identified intact charcoal-rich sands and fire-altered rock dating back more than 3,000 years that, while originally situated on land, are now located well into the marine intertidal area. Cross-referencing the archaeological findings with oral history accounts from Elders of the Tsleil-Waututh Nation, the archaeology team identified areas where foreshore lands have receded (up to 12 m in some places) as a result of shoreline erosion. With archaeological clam shell samples, the Nation is considering exploring the use of isotopic oxygen analysis in combination with carbon dating, in order to shed light on historical oceanic conditions and temperatures, and potential impacts to the Tsleil-Waututh way of life.

The CCCRP is a culturally and locally relevant strategy in building resilience to current and potential future impacts of climate change. The CCCRP is a manifestation of Tsleil-Waututh stewardship and sacred obligation to care for the lands, waters and air, in acknowledgement of our changing climate.

2.7 Cities and towns are moving from adaptation planning to implementation

Implementation of adaptation initiatives by cities and towns is not keeping pace with the risks posed by current weather extremes and future climate changes. However, examples of implementation are becoming more common, and the barriers to action are being reduced. Promising practices like mainstreaming and innovative funding arrangements offer opportunities to scale up and accelerate implementation.

Although adaptation planning has been progressing quickly in cities and towns, adaptation implementation has been slower to advance due to a variety of barriers. These barriers are generally well understood, and relate to financing, decision-support tools, competing priorities, governance and professional silos. A number of emerging strategies to address these barriers are likely to accelerate the transition from planning to implementation. These include the creation of adaptation plans that explicitly focus on implementation, mainstreaming of adaptation into existing operations, practices and planning within local governments (e.g., incorporating climate risks into asset management), and the inclusion of First Nations, Métis and Inuit peoples in the design and implementation of climate change adaptation initiatives.

2.7.1 Introduction

Awareness of the need to adapt to climate change is no longer a significant barrier; tools for assessing vulnerability and risk are increasingly available, and adaptation plans and strategies are now common (*see* Box 2.6; Federation of Canadian Municipalities, 2019; McMillan et al., 2019; Moghal et al., 2017). There is also evidence of implemented actions (*see* Case Story 2.6) and novel policies. For example, the Canadian Institute of Planners' policy on climate change planning "envisions a future in which Canadian communities are planned, designed, developed, and managed to contribute to climate stability and to be more resilient in the face of unavoidable changes in the climate, and in the process, to become more liveable, prosperous, and equitable" (Canadian Institute of Planners, 2018, p. 3). However, adaptation implementation in cities and towns has not kept pace with increasing climate risks in Canada (ICLEI Canada, 2016), nor has it in other counties (e.g., Woodruff and Stults, 2016). There is a tendency to overestimate the capacity of adaptation planning to deliver the intended outcomes of adaptation (Mimura et al., 2014), and so, the increasing prevalence of adaptation planning in Canada's cities and towns is not an appropriate indication of implementation. Implementation remains the primary challenge for cities and towns seeking to adapt to climate change.

2.7.2 Barriers to adaptation

A number of barriers make it difficult to implement adaptation. The barriers presented in Table 2.3 are drawn from Canadian and international literature, and vary in their extent across Canada. If they are understood and considered early on, many of the barriers discussed below can be overcome (ICLEI Canada, 2016). Where appropriate, these efforts should consider multiple barriers simultaneously (Hamin et al., 2014).

Table 2.3: Common barriers to adaptation

CHALLENGE/BARRIER	DESCRIPTION
Financing	• Conflicting incentives when municipal revenue is contingent on development (e.g., property tax, development cost charges) • Funding largely limited to large-scale infrastructure projects, which favour larger cities • Limited innovative financial models (e.g. green/resilience bonds, cost-sharing schemes, public-private partnerships) • Public opposition to innovative approaches to financing adaptation
Uncertainty	• Inherent uncertainty associated with using future conditions to make decisions • Lack of perceived immediacy of climate change consequences • Strategic and institutional uncertainty
Data and tools	• Limited economic studies on costs of damages of climate change impacts • Limited economic studies or cost-benefit analyses for adaptation • Lack of higzhly context-specific data • Too many tools and frameworks resulting in information overload • Few tools to specifically support the implementation of adaptation initiatives • Limited guidance and tools that support community engagement on adaptation
Governance	• Federal departments are politically limited in direct transfer payments to local governments, requiring coordination and relationships with provincial governments and/or third parties (e.g., FCM) • Disconnect between needs of local action and provincial policy/legislation • Limited enabling conditions, such as mandates, policy, regulations, standards and guidelines

CHALLENGE/BARRIER	DESCRIPTION
Governance (continued)	• Limited political will, motivation, willingness to act and belief that action will be effective Limited jurisdictional power over private property • Limited coordination with private sector and property owners, as well as vulnerable groups • Limited public support and insufficient level of services for the current demand • Lack of non-environmental considerations in adaptation
Human resources	• Limited internal capacity, combined with limited national mandates and definitions of adaptation • Limited collaboration across professional associations • Compartmentalization and institutional fragmentation

Sources: BC Auditor General, 2018; Dohertyet al., 2016; ICLEI Canada, 2016; Nordgren et al., 2016; Adaptation to Climate Change Team, 2015; Biesbroek et al., 2015; Eisenack et al., 2015; Environmental Commissioner of Ontario, 2015; Ford and King, 2015; Archer et al., 2014; Moser, 2014; Pahl et al., 2014; Toman, 2014; Hallegatte and Corfee-Morlot, 2011; Mees and Driessen, 2011; Burch, 2010.

2.7.3 Advancing adaptation implementation

There are many tools and resources that support adaptation planning (e.g., planning guides—*see* Figure 2.15, FCM's staff support grants, Canadian Centre for Climate Services Support Desk). These include tools and resources that support implementation, including guidance on designing implementation schedules and mechanisms, and best practice case studies (ICLEI Canada, 2016). It is important that adaptation-planning processes consider implementation (e.g., City of Barrie, 2018; Zukiwsky et al., 2016). Implementation-ready plans address issues such as feasibility, resources, accountability, partnerships, authority and interaction with other initiatives (Ontario Centre for Climate Impacts and Adaptation Resources, 2015) and emphasize "no-regrets" options that address one or more climate hazards, in addition to non-climate issues that are priorities for the local government (Chen et al., 2016). Focusing explicitly on implementation can help to ensure that plans reach their aspirational outcomes (e.g., reducing risk to people and property), especially if the initiative is an area of high public concern, and there are clear cost implications (Picketts, 2015).

Figure 2.15: The traditional adaptation planning process (steps 1–6), with enabling actions added. Source: Adapted from City of Vancouver, 2018.

Rather than developing new or stand-alone plans and strategies, many cities and towns are incorporating climate change considerations into a wide array of municipal operations, policies, plans and services, including infrastructure decisions, asset management, official community plans and land-use plans, capital plans, master plans and emergency management frameworks (City of Vancouver, 2018). Mainstreaming of climate change adaptation into existing frameworks and operations is an efficient strategy to overcome implementation barriers, such as insufficient human and financial resources, lack of momentum and competing priorities (ICLEI Canada, 2016). This strategy is more effective when accompanied by efforts to build and maintain internal capacity (Picketts, 2015), and to create forums for collaboration across jurisdictional boundaries (Adaptation to Climate Change Team, 2017).

Climate change adaptation requires coordination among broad partner networks (Rosenzweig and Solecki, 2018). Collaborative forums provide municipal representatives who have implemented climate adaptation initiatives with the opportunity to share their experience (i.e., peer-to-peer learning). For example, municipalities in Quebec are looking for implementation examples from similar cities and towns (Bleau et al., 2018). An example of a program that seeks to facilitate this type of collaboration is the University of British Columbia's Resilient-C project that enables communities to share knowledge and resources to support coastal hazard risk reduction (Resilient-C Research Team, 2020). Similarly, FCM's Climate Adaptation Partnership Grants have resulted in projects that leverage non-profit expertise to enable groups of cities and towns to collaborate; such an approach also supports the scaling up of action.

Box 2.6: Benchmarking adaptation activity in Canadian cities

Between 2004 and 2014, most of the adaptation activity in Canada was occurring at the municipal level, with the majority of this work involving planning and capacity building, but few examples of implemented initiatives (Eyzaguirre and Warren, 2014). A number of surveys provide insight into the state of play of adaptation in Canada's cities and towns. The 2018 Local Adaptation in Canada survey, carried out by the Federation of Canadian Municipalities (FCM), the University of British Columbia and the University of Waterloo, found that more than half of the 180 local governments respondents had initiated formal adaptation planning discussions in their community within the last four years (McMillan et al., 2019). These discussions are being advanced by a range of municipal departments, but are still sometimes ad hoc and reactive (*see* Figure 2.16), and often do not result in implementation due to a lack of human and financial resources (McMillan et al., 2019). This survey builds on a similar survey delivered in 2012 as part of the National Municipal Adaptation Project (National Municipal Adaptation Project, 2014), though direct comparisons between the two surveys are not possible due to differences in survey questions and methodology (McMillan et al., 2019).

A Climate Adaptation Maturity Scale was developed by FCM to facilitate the self-assessment of a municipality's institutional readiness and progress in adapting to climate change. The scale helps municipalities and FCM to rapidly self-assess their current state, as well as to identify areas of potential improvement across three competency areas, as they relate to climate change adaptation: 1) policy; 2) human resources and governance; and 3) technical and risk management capacity (Federation of Canadian Municipalities, 2017). It uses the following population categories: small (< 10,000), medium (10,000–100,000) and large (> 100,000). Based on the results from 110 ongoing adaptation projects, it was found that larger cities have higher baseline capacity in the policy and human resources and governance dimensions (Federation of Canadian Municipalities, 2019). Municipalities will be invited to do a second self-assessment following the completion of their project. The results from 16 completed projects (*see* Figure 2.16) show that, even though projects undertaken by large municipalities end with a higher competency level in all three areas, small and medium-sized municipalities also show a significant progression on aspects of adaptation during their project.

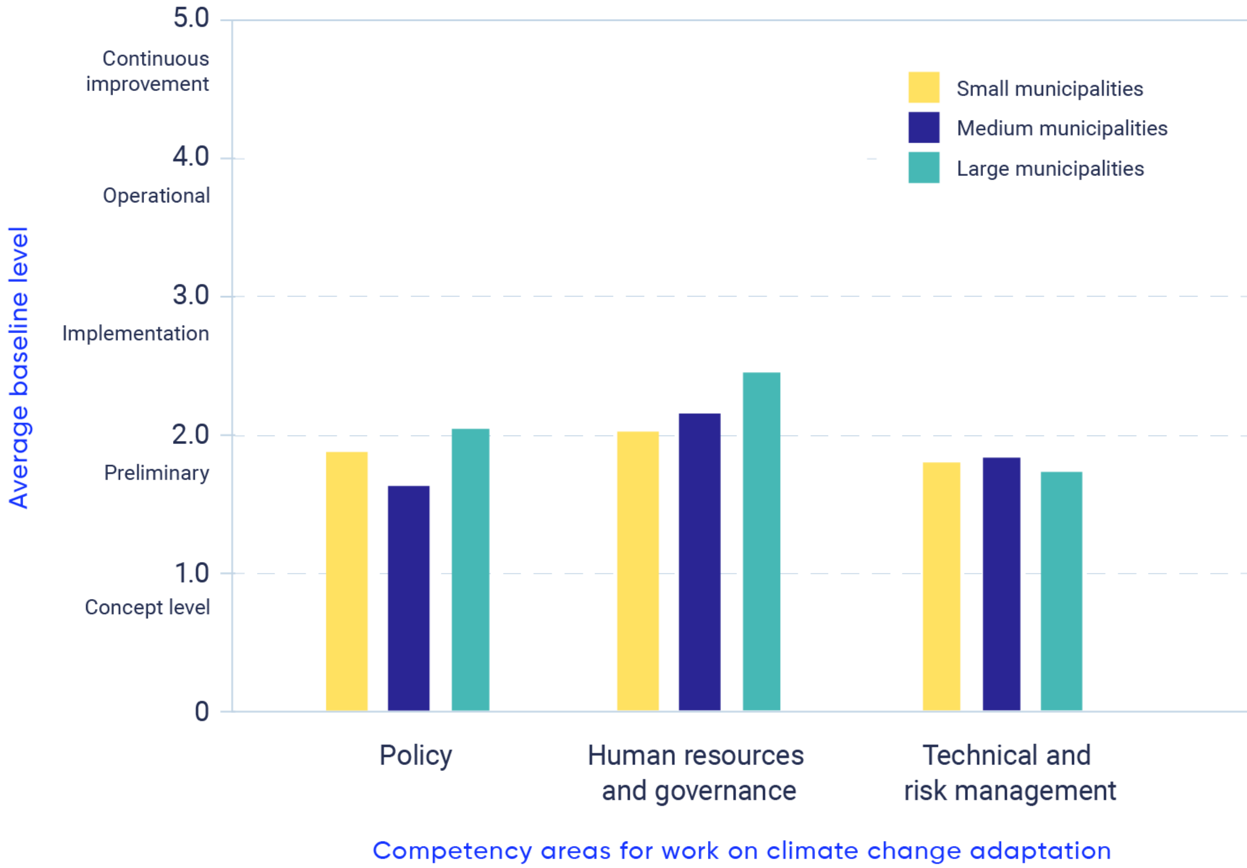


Figure 2.16: Graphical representation of baseline self-assessments made using FCM's Climate Adaptation Maturity Scale provided by municipalities that received FCM-support towards local adaptation projects. The five-point scale ranges from 1.0 (concept level) to 5.0 (continuous improvement level), and includes three competency areas: 1) policy, 2) human resources and governance, and 3) technical and risk management. This graph shows the average self-assessment values provided by small municipalities (e.g. less than 10,000), medium-size municipalities (e.g. 10,000-100,000) and large municipalities (e.g. more than 100,000) at the start of their adaptation projects. Data source: Federation of Canadian Municipalities, 2019.

A 2019 landscape assessment and needs analysis conducted by FCM and Environment and Climate Change Canada scanned highest-order planning documents (e.g., official community plan) for 732 local governments for evidence of a commitment to climate change adaptation. This scan revealed that 19% of the municipalities demonstrated a commitment to climate change adaptation, 58% showed no commitment, and 23% had no high-order planning document available online (Federation of Canadian Municipalities and Environment and Climate Change Canada, 2019). Of those that had made commitments, 28% were in Ontario, 25% in British Columbia, and 10% from each of Alberta and Quebec. A secondary scan of 120 local governments revealed that a commitment to climate change by larger municipalities (>50,000) tended to be in a stand-alone adaptation or in resilience plans, whereas for smaller municipalities, if references to climate change were present, they were in broader sustainability or community development plans. This finding is supported by additional research in the Canadian context (Moghal et al., 2017).

The above findings focus largely on capacity building and planning, and do not represent a significant departure from those reported in the 2014 assessment (Eyzaguirre and Warren, 2014). Although there is evidence of more widespread implementation, the above surveys do not provide sufficient insight into the extent and nature of implemented adaptation initiatives in Canada. Despite this shortcoming, the surveys discussed above represent a relatively rich, albeit fragmented, source of baseline data for future research and assessments, and provide a useful point of comparison. It should be noted that there are also international surveys (e.g., Aylett, 2015; Carmin et al., 2012) and surveys conducted by industry associations (e.g., Canadian Institute of Planners, 2019) that contain some element of the climate change adaptation state of play in Canadian cities and towns, although these are less relevant for this chapter.

Case Story 2.6: Adaptation measures and co-benefits through the upgrading of Rue Saint-Maurice in Trois-Rivières, QC

Trois-Rivières, Quebec, is a riverside city with a population of 134,410. The City has had a climate change adaptation plan since 2013 (SNC-Lavalin Environnement, 2013) and has participated in two PIEVC (Public Infrastructure Engineering Vulnerability Committee) assessments (Osseyrane and Kamal, 2013; Rivard et al., 2013). A significant adaptation intervention that resulted from the plan is “Le Grand Projet de la Rue Saint-Maurice,” which involved significant upgrades to a 1.3-km stretch of residential road (Ville de Trois-Rivières, 2018). The project used a combination of built and natural infrastructure, and aimed to reduce the urban heat island effect, increase the presence of plants, beautify the landscape, improve neighbourhood safety for pedestrians and motorists, and to help replenish the water table with drinking water through sound stormwater management (*see* Figure 2.17; Ville de Trois-Rivières, 2018). Parking spaces along the street have been replaced by more than 135 trees, 1,000 shrubs and 18,000 plants. The project also had a significant built infrastructure component, including the installation of 5.05 km of pipes and 103 sumps to manage the stormwater not absorbed by the green infrastructure.

Figure 2.17: An overview of the adaptation and GHG emissions reduction measures implemented through the upgrading of Rue Saint-Maurice in Trois-Rivières, QC. Photo courtesy of Ville de Trois-Rivières.

Monitoring and evaluation data for this project is not yet available, but will be once the project has been completed. It is expected that a research team will collect pre- and post-intervention data relating to peak flow, water volume, infiltration and water quality parameters (Ouranos, 2017). The project was funded primarily by the Fund for Drinking Water and Wastewater Treatment, and there are plans to conduct similar projects elsewhere in Quebec once the pilot has been evaluated.

2.8 Monitoring and evaluation of adaptation is an important and often overlooked step

Monitoring and evaluation methods are required to track adaptation progress, and measure whether adaptation efforts are resulting in their desired outcomes. While promising approaches exist, monitoring and evaluation of adaptation projects and outcomes are still rare, and there is value in helping cities and towns to develop approaches that are effective and comprehensive.

Although there has been considerable conceptual work on monitoring and evaluation (M&E) of adaptation, it remains difficult for cities and towns to apply this step. This is partly due to the fact that the adaptation field in Canada is just beginning to enter the implementation phase in a significant way. It is likely that this transition will spur the advancement of M&E approaches that cities and towns can use to overcome inherent difficulties, including shifting baselines, and attribution and resource requirements. M&E approaches work best when they reflect who is benefitting from adaptation, and when they embed accountability into the outcomes of investments in adaptation, take multiple co-benefits into account, and enable course corrections. Operationalizing adaptation monitoring and evaluation for specific contexts will be an important area of practice in the near term.

2.8.1 Introduction

As cities and towns across Canada begin to move from adaptation planning to implementation, there is an urgent need for monitoring and evaluation (M&E) approaches that can be used to identify baseline conditions, guide action, track progress and evaluate the extent to which adaptive capacity and/or resilience are being achieved. The adaptation M&E imperative operates across all scales. Calls for M&E can be seen in the Paris Agreement (Ford et al., 2015), Sendai Framework for Disaster Risk Reduction, Pan-Canadian Framework on Clean Growth and Climate Change, provincial adaptation plans (BC Auditor General, 2018), and at the local level. There is a strong literature base offering guidance on adaptation M&E (e.g., Brown et al., 2018; Leagnavar et al., 2015; Bours et al., 2014; Dinshaw et al., 2014; Pringle, 2011; Jacob et al., 2010), in addition to strong proxy literatures (e.g., disaster resilience, program evaluation, risk management). However, translating usable indicators and approaches from this literature is likely to be difficult for cities, especially those with limited capacity.

2.8.2 Progress and approaches

There are several practical examples of adaptation M&E in Canada. One of the most salient is ICLEI Canada's Building Adaptive and Resilient Communities (BARC) program, which is a participatory planning framework for climate adaptation that requires consideration of M&E. This requirement has led to a number of Canadian adaptation plans that incorporate proposed indicators, but no formal monitoring and evaluation strategies to date (e.g., City of Vancouver, 2012, p. 54). A more regional example of adaptation indicators in the Canadian context can be seen in the Columbia Basin Trust's "State of The Basin" indicators (Columbia Basin Trust, 2015). The City of Surrey, BC, uses a series of sustainability and adaptation indicators to display progress and to encourage action (*see* Case Story 2.7).

In 2018, Environment and Climate Change Canada convened an Expert Panel on Climate Change Adaptation and Resilience Results (EPCCARR) that developed a series of indicators—structured around the five key focus areas in the adaptation pillar of the Pan-Canadian Framework—that could be used to measure progress on adaptation (EPCCARR, 2018). These include process and outcome indicators, many of which refer to measurable developments at the local government or community level (e.g., number of days of disruption to basic services and critical infrastructure). Potential challenges for mobilization of EPCCARR indicators at the city-level M&E include the lack of relevant data, and the fact that data are not organized in ways that might be useful for M&E processes (EPCCARR, 2018). Training and technical assistance on data collection and organization would facilitate consistent M&E application.

There are several international resilience planning frameworks that include M&E guidance for cities. The largest of these is UNISDR's Resilient Cities and the City Resilience Framework, with the accompanying City Resilience Index, associated with the Rockefeller Foundation's 100 Resilient Cities program. The City Resilience Index measures relative performance over time, rather than creating comparisons between cities, and provides indicators and metrics that can be used as a common basis for monitoring and evaluation, to create benchmark comparisons with other cities, and that are meant to identify areas of weakness and to suggest actions that can improve resilience (ARUP and Partners, 2016). Similarly, the Climate Risk and Adaptation Framework and Taxonomy (CRAFT) is a decision-support tool that relies in part on process indicators to demonstrate progress internally and in relation to other cities (C40 Cities, 2016). However, neither of these approaches was developed with the active participation of Canadian cities, and they have limited applicability in the Canadian context, as their primary focus is on the largest cities.

There are also M&E frameworks that do not include the use of indicators. For example, outcome harvesting uses program documents and interviews to quantify progress on projects (Eyzaguirre, 2015; Wilson-Grau, 2015). This approach can help overcome some of the challenges related to data availability and organization described above. However, other challenges still remain. Many adaptation initiatives are not initially labelled as such (i.e., unintentional adaptation), and are therefore not included in M&E reporting, even though they contribute to reducing vulnerability (Hughes, 2015). For example, the installation of larger culverts may have been motivated by analysis of historical trends, rather than influenced by a changing climate.

Adaptation also occurs over long timelines, whereas project outcomes need to be evaluated over the course of decades, and often only after an extreme event has occurred (Moser and Boykoff, 2013). There are also challenges associated with attribution. Cities and towns are complex systems, and it can be difficult to disentangle causal pathways such that an outcome (e.g., reduced flood damage) can be attributed to an adaptation intervention (e.g., investment in green infrastructure). Similarly, successful adaptation often means measuring avoided impacts (e.g., fewer hospital visits during a heat wave) (Bours et al., 2014). Finally, articulating the co-benefits associated with adaptation initiatives is another significant challenge faced by those developing climate adaptation M&E plans.

The selection of an M&E approach should take into account its appropriateness for the context, and its capacity for precision and accuracy, explanatory power and utility (Constas, 2015). Monitoring and evaluation plans are most effective when they are created early in the planning process, and used to communicate results and harmonize action and reporting across municipal departments and with external stakeholders (ICLEI Canada, 2016). It is also important that M&E be designed and accomplished in a participatory way (Sharifi, 2016; Villanueva, 2011). As Moser and Boykoff (2013, p. 3) write, "Success is not simply to be decided on scientific, rational, objective, or procedural grounds, but is in important ways normative, historically contingent, and context-specific." For example, including various perspectives—Indigenous, gender, business, marginalized populations—in the design of M&E frameworks can ensure that resilience objectives are mutually agreed upon and equitable (Doorn, 2017; EPCCARR, 2018). This will require creative development of engagement approaches, as well as expanded educational tools and resources.

Case Story 2.7: Tracking progress on adaptation through the City of Surrey's Sustainability Dashboard

The City of Surrey is a coastal city in British Columbia with a population of 517,885. For over eight years, the City has been using a Sustainability Dashboard to communicate progress on items relating to its Sustainability Charter, which addresses the following themes: inclusion, built environment and neighbourhoods, public safety, economic prosperity and livelihoods, ecosystems, education and culture, health and wellness, and infrastructure. The dashboard is updated annually—except where reliant on census data—and, although it is explicitly focused on sustainability, there are several indicators that report on data relevant to climate change adaptation (e.g., shade trees planted on public property, extent of green infrastructure network). Some of the indicators also display links that encourage individuals to take action. For example, the indicator page for the number of trees planted on public property contains a link explaining how residents can add to Surrey's urban forest.

Surrey is involved in the development of World Council for City Data's ISO 37123 for Resilient Cities, and plans to explore how these indicators could be integrated into the dashboard in the future. In 2016, the City of Surrey was certified as a World Council for City Data's ISO 37120 Platinum Certified City. However, the decision about which adaptation and/or resilience indicators to report on has not been straightforward. Surrey's 2013 Climate Adaptation Plan contains 36 proposed indicators relating to the action items from the plan (City of Surrey, 2013). An internal study has concluded that some of these indicators are no longer appropriate, while others are weakened by lack of data availability and accountability, as well as other factors. However, most importantly, the City is currently transitioning towards a data-driven decision-making (D3M) approach that seeks to harmonize data collection and reporting across all city departments and initiatives. The outcomes of this process will help the City to determine which adaptation-related data to collect, and will also drive the creation of a new public-facing dashboard that uses a contemporary interface and data management system (e.g., Power BI), instead of the bespoke dashboard created for the city in 2011.

2.9 Moving forward

2.9.1 Knowledge gaps and research needs

As the climate change adaptation field matures in Canada, there is a need for conceptual and practical guidance in a number of areas. First, decision-makers across Canada would benefit from more explicit guidance on how to mainstream adaptation into existing workflows (e.g., master planning processes) and business practices (e.g., procurement, financing and project management). This would help cities and towns to embed adaptation across the organization, which would likely strengthen implementation.

There is a strong demand for research findings and methodological guidance relating to the quantification of economic, as well as social and environmental costs of climate impacts. These analyses can support compelling projected returns on investment for adaptation projects. There is also a demand for cost benefit analyses that can be applied to adaptation initiatives (Bleau et al., 2018). The Costs and Benefits of Climate Change Impacts and Adaptation chapter in this assessment represents a significant step forward in addressing this need.

The adaptation field itself could be the subject of future research. An assessment of the climate change adaptation field in the United States was guided by the following question: "What would a strong, mature adaptation field look like, and what would it take to build it?" (Moser et al., 2017, p. 8). Such a study in Canada could help to more clearly articulate the role that cities and towns play in adapting to climate change, and how they could be supported by others as the field matures and as adaptation initiatives become more common. Similarly, although frameworks that evaluate plan quality are common (Guyadeen et al., 2019; Dokoska et al., 2018), research that examines the quality of adaptation plans is only beginning to emerge (e.g., Woodruff and Stults, 2016).

2.9.2 Emerging issues

It is expected that several issues of relevance to cities and towns will emerge in the adaptation field in the coming years. One such issue relates to determining the appropriate relationship between climate change adaptation and resilience. Although inconsistently defined (Meerow et al., 2016; Meerow and Stults, 2016), the concept of resilience applied in the urban context often connotes a broad scope that includes non-climatic stressors like lack of affordable housing, economic downturns, or decreasing populations, such as those observed in Quebec and eastern Canada (Statistics Canada, 2017d). Although the concept of resilience can encourage local governments to govern collaboratively across disciplines, thereby taking more of a systems approach, and to consider the desirable qualities of resilient systems (e.g., flexibility, redundancy), this concept can be challenging to apply in practice, as it adds complexity to the already complex endeavour of adapting to climate change. Navigating this discursive and practical terrain is an emerging issue in the field of climate change adaptation in Canada, where an increasing number of cities are issuing requests for proposals for climate resilience strategies.

This chapter has highlighted some of the emerging issues related to Indigenous peoples and climate change adaptation in cities and towns. The inclusion of Indigenous people in planning and implementation processes within and adjacent to cities and towns is an emerging area of practice. Similarly, First Nations, Métis and Inuit communities and scholars have stressed the importance of considering Indigenous Knowledge Systems in addition to Western science when addressing climate change (EPCCARR, 2018). The inclusion of the processes and products of Indigenous Knowledge Systems into adaptation planning and implementation is likely to be an emerging priority in the Canadian adaptation field.

The appropriate and effective inclusion of social equity into climate change adaptation planning and implementation processes is another emerging issue facing decision-makers in cities and towns. Considering equity issues is thought to increase adaptive capacity and well-being in cities (Rosenzweig and Solecki, 2018), and can increase the likelihood of adaptation implementation (Gonzalez et al., 2017), although this has not been explored empirically in Canada. It is increasingly acknowledged that an equity lens should be applied during adaptation planning and implementation, but conceptual and practical guidance on applying this lens is generally lacking, especially in small and medium-sized cities and towns.

The declaration of climate emergencies has also emerged as a practice by many cities and towns across Canada. (Climate Emergency Declaration, 2020). The objective of the climate emergency declaration is to highlight that unless governments acknowledge and publicly declare climate change as the utmost global emergency, sufficient and profound action will not take place. Since climate emergency declarations are intended to encourage action on mitigation and adaptation, they are likely to be an important component of the adaptation landscape in Canada in the coming years.

Another emerging issue faced by adaptation practitioners in Canada is the need to connect adaptation with greenhouse gas mitigation efforts. This approach is increasingly referred to as low carbon resilience (LCR) (Nichol and Harford, 2016). LCR has strong relevance at the local government level, with particular emphasis in the areas of asset management and corporate strategic planning (Adaptation to Climate Change Team, 2019). Discussion of this approach is emerging in the literature (IPCC, 2018), and practical application is being researched in the local government context, where it is being shown to have multiple co-benefits in terms of health, equity, biodiversity and other key areas (Shaw et al., 2019) and is also occurring in the building sector. For example, the US Green Building Council's RELi standard provides guidance on LCR approaches, and there is a strong push to design or retrofit buildings for low carbon resilience (BOMA Canada, 2019; Bristow and Bristow, 2017).

There are also emerging issues that relate to continued technological development in cities and towns. The National Research Council of Canada identifies capabilities in smart infrastructure and cities of the future as a key opportunity for Canada (National Research Council of Canada, 2019). It is essential that efforts to create smart cities take into account the need to adapt to climate change. For example, self-driving cars could unlock tremendous potential for green infrastructure, including through the conversion of existing road infrastructure to more permeable surfaces that support stormwater management. There are similar opportunities relating to the role of big data (Ford et al., 2016) and artificial intelligence.

2.10 Conclusion

Canada's cities and towns will continue to be affected by climate change. Although the extent of these impacts remains unclear, early action is required to minimize the extent of negative impacts and to leverage the opportunities associated with positive impacts. As shown in Box 2.6, Canada's cities and towns continue to make progress on adaptation to climate change, and the field is entering the era of implementation. While much of this implementation is reactionary, strategic and proactive implementation is beginning to emerge. With a concerted, supported and well-informed effort, implementation is likely to increase the adaptive capacity and resilience of cities and towns in the future.

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