UNIVERSITY OF WATERLOO

INTACT CENTRE ON CLIMATE ADAPTATION

IRREVERSIBLE EXTREME HEAT: PROTECTING CANADIANS AND COMMUNITIES FROM A LETHAL FUTURE

Supported by:

[intact]

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Executive Summary

Urban areas are the hot spots of global warming. Extreme heat, alongside flooding and wildfire, is a key risk to the health and well-being of Canadians. The situation is growing more dangerous, driven by irreversible climate change—Canada is warming, on average, at twice the global rate.[1] **Urgent action is required NOW to manage risk and avoid worsening impacts – and ultimately FATALITIES – resulting from rising heat.**

Extremely hot temperatures and heat waves can be deadly and have a severe impact on health, infrastructure and services, the natural world, and ultimately, the economy. **Not all Canadians will be affected in the same way, and those most vulnerable will require additional support.**

Urban centres face the greatest risk because of the urban-heat-island effect. Surface daytime temperatures can be 10 – 15°C hotter in urban heat islands, while nighttime temperatures can be up to 12°C hotter than in surrounding rural areas. Large geographical areas of Canada that are also particularly at risk include: low-lying areas from the West Coast to the Rocky Mountains (British Columbia), the Prairies bordering the United States (southern Alberta, Saskatchewan, and Manitoba) and north of Lake Erie through the St. Lawrence River Valley (southern Ontario and Quebec).

During episodes of extreme heat, everyone is at risk from heat illnesses. But the danger is greatest for those who are already more vulnerable or less able to protect themselves. This includes people who are more exposed to extreme heat (including people experiencing homelessness or those living or working outside), those who are more sensitive to extreme heat (such as the elderly or chronically ill) and those with fewer resources to adapt (for instance, people on lower incomes who cannot afford actions to retrofit their homes). Extreme heat frequently adds to existing inequality; marginalized or racialized communities often live with combined risk factors, making them even more vulnerable.

The good news is that heat-related illness and death are largely preventable with knowledge, education, and adaptive action. However, resilience to extreme heat cannot be achieved by relying on air conditioning alone.[2]

This guide presents a compendium of practical actions that Canadians can undertake to reduce risks in relation to extreme heat (Table 1) that fall into three categories:

- changing behaviour (non-structural)
- working with nature (green infrastructure)
- improving buildings and public infrastructure (grey infrastructure)

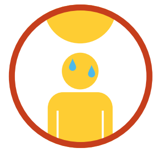
Individuals, property owners and managers, and communities all have a role to play, by acting on their own and encouraging others to act; this will build resilience to extreme heat at the local and community scale.

Ideally, actions to reduce risks from extreme heat should be designed to deliver additional benefits. Solutions that work with nature can improve biodiversity, help to reduce flooding, and help to increase carbon storage—while also keeping people cooler. In other settings, energy efficiency and resilience to extreme heat can be improved at the same time, reducing energy consumption and greenhouse-gas emissions. Public or private organizations considering strategic investments or incentives to increase Canadians' resilience to extreme heat should consider these "win-win" opportunities to maximize return on investment, in terms of the social, environmental and financial benefits for the country and the economy.

Facing the heat is a growing challenge in Canada. The practical actions described in this guide will enable numerous Canadians to adapt to rising temperatures while helping to reduce greenhouse gases and build more resilient, sustainable communities. However, several actions can only be implemented by those who own property. Tenants and others with fewer resources to adapt to heat will have more limited options and are often most at-risk; these vulnerable groups require targeted support.

Canadian alarm bells should be ringing loud and clear in relation to extreme heat. While flood and fire may be Canada's most costly natural disasters, extreme heat is the "silent killer". If an extreme heat event coincided with an extended power outage – with no electricity supply to air conditioners and fans – lack of preparedness could result in widespread fatalities. Everyone has a responsibility to reduce their own risks from extreme heat, and an opportunity to help protect others more vulnerable than themselves.

Table 1: Practical adaptation strategies to reduce risks from extreme heat



Actions by Individuals

Non-structural (planning and behavioural changes)	**Green Infrastructure*** (working with nature)	**Grey Infrastructure** (improving buildings and public infrastructure)
IND-1 Work with neighbours, friends and family to prepare**	**GI-1** Plant and maintain trees	**BI-1** Enhance insulation and airtightness
IND-2 Arrange to receive public heat warnings**	**GI-2** Expand vegetation cover and absorb water to keep gardens and balconies cooler**	**BI-2** Install cool (reflective) roof / wall / paving surfaces
IND-3 Learn how to use natural ventilation**	**GI-3** Install a green (vegetated) roof	**BI-3** Use concrete, brick, stone and tile finishes that absorb heat
IND-4 Minimize “waste” indoor heat production, for example by switching off unused appliances**	**GI-4** Grow a green (vegetated) façade**	**BI-4** Install windows that reduce heat gain from the sun
IND-5 Plan for modified working, living and sleeping arrangements**		**BI-5** Install shading devices (shutters, awnings, overhangs, blinds, heat-resistant curtains) **
		BI-6 Install temperature and humidity monitors or controls**
		BI-7 Use ceiling / portable fan(s)**
		BI-8 Install and maintain air conditioning / heat pump

* In places at risk of wildfire, particularly at the wildland-urban interface, the use of green infrastructure must be considered alongside FireSmart guidance.[3]
** Denotes actions that may be most achievable by tenants and those with fewer resources

Actions by Property Owners and Managers

(multi-unit residential and commercial buildings)

Non-structural (planning and behavioural changes)	**Green Infrastructure*** (working with nature)	**Grey Infrastructure** (improving buildings and public infrastructure)
PROP-1 Understand building-scale vulnerabilities to extreme heat **PROP-2** Provide information and help occupants adapt **PROP-3** Identify and support vulnerable occupants (e.g. the elderly or those living alone) **PROP-4** Use natural ventilation in common areas **PROP-5** Develop extreme-heat emergency plan with occupants	**GI-1** Plant and maintain trees in grounds and parking lots **GI-2** Expand vegetated areas and absorb water around buildings, on balconies and in parking lots **GI-3** Install a green (vegetated) roof **GI-4** Grow a green (vegetated) façade or wall	**See individuals BI-1 to BI-8, plus:** **BI-9** Install and maintain backup power generation (e.g. to maintain air conditioning in designated "cool" rooms) **BI-10** Arrange for backup water supply during power outages (pumped water supply cannot function properly without power)

* In places at risk of wildfire, particularly at the wildland-urban interface, the use of green infrastructure must be considered alongside FireSmart guidance.[3]

Actions by Communities

Non-structural (planning and behavioural changes)	**Green Infrastructure*** (working with nature)	**Grey Infrastructure** (improving buildings and public infrastructure)
COM-1 Assess and map vulnerability to extreme heat	**GI-1** Plant and maintain trees (including in urban forests, green corridors, and urban parks)	**BI-11** Adapt community infrastructure to extreme heat (e.g. transport, utilities, water supply)
COM-2 Use education and outreach campaigns to encourage preventive action	**GI-2** Expand vegetated areas and water bodies and absorb more water (forming a blue-green infrastructure network)	**BI-12** Reduce vehicular traffic
COM-3 Set up community support programs for vulnerable populations (e.g. underserved communities)		**BI-13** Install "cool" reflective or permeable pavements
COM-4 Require heat-sensitive urban planning, infrastructure design, and operation		**BI-14** Expand artificial shade (e.g. using canopies or shelters)
COM-5 Provide incentives to increase passive cooling and reduce "waste" heat (e.g. by subsidising tree planting or home retrofits)		**BI-15** Install water-based cooling systems (e.g. ponds and sprinklers) and drinking fountains
COM-6 Develop extreme-heat emergency plan		

* In places at risk of wildfire, particularly at the wildland-urban interface, the use of green infrastructure must be considered alongside FireSmart guidance.[3]

Chapter
1

Urgent Need for Action to Combat Extreme Heat in Canada

Extreme heat is a serious and growing risk to Canadians. Extreme-heat events have already caused premature deaths and disrupted natural systems and the economy. We cannot prevent extreme weather caused by climate change in the short term, but we can—indeed must—adapt to it. To reduce negative impacts on health and the economy from extreme-heat events, Canadians must act swiftly. People who are already marginalized or underserved are among those who are most at risk from extreme heat; they will require additional support to counter these existing inequalities.

!

526

Deaths as a result of extreme heat in British Columbia, June 25 to July 1, 2021.

The Intergovernmental Panel on Climate Change (IPCC), the United Nations body responsible for assessing climate science, states that there will be an increase in the frequency, intensity and duration of extreme-weather events, including floods, droughts and heat waves, throughout the 21st century. It says many changes caused by past and future greenhouse-gas emissions will be irreversible for centuries to millennia.[4] Canada is warming, on average, at twice the global rate; annual mean temperatures increased by 1.7°C between 1948 and 2016.[5]

While floods are recognized as the most costly natural disasters in Canada, in terms of insured property damage by water,[6] extreme heat is a leading cause of death among climate change-related weather events.[7] The severe implications for health were underscored by the impact of the heat wave in western Canada in the summer of 2021. Preliminary findings indicate that 526 people died as a result of extreme heat in British

Columbia between June 25 and July 1, and that most of these deaths (69 per cent) were of people aged 70 and over.[8]

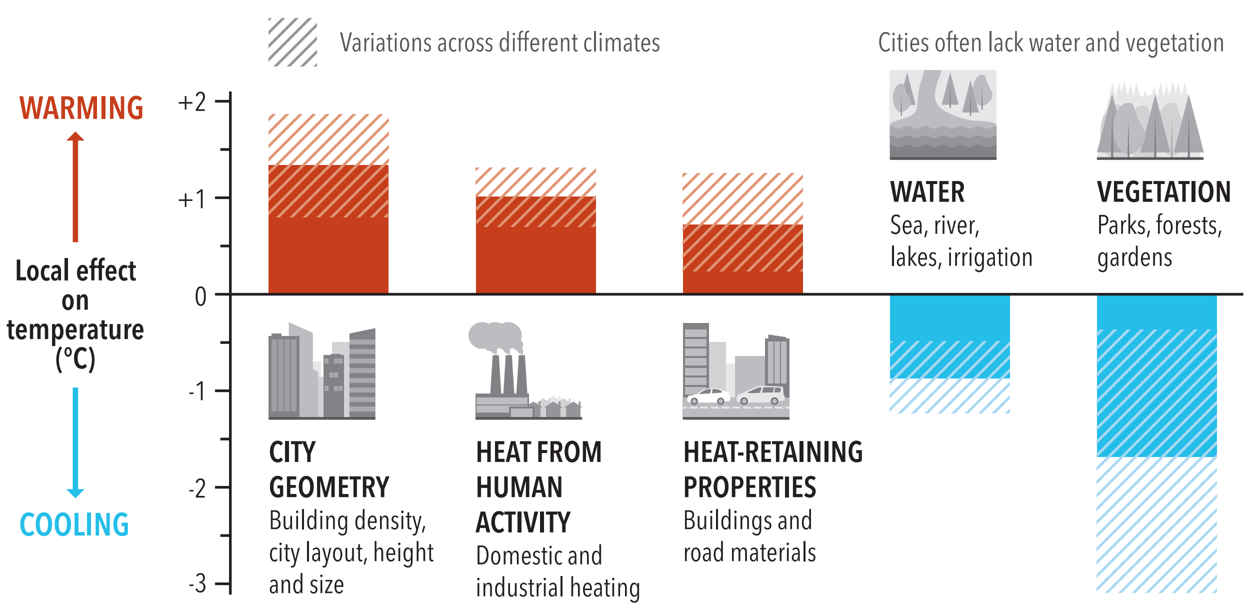
In addition to the dangers to human health, extreme-heat events pose risks to infrastructure such as train tracks, roads and electricity grids, and can harm plants and animals (including those supporting food production). All can adversely affect the economy.

As "record-breaking" temperatures and heat waves will become even more frequent and intense in the future, communities need to prepare. This report sets out the adaptive actions that individuals, property owners and managers, and communities can take to reduce these risks. These actions are presented in three categories:

- **Non-structural** —planning and behavioural changes
- **Green Infrastructure**—using nature to help us stay cool
- **Grey or "Built" Infrastructure** —new designs and retrofits that cool buildings and keep infrastructure functioning

The actions are particularly relevant for urban areas, which are the hot spots of global warming, as identified by the IPCC (Fig. 1).

Figure 1. Why cities are the hot spots of global warming (adapted from IPCC, 2021)[9]



Chapter 1 identifies the impacts of extreme heat; Chapter 2 illustrates the areas of Canada likely to be the most exposed to extreme heat from 2051 through 2080; Chapter 3 presents the 35 practical actions to reduce the risks, and Chapter 4 demonstrates the multiple benefits of specific actions.

The information about practical ways to tackle extreme heat is founded on a review of research and best practices, as well as advice from subject-matter experts. While the 35 actions are oriented to urban settings, many of them can also be used in rural areas.

This report does not address risks associated with drought, wildfire, thunderstorms or reduced air quality, which may be connected to extreme heat. Nor does it address the additional challenges that warming temperatures are bringing to communities in Canada's North. Several of the practical actions may be appropriate for use by Indigenous communities in southern Canada, but we do not explicitly address the risks to Indigenous communities, or opportunities to learn from and use traditional Indigenous knowledge. Further research is recommended to address this gap.

At the end of the report, references are presented in an accessible format, to encourage further reading.

1.1

Urban Heat Islands: A Key Challenge for Canada's Cities and Towns

Extreme heat is a specific challenge for Canada's cities and towns, one that the federal government has highlighted as a key national issue in its series of reports "Canada in a Changing Climate.[10]

During heat events, conditions are worse in urban areas, because of the urban-heat-island effect. An urban heat island is an urban area that is significantly warmer than surrounding areas. The air, or surfaces, or both, may exhibit these warmer temperatures.

The layer of air where people live—from the ground to below the tops of trees and roofs—is the air where the urban-heat-island effect is most pronounced. In a city of one million people or more, the annual mean air temperature can be one to three degrees Celsius warmer than surrounding rural or suburban areas. On a clear, calm night, this temperature difference can be as much as 12°C,[11] effectively extending the daytime heat into the evening hours, and making it more difficult to cool and ventilate buildings at night.

10-15°C

How much higher the daytime surface temperatures in urban heat islands can be compared to rural areas.

Hard surfaces can show bigger differences in temperature. On average, the difference between surface temperatures in urban heat islands and surrounding rural areas is between 10°C and 15°C during the day.[12] The hot surfaces in urban areas increase the experience of heat outdoors, particular where shade is limited.

Figure 2 shows how air and surface temperatures vary with different land uses and times of day; both tend to be warmest in core urban areas.[13] In almost all locations, surfaces are warmer than the air during the day, but at night, their temperatures become similar. A significant exception is water—the pond in Figure 2 maintains a fairly constant surface temperature day and night, because of its capacity to store and emit heat.

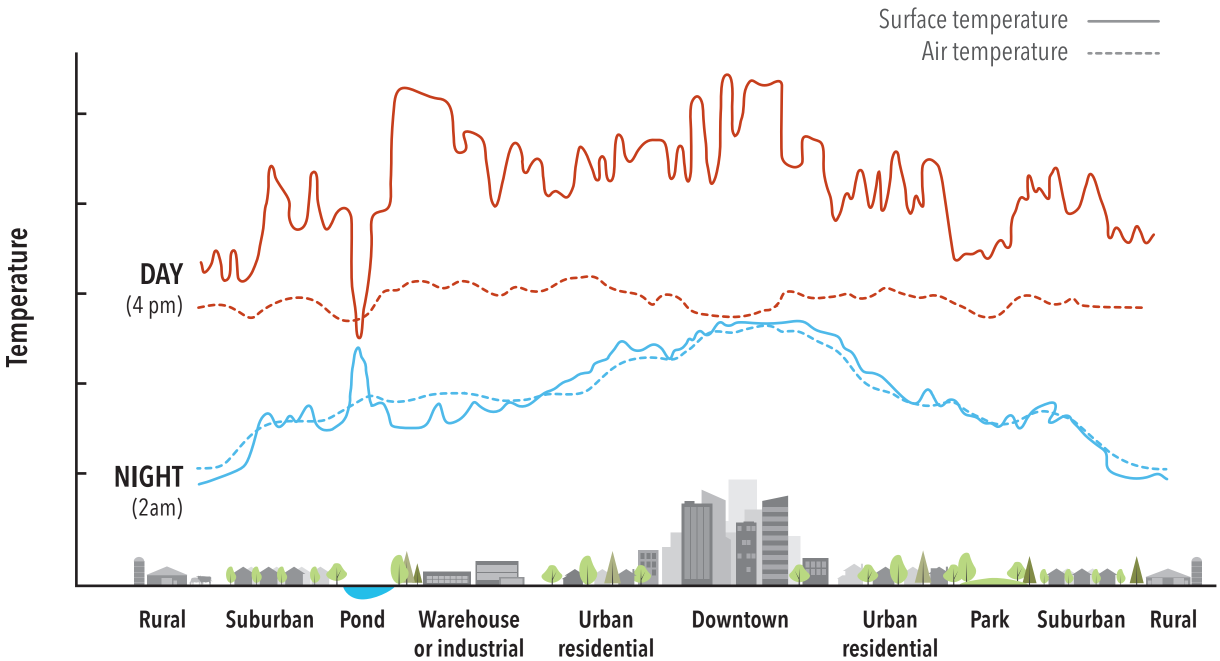
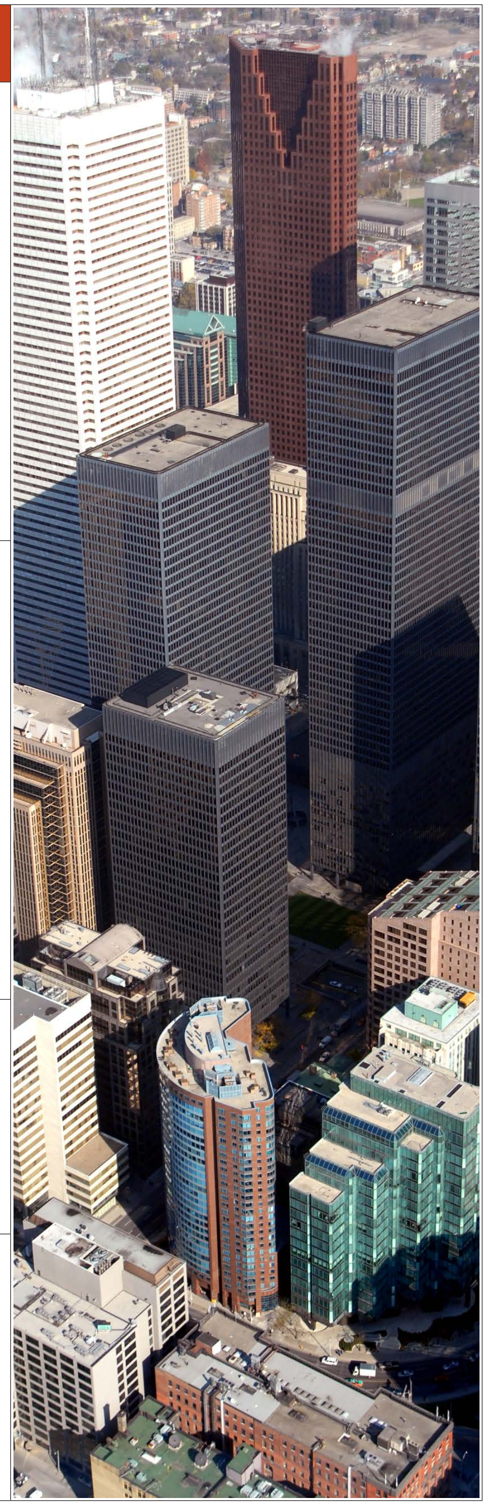


Figure 2. A schematic representation of the urban heat island effect and the variation of surface and air temperatures over different land uses (adapted from EPA, 2008)

Most Canadians live in urban areas. On July 1, 2020, 27.3 million people, or just over seven in 10 people (71.8 per cent), were living in one of Canada's 35 census metropolitan areas (CMAs)—defined as areas with a total population of at least 100,000, of which 50,000 live in the core.[14] In these areas, it is urgent to adapt to extreme heat in order to limit the potential health impacts on millions of people. Table 2 outlines four key factors that contribute to the formation of urban heat islands in these areas.

Table 2. Factors contributing to the urban-heat-island effect (adapted from various sources [15,16,17,18])

Factor	Description
Replacement of natural "green" infrastructure with man-made "grey" infrastructure.	Trees, vegetation and water bodies (rivers, lakes and ponds) tend to cool the surrounding air and surfaces by providing shade, transpiring water from their leaves, and by evaporation. Man-made surfaces—such as roofs, sidewalks, roads, buildings, and parking lots—provide less shade and evaporate less moisture than natural landscapes. Man-made materials also tend to absorb, and later emit, more of the sun's heat than natural surfaces.
Urban geometry	The sizes and spacing of buildings in a city influence the flow of wind, and its ability to absorb and release solar energy. In heavily developed areas, the surfaces and structures of buildings that are near each other become large thermal masses that cannot readily release their heat. Cities with many narrow streets and tall buildings also create urban canyons, which can block the natural flow of wind that would cool the area.
Heat generated from human activities	Vehicles, air-conditioning units, buildings, and industrial facilities all emit heat. These sources of human-generated "waste" heat can contribute to heat-island effects.
Geographical setting	In some cities, local or regional geographic features can help to form urban heat islands. For example, nearby mountains can block wind from reaching a city, or create wind patterns that pass over rather than through a city.

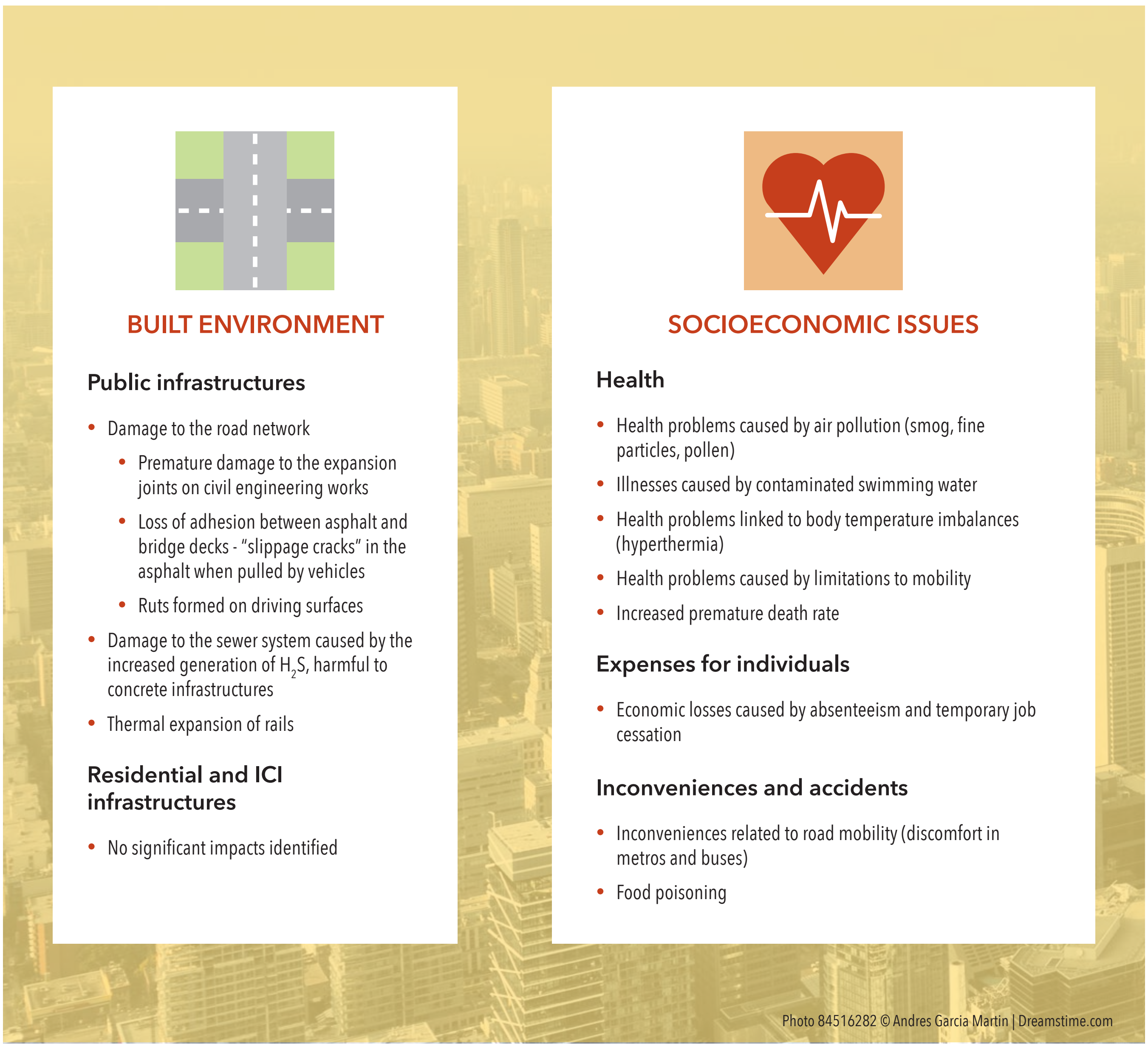


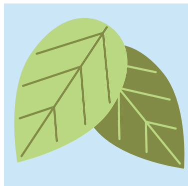
1.2

Impacts of Extreme Heat

The risks of extreme heat are commonly considered in terms of health impacts, with the media focusing largely on heat-related deaths. However, extreme heat also has adverse effects on infrastructure and services, natural systems and ultimately, the economy, as exemplified by the range of impacts identified by the City of Montreal (Fig. 3). The following sections describe these impacts.

Figure 3. Examples of potential impacts of heat waves on cities (extract from the City of Montreal's Climate Change Adaptation Plan for the Agglomeration of Montreal 2015-2020.[19])





NATURAL ENVIRONMENT

Plants

- Increased water stress
- Management of undesirable plant species: loss of effectiveness of some herbicides

Insects

- Reduced insect populations (pests and auxiliaries) as they reach their thermal development limit
- Management of pest insects: loss of effectiveness of many pesticides

Fauna

- Changes to bird communities

Water bodies

- Proliferation of cyanobacteria
- Change to the structure of communities of aquatic organisms

MUNICIPAL OPERATIONS

Increased demand for cooling-off areas

- Demand to extend the opening hours of air-conditioned public spaces (libraries, community centres, etc.)
- Increased demand for pools, wading pools and splash pads
- Curtailed outdoor works

Increased demand for drinking water

- Shorter system idle time will weaken the system in case of problems
- Higher costs for chemical products and electricity
- Increased presence of cyanobacteria in the water requiring ozone treatment (not available in all plants)
- Faster degradation of chlorine in the system, which will increase rechlorination needs and associated operating costs

Increased complaints

- Problems with bad smells from manholes during heat waves and drought periods
- Problems with residual material management (bad smells, proliferation of flies, etc.)

Photo 84516282 © Andres Garcia Martin | Dreamstime.com

1.2.1 Health

Extreme heat directly affects physical health, as well as mental health and general well-being, for example, by limiting outdoor work and recreation. A person's experience of heat is affected by four physical factors: the air temperature; the transfer of heat from the sun (solar radiation); the humidity level, and air velocity or speed. Increases in three of these factors—temperature, solar radiation and humidity—generally contribute to a feeling of greater heat. An increase in air speed, however, has a cooling effect, as it encourages the evaporation of sweat from the skin.[20]

Physical Health

When indoor or outdoor temperatures are very hot, people are more likely to suffer from heat exhaustion and heat stroke, which may be fatal. Symptoms of heat exhaustion include sweating, fatigue, weakness, dizziness, headache, general malaise, and nausea or vomiting after intense exposure to heat.

Heat stroke is a medical emergency. It is a severe form of heat illness that needs to be treated immediately on-site, by cooling and hydrating the sufferer while awaiting emergency assistance.[21] Extreme heat may also cause non-fatal illnesses, including heat edema (swelling of hands, feet and ankles), heat rash and heat cramps, and it may contribute to fainting, as well as aggravating existing health conditions.[22,23]

As well, people can be burned by extremely hot surfaces, especially those in direct sunlight such as metal surfaces in children's playgrounds.[24]

The effects of high temperatures on physical health are already being felt across Canada. The previously mentioned heat wave in western and central Canada in 2021 was prefaced by the summer of 2018 in southern Quebec, the hottest summer on record there in 146 years of meteorological observations; across the nine regions affected, 86 excess deaths were reported, possibly heat-related.[25] Similar events also occurred in Quebec in July 2010 (280 excess deaths) and in British Columbia in July 2009 (156 excess deaths).

Around the world, climate change is contributing to the number of deaths caused by extreme heat. One study of 43 countries concluded that, on average, climate change was responsible for 37 per cent of warm-weather, heat-related deaths in the 27 years from 1991 to 2018, and that increased mortality as a result of climate change is evident on every continent.[26]

Heat-related deaths are largely preventable with knowledge, education and adaptive action.[27] Figure 4 clearly highlights the serious consequences of failing to adapt.

86

Number of excess heat-related deaths in Quebec during the summer of 2018 - the hottest on record.

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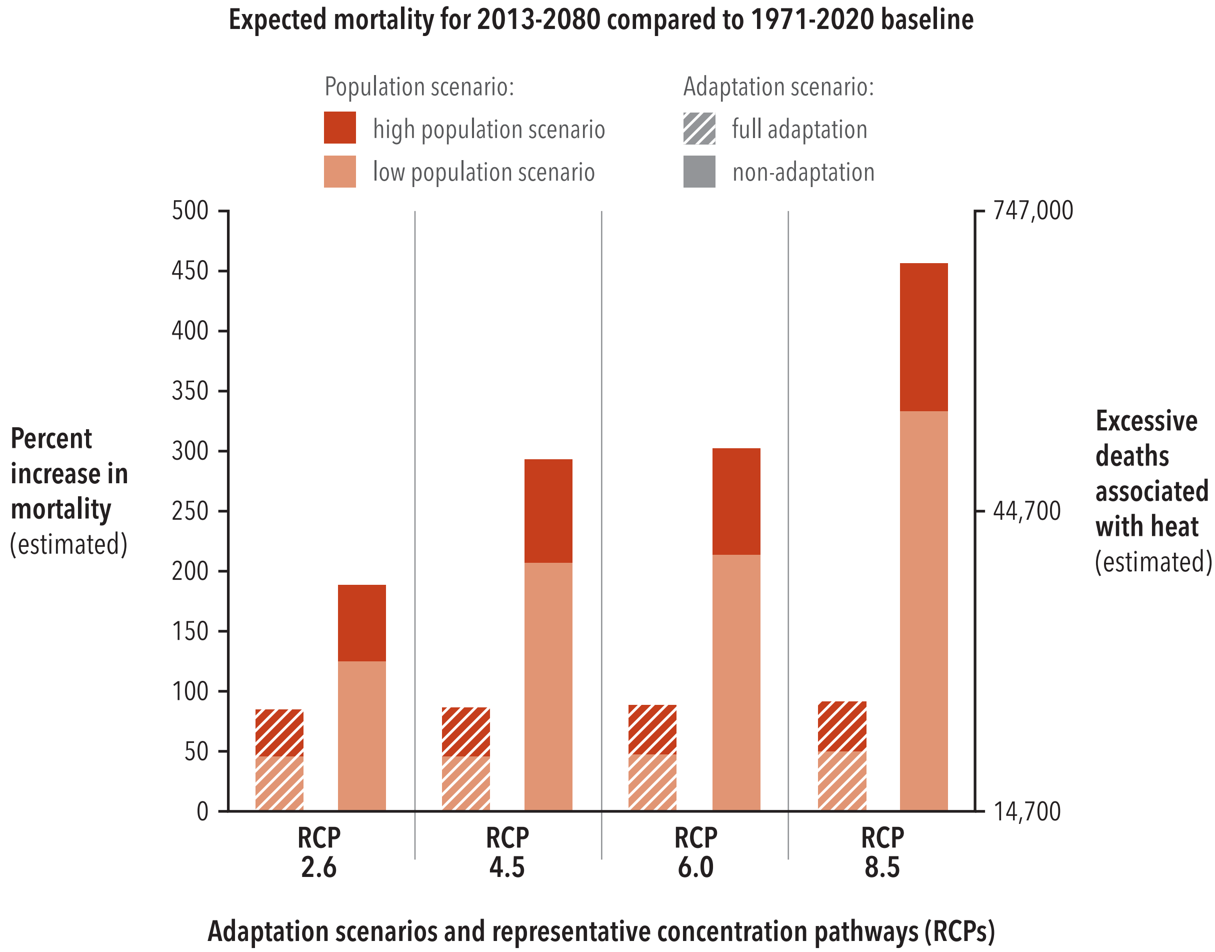

Figure 4. Excess mortality associated with heat waves in Canada under various scenarios, 2031-2080, compared with baseline for 1971-2020 (Reproduced from Health Canada, 2020,[28] based on data from Guo et al, 2018[29])

Mental Health and Well-being

A growing volume of evidence indicates that extreme heat adversely affects mental health and well-being.[30] Heat stress directly caused by heat waves has been associated with mood disorders and anxiety. Hotter cities may also experience more violence than cooler cities, as an increase in discomfort leads to increased feelings of hostility, aggressive thoughts and possibly violent actions. Exposure to extreme heat can also lead to psychological fatigue, and high temperatures have been associated with increased suicide rates.[31] Well-being may also be affected by the need to stay indoors, which would limit outdoor recreational and social activities.

Populations at Risk

While extreme heat can put everyone at risk from heat illnesses, the health risks are greatest for people with particular risk factors (Table 3). This includes those who may be more exposed to extreme heat, those who are more sensitive to extreme heat and those with less access to information or resources to adapt. Social isolation and compromised mental health (in particular schizophrenia) were underlined as specific factors contributing to the vulnerability of those who died in the 2018 heat wave in Montreal.[32]

Several risk factors may contribute to high-risk individual circumstances. For example an elderly, chronically ill person may also be socially isolated and live in housing that is poorly adapted to extreme heat in an urban-heat-island area. Extreme heat can also exacerbate existing inequalities, affecting underserved or marginalized neighbourhoods more severely, where several of the risk factors identified in Table 3 are present.

Table 3. Risk factors increasing vulnerability to extreme heat (compiled using various sources) close this space[33]

Risk Factors	Populations at Risk
Increased exposure to extreme heat	• People living in urban-heat-island areas with limited vegetation and natural habitat • People living outdoors • People living in housing that is poorly adapted to extreme heat (higher floors of apartment buildings; prisons; housing without access to air conditioning or without ventilation) • People with mobility issues • People who are socially isolated (living alone, do not leave home) • People who work in the heat (outdoors and indoors) • People who exercise in the heat
Increased sensitivity to extreme heat	• Older adults • Infants and young children • Pregnant women • People with chronic illnesses such as breathing difficulties, heart conditions, obesity or diabetes • People living with mental illness • People who are malnourished or dehydrated • People taking certain medications • People taking certain drugs or alcohol
Limited access to resources and/or information	• People with low incomes • People experiencing homelessness • People living in underserved communities • People who neither speak nor understand English or French

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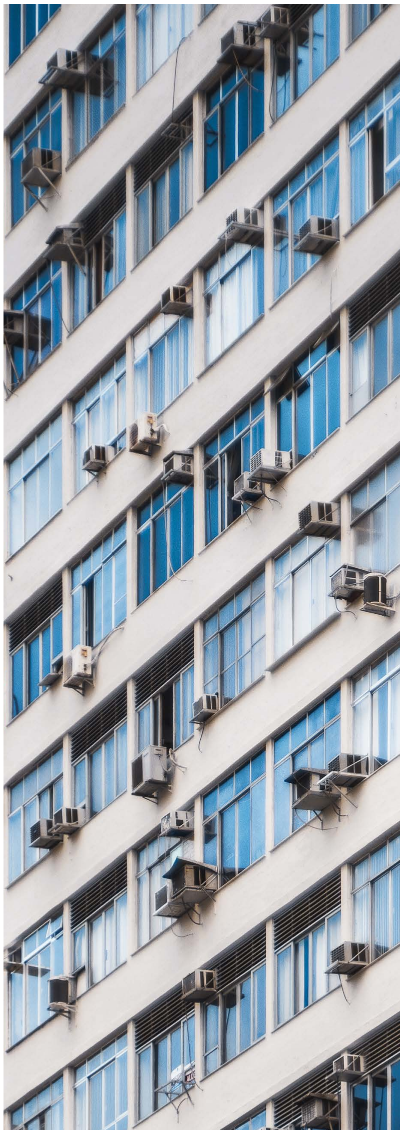
People who have been less exposed to heat are less acclimatized and may be more vulnerable.[34] As a result, health risks from extreme heat may be greater when heat waves occur outside the typically hottest times of year (for example, in the spring) when people are not acclimatized to heat.[35] Similarly, in locations where people are accustomed to lower temperatures, impacts on death rates may be seen at daily average temperatures as low as 20°C. The opposite is true in places where average temperatures have been historically higher: in these cases, adverse health problems typically occur at higher temperatures.[36]

1.2.2 Infrastructure and Services



Extreme heat represents a significant risk to the infrastructure and services that Canadians rely on. The hazards of heat should be factored into the design, operation, and maintenance of infrastructure and systems, as well as associated emergency-management plans. Specific examples of heat's effect on various systems are highlighted below. Many are interdependent and can lead to cascading impacts:

Electrical Power Infrastructure

As Toronto Hydro has noted, extreme heat may cause problems for electrical distribution systems when peak demand for electricity (for instance, to operate air conditioning) occurs at the same time as high temperatures are limiting the efficiency of electricity transmission and equipment-cooling. Transmission equipment, such as power transformers, may be forced to operate beyond its design specifications, increasing the likelihood of failure.[37] Power outages during heat events could have severe consequences, particularly in multi-unit residential buildings, where:

- Residents may rely on electrical cooling systems (fans and air conditioning)
- Water pumps require electricity to move water throughout the building, in particular to higher floors
- Residents rely on elevators to enter and leave the building, or to get to spaces that can be cooled

In these situations, power outages may put vulnerable populations at even greater risk of heat exhaustion or heat stroke.

Digital Infrastructure and Telecommunications

Extreme temperatures place additional burdens on cooling equipment used in data centres, telecommunication exchanges and base stations.[38] If appropriate temperatures cannot be maintained, equipment may fail and Internet and other telecom services may be disrupted more often.[39] Broad power outages may severely disrupt telecommunications.

Transportation Infrastructure

Rail: As identified by Metrolinx, a major southern Ontario transit provider, temperatures above 32°C can warp rail tracks and cause "sun kinks" (imperfections in steel caused by heating and expansion). Longer periods of high heat (such as three days or more) increase these risks.[40] During extreme-heat events, it is normal practice for railways to operate trains at slower speeds to reduce the risk of damage to tracks that can cause derailments.

Roads: While most asphalt and concrete used in Canada is designed to withstand temperatures between -20˚C and 30˚C, projected temperatures for many Canadian cities in the 21st century exceed this range. In extreme heat, roads may soften and become rutted when vehicles depress the hot surfaces. Damage may also be caused by "bleeding" in hot weather when asphalt moves upwards and above a pavement's surface treatment (the waterproof layer upon which vehicles drive).[41]

Bridges: Bridges are designed to withstand some expansion and contraction through the use of flexible materials embedded between fixed points. However, as temperatures increase, the limits of these expansion joints can be exceeded, displacing or cracking deck materials.[42]

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Water and Wastewater Infrastructure

Extreme temperatures may increase community demand for water and wastewater treatment services at times when water levels are low. Higher water temperatures and lower water levels may adversely affect the quality of water at its source, and algal blooms may cause particular problems.[43] Less available water can affect communities' firefighting abilities, and this in turn could increase the risks posed by wildfires (see Section 1.3).

Buildings

Extreme heat places additional demands on heating, ventilation and air conditioning (HVAC) systems, which may not be designed with sufficient capacity to meet these demands.[44] Some building components, such as roofs, caulking and glazing, can also be affected by direct heating and expansion.

Health and Social Services

Extreme heat increases the demand for health-care, emergency, and social services. In British Columbia, for example, Vancouver Fire Rescue Services reported a threefold increase in call volume, and waits of up to 11 hours for ambulances, during the 2021 heat wave.[45] The 2010 heat wave in Quebec led to approximately 3,400 more admissions to emergency departments than would otherwise have occurred.[46]

Health-care and social-services facilities (including long-term care homes) need to maintain appropriate temperatures to protect patients—many of whom are likely to be more vulnerable to heat illnesses—and employees. They also need to be able to continue to deliver emergency and non-emergency health and social services, including surgery and storing medications at the correct temperatures.[47]

3,400

Number of additional emergency department admissions in 2010 heat wave in Quebec

Food Systems

Extreme temperatures and heat waves can have a severe negative effect on Canadian crops (including cereals, vegetables and fruit), particularly when coupled with drought and wildfires. Extreme heat also causes more deaths of farm animals[48] and reduces cattle reproduction and the quantity of milk produced.[49] On the Prairies, in the summer of 2021, heat waves coupled with drought led to the emergency culling and auctioning of cattle, as farmers and ranchers could not feed their livestock.[50]

The distribution of food also depends on infrastructure and electricity, including for refrigeration. As highways, roads and electrical power supplies are vulnerable to extreme heat, it may be challenging during future heat waves to distribute food and keep it fresh and safe.[51] Extreme temperatures may also be dangerous for agricultural workers working outdoors.

1.2.3 Natural Systems

Extreme heat affects the movement, behaviour, health and mortality of animals,[52] and certain populations are particularly vulnerable. For example, high temperatures may result in mass deaths of ocean animals at low tide.[53] High water temperatures and poor water quality can also kill fish, particularly cold-water species such as salmon and trout,[54] and may cause excessive algal blooms in rivers and lakes.[55] Extreme heat, coupled with drought and fire, can also result in catastrophic losses of vegetation.

1.2.4 Economy

The economic impacts of extreme-heat events have historically been less well documented than those for flooding. Because the costs of extreme heat are not dominated by damage to property or other insurable goods, they are not reflected in the catastrophic losses reported each year by the property and casualty insurance industry.[56]

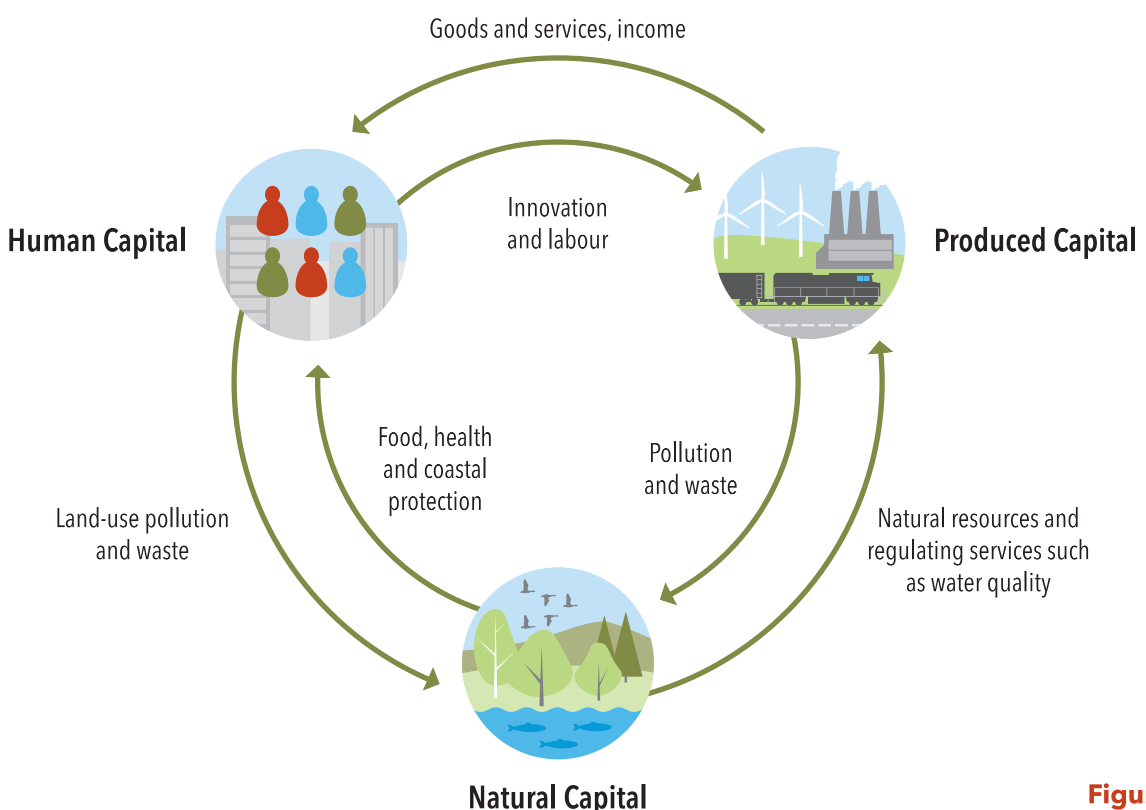


Figure 5. Interaction between different types of capital (adapted from Dasgupta, 2021[57])

Traditionally, definitions of the economy have focused on produced capital (financial and manufactured outputs). Increasingly, however, human capital and natural capital — reflecting the value of people and society and services provided by nature — are considered an integral part of the economy (Fig. 5). Since extreme heat is a major risk to both human and natural capital, on which produced capital depends, it is also a risk to the economy as a whole, as well as posing direct physical risks for several specific industry sectors, such as agriculture.

In 2021, the Canadian Institute for Climate Choices estimated the potential costs of more frequent heat waves caused by climate change, with modeling that considered a variety of greenhouse-gas emission scenarios.[58] Among its key findings:

1. Rising temperatures are likely to have a large negative impact on economic productivity, especially in sectors where work takes place outdoors or in poorly cooled spaces (manufacturing; quarrying; oil and gas extraction; utilities; transportation; agriculture; forestry; fisheries, and construction). Estimates indicated that under a high-emissions scenario, climate change could lead to a loss of 128 million work hours annually by the end of the century, the hours worked by 62,000 full-time employees, at a cost of almost $15-billion.

2. The costs of lost life and reduced quality of life from heat-related deaths are substantial. By the middle of the century (2050), the annual costs would be similar under the low- and high-emissions scenarios—$3-billion and $3.9-billion respectively. However, by the end of the century, the cost of failure to reduce emissions becomes much more apparent. In the high-emissions scenario, heat-related deaths would cost $8.5-billion annually, compared with $5.2-billion if global emissions are substantially reduced.

$23.5-billion

Estimated annual cost of work hours lost due to climate change and heat-related deaths by the end of the century

It is not possible, and may be considered inappropriate, to assign to every loss a dollar value, considering that people's lives are being lost. However, it is clear that the potential economic costs of extreme heat in the absence of adaptation are significant, particularly in terms of human capital.

1.3

Related Impacts

Extreme heat is commonly related to other climate risks, as outlined below. After extreme temperatures or heat waves, many communities may suffer cascading or combined impacts, which result in a bigger overall impact.[59]

When taking action to address extreme heat, it is important to consider other climate-related risks, in order to avoid what is known as "maladaptation"—adaptation that could end up increasing the overall climate-related risks. For example, in places where wildfire is a risk, particularly within the wildland-urban interface (WUI), it would be inappropriate to plant shade trees too close to buildings, because they are combustible and would increase the risks to the building from wildfires.

Air Quality

Warmer temperatures contribute to the production of air pollution, causing an increase in ground-level ozone, smog, and other pollutants.[60] Poor air quality increases airborne allergens, worsens pre-existing cardiovascular and respiratory conditions, and in some circumstances can cause long-term health issues.[61] [62] As air pollution increases, so do associated health-care costs and deaths. Given the temperatures projected for the end of this century, average summer ozone concentrations could increase by 22 per cent, according to modeling by the Canadian Institute for Climate Choices using different scenarios. It projects that the associated deaths and lost quality of life in Canada could cost $87-billion per year by mid-century, and $245-billion by the end of the century.[63]

Drought and Wildfires

Extreme-heat events are frequently related to dry, drought conditions and subsequent wildfires, as experienced in the summer of 2021 across western and central Canada.

Droughts affect both rural and urban communities, and can place severe pressure on water infrastructure and resources.

Wildfire smoke reduces air quality; it contains toxins and fine particles, making it harmful to breathe, which makes people sick and leads to higher health-care costs. Because these impacts may be felt across large areas, daily air-quality forecasts are used to anticipate the impacts of wildfire smoke across the country.[64]

Thunderstorms and Flash Floods

Where moisture is available, such as near large bodies of water, extreme heat may contribute to the formation of thunderstorms.[65] In Canada, thunderstorms are most prevalent from late May to early September, peaking in July, and usually occur on summer afternoons.[66] They may cause intense rainfall and flash floods, particularly in urban areas, damaging property and endangering lives. Flooding may also be caused by extreme heat that results in rapid snowmelt in mountainous areas upstream.

Chapter 2

Hotting Up: An Overview of Extreme Heat Projections for Canadian Communities

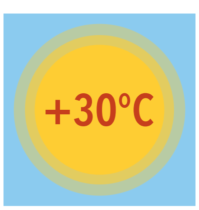
Extreme temperatures and heat waves already occur across Canada and will become more extreme in the future. This chapter provides an overview of projections for extreme temperatures and heat waves for Canadian communities from 2051 through 2080. Children born in 2021 will be in the prime of their lives—age 30 to 59—at this time.

Details about how the projections were obtained and used are in Appendix A. Readers can explore the projections first-hand and obtain additional data for their communities using Canada's Climate Atlas, https://climateatlas.ca. It should be noted that climate projections are subject to significant uncertainty, and future conditions will depend on the actions taken to reduce greenhouse gases and slow climate change.

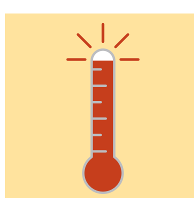
2.1

National Trends

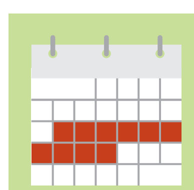
Much of Canada will experience extreme temperatures in the years 2051–2080, according to projections. Three indicators of heat are presented here:



Very hot days over 30°C



Warmest maximum temperature

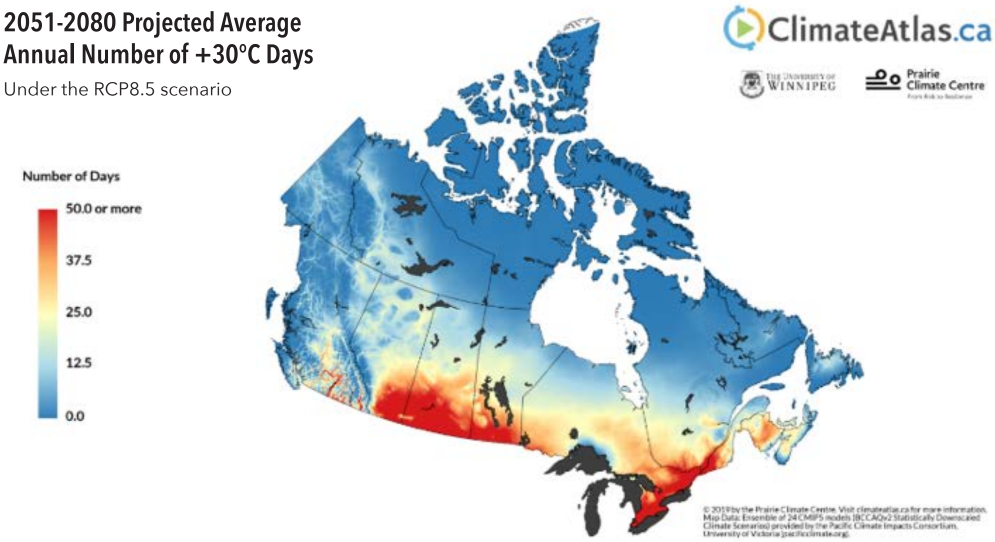


Average heat-wave length

All are based on a high-carbon scenario (see Appendix A for details). Based on these indicators, exposure to extreme heat will be most pronounced in three areas of Canada (Fig. 6): low-lying areas from the West Coast to the Rocky Mountains (British Columbia), the Prairies bordering the United States (southern Alberta, Saskatchewan, and Manitoba) and north of Lake Erie through the St. Lawrence River Valley (southern Ontario and Quebec).

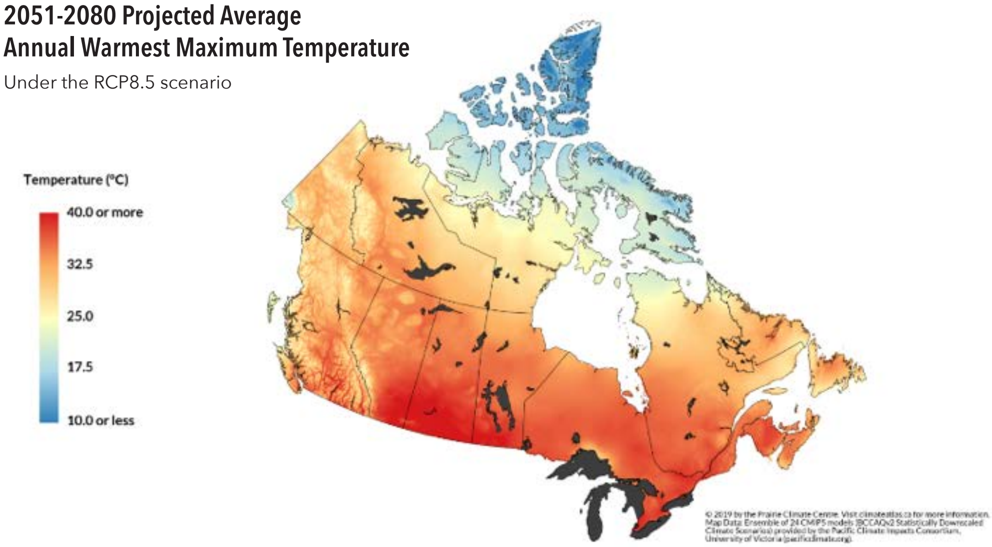
2051-2080 Projected Average Annual Number of +30°C Days

Under the RCP8.5 scenario



2051-2080 Projected Average Annual Warmest Maximum Temperature

Under the RCP8.5 scenario



2051-2080 Projected Average Annual Length of Heat Waves

Under the RCP8.5 scenario

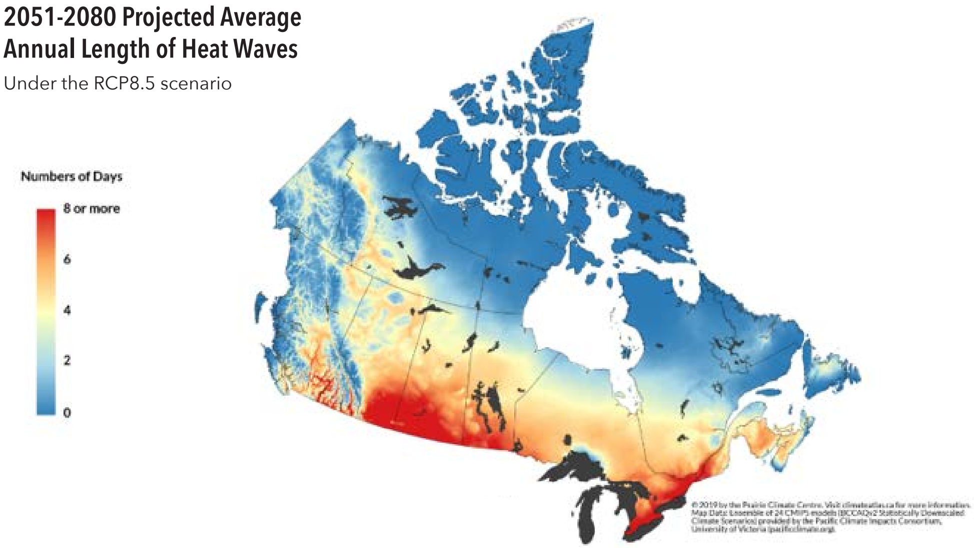


Figure 6. Indicators of extreme heat projected for Canada, 2051-2080. Maps from Prairie Climate Centre. The Climate Atlas of Canada (version 2, July 10, 2019). https://climateatlas.ca

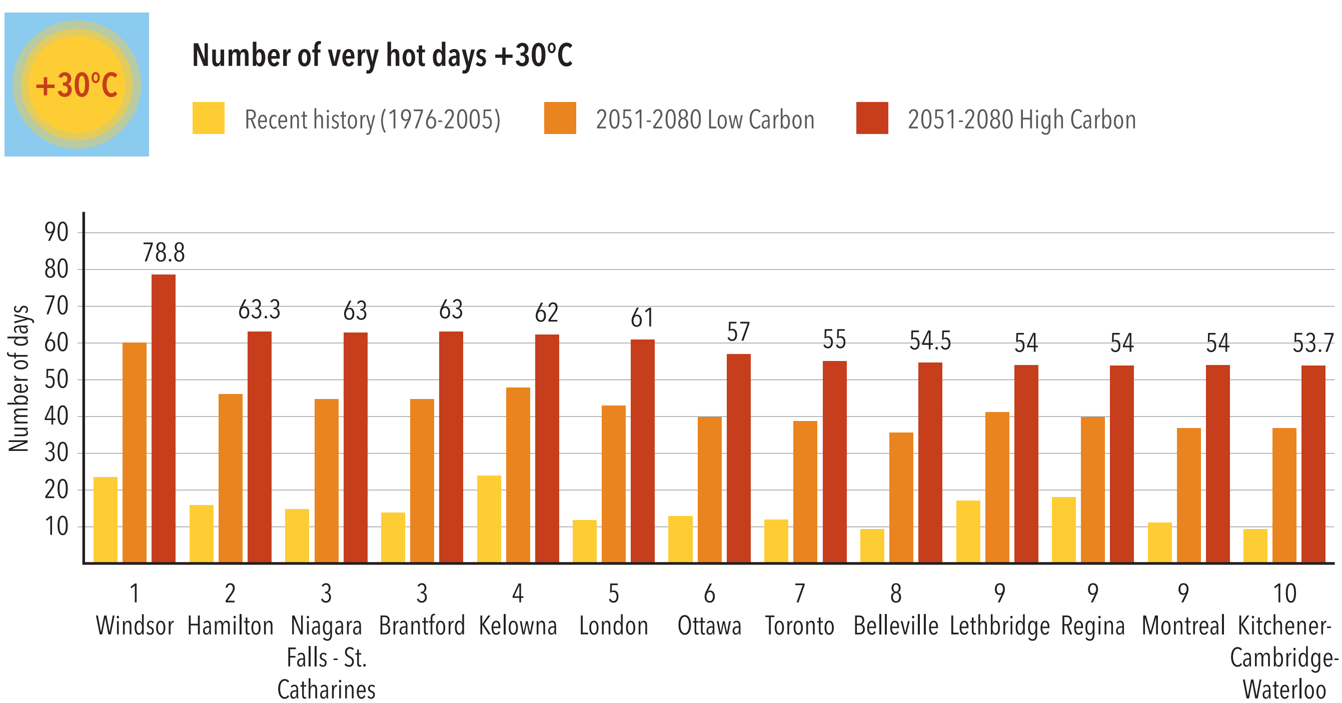
2.2

Exposed Communities

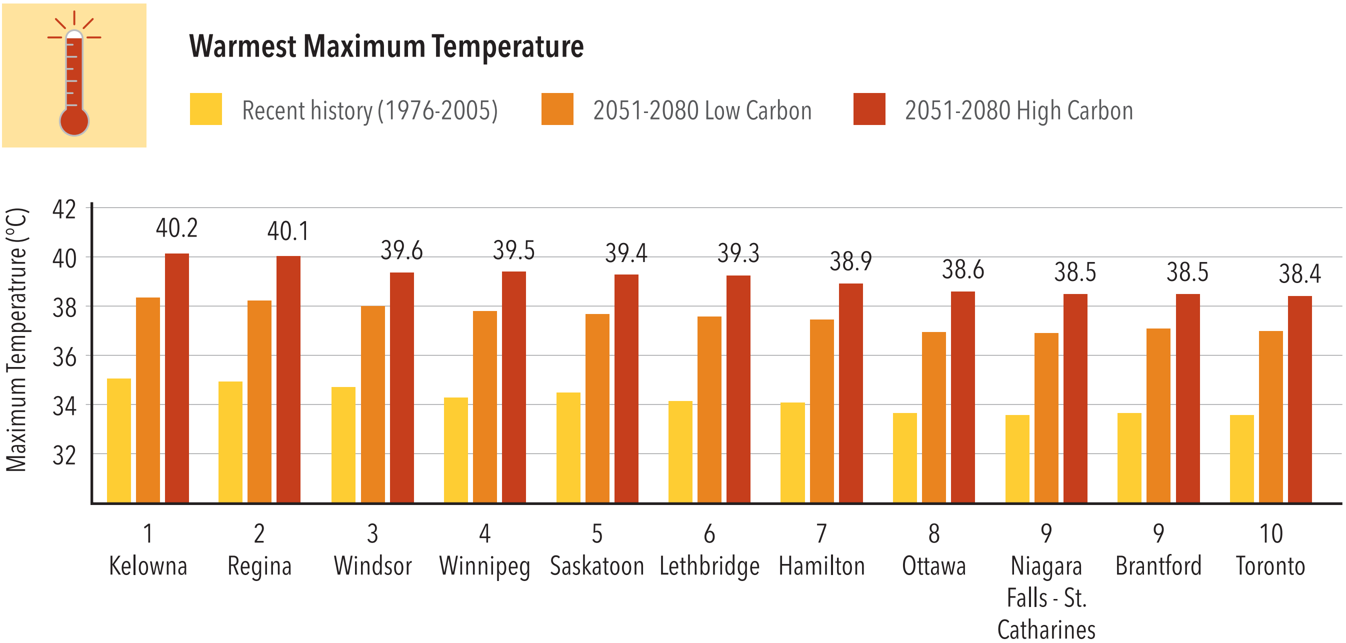
This section describes the top 10 "hottest" metropolitan areas in Canada in the period 2051–2080, based on projections for the three previously described indicators of extreme heat (Fig. 7; see Appendix A for details). Where projected conditions were the same, the same ranking was applied, meaning more than 10 metropolitan areas were identified. The projections only reflect exposure to the selected climate conditions. They do not consider the urban-heat-island effect within cities, or the vulnerability or preparedness of their populations. Nor do they include other factors that contribute to the experience of heat, such as humidity and air circulation.

A number of metropolitan areas feature in all three "top 10" lists, and all are in the geographical areas of Canada identified in Section 2.1 as most at risk. Notably, the large cities of Toronto, Montreal, and Ottawa are each included in at least one "top 10" list.

Figure 7. "Top 10" metropolitan areas based on projections for three indicators of extreme heat.



Warmest Maximum Temperature



Average length of heat wave

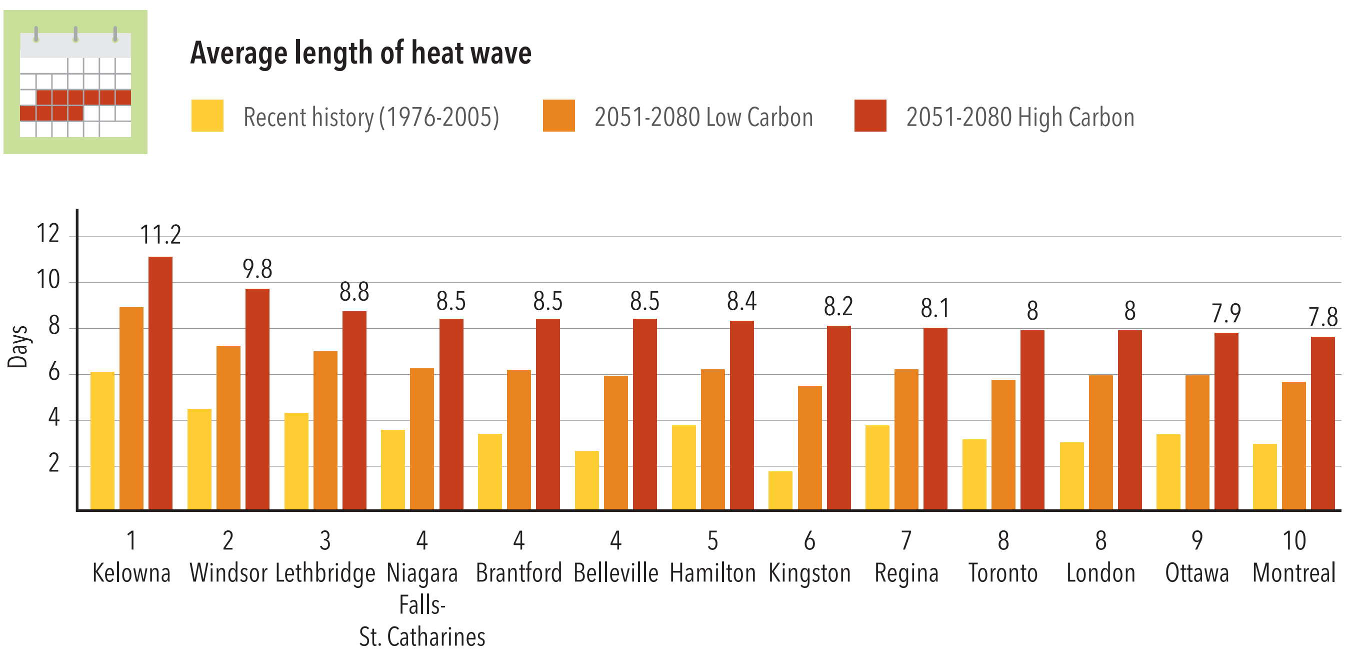


Table 4 and Figure 8 show the metropolitan areas and selected smaller communities across Canada that will be the most exposed to extreme heat, according to the projections and indicators examined for 2051-2080. Communities neighbouring these locations will likely be similarly exposed. And communities outside the areas identified may also be at risk from extreme-heat events because of other factors that influence their vulnerability —particularly if they do not adapt to reduce that vulnerability.

Table 4. Metropolitan areas and smaller communities projected to be most exposed to extreme heat, 2051–2080

Geographic Area	Provinces	Metropolitan Areas identified in the Top 10 lists	Smaller Communities (examples)
Low-lying areas from the West Coast to the Rocky Mountains	British Columbia	Kelowna	Kamloops Penticton Vernon Creston
Prairies of southern Canada along the U.S. border	Alberta	Lethbridge	Medicine Hat Taber Drumheller Brooks
	Saskatchewan	Regina Saskatoon	Estevan Maple Creek Weyburn Leader
	Manitoba	Winnipeg	Emerson Morden Souris Steinbach
North of Lake Erie through the St. Lawrence River Valley	Ontario	Windsor Hamilton Niagara Falls-St. Catharines Brantford London Ottawa Toronto Belleville Kingston	Chatham Sarnia Leamington Kitchener-Waterloo
	Quebec	Montreal	Saint-Jean-sur-Richelieu Salaberry-de-Valleyfield

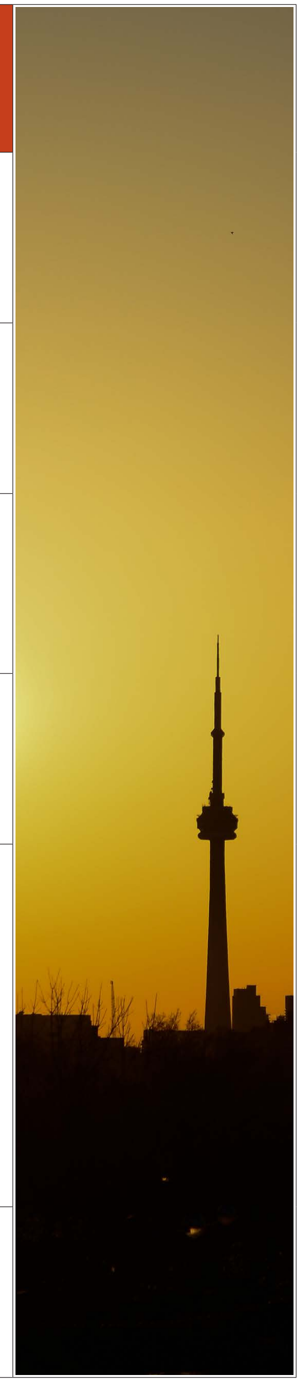


Photo 60911310 © Chengusf | Dreamstime.com

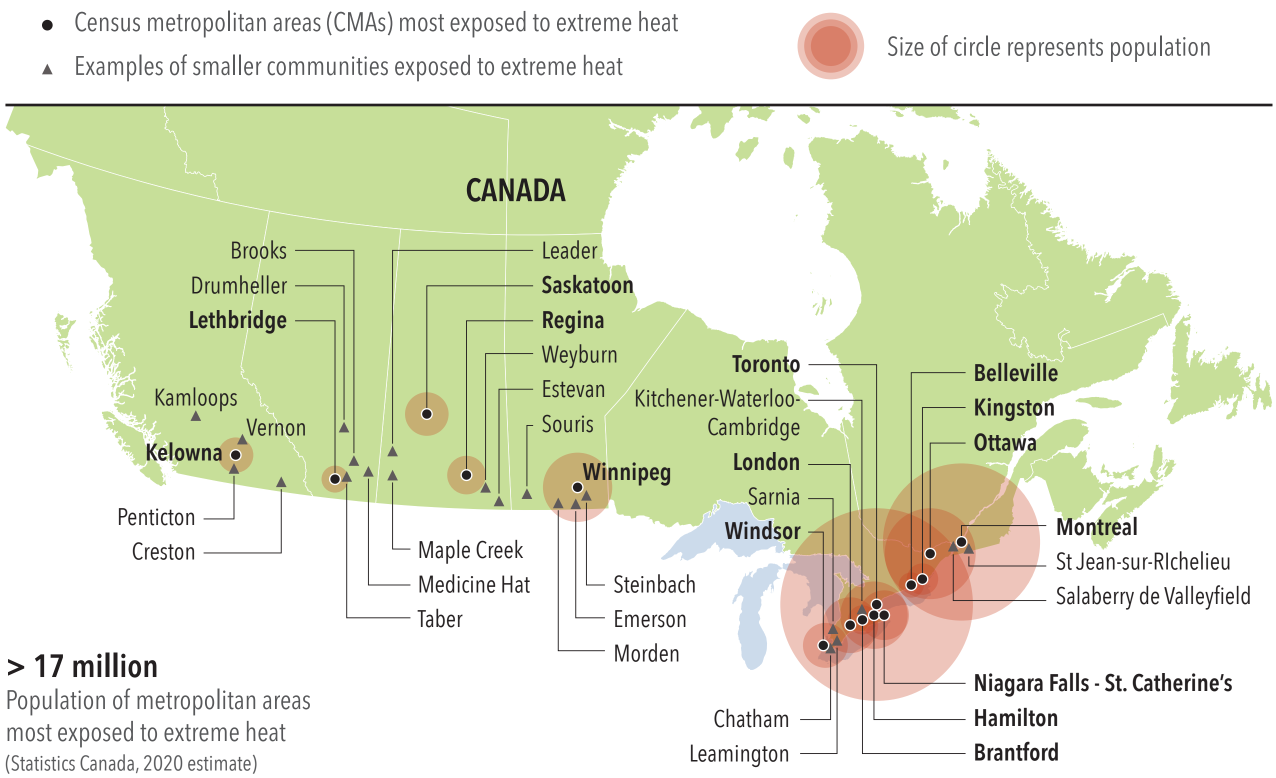


Figure 8. Map of Metropolitan Areas and smaller communities where projected extreme heat indicators are most severe in 2051-2080

Chapter 3

Resilience to Extreme Heat: 35 Practical Actions

This chapter focuses on practical actions that can be carried out by individuals, property owners and managers and communities to lessen the urban-heat-island effect and reduce human vulnerability to heat-related illnesses. People can act to reduce the risks from extreme heat before a heat wave occurs (often termed "prevention") as well as during a heat wave (termed "protection").

The emphasis here is on prevention, to prepare for extreme heat and adapt to it, outdoors and indoors.

While air conditioning is an effective public-health strategy for reducing heat-related illness and death, reliance on air conditioning alone will not make our communities resilient to heat. Air conditioning contributes to the urban-heat-island effect by generating "waste" heat outdoors, and it uses more electricity at peak times, potentially contributing to power outages (see Section 1.2.2.). This can also contribute to increased greenhouse-gas production where electricity is produced using fossil fuels. There are many ways to encourage "passive" cooling (cooling that does not use energy).

Table 5 outlines 35 practical actions to reduce risks from extreme heat. These actions can be broadly categorized into three types:

- **Non-structural** —planning and behavioural changes
- **Green Infrastructure**—using nature to help us stay cool
- **Grey (Built) Infrastructure** —new designs and retrofits that cool buildings and keep infrastructure functioning

Many communities have started adapting to extreme heat conditions,[67,68,69] but urgent action is still required. Health professionals have a central role to play, and a wealth of resources is provided by Health Canada and provincial health organizations. Several actions can only be implemented by those who own property. Tenants and others with fewer resources available to adapt to heat will have fewer options and are often most at risk; these vulnerable groups require specific support.

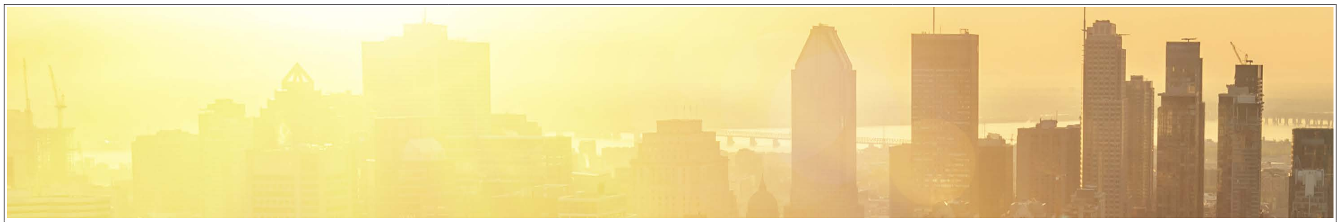
The balance of this chapter describes each action in more detail. The information provided is founded on a review of research and best practices, as well as advice from subject-matter experts. At the end of the report, references are presented in an accessible format, to encourage further reading.

Table 5: Practical adaptation strategies to reduce risks from extreme heat. **This table is interactive.** Click on an action reference (e.g. IND-1) to move to the description in the report. Click on any "Actions" icon (e.g. individuals, property owners and managers, or communities) in the report to return to this table.

Actions by Individuals

Non-structural (planning and behavioural changes)	**Green Infrastructure*** (working with nature)	**Grey Infrastructure** (improving buildings and public infrastructure)
IND-1 Work with neighbours, friends and family to prepare**	**GI-1** Plant and maintain trees	**BI-1** Enhance insulation and airtightness
IND-2 Arrange to receive public heat warnings**	**GI-2** Expand vegetation cover and absorb water to keep gardens and balconies cooler**	**BI-2** Install cool (reflective) roof / wall / paving surfaces
IND-3 Learn how to use natural ventilation**	**GI-3** Install a green (vegetated) roof	**BI-3** Use concrete, brick, stone and tile finishes that absorb heat
IND-4 Minimize "waste" indoor heat production, for example by switching off unused appliances**	**GI-4** Grow a green (vegetated) façade**	**BI-4** Install windows that reduce heat gain from the sun
IND-5 Plan for modified working, living and sleeping arrangements**		**BI-5** Install shading devices (shutters, awnings, overhangs, blinds, heat-resistant curtains) **
		BI-6 Install temperature and humidity monitors or controls**
		BI-7 Use ceiling / portable fan(s)**
		BI-8 Install and maintain air conditioning / heat pump

* In places at risk of wildfire, particularly at the wildland-urban interface, the use of green infrastructure must be considered alongside FireSmart guidance.[70]
** Denotes actions that may be most achievable by tenants and those with fewer resources

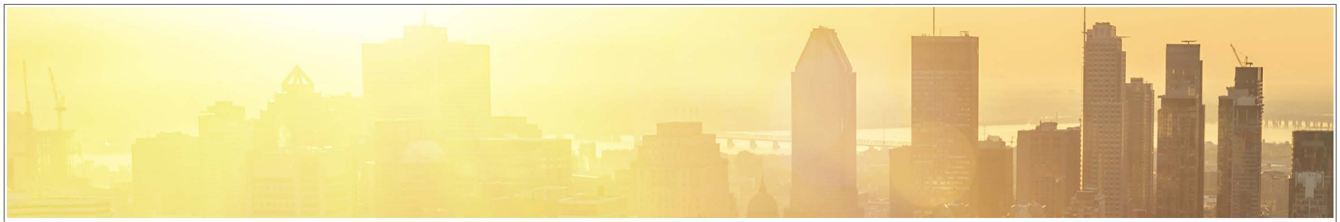


Actions by Property Owners and Managers

(multi-unit residential and commercial buildings)

Non-structural (planning and behavioural changes)	**Green Infrastructure*** (working with nature)	**Grey Infrastructure** (improving buildings and public infrastructure)
PROP-1 Understand building-scale vulnerabilities to extreme heat **PROP-2** Provide information and help occupants adapt **PROP-3** Identify and support vulnerable occupants (e.g. the elderly or those living alone) **PROP-4** Use natural ventilation in common areas **PROP-5** Develop extreme-heat emergency plan with occupants	**GI-1** Plant and maintain trees in grounds and parking lots **GI-2** Expand vegetated areas and absorb water around buildings, on balconies and in parking lots **GI-3** Install a green (vegetated) roof **GI-4** Grow a green (vegetated) façade or wall	**See individuals BI-1 to BI-8, plus:** **BI-9** Install and maintain backup power generation (e.g. to maintain air conditioning in designated "cool" rooms) **BI-10** Arrange for backup water supply during power outages (pumped water supply cannot function properly without power)

* In places at risk of wildfire, particularly at the wildland-urban interface, the use of green infrastructure must be considered alongside FireSmart guidance.[70]



Actions by Communities

Non-structural (planning and behavioural changes)	**Green Infrastructure*** (working with nature)	**Grey Infrastructure** (improving buildings and public infrastructure)
COM-1 Assess and map vulnerability to extreme heat	**GI-1** Plant and maintain trees (including in urban forests, green corridors, and urban parks)	**BI-11** Adapt community infrastructure to extreme heat (e.g. transport, utilities, water supply)
COM-2 Use education and outreach campaigns to encourage preventive action	**GI-2** Expand vegetated areas and water bodies and absorb more water (forming a blue-green infrastructure network)	**BI-12** Reduce vehicular traffic
COM-3 Set up community support programs for vulnerable populations (e.g. underserved communities)		**BI-13** Install "cool" reflective or permeable pavements
COM-4 Require heat-sensitive urban planning, infrastructure design, and operation		**BI-14** Expand artificial shade (e.g. using canopies or shelters)
COM-5 Provide incentives to increase passive cooling and reduce "waste" heat (e.g. by subsidising tree planting or home retrofits)		**BI-15** Install water-based cooling systems (e.g. ponds and sprinklers) and drinking fountains
COM-6 Develop extreme-heat emergency plan		

* In places at risk of wildfire, particularly at the wildland-urban interface, the use of green infrastructure must be considered alongside FireSmart guidance.[70]

** Denotes actions that may be most achievable by tenants and those with fewer resources

3.1

Non-Structural

3.1.1 Individuals (IND)

IND-1: Work with neighbours, friends and family to prepare

Although the risk of heat-related illness, including heat exhaustion and heat stroke, is greater for vulnerable populations (see Section 1.2, Table 3), anyone can be affected. Heat-related deaths are largely preventable through knowledge, education, and adaptive action.[71] By talking to neighbours, friends and family about the risks of extreme heat, and helping them to prepare in advance, everyone can help to avoid heat-related illnesses and deaths.

It is important to communicate with the elderly, people who may be socially isolated, and those who are less able to prepare themselves and their homes (see Table 3). If possible, it is most effective to visit people in person, before a heat event occurs, to discuss their unique circumstances and risks, and then help them take precautions to reduce those risks. Lastly, it is important to help vulnerable people formulate a specific plan about what to do during an extreme-heat event, based on public-health directives. Ideally, the plan should provide for someone to check on the isolated or elderly person regularly, and in-person.

Key additional benefits: Preparing plans with neighbours, friends and family can strengthen community ties and help reduce social isolation.

Potential limitations: Working with others takes time and it may be difficult to get results if people do not appreciate the risks. Many Canadians may be more worried about cold weather than extreme heat. (However, many strategies to increase heat-resilience around the home may also contribute to better overall energy efficiency, ensuring that the house is more comfortable in every season.)

IND-2: Arrange to receive public heat warnings

Environment and Climate Change Canada issues periodic heat warnings across Canada. In collaboration with public-health messaging from Health Canada, these warnings notify the public of extreme-heat conditions, their likely duration, and recommend precautions to protect people against heat-related illnesses during such events.[72] These alerts are broadcast by a variety of media including television, radio, Internet, social media and digital weather applications available for smart phones.

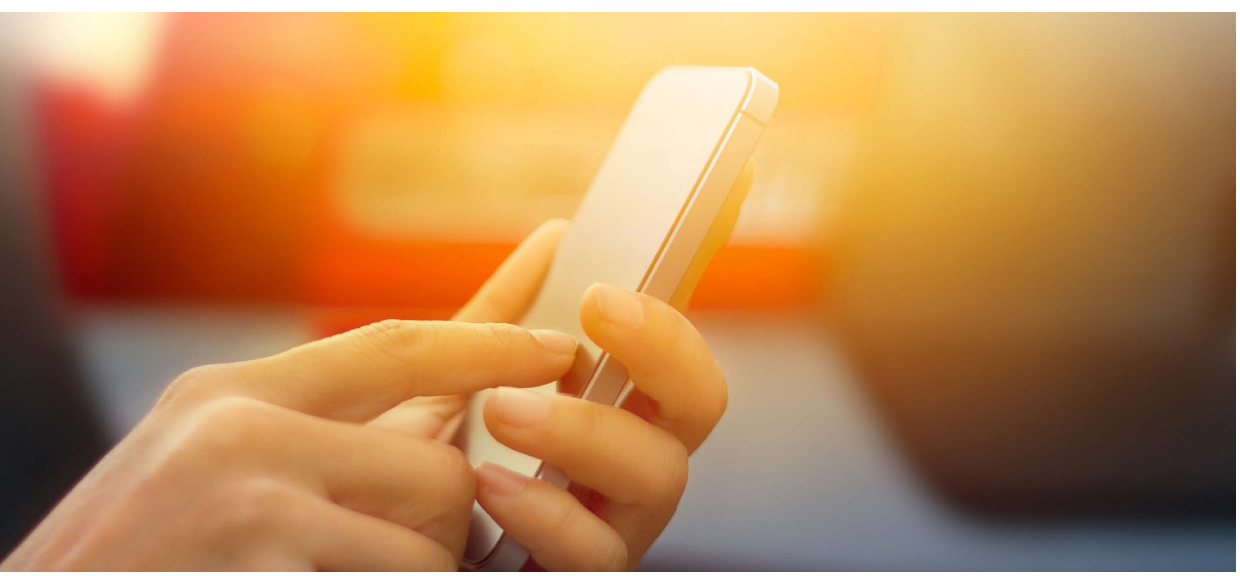
Heat warnings are issued in provinces and territories according to criteria outlined by the federal government, in co-ordination with provincial and territorial health authorities. These criteria are based on regional relationships between climate and health effects, and differ between provinces and territories (Appendix B).[73]

Individuals can receive heat warnings and other weather alerts in English or French directly on their smart phones, by downloading and using Environment and Climate Change Canada's free "WeatherCAN" application, available from Google Play and Apple's App Store.[74] The application sends notifications about weather alerts for your current location, as well as for saved locations anywhere in Canada.

Canada

WeatherCAN

The WeatherCAN app also provides access to MetNotes—short notes written by meteorologists with additional information about weather forecasts. These brief messages may cover the potential impact of the weather, an early heads-up about severe weather, or information for people attending outdoor events affected by weather.[75]



Heat warnings are also reported by other commonly used weather services, but some of these alternatives may rely on the user opening the application, rather than providing alerts. People without smart phones or the Internet can use alternative sources, such as the Weather Network television channel or Environment Canada's Weatheradio network, which broadcasts on the VHF public radio band around the clock.

Key additional benefits: The WeatherCAN application also provides current conditions, hourly and seven-day forecasts for more than 10,000 locations in Canada, a message centre with information relevant to the current weather, and can be displayed in English and French.

Potential limitations: Some at-risk populations, such as the elderly, may not use smart phones. Government heat warnings do not prevent extreme-heat events; they raise awareness about the situation and the need for generic protective measures to reduce the risk of illness. People who do not speak English or French may not understand heat warnings.

Heat warnings provided by WeatherCAN lack community-level information that could support residents, and should ideally be supplemented by more local emergency-response plans. (See Action COM-6).

In Canada, heat events are not named in the same way as hurricanes. The Extreme Heat Resilience Alliance, an international organization, is working to build and activate the international co-operation needed to make it standard practice for countries to name and rank heat waves.[76]

IND-3: Learn how to use natural ventilation

Natural ventilation is a passive measure that encourages air circulation in buildings and can be highly effective in reducing overheating.[77] There are two types of natural ventilation: natural-draft ventilation and cross-ventilation.

Natural-draft ventilation can be created by allowing cooler air to enter a building at its base, or north side, and letting hotter air exit through an opening at the top of the building. This is often very effective at night, when outside air is cooler than indoor air. Cross-ventilation is achieved by opening doors or windows on opposite walls to encourage air currents, and is more effective than single-sided ventilation.

People can learn the best ways to optimize natural ventilation in their buildings or apartments. Where nights are cooler, this may involve opening windows or doors to create natural ventilation at night and early in the morning, and closing them to shut out very hot or humid air—preserving the cooler air inside—during the day. If it is windy, increased ventilation may help people feel more comfortable by circulating air more quickly and cooling the skin through evaporation.[78]

Ventilation at night may be especially important in buildings that make use of thermal mass to passively control heat. Exposed hard surfaces—such as concrete floors, brick, natural stone and tile—can act as a thermal mass that absorbs heat during the day and releases it at night (see Section 3.2). Nighttime ventilation helps to cool these surfaces so that they can absorb heat again the next day.[79]

Key additional benefits: Natural ventilation helps provide fresh oxygen, and can improve air quality, reduce pathogens and alleviate odours.

Potential limitations: For natural ventilation to work, residents may need to make constant adjustments to openings to make the best use of natural ventilation. During heat waves in urban heat islands, if outdoor temperatures and humidity remain high overnight, it may reduce the potential for cooling by natural overnight ventilation. Rising temperatures due to climate change will similarly decrease the potential to use natural ventilation to cool buildings over time.[80] Poor air quality, wildfire smoke or high pollen counts may make it inadvisable to open windows.

The use of natural ventilation is also highly dependent on building design, and is not possible in all buildings. In particular, ventilation designs in multi-unit residential buildings may involve the creation of air pressure in hallways. As a result of the hallway air pressure, when windows are opened in suites, air will tend to exit rather than enter the building. This makes it impossible to create drafts within individual suites.

Even without air pressure in hallways, it is not possible to create cross-ventilation or natural-draft ventilation in suites that have windows only on one side, and at one elevation. In multi-unit buildings, windows may also be inoperable on higher floors for safety reasons.

IND-4: Minimize "waste" indoor heat production

Heat produced by electrical devices increases heat in the home as well as wasting energy. "Waste" heat can be reduced with energy-efficient LED light bulbs that produce almost no heat,[81] and by choosing energy-efficient appliances.[82]

During heat events, appliances and office equipment should be used as little as possible, and all devices not in use should be turned off and not left on standby.[83] "Waste" heat can be minimized by changing some behaviours to avoid generating extra heat. In the home, for example, residents can cook food in a microwave rather than an oven; have cold meals and drinks, instead of heating them; and air-dry clothes and dishes instead of using a dryer or dishwasher.

Key additional benefits: Minimizing "waste" heat will reduce energy consumption and can result in lower energy bills.

Potential limitations: It may be difficult to avoid using some electrical appliances, such as computers.

IND-5: Plan for modified working, living and sleeping arrangements

Extreme heat can make it more difficult to work and sleep. In homes with different rooms and floors, it may be possible to arrange working, living and sleeping areas differently during extreme-heat events so that people can benefit from cooler areas of the house, such as basements, lower floors, and rooms that receive less sunlight (for instance, north-facing rooms). People may also be able to arrange with their employers to work at cooler times of the day.

Key additional benefits: The modification of working or sleeping arrangements may reduce the energy required to cool the home, especially overnight.

Potential limitations: Individual circumstances, including the size of a home, its layout, and the number of residents, may limit people's ability to modify their working and sleeping arrangements.

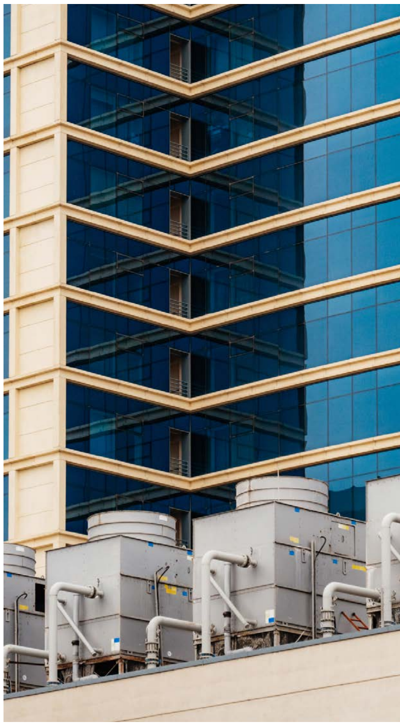
3.1.2 Property Owners and Managers (PROP)

PROP-1: Understand building-scale vulnerabilities to extreme heat

Property owners and managers should assess their buildings to determine specific vulnerabilities to extreme heat, examining their infrastructure, operations, employees and tenants. They can undertake a climate-vulnerability assessment and then develop a climate-adaptation plan; this approach would look at extreme heat alongside other climate-related risks such as floods, wildfire and hail.

Multi-unit residential buildings may have specific vulnerabilities that include:

- Older building infrastructure that was not designed to be resilient to extreme heat
- Higher temperatures on higher floors from solar radiation
- Limited opportunity for natural ventilation, as a result of building design, particularly in buildings with pressurized hallways or where windows do not open wide for safety reasons
- A reliance on a power supply to operate elevators, provide air conditioning, and pump water to higher floors
- Vulnerable residents



Commercial buildings may have additional vulnerabilities , including:

- Specific heat-sensitive equipment such as freezers, data servers and laboratory equipment
- A reliance on a power supply to run the heating, ventilation and air-conditioning (HVAC) system
- Large, sun-exposed parking lots that contribute to locally high outdoor temperatures and the wider urban-heat-island effect

Key additional benefits: Climate-adaptation planning can help property owners and managers adapt to different climate risks and save money in the long term by avoiding damages, business disruption and adverse impacts on tenants.

Potential limitations: If a large building is in an urban heat island, an effective climate-adaptation plan can contribute to reducing the heat-island effect, but wider action within the community will be required to make a significant difference (see Action COM-4).

PROP-2: Provide information and help occupants adapt

Owners and managers of residential buildings can offer information and educational materials to help their tenants act in their own homes and social networks to reduce the risks of extreme heat. (see Section 3.1.1). Information and training may be provided through face-to-face discussions, tenant meetings, newsletters, social media, and posters in common areas and elevators. Property owners and managers can consult with local public health agencies for advice and heat-health educational materials to share.

Commercial tenants will play a significant role in managing indoor temperatures and the heat produced in their spaces. By engaging tenants to carry out best practices, managers can decrease the likelihood of business disruptions. “Green leases” can be useful for building owners and tenants to agree on operations to reduce climate-related impacts, including how to manage heat.

Best practices that tenants may be able to control include:

- Minimizing the production of “waste” indoor heat
- Using natural ventilation (where possible)
- Installing surfaces that may provide a thermal mass to absorb and reduce heat in the daytime (such as concrete, brick, stone and tile surfaces)
- Installing and using indoor shading devices
- Installing and using fans and air conditioning systems/heat pumps

Key additional benefits: Taking the initiative to support occupants can increase their satisfaction with building services and enhance relationships, while also reducing energy consumption in the building.

Potential limitations: Building occupant relationships takes time, and co-operation is required between different parties.

PROP-3: Identify and support vulnerable occupants

Many multi-unit residential buildings are poorly adapted to extreme heat, while also housing vulnerable populations (Table 2). The vulnerability of residents can be reduced by identifying those particularly at risk (including the elderly, people living alone and people with reduced mobility) and offering them specific support. Building managers and/or a "neighbours-helping-neighbours" support network can provide this assistance.

For example, Community Resilience to Extreme Weather (CREW) has developed tools and strategies for people to help each other, training extreme-weather volunteers[84] and strengthening social networks.[85] Its "Extreme Weather Volunteer" program in Toronto includes:

- Information sessions about future extreme weather in Toronto, and what it means for human health
- Workshops to train designated volunteers in neighbourhoods or multi-unit buildings in procedures for weather emergencies such as extreme heat or cold, floods and power outages, and more
- Scenario role-playing
- Roundtable discussions and brainstorming
- Mapping of community-specific risks and assets
- The development of a neighbours-helping-neighbours protocol

Commercial buildings can also help to support vulnerable people in the surrounding community by providing publicly accessible, air-conditioned spaces for temporary relief.

Key additional benefits: Building stronger social networks within buildings can increase resilience to factors far beyond extreme heat. It can also improve the quality of life for residents by creating "virtual villages" in which they are supported.

Potential limitations: Community programs often rely on volunteers. The creation of jobs for "resilience wardens" may better ensure that residents continue to participate.

PROP-4: Use natural ventilation in common areas

As in individual homes, natural ventilation, where possible, can help larger buildings cool down while reducing energy consumption. This is particularly important for buildings where thermal mass (exposed concrete floors, exposed brick, natural stone and tiling) is being used to absorb heat during the day. Property owners and managers should ensure that natural ventilation is used in communal areas to facilitate cooling, where possible. This may be achieved by opening and closing windows at different times of the day, either in person or through automation.

Key additional benefits: Natural ventilation helps provide fresh oxygen, can improve air quality, reduce pathogens and alleviate odours. This may increase the well-being of occupants.

Potential limitations: During heat waves in urban heat islands, if outdoor air temperatures and humidity remain high overnight, the potential for cooling by natural ventilation may be reduced. Rising temperatures due to climate change will similarly decrease the potential to use natural ventilation to cool buildings over time.[86] Poor air quality, wildfire smoke or high pollen counts may also make it inadvisable to open windows.

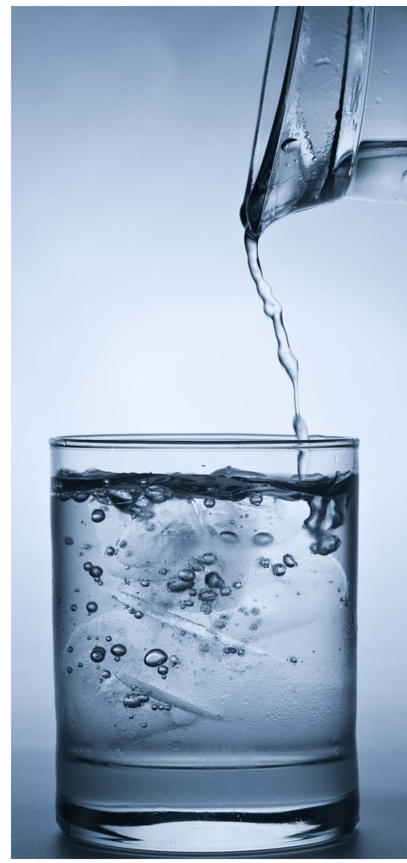
The use of natural ventilation is also highly dependent on building design, and is not possible in all buildings. In particular, ventilation designs in multi-unit residential buildings may involve the creation of air pressure in hallways. As a result of the hallway air pressure, when windows are opened in suites, air will tend to exit rather than enter the building. This makes it impossible to create drafts within individual suites.

Even without this air pressure in hallways, it is not possible to create cross-ventilation or natural-draft ventilation in suites that have windows only on one side, and at one elevation. In multi-unit buildings, windows may also be inoperable on higher floors for safety reasons.

PROP-5: Develop extreme-heat emergency plan with occupants

An emergency plan for extreme-heat events should be developed with tenants alongside the adaptation plan for the building. Emergency planning should consider:

- Cooling rooms or mobile cooling systems, particularly for vulnerable residents in multi-unit residential buildings
- Arrangements to provide drinking water
- How to ensure the uninterrupted operation of critical building infrastructure
- How to operate during power outages
- A communications plan that includes reaching out to vulnerable residents



New tenants must be made aware of the plan regularly. Simulation exercises may help to ensure that everyone is prepared.

In some municipalities, landlords are required by law or policy to offer cooling rooms and to inform tenants of their location. For example, Toronto's "RentSafeTO: Apartment Building Standards Program" requires landlords to tell their tenants how to find their cooling room as well as the closest publicly accessible air-conditioned space.[87]

Key additional benefits: Emergency planning for heat can be part of existing emergency plans and can help build positive tenant relationships.

Potential limitations: Building tenant relationships takes time, and co-operation is required between many different parties to define appropriate roles and responsibilities.

3.1.3 Communities (COM)

COM-1: Assess and map vulnerability to extreme heat

Communities can understand their risks from extreme heat by examining the extent of urban heat islands together with the location of vulnerable populations (Table 2, page 17), infrastructure and natural systems. Several communities in Canada have already developed tools to map heat vulnerability.

Montreal assessed heat risk as part of its Climate Change Adaptation Plan for 2015-2020. The location of intra-urban heat islands was mapped using an analysis of surface temperatures calculated from satellite imagery. Montreal has defined an intra-urban heat island as "a place in an urban environment where the air temperature is higher than elsewhere, with the effect of increasing the heat felt locally." Additional maps were developed to show social, territorial (infrastructural) and environmental sensitivity to heat. The indicators were then combined to show the overall vulnerability to heat waves across the metropolitan area (Fig. 9).[88]

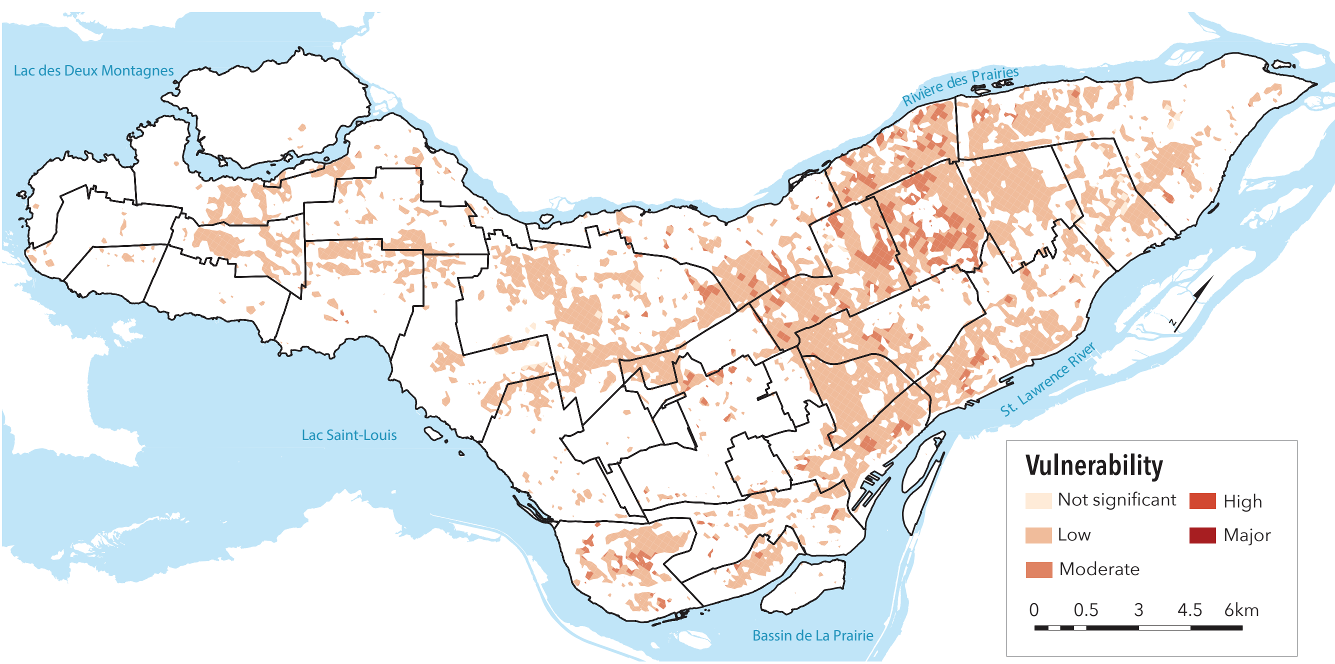


Figure 9. Vulnerability to heat waves in the Montreal metropolitan area (Source: Ville de Montréal, 2017.)[89]

The City of Toronto has also developed an interactive map for the public that can be used to explore areas of vulnerability to heat, the locations of public cooling spaces and services, and statistics relating to populations at risk (for example, seniors, seniors living alone, low-income residents, and those in rental buildings of more than five storeys).[90]

In British Columbia, Vancouver Coastal Health has developed seven regional maps illustrating vulnerability to higher summer temperatures.[91] In Quebec, Laval University has produced an atlas of climate vulnerability for municipal areas of the province that includes vulnerability to heat waves.[92]

Key additional benefits: Assessing the heat-sensitivity of different geographical areas can help to identify where different adaptive actions should be prioritized. Making such information publicly accessible can raise awareness and help people understand the specific risks in their areas.

Potential limitations: Assessments need to be updated regularly to demonstrate how vulnerability to urban overheating evolves over time. This is required to reflect changes in climatic conditions as well as changes in the community's capacity to adapt.

COM-2: Use education and outreach campaigns to encourage preventive action

Communities can provide information for different stakeholders about the risks of extreme heat, and preventive measures that can reduce these risks before an extreme-heat event occurs. Often, public-service messages focus on ways to protect people in a heat wave (such as staying hydrated, seeking shade and checking on neighbours). There is often less information about how to reduce risks ahead of time, by adapting and planning.

Outreach may target specific areas identified as highly vulnerable to heat (Action COM-1), as well as people involved in urban planning and building design.

This report identifies specific actions for individuals and building owners or managers (Table 1) that could form the basis of education and outreach campaigns designed to encourage preventive action.

photo: preventioncdnndg.org

Additional sources of information include:

- The website Climate Resilient Home (www.climateresilienthome.ca)
- BC Housing's "Design Discussion Primer – Heat Waves"[93]

- The booklet "Protect your home from: Extreme heat" by the Institute of Catastrophic Loss Reduction[94]
- The Canadian Red Cross's website "Heat Waves: Before, During & After"[95]
- The Vivre en Ville website feature "Construire avec le Climat" (Build with the Climate) designed to inform real-estate developers[96]

A wealth of other resources is identified in the References section.

Key additional benefits: Outreach about reducing risks from extreme heat can be combined effectively with existing campaigns focused on energy efficiency, as several of the actions for buildings are the same. Information about extreme heat may also be combined with that for other climate-related risks, such as flooding and wildfire.

There are also opportunities to engage young people in campaigns to raise awareness about extreme heat. In Montreal for example, the "Green Patrol" is a group of about 50 students that engages with the public about issues including climate change, heat-wave impacts, and community resilience.[97] The city has made a commitment to continue the initiative as part of its 2020–2030 climate plan.[98]

Potential limitations: Information does not necessarily lead to action. Follow-up surveys are needed to monitor and improve the effectiveness of outreach campaigns in producing the actions desired.

COM-3: Set up community support programs for vulnerable populations

Many cities leverage their emergency services to assist vulnerable populations during heat events. For example, the public health authority in Montreal maintains a list of the addresses and telephone numbers of vulnerable people and places, including private residences, seniors' homes and shelters for the homeless. Door-to-door visits and automated calls are made by public security staff during heat events.[99]

In addition, municipalities may support community-led initiatives that strengthen social networks and encourage help among neighbours. For example, the Quebec Network of Healthy Cities and Towns developed the "Voisins solidaires" program, which recommends ways to connect, and strengthen relationships, with people in the same community, focusing on seniors. [100]

Key additional benefits: Building stronger social networks within communities can increase resilience to factors far beyond extreme heat, and improve the quality of life for residents.

Potential limitations: Many "checking-in" programs for vulnerable populations focus on what to do during an extreme-heat event; they could be expanded to develop adaptation strategies in advance. Community relationships take time to build, and co-operation is required between many different parties. In-person check-in programs also require available staff or volunteers to deliver them.

COM-4: Require heat-sensitive urban planning, infrastructure design, and operation

Reducing the urban-heat-island effect requires the combination of several measures deployed on a large scale. Strategic urban planning is therefore vital, in relation to both the natural and built environment. For example, strategic planning is required to create publicly accessible "green" urban corridors or to make the most of the cooling benefits of wind, by planning developments to promote air circulation. Strategic approaches can be supported by guidelines and protocols for urban development and long-term infrastructure management plans.

Municipalities may choose to make heat-resilient development a legal requirement. Green roofs are a leading example:

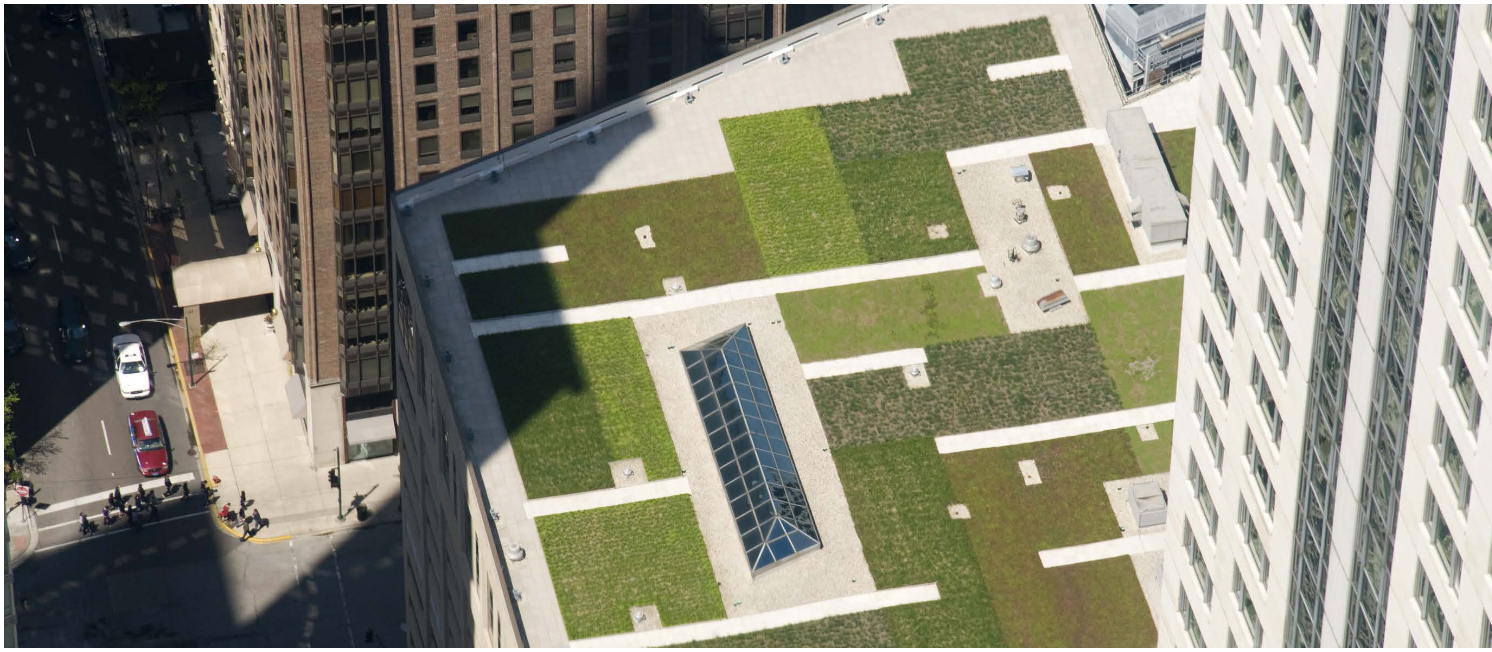
1. In 2006, Port Coquitlam, BC was the first Canadian municipality to require green roofs for commercial or industrial buildings of 5,000 square metres or more.

2. In 2009, the City of Toronto, ON adopted a bylaw requiring new buildings or additions to have green roofs on 20 to 60 per cent of the available roof space; it applies to commercial, institutional and residential buildings with a minimum gross floor area of 2,000 square metres.[101]

3. In Montreal, QC the borough of Rosemont–La-Petite-Patrie requires either a green roof, or a cool roof, when a flat or shallow-sloped roof is newly built or renovated.[102]

4. The City of Gatineau, QC passed a similar bylaw in 2020. Gatineau also requires islands of greenery in parking lots, and trees and permeable ground in school playgrounds.[103]

The way that buildings are operated can also affect the safety of their occupants. Some jurisdictions may require building owners or managers to keep indoor temperatures within a certain range, or provide cooling rooms. There is currently no consistent national standard for maximum indoor temperature in Canada. However, the Canadian Centre for Occupational Health and Safety maintains fact sheets about legislation in different jurisdictions,[104] guidelines for workers[105] and guidelines for office work.[106]



In addition to legal approaches, communities may use a variety of official standards, guidelines and certification programs in their efforts to reduce urban heat. Canadian heat-related standards, and guidelines for reducing heat, include:

- BNQ 3019-190 Guidelines – Reducing the Urban Heat Island Effect – Parking Lot Development – Design Guidance (Bureau de normalisation du Québec)[107]
- Thermally Comfortable Playgrounds: A review of literature and survey of experts (Standards Council of Canada)[108]
- CSA Z1010-18: Management of work in extreme conditions (Canadian Standards Association)[109]

Certification programs that are associated with particular standards or guidelines may encourage stakeholders to act. For example, "Eco-Responsible Parking (Stationnement écoresponsable)," based on Quebec's BNQ 3019-190, gives businesses the opportunity to promote their efforts to their customers.

International certification schemes that may be useful in urban planning for heat-resilience include the LEED (Leadership in Energy and Environmental Design) rating system for buildings[110] and the Envision framework from the Institute for Sustainable

Infrastructure, which specifically assesses the climate-resilience of various types of infrastructure—including water, energy, waste, transportation, information and natural infrastructure.[111]

Key additional benefits: Strategic urban planning to tackle urban heat can form part of a municipal climate-adaptation plan or sustainability plan, and typically delivers several social, environmental, and financial co-benefits. Several non-government organizations (NGOs) and consultancies can offer specialist expertise to support communities.

Potential limitations: Strategic urban planning for heat resilience requires co-operation between several different municipal departments and stakeholders. Strategic planning is also challenging to implement in existing urban areas that are already highly developed. The necessary specialists may be unavailable in some municipalities. There are few design standards relating to extreme heat in Canada, and overheating is yet to be addressed by the National Building Code of Canada.

COM-5: Provide incentives to increase passive cooling and reduce "waste" heat

Actions to prevent or reduce the risks from extreme heat can be encouraged with incentives such as subsidies and rebates. Several incentives are available through different organizations across Canada to improve energy efficiency, without acknowledging their potential contribution to reducing the risks of extreme heat.

For example, the Canada Greener Homes Grant provides rebates for building retrofits or renovations that improve energy efficiency, but currently does not mention that the eligible retrofits may help control indoor temperatures during extreme-heat events.[112]

The related EnerGuide home evaluation could be used to identify benefits related to heat resilience.[113] Natural Resources Canada also maintains a database of energy-efficiency programs with incentives across the country.[114]

Some municipalities offer incentives for green infrastructure initiatives, including:

- City of Toronto: the Eco-Roof Incentive Program subsidizes the installation of green and cool roofs.[115]
- City of Ottawa: the Trees in Trust program provides tree-planting on private property in exchange for three years of tree care by the property owner; the

Schoolyard Tree Planting Grant Program provides grants to support tree-planting in schoolyards.[116]

- City of Montreal: the program "Un arbre pour mon quartier Soverdi," supported by the city, invites residents to plant one or more trees on their land, and will subsidize the cost.[117]

Communities may also encourage citizens to participate in programs from major utility companies that offer customers subsidies for reducing indoor waste heat and improving heat control in their buildings.

Key additional benefits: Many actions that increase energy efficiency also reduce energy use and costs for individuals and building owners, while improving heat control in buildings and reducing greenhouse-gas emissions.

Potential limitations: At present, incentive programs rarely mention the beneficial link between boosting energy efficiency and reducing the risks of heat-related illnesses. The effectiveness of incentive plans depends on how many people choose to participate.

COM-6: Develop extreme-heat emergency plan

Every community should prepare for future climate-related rising temperatures by creating an emergency-response plan for extreme heat. Emergency plans rely on the collaboration and co-ordination of several stakeholders including emergency services, non-profit organizations, volunteers, government, and media outlets.[118] In particular, organizations representative of the population groups at greatest risk should be involved in emergency planning to reflect specific needs.

Emergency plans may consider thresholds for action that are based on regional relationships between health effects and climate. For example, in Quebec, special weather statements are issued to public health units based on the provincial SUPREME system established by the Institut national de santé publique du Québec (INSPQ), using criteria specific to different regions of Quebec.[119]

Specific plans for heat waves can encompass many components, including securing the additional human resources required to respond; the broadcast of public-information messages about how to protect oneself during a heat wave; how to respond to power outages, and "check-in" programs for vulnerable populations

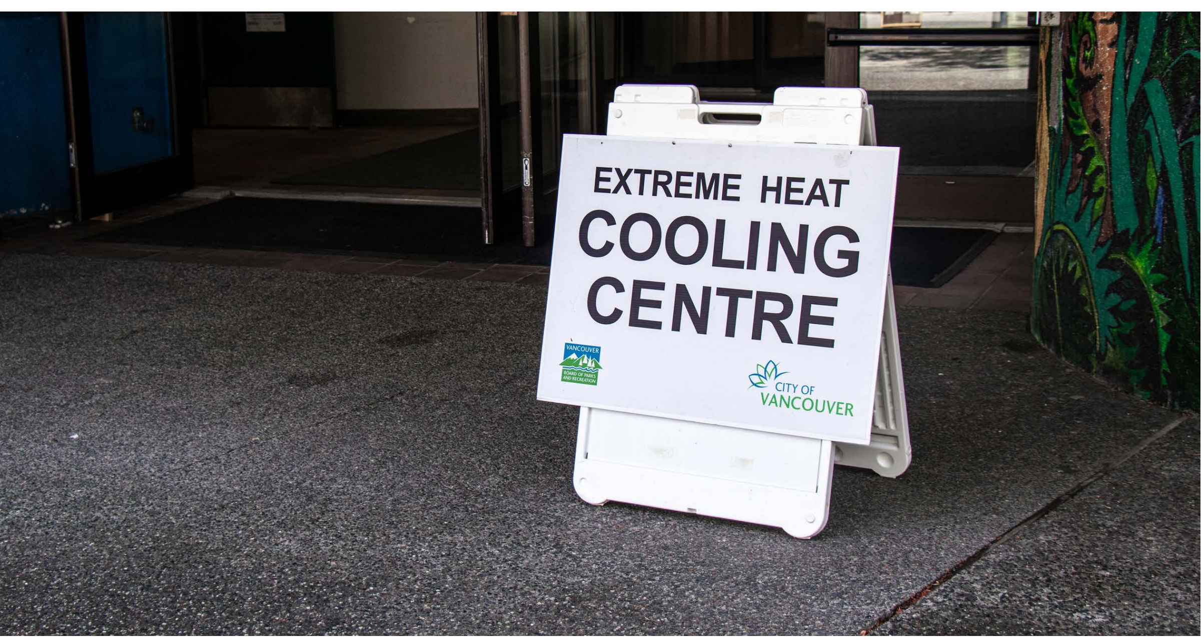
(Action COM-3). Health Canada offers specific guidance for communities about "Heat Alert and Response Systems."[120]

Community emergency response plans may include:

- Extending the opening hours of beaches, swimming pools and water parks or games, and certain air-conditioned municipal buildings such as libraries or town halls
- Opening cooling or refreshment centres. Many cities have interactive maps showing the location of cooling centres.[121]
- Visiting children's day camps to remind people of preventive measures.
- Visiting groups of municipal workers who are most at risk.
- Offering free public transportation to travel to air-conditioned places.
- Offering free drinking water in all municipal areas.
- Appealing to owners and managers of apartment buildings to check their tenants to ensure that their health does not deteriorate.
- Establishing patrols in the most disadvantaged areas of the community to distribute bottled water and provide assistance as needed.

Key additional benefits: Emergency response planning can help bring together the different parties that are also required to take preventative action to reduce risk before an extreme-heat event.

Potential limitations: Emergency planning does not address the underlying causes of the urban heat island effect. Preventative action is required to reduce risk in advance of an extreme-heat event, as well as planning how to respond to an emergency situation.



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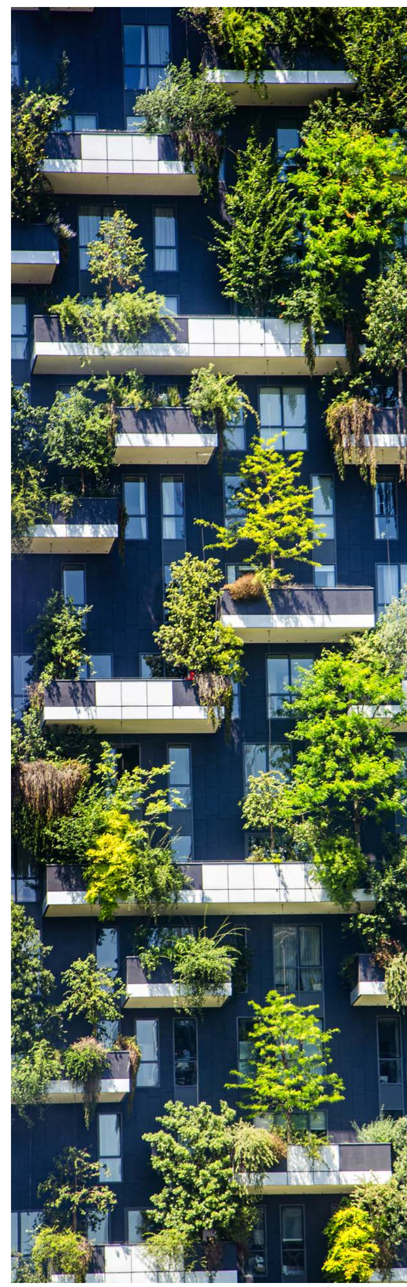
3.2

Green Infrastructure (GI)

3.2.1 Using Nature

GI-1: Plant and maintain trees



Deciduous trees can be planted and maintained to provide shade, particularly along the south, east and west sides of low-rise homes and buildings, while still allowing heating by the sun in winter. High-rise buildings can be designed to support cooling vegetation on balconies, as demonstrated by the Bosco Verticale (Vertical Forest) residential towers in the centre of Milan.[122] Canada's first "vertical forest" is planned for Toronto in 2023, as part of the Designer's Walk development near Davenport Road and Bedford Road.[123]

Trees help to cool areas by providing shade and through evapotranspiration (when water produced by the tree evaporates from its leaves, cooling the surrounding air).[124] Some tree species are more effective than others – species with both a high leaf-area density and a high transpiration rate are more effective at cooling the air.[125] Existing mature trees should be maintained and well cared for; excessive pruning and damage to roots should be avoided. A selection of different native species that are well adapted to regional and future climate conditions should be used, [126] as diversity can help to maintain the urban forest in the long term.[127] In areas with limited space, such as balconies, shrubs may be grown.

Many communities are planting trees on a large scale to reduce the urban-heat-island effect. For example, in 2020, the City of Brampton approved a program to plant one million trees by 2040.[128] Montreal's Climate Plan 2020-2030 aims to, "plant, maintain and protect 500,000 trees, especially in zones vulnerable to heat waves."[129] Trees and vegetation may also be planted and maintained in strategic green or "cooling" corridors, including along urban river valleys.[130]

Key additional benefits: Trees and vegetation promote physical and mental health for urban residents alongside the protection they offer from extreme heat. [131,132] According to several studies, the shade provided by trees and vegetation can decrease indoor air temperatures enough to reduce the energy required to cool the building, reducing costs.[133] Conifers may help protect homes from cold winds in the winter.[134]

Toronto's urban forest contributes to energy savings of $6.42-million annually through shading and climate moderation, the city and Toronto-Dominion Bank have reported.[135] The presence of mature trees can also increase property values.[136] Trees and vegetation also store and sequester carbon, improve air quality,[137] and contribute to local wildlife habitat and biodiversity.[138] There is an opportunity for communities to partner with the Government of Canada, which has committed to planting two billion trees over the next 10 years.[139]

$6.42-million

Annual energy savings provided by urban forest shading and climate moderation in Toronto.

Potential limitations: Younger trees do not initially offer the same benefits as mature trees and need to be well cared for and watered to help them grow over time. Trees and vegetation compete for space with other activities in gardens, on balconies, around buildings and in communities. Increasing the tree canopy may also unintentionally displace marginalized populations living in neighbourhoods that have traditionally been underserved by natural infrastructure, and who cannot afford increasing property values. Pollen from certain species of trees, in particular birch and alder, may cause allergic reactions.[140]

Dense trees may block beneficial winds that can contribute to natural ventilation and help to reduce air pollution at street level.[141] When planting trees, water and sewer pipes and electric cables should be avoided.

Tree-planting in places at risk of wildfire, particularly at the wildland-urban interface, must be done with care. According to FireSmart guidance,[142] deciduous trees and shrubs should be kept at least 1.5 metres away from buildings. Conifers should be avoided within 10 metres of buildings. In the area 10 metres to 100 metres away from buildings, single trees or groups of trees should have at least three metres of space between their outermost branches; the lower branches of conifers should be removed to a height of two metres from the ground.

GI-2: Expand vegetation cover and absorb water to keep gardens and balconies cooler

Artificial surfaces absorb, store, and re-emit more solar radiation or heat than natural and vegetated surfaces. To reduce heat on an individual property or building lot, artificial surfaces should be reduced in size and vegetation should be increased on the grounds, in gardens and parking areas -- and even on balconies and terraces, where plants may be grown in containers.

Replacing artificial surfaces with vegetation also helps retain and absorb water, and increases the moisture content of soil. Through evaporation, wet soils have cooling capacities similar to those of vegetation, and therefore provide more cooling than dry soils.[143] Water absorption can be encouraged by using permeable vegetated surfaces on paths and in parking areas (including grass and vegetated permeable paving). Rain gardens can also increase the absorption and retention of surface water.[144]

At the larger community level, vegetation, rivers, and wetlands can be a strategic component of public infrastructure, often referred to as "blue-green" infrastructure. Communities and organizations can support residents in creating green alleyways or streets, and protecting and linking important wildlife habitats such as urban forests. These activities can complement de-paving initiatives, the creation of ecological corridors, and projects to restore wetlands and river corridors.

Examples of initiatives that bring more vegetation into urban areas include:

- The "Depave Paradise" project by Green Communities Canada that supports volunteers and neighbourhoods in replacing unwanted pavement with gardens of native plants.[145]
- The "Greening Canada School Grounds" program by Tree Canada that has improved 700 schoolyards since 1992.[146]
- The "Butterfly Way Project" by the David Suzuki Foundation created pollinator gardens in more than 400 communities across Canada in 2021.[147]
- The "Green Alleyway Support Program" in the City of Montreal that has supported neighbourhoods in creating at least 444 green alleyways in city.[148] [149]
- The use of "Natural Heritage System" planning by municipalities and river-basin organizations in Ontario to identify opportunities to enhance natural systems.[150] [151]
- The "Rain City Strategy" in Vancouver, which uses green infrastructure to soak up and manage rainwater.[152]

Communities can create more space for natural infrastructure by reducing the space taken up by built infrastructure. For example, open-air parking lots can be replaced with underground or multi-storey parking lots.

More than 30 Canadian municipalities have also made inventories of the natural assets within their jurisdictions that help to regulate temperatures. These municipalities are actively managing their natural assets alongside their built infrastructure as part of regular municipal asset management.[153]

Key additional benefits: Blue-green infrastructure can enhance stormwater management by retaining water, which helps to protect communities against flooding and erosion. It can also remove pollutants, which reduces water-treatment costs. Blue-green corridors also enhance habitats and biodiversity, and can provide opportunities for recreation, walking and cycling, when combined with foot paths and bike lanes.

Community greening projects, such as green alleyways, can help strengthen community relationships and support mental well-being.[154] And fruit and vegetable gardens, on balconies, in yards or on public land, can help control local temperatures as well as provide food.

Potential limitations: In large urban centres, high land costs and constraints on land use may make it difficult and expensive to reintroduce vegetation and water bodies. In areas at risk of wildfire, particularly at the wildand-urban interface, vegetation should be kept 1.5 metres away from buildings. Vegetation in the area between 1.5 metres and 10 metres from buildings should be fire-resistant, and grass should be no longer than 10 centimetres.

During prolonged, dry extreme-heat events, soils and rain gardens will dry out and their ability to reduce temperatures will decrease with time. Water bodies retain heat, and may exacerbate heat stress during oppressive (humid) conditions at night. Their ability to cool the local environment will also decrease through the day and through the summer.[155]

3.2.2 Green Buildings

GI-3: Install a green (vegetated) roof

A green roof is a layer of vegetation grown on top of a roof, covering a portion of the roof or its entirety.[156] Green roofs are used to replace traditional, heat-absorbing roofing materials with plants, shrubs, and small trees. The construction of green roofs can be complex, but typically includes high-quality waterproofing, a root-repellent system, a drainage system, filter cloth, a lightweight growing medium, and plants.[157]

Compared with traditional roofs, green roofs have cooler surfaces and transfer less heat to the inside of the building. Water absorbed by soil and plants on the roof is evaporated, which helps to cool the surface. The plants also provide some shade, which lowers the surface temperature. The soil also provides extra insulation, which helps to reduce the transfer of heat to the interior of the building.[158]

Green roofs may be extensive (shallower and simpler with low-lying plants) or intensive (deeper and more complex, supporting a variety of plants similar to a garden). Numerous communities and research centres have compared the surface temperatures of green roofs and conventional roofs. A New York study found that at peak daytime temperatures, the surface temperature of green roofs was on average $33^{\circ}C$ cooler than the surface of traditional roofs.[159] [160] [161] A Chicago study found that on a hot August day the air temperature one metre above a green roof was $3.9^{\circ}C$ lower than the temperature above an adjacent traditional black roof.[162] Green roofs are now required in some Canadian municipalities (see Action COM-4).

6-10%

Overall energy cost savings due to Walmart's 6,970-square-metre green roof in Chicago.

Key additional benefits: Although the costs of building and maintaining green roofs may exceed those of conventional roofs in the short term, they generally last about two or three times longer than conventional roof surfaces.[163]

Green roofs may help reduce energy use and costs. A study by Walmart for a single-storey store in Chicago found that a 6,970-square-metre green roof reduced the energy required to heat the building by 6 per cent to 11 per cent, and cut the energy required to cool it by 7 per cent to 15 per cent. The result was an overall cost savings of between 6 per cent and 10 per cent when compared with Walmart's standard white roof.[164]

Intensive green roofs can create outdoor garden spaces for residents. They reduce stormwater runoff by capturing rainwater in the substrate and increasing rates of evapotranspiration. The plants on green roofs can also capture airborne pollutants, improving air quality.[165] In certain places, green roofs may be eligible for subsidies.[166] [167]

Potential limitations: The National Building Code does not address the construction of green roofs, and provincial standards for their construction may differ.[168] In some communities, changes to bylaws may be required in order to permit green roofs. Professional advice is required when installing a green roof to ensure that the extra weight can be supported and the roof is functional.

Green roofs may be expensive to install. Prices will vary, depending on the type, location, materials, and design.[169] Appropriate maintenance is critical, especially for intensive green roof designs. In drought conditions, green roofs may be difficult to maintain, and may require irrigation. Because they are combustible, and can increase the risk of wildfire, green roofs are not appropriate in wildland-urban interface areas.

GI-4: Install a green (vegetated) facade

A green façade uses climbing plants to cover a wall, reducing the temperature of the building envelope and increasing its thermal mass, which helps to reduce the transfer of heat to indoor spaces. Care should be taken to avoid invasive species and choose appropriate climbing plants such as Boston ivy, Virginia creeper, climbing honeysuckle, or climbing hydrangea.[170] Limited space is required at the foot of the wall for the plants' roots.[171]

Another cooling mechanism is a green or "living" wall. Living wall systems consist of pre-vegetated panels, modules, blankets or bags affixed to a structural wall or free-standing frame. These modules are designed to support a greater diversity and density of plant species than green façades.[172]

Green walls can reduce temperature fluctuations at the wall's surface to a range of 5°C to 30°C, compared with fluctuations of 10°C to 60°C for an ordinary wall. In turn, this limits the transfer of heat through the wall from the outside to the inside. Green walls achieve this by trapping a layer of air within the mass of plants, by reducing the ambient outdoor temperature through evapotranspiration and shading, and by creating a buffer against wind during the winter months.[173]

Key additional benefits: Climbing plants on green façades and walls take up little space on the ground, and may protect the surface of the building from sunlight, wind and rain.[174] Green façades are also aesthetically pleasing and contribute to local biodiversity, and some climbing plants produce edible fruits such as grapes and beans.

Potential limitations: Some climbing plants, such as those using tendrils or hooks, may require support in the form of a trellis or wires. If the plants need to be removed from the wall at any point, this must be done carefully to avoid damage.

Living walls may be more challenging to maintain than green façades; watering, for instance, may be more difficult because some plant roots are located higher up on the wall.[175] Green façades and walls must be designed for the cold winters in Canada with appropriate plant species, and in order to avoid freezing irrigation pipes or cisterns.[176]

They may also be difficult to maintain in droughts, and are not appropriate in wildland-urban interface areas as they are combustible and increase wildfire risk to buildings.[177]

3.3

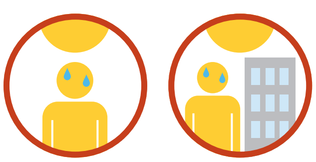
Grey (Built) Infrastructure (BI)

Adaptation to extreme heat using grey, or built, infrastructure includes retrofitting existing infrastructure and considering extreme-heat resilience in the design of new infrastructure. Actions described in this section are largely focused on practical measures that individuals, property owners and managers, and communities can apply to retrofit existing infrastructure, since heat-resilient design for new buildings (which may include orientation, ventilation, window-to-wall ratios and thermal mass) is a professional discipline of its own.

The grey-infrastructure actions have been organized according to the following different types of approaches:

- Passive cooling for buildings (does not require power)
- Active cooling for buildings
- Emergency preparedness of buildings
- Community infrastructure

3.3.1 Passive Cooling for Buildings



BI-1: Enhance insulation and airtightness

Effective insulation in a building can enhance its ability to regulate the indoor temperature, helping to keep hot air out in summer and cold air out in winter.[178] Insulating the exterior walls, basement and attic space will control the transfer of heat. Air leakage can be reduced by using sealants around potential weak points such as windows, doors, cracks in the walls, interior trim and ceiling light fixtures.[179]

In addition to these measures, owners of multi-unit residential or commercial buildings should consider insulating hallways, lobbies, elevator shafts, stairwells, loading docks, service rooms and other common areas.

Key additional benefits: Insulating a house and making it airtight can improve its overall energy efficiency; the home will require less heating in winter and, where air conditioning is used, less cooling in summer, saving on costs. An EnerGuide home evaluation can help Canadian homeowners identify retrofits that can improve their insulation and airtightness.[180] Some expenses for insulating and sealing a house may be eligible for reimbursement under the Canada Greener Homes Grant program.[181]

Potential limitations: If a building is not well designed (for instance, with respect to its orientation, ventilation, window-to-wall ratios and thermal mass), and its insulation and airtightness are improved, unwanted hot air could be trapped inside, making overheating worse.[182] Inadequate ventilation in a building could also result in condensation, mould, and poor air quality.[183]

BI-2: Install "cool" (reflective) roof / wall / paving surfaces

Cool roofs, walls and paving surfaces reflect more solar radiation and sunlight and absorb less heat than their conventional counterparts. Roof and pavements, in particular, have historically been made with dark, heat-retaining materials such as asphalt shingles and tar. These materials absorb large amounts of solar radiation.

Cool roofs, walls and paving surfaces use light-coloured materials or reflective coatings to reflect sun and heat away from the surface, which results in a lower temperature.[184] For example, on a very hot day with an outdoor temperature of 38°C, a traditional roof can reach a temperature of 66°C or more. A cool roof under the same conditions may be more than 28°C cooler.[185]

In parking lots, reflective paving surfaces can help to cool surface temperatures. Permeable parking surfaces, such as gravel, can also absorb water and help to cool the ambient air through evaporation.

Key additional benefits: Cool roofs and walls help reduce the cost of energy required for cooling in air-conditioned homes.

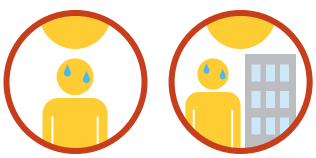
Potential limitations: Cool roofs may become less effective with the accumulation of dirt and dust, and therefore must be maintained. Cool roofs and walls may increase residential heating costs in the winter. In cooler Canadian climates, they will therefore likely have a smaller overall impact on household energy efficiency.[186] However, as temperatures increase with climate change, this limitation will likely become less significant.

BI-3: Use concrete, brick, stone and tile finishes that absorb heat

Concrete, brick, stone and tile finishes are referred to as "thermal mass." These surfaces absorb heat during the day and release it at night, helping to regulate air temperature by retaining heat in winter and staying cool in the summer. Thermal masses should be located where they can absorb heat energy from the lower-angle sun in the winter, and be hidden from higher-angle sun in the summer, under overhangs.[187] [188]

Key additional benefits: The use of thermal masses can reduce the energy required for cooling, thereby reducing costs.

Potential limitations: Thermal mass surfaces may require night ventilation to cool them down so they are ready for the next day. Some exposed surfaces may be too cold for comfort (for instance, for bare feet).



BI-4: Install windows that reduce heat gain from the sun

Windows, glass doors and skylights are one of the primary ways that heat moves into buildings. High-performance glazing, or glass, can significantly improve indoor temperatures by reducing the amount of heat transferred into the building.

Features that achieve this include double and triple layers of glass, inert gas fillings (such as argon and krypton) between layers, insulated frames, and low-conductivity edge seals. Low emissivity (low-E) coatings on glass are also effective in reducing heat gain from the sun.[189] A lower-cost alternative is heat-controlling window films.

Key additional benefits: Using high-performance glass in windows, doors and skylights can improve the overall energy efficiency of a home, reducing heating requirements and costs in winter and keeping the home cooler in summer. The installation of energy-efficient windows and doors may be eligible for reimbursement under the Canada Greener Homes Grant program.[190]

Potential limitations: Heat-resilient glazing can be a costly investment. To avoid trapping unwanted heat inside a building, the building's design characteristics and internal heat gains should be considered before installing windows that reduce the transfer of heat.[191]

BI-5: Install shading devices

Devices that shade windows can help to reduce the heat entering a building where shade is not provided by trees. Trees and exterior devices such as shutters, awnings and overhangs are more effective at providing shade than indoor apparatus, because they block solar heat before it reaches the glass.[192, 193] Indoor blinds and curtains are less effective but easy to operate, and several models are designed specifically to limit heat.

Key additional benefits: Shading devices can reach areas that are not shaded by trees or other vegetation, and can improve privacy, particularly at night when lights are on in the home. Some indoor shades have electronic settings that can be adjusted for weather conditions, time of day and activities taking place in the home.

Potential limitations: External shading devices are not common in Canada at present. Some shading devices may restrict light, natural ventilation, and views outside the building, particularly if they are fixed in place.

3.3.2 Active Cooling for Buildings

BI-6: Install temperature and humidity monitors or controls

During extreme-heat events it is important to monitor both the temperature and the relative humidity level inside and outside a building. This information can alert people to conditions that create a high risk of heat-related illness, so that they can take further precautions to protect themselves and others. “Smart” thermostats can automatically activate air conditioning and ventilation when the temperature and humidity reach certain thresholds, and avoid wasting electricity when cooling is not required.

Key additional benefits: Using a thermostat that can be programmed to control temperature and air conditioning can reduce energy requirements and may result in cost savings.

Potential limitations: Temperature / humidity monitors do not themselves help to reduce extreme-heat conditions unless they are linked to the operation of air conditioning or other cooling systems.

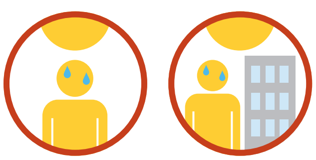
BI-7: Use ceiling or portable fans

Increased ventilation can help homeowners and tenants feel more comfortable by increasing the movement of air, which also helps to cool the skin through evaporation.[194] In the summer, ceiling fans should rotate counter-clockwise, so that the blades push air down to create a wind-chill effect that makes occupants feel cooler.[195]

Key additional benefits: Fans may be used with air conditioning to help circulate cooled air and use less energy.[196] In the winter, ceiling fans can be operated clockwise to help circulate warm air, which may conserve energy and reduce costs.[197]

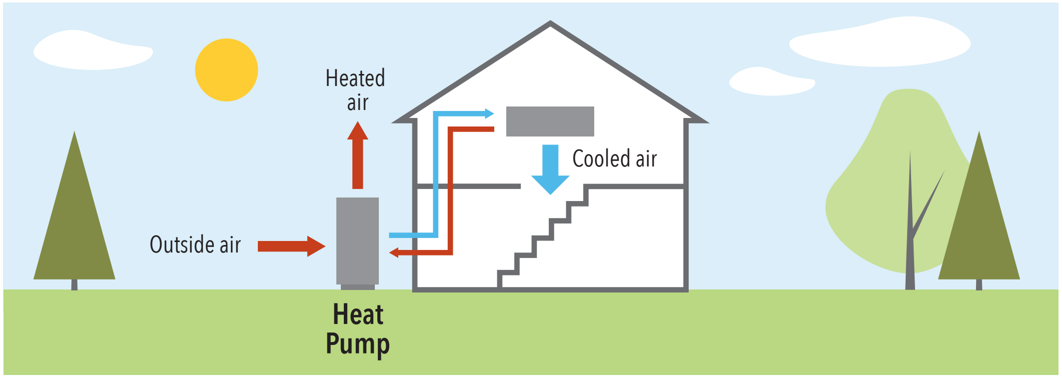
Potential limitations: Ceiling fans and portable fans do not lower room temperatures, and they may be counterproductive when the air temperature is very hot.[198 199]

Regardless of humidity levels, the maximum temperature for the safe use of fans is 39°C for healthy adults 18 to 40 years old; 38°C for healthy adults under 65; and 37°C for older adults who take certain medications.[200]



BI-8: Install and maintain air conditioning or heat pumps

Air conditioning can help people keep cool during extreme-heat events. However, all the factors that may contribute to indoor heat should be addressed before the requirement for air conditioning is determined. Actions to minimize indoor heat can significantly reduce the need for air conditioning. Air conditioning or heat pumps may be installed in specific rooms or as a centralized system. Heat pumps supply heat in the winter and cooling in the summer, and in some cases, they heat water.[201] Professional advice is recommended.



Air conditioning systems, like furnaces, should be maintained regularly to ensure that they are working properly and also efficiently.[202] Experts advise the following steps:

- Clean the air filters at least once each season. A dirty air filter reduces airflow and, in some cases, this could damage the air-conditioning unit.
- Keep the condenser clean and free of leaves and other debris
- Clean drain holes or tubes that become blocked
- If the unit's performance seems to have deteriorated, have it serviced. A small loss of refrigerant can cause a significant drop in efficiency. It is important to have leaks fixed, and refrigerant should be recycled.

In multi-unit residential and commercial buildings, cooling rooms can give residents or workers access to air conditioning; cooling rooms are mandated for multi-unit residential buildings in some locations, including Toronto.

Air conditioning is also required in buildings such as health-care facilities and long-term care homes. Additionally, many municipalities have developed and promoted cooling centres for use during extreme-heat events, such as libraries, shopping malls, community centres and other existing air-conditioned locations.

Key additional benefits: Heat pumps can cool buildings as well as heat them. A heat pump may be a good choice when an air-conditioning or heating system needs to be replaced, because the cost to switch from a heating-only or cooling-only system to a heat pump is often quite low.[203]

Potential limitations: Air conditioning produces heat (outdoors) that contributes to the urban-heat-island effect. Unlike many other heat-reducing actions identified in this report, the use of air conditioning increases energy consumption and the associated costs. The resulting increased demand for energy during peak periods may necessitate the use of additional, non-renewable energy sources, increasing greenhouse-gas emissions. If there is a power outage during a heat event, which may occur due to excessive demand, air conditioning will not work.

Air conditioning systems are also expensive to install, and the people who are most vulnerable to heat may not be able to afford them. It may be necessary to upgrade a building's electrical system to enable the installation of air conditioning, and in some apartment buildings it may not be possible for tenants to add their own systems.

Cooling rooms and networks are effective only if people use them; vulnerable people may need help to get to cooling rooms. Socially isolated individuals may not be willing to use cooling rooms, whether in a residential building or a public cooling centre.

3.3.3 Emergency Preparedness of Buildings

BI-9: Install and maintain backup power generation

During extreme-heat events, building owners and managers can reduce the risks caused by power outages that may cause a buildup of indoor heat and elevate the risk of heat-related illnesses. Building owners can install backup power generation, in addition to measures that improve what is known as "passive survivability."[204] Passive survivability is a construction term that means the ability to survive without help from electricity.

The National Building Code requires emergency generators for health-care facilities, life-safety systems and emergency building services; these requirements include an emergency power supply for two hours for working elevators, a water supply for firefighting, and electric fans to maintain ventilation and air quality.[205] With an emergency power supply, residents can evacuate their apartments and emergency services personnel can access the building.

The national standards relevant to extreme-heat emergencies include CSA Z32-09, "Electrical safety and essential electrical systems in health care facilities"[206] and CSA C282-15, "Emergency electrical power supply for buildings."[207]

There is no current code or standard in any Canadian jurisdiction that addresses sustained, area-wide power outages that affect a multi-unit residential building when there is no emergency in the building itself. Extreme heat is not currently considered an emergency by the National Building Code.

In 2016, the City of Toronto developed minimum guidelines for the provision of backup power in multi-unit residential buildings. The guidelines—which can be adopted voluntarily but are not mandatory—include providing backup power for 72 hours, and backing up air conditioning or cooling systems for a common refuge area.[208] However, Waterfront Toronto—the waterfront revitalization organization involving the federal, provincial and municipal governments—is requiring developers to demonstrate how they will address these backup-power guidelines in the design of all new residential projects.[209]

Key additional benefits: Backup power generation helps increase resilience to flooding, wildfires, ice storms and other natural hazards that may cause power outages.

Potential limitations: The installation of backup power generation does not reduce occupants' exposure to extreme heat when systems are functioning normally (such as when there is no power outage).

BI-10: Arrange for backup water supply during power outages

The upper floors of high-rise buildings depend on electrical power for their tap water. During power outages, especially in a heat wave, people need water to stay hydrated and reduce the risks of heat-related illnesses.

Building owners can maintain a water supply with backup power to operate domestic water booster pumps.[210] They can also install outdoor water fixtures connected to a gravity-fed source in a location easily accessible to building occupants.[211]

Key additional benefits: Maintaining a water supply during power outages helps increase resilience to flooding, wildfires, ice storms and other natural hazards that may cause power outages.

Potential limitations: Installation of alternative water supplies does not reduce occupants' exposure to heat illnesses when systems are functioning normally (outside a power outage).

3.3.4 Community Infrastructure

BI-11: Adapt community infrastructure to extreme heat

Extreme heat is a danger to community infrastructure and public health. Community infrastructure may be owned and operated by the municipality (water treatment, roads and sewers, for instance) or by other parties (such as electricity and gas utilities and railways).

Once a community and/or owner has assessed infrastructure for vulnerabilities to extreme heat (Action COM-1), they can work to reduce the risks to the infrastructure itself, and the associated impacts on health. When communities are designing new infrastructure or adapting existing infrastructure to be heat-resilient, they should consider future potential climatic conditions, including the risks from extreme heat, as a matter of routine.

Key additional benefits: Communities may work with infrastructure owners strategically, to reduce health risks during extreme-heat events. For example, in Montreal, the urban transportation provider, STM, helps move people to cooling centres.[212]

Potential limitations: Adapting aging infrastructure to be climate resilient can be challenging and costly and needs integrating into long-term planning. Close collaboration is likely to be required between communities and infrastructure owners, who may have different objectives. Many identified actions may be outside the control of the community itself.

BI-12: Reduce vehicular traffic

Motorized vehicles produce heat in urban areas and reduce air quality. Communities can take steps to reduce the use of such vehicles, including:[213]

- Providing safe public transportation options, and routes dedicated to self-propelled transportation such as walking and bicycling
- Increasing urban density

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- Developing mixed-use neighbourhoods that give people access to businesses and services without using a car
- Restricting the use of motorized vehicles in urban centres

Key additional benefits: Reduced vehicular traffic also reduces the production of greenhouse gases. Infrastructure that encourages active, or self-propelled, transport (such as foot paths and bike lanes) can boost recreational opportunities and citizens' feelings of well-being.

Potential limitations: To reduce the heat created by motor vehicles, people must decide to change their modes of transport, and/or continue to work from home post-pandemic.

BI-13: Install "cool" reflective or permeable pavements

Traditional asphalt and concrete roads store and emit heat. "Cool pavements" use alternative materials that are more reflective or permeable, and this helps to reduce surface and ambient temperatures.

Permeable pavements or similar surfaces (such as driveways or patios of crushed stone over soil) contain voids that allow air, water, and water vapour inside. When wet, these pavements can lower surrounding air temperatures through evaporative cooling.

Reflective pavements are lighter in colour, or more reflective, than traditional dark asphalt. This helps them absorb less heat, so they are less hot.[214] The United States Green Building Council (USGBC) suggests that the most cost-effective way of increasing reflectivity in road surfaces is by increasing the albedo (the proportion of absorbed light that a surface reflects back into the atmosphere) of the resurfacing materials that cities already use in road maintenance.[215]

Key additional benefits: Reducing the surface temperatures of dark pavement can also reduce the risk of premature failure of that pavement, such as rutting in asphalt pavements (depressions in the wheel paths). Reflective pavements can enhance visibility at night, potentially reducing the amount of lighting needed. And permeable pavements have been found to recharge the underlying groundwater, as well as reduce stormwater runoff and associated pollution.[216,217]

Potential limitations: Results from pilot projects, including the Cool Streets project in Los Angeles, suggest that reflective surfaces may not be appropriate for sidewalks, because the reflectivity may expose pedestrians to more heat.[218] [219] Permeable pavements are not appropriate for areas with high-speed traffic (although they can be used on smaller residential streets and in parking lots).[220]

Permeable or cool pavements require maintenance, and communities should factor this into their decisions. Care should also be taken to avoid additional clean water entering sanitary sewer pipes through the ground.

BI-14: Expand artificial shade

Communities of all sizes can create shade with a variety of structures, including portable items (such as canopies, tents and umbrellas), canopies or awnings attached to buildings, and free-standing open-air structures with roofs.[221]

Key additional benefits: Shade can be created in places where the potential for trees to grow is limited. Man-made or constructed shade is effective: in low-humidity conditions, people cannot discern a difference in temperature between natural shade and constructed shade, according to a recent study.[222] Also, shade structures that incorporate solar panels can provide a source of renewable energy.

Potential limitations: Constructed shade does not offer the same ecosystem-service benefits as trees (see action GI-1).

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BI-15: Install water-based cooling systems and drinking fountains

Man-made pools, ponds and fountains are commonly found in urban settings, and they can have a cooling effect. On hot days, the surface temperature of these water bodies may be several degrees lower than that of the surrounding built environment. Warm air will evaporate water from their surfaces, which will cool the surrounding air temperature.

Communities can also employ more active water-based cooling methods, such as sprinklers and evaporative wind towers.[223] Drinking fountains also help keep residents hydrated on hot days.

Key additional benefits: Water features are often used to increase aesthetic value in communities, and may also offer opportunities for recreation, such as splash pads for children.

Potential limitations: There is limited knowledge about the potential of water-based evaporative techniques to mitigate heat. In drought conditions, the use of water may be restricted. During periods of high humidity, the cooling effects of water bodies may be constrained. Water systems need to be designed and maintained to prevent the spread of diseases, such as Legionnaires' disease, that may flourish in high temperatures.[224]

Chapter
4

Achieving Multiple Benefits

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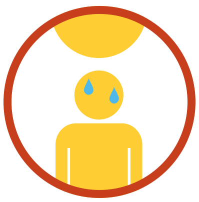
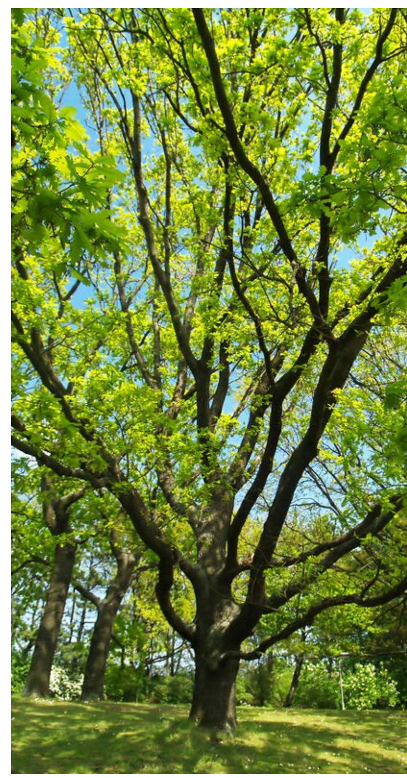
Many actions that reduce the risks of heat-related illnesses also bring additional, tangible benefits, often termed "co-benefits."

For individuals, investing in extreme-heat resilience can result in direct co-benefits such as:



- Improved comfort, well-being, and mental health
- Lower energy bills
- Improved productivity
- Enhanced property values
- Stronger social networks and relationships



For property owners and managers, investing in extreme-heat resilience can result in co-benefits such as:

- Better experiences for tenants
- Lower operating costs
- A greater chance of avoiding business interruptions
- An enhanced reputation
- Improved performance in terms of Environmental, Social and Governance (ESG) criteria
- Additional foot traffic in pedestrian and retail environments
- Higher property values and rent premiums, and lower vacancy rates

For communities, investing in extreme-heat resilience can result in co-benefits such as:

- Reduced greenhouse-gas production (where energy is produced using fossil fuels)
- Carbon sequestration and storage by vegetation and soils
- Improved habitats and biodiversity
- Flood and erosion regulation
- Improved air quality
- Opportunities for recreation and self-propelled transportation

Table 6 provides an overview of key co-benefits that may be associated with each of the 35 practical actions described in Chapter 3. It is worth noting that many co-benefits can be achieved with natural infrastructure solutions, which can be applied at all scales.

Table 6: Co-benefits associated with practical actions to reduce risks from extreme heat (as described in Chapter 3)

		Human Co-Benefits			Ecosystem Service Co-Benefits						Direct Financial Co-Benefits		
Ref.	Action	Knowledge and Education	Social Networks and Relationships	Recreation / Active Transport	Improved Air Quality	Reduced GHG Production	Vegetation and Soils	Improved Habitat and Biodiversity	Improved Water Quality	Flood and Erosion Regulation	Enhanced Value / Longer Design Life	Improved Business / Work Continuity	Energy-Efficiency and Cost Savings
IND-1	Work with neighbours, friends and family to prepare	■	■										
IND-2	Arrange to receive public heat warnings	■											
IND-3	Learn how to use natural ventilation	■			■	■							■
IND-4	Minimize "waste" indoor heat production	■			■	■							■
IND-5	Plan for modified working, living and sleeping arrangements					■							■
PROP-1 COM-1	Understand building-scale vulnerabilities / assess and map vulnerability to extreme heat	■											
PROP-2 COM-2	Provide information and outreach to help occupants adapt / encourage preventive action before a heat event		■								■	■	
PROP-3 COM-3	Identify and support vulnerable occupants / set up community support programs	■	■										
PROP-4	Use natural ventilation in common areas				■	■							■
PROP-5 COM-6	Develop extreme-heat emergency plan with occupants		■									■	
COM-4	Require heat-sensitive urban planning, infrastructure design, and operation	■			■	■					■	■	■
COM-5	Provide incentives to increase passive cooling and reduce "waste" heat	■											

Ref.	Action	Human Co-Benefits			Ecosystem Service Co-Benefits						Direct Financial Co-Benefits		
		Knowledge and Education	Social Networks and Relationships	Recreation / Active Transport	Improved Air Quality	Reduced GHG Production	Vegetation and Soils	Improved Habitat and Biodiversity	Improved Water Quality	Flood and Erosion Regulation	Enhanced Value / Longer Design Life	Improved Business / Work Continuity	Energy-Efficiency and Cost Savings
GI-1	Plant and maintain trees		■	■	■	■	■	■	■	■	■	■	■
GI-2	Expand vegetated areas and water bodies and absorb more water		■	■	■	■	■	■	■	■	■		
GI-3	Install green roofs			■	■	■	■	■	■	■	■	■	■
GI-4	Grow green façades or green walls on buildings				■	■	■	■	■	■	■	■	■
BI-1	Enhance insulation and airtightness					■					■	■	■
BI-2	Install cool roofs, walls and paving surfaces					■					■	■	■
BI-3	Use concrete, brick, stone and tile finishes to absorb heat					■							■
BI-4	Install windows that reduce heat transfer					■							■
BI-5	Install shading devices					■						■	■
BI-6	Install temperature and humidity monitors or thermostat controls					■						■	■
BI-7	Install ceiling or portable fans											■	■
BI-8	Install and maintain air conditioning or heat pumps				■							■	
BI-9	Install and maintain backup power generation											■	
BI-10	Maintain a water supply during power outages											■	
BI-11	Adapt community infrastructure to extreme heat			■							■	■	■
BI-12	Reduce vehicular traffic			■	■	■							
BI-13	Install cool or permeable pavements			■					■	■			
BI-14	Expand artificial shade			■									
BI-15	Build water-based cooling systems and drinking fountains			■									

Chapter
5

Conclusion and Next Steps

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Extreme heat is an urgent national issue for Canada. To avoid worsening impacts, fatalities and costs resulting from rising temperatures, **swift action is required**.

To become resilient in the face of extreme heat—to withstand and recover from dangerously hot weather—Canadians must learn to adapt.

This report presents a compendium of practical actions that can be used by everyone, at home, in multi-unit buildings, and in the wider community, to build heat-resilience. As with efforts to improve resilience to flooding and wildfires, the challenge is not necessarily "knowing what to do," but rather, putting preventive actions into practice on the ground.

To help accelerate Canada's progress in preparing for a hotter future, decision-makers should capitalize on these key opportunities:

1. Governments and other organizations should recognize extreme-heat events as "natural disasters" and include extreme heat in their messaging, in the same way that flooding and wildfire are seen as natural disasters.[225]

2. Public-health agencies and other organizations should expand their existing communications with more information about how to reduce heat-related risks before a heat event. Messages about how to respond during a heat event should also be amplified. All messages should include easy-to-understand infographics and be adapted to specific vulnerable populations, in a range of languages.

3. The public sector and private investors should co-operate to maximize win-win situations. For example, tree-planting programs designed to store carbon could be carried out in places where they could reduce the urban-heat-island effect too—resulting in more than one benefit. Programs to improve energy efficiency in buildings could be expanded to reduce extreme-heat risks at the same time.

4. Home inspections or evaluations (for instance, as part of the EnerGuide program[226]) should include advice about how to increase the dwelling's resilience to climate, including extreme heat. Any future initiative to rate homes on their climate-readiness should include heat-resilience as a factor.

Ultimately, a desire to build Canadians' resilience to extreme heat must become the norm, not the exception, in decision-making by everyone from homeowners and tenants to businesses and community leaders. Everyone has a responsibility to reduce their own risks from extreme heat, and an opportunity to help protect others more vulnerable than themselves.

Appendix A: Assessment of Extreme Heat Projections

The assessment of extreme-heat projections presented in Chapter 2 was undertaken using data from the Climate Atlas of Canada portal (www.climateatlas.ca). Details of the assessment are provided below:

Communities

This analysis included all 35 census metropolitan areas (CMAs) in Canada (defined as areas with a total population of at least 100,000, of which 50,000 live in the core),[227] as well as the capital cities and a selection of representative small and medium-sized communities in each province. In total, 70 communities were considered (see Table A1.)

Indicators

Climate projections were considered for three indicators of extreme heat, for which the full definitions are provided below:

- Very Hot Days (30°C +): A very hot day is one when the temperature rises to at least 30°C. Data are available with respect to projected changes in the average number of very hot days per year.
- Warmest Maximum Temperature: The warmest maximum temperature is the highest temperature of the year. Data are available about projected changes in the average annual warmest maximum temperature.
- Average length of heat waves: A heat wave occurs when the temperature reaches or exceeds 30°C at least three days in a row. Data are available about projected changes in the average length of heat waves in days.

Climate Scenarios

Climate projections were extracted for two possible climate futures. Each assumes a different level of future greenhouse-gas (GHG) emissions, which leads to either more global warming, or less. The technical name for these scenarios is "Representative

Concentration Pathways (RCPs)."

1. The More Climate Change / "High Carbon" Scenario: This scenario assumes that world GHG emissions continue to increase at current rates through the end of the twenty-first century. This large volume of GHG emissions results in more-severe global warming. This scenario is also called the "high-carbon" future, and is based on the RCP 8.5 emissions scenario.

2. The Less Climate Change / "Low Carbon" Scenario: This scenario assumes that GHG emissions increase until about 2050 and then rapidly decline. This decline in emissions leads to less-severe global warming than the alternative high-carbon scenario. This scenario is also called the "low-carbon" future, and is based on the RCP 4.5 emissions scenario.

Time Horizons

This analysis was based on data for the relatively recent past (1976–2005) and climate projections for the near future (2051–2080).

Assessment

National maps of climate projections for 2051–2080 under the "High Carbon" scenario were examined to identify key trends in the three extreme-heat indicators (presented in Section 2.1.)

Climate projections for the 35 census metropolitan areas were subsequently ranked to identify the top 10 CMAs considering each of three extreme-heat indicators (presented in Section 2.2.). Where projected conditions were the same, the same ranking was applied, meaning more than ten metropolitan areas were identified.

From the 70 communities considered in total (Table A1), additional communities were identified that had climate projections similar to those of the top 10 in any of these respects:

- Number of Very Hot Days (30°C +): 53.7 days or more per year
- Average Annual Warmest Maximum Temperature: 38.4°C or above
- Annual average heat-wave length: 7.8 days or longer

Table A.1.: Metropolitan areas and communities in Canada assessed for extreme-heat projections

Province or Territory	Census Metropolitan Areas	Smaller communities
Alberta	Calgary Edmonton Lethbridge	Brooks Drumheller Medicine Hat Taber
British Columbia	Abbortsford-Mission Kelowna Vancouver Victoria	Creston Kamloops Penticton Vernon
Manitoba	Winnipeg	Emerson Morden Souris Steinbach
New Brunswick	Moncton St John	Fredericton Woodstock
Newfoundland and Labrador	St. John's	Labrador City
Nova Scotia	Halifax	Windsor
Northwest Territories		Inuvik Yellowknife
Nunavut		Iqaluit Rankin Inlet
Ontario	Barrie Belleville Brantford Greater Sudbury Guelph Hamilton Kingston Kitchener-Waterloo-Cambridge London Niagara Falls-St. Catharines Oshawa Ottawa Peterborough Toronto Thunder Bay Windsor	Chatham Leamington Sarnia

Province or Territory	Census Metropolitan Areas	Smaller communities
Prince Edward Island		Charlottetown Summerside
Quebec	Montreal Quebec City Saguenay Sherbrooke Trois-Rivières	Saint-Jean-sur-Richelieu Salaberry-de-Valleyfield
Saskatchewan	Regina Saskatoon	Estevan Leader Maple Creek Prince Albert Weyburn
Yukon Territory		Carmacks Whitehorse

Appendix B: Heat Warning Criteria in Canada

Table B.1. Criteria used by Environment and Climate Change Canada for issuing a Heat Warning, by province and territory (Source: Government of Canada. 2020.)[228]

Location	Threshold criteria
Alberta: Extreme south (including Pincher Creek, Cardston, Lethbridge, and Medicine Hat)	Two or more consecutive days of daytime maximum temperatures are expected to reach 32°C or warmer and nighttime minimum temperatures are expected to fall to 16°C or warmer.
Alberta: Remainder of Alberta (including the Cities of Edmonton, Red Deer and Calgary)	Two or more consecutive days of daytime maximum temperatures are expected to reach 29°C or warmer and nighttime minimum temperatures are expected to fall to 14°C or warmer.
British Columbia, Northeast: Northern Interior; Central Interior, including Chilcotin, Cariboos, Prince George, North Thompson, and North Columbia; BC Peace region; Bulkley Valley and the Lakes, and Fort Nelson	Two or more consecutive days of daytime maximum temperatures are expected to reach 29°C or warmer and nighttime minimum temperatures are expected to fall to 14°C or warmer.
British Columbia, Northwest: Central and Northern Coast (inland and coastal regions); Northern Vancouver Island; Northwestern BC	Two or more consecutive days of daytime maximum temperatures are expected to reach 28°C or warmer and nighttime minimum temperatures are expected to fall to 13°C or warmer.
British Columbia, Southeast: Southern interior (including South Thompson and Okanagan); Kootenays; Columbias (south)	Two or more consecutive days of daytime maximum temperatures are expected to reach 35°C or warmer and nighttime minimum temperatures are expected to fall to 18°C or warmer.
British Columbia, Southwest: Western Metro Vancouver including the North Shore; City of Vancouver; Richmond; Howe Sound; Whistler; Sunshine Coast; Vancouver Island (except northern sections)	Two or more consecutive days of daytime maximum temperatures are expected to reach 29°C or warmer and nighttime minimum temperatures are expected to fall to 16°C or warmer.

Location	Threshold criteria
British Columbia, Southwest inland: Eastern Metro Vancouver including Coquitlam and Surrey; Fraser Valley	Two or more consecutive days of daytime maximum temperatures are expected to reach 33°C or warmer and nighttime minimum temperatures are expected to fall to 17°C or warmer.
Manitoba, North	Two or more consecutive days of daytime maximum temperatures are expected to reach 29°C or warmer and nighttime minimum temperatures are expected to fall to 16°C or warmer. Or Two or more consecutive days of humidex values are expected to reach 34 or higher.
Manitoba, South	Two or more consecutive days of daytime maximum temperatures are expected to reach 32°C or warmer and nighttime minimum temperatures are expected to fall to 16°C or warmer. Or Two or more consecutive days of humidex values are expected to reach 38 or higher.
New Brunswick	Two or more consecutive days of daytime maximum temperatures are expected to reach 30°C or warmer and nighttime minimum temperatures are expected to fall to 18°C or warmer. Or Two or more consecutive days of humidex values are expected to reach 36 or higher.
Newfoundland and Labrador	Two or more consecutive days of daytime maximum temperatures are expected to reach 28°C or warmer and nighttime maximum temperatures are expected to fall to 16°C or warmer. Or Two or more consecutive days of humidex values are expected to reach 36 or higher.
Northwest Territories	Two or more consecutive days of daytime maximum temperatures are expected to reach 29°C or warmer and nighttime minimum temperatures are expected to fall to 14°C or warmer.
Nova Scotia	Two or more consecutive days of daytime maximum temperatures are expected to reach 29°C or warmer and nighttime minimum temperatures are expected to fall to 16°C or warmer. Or Two or more consecutive days of humidex values are expected to reach 36 or higher.

Location	Threshold criteria
Nunavut	No Heat Warning program at this time.
Ontario, extreme Southwest (Essex and Chatham-Kent Counties)	Two or more consecutive days of daytime maximum temperatures are expected to reach 31°C or warmer and nighttime minimum temperatures are expected to fall to 21°C or warmer. Or Two or more consecutive days of humidex values are expected to reach 42 or higher.
Ontario, North	Two or more consecutive days of daytime maximum temperatures are expected to reach 29°C or warmer and nighttime minimum temperatures are expected to fall to 18°C or warmer. Or Two or more consecutive days of humidex values are expected to reach 36 or higher.
Ontario, remainder of Southern Ontario (including the District of Parry Sound)	Two or more consecutive days of daytime maximum temperatures are expected to reach 31°C or warmer and nighttime minimum temperatures are expected to fall to 20°C or warmer. Or Two or more consecutive days of humidex values are expected to reach 40 or higher.
Prince Edward Island	Two or more consecutive days of daytime maximum temperatures are expected to reach 28°C or warmer and nighttime minimum temperatures are expected to fall to 18°C or warmer. Or Two or more consecutive days of humidex values are expected to reach 36 or higher.
Quebec, except Nunavik	The humidex value is 40 or higher and the temperature is 30°C or warmer, and both conditions persist for at least one hour. Or The temperature is 40°C or warmer.
Saskatchewan, North and Central (including Meadow Lake, The Battlefords, Prince Albert, and Hudson Bay)	Two or more consecutive days of daytime maximum temperatures are expected to reach 29°C or warmer and nighttime minimum temperatures are expected to fall to 14°C or warmer. Or Two or more consecutive days of humidex values are expected to reach 34 or higher.

Location	Threshold criteria
Saskatchewan, South	Two or more consecutive days of daytime maximum temperatures are expected to reach 32°C or warmer and nighttime minimum temperatures are expected to fall to 16°C or warmer. Or Two or more consecutive days of humidex values are expected to reach 38 or higher.
Yukon Territory	Two or more consecutive days of daytime maximum temperatures are expected to reach 28°C or warmer and nighttime minimum temperatures are expected to fall to 13°C or warmer.

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IND-4: Minimize "waste" indoor heat production

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COM-1: Assess and map vulnerability to extreme heat

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COM-2: Use education and outreach campaigns to encourage preventive action

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COM-3: Set up community support programs for vulnerable populations

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COM-4: Require heat-sensitive urban planning, infrastructure design, and operation

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COM-5: Provide incentives to increase passive cooling and reduce "waste" heat

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GI-1: Plant and maintain trees

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GI-2: Expand vegetated areas and absorb more water

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GI-3: Install green roofs

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GI-4: Grow green façades or green walls on buildings

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BI-1: Enhance insulation and airtightness

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BI-2: Install cool roofs, walls and paving surfaces

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BI-3: Use concrete, brick, stone and tile finishes to absorb heat

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BI-4: Install windows that reduce heat gain from the sun

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BI-5: Install shading devices

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BI-7: Use ceiling or portable fans

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