Adaptation Return On Investment (RoI) Project

Task 9 : Final Toolkit Packaging Guide to Revise the Base Model

Defence Research and Development Canada (DRDC)
Public Safety Canada (PSC)

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1. Introduction

1.1 Purpose

The Adaptation Return on Investment (RoI) Project is part of the Canadian Safety and Security (CSS) Program, managed by Defence Research and Development Canada (DRDC) CSS in collaboration with Public Safety Canada. AECOM and the Institute of Catastrophic Loss Reduction (ICLR), in partnership with Public Safety Canada, City of Ottawa, City of Clarence-Rockland and the City of Calgary, are developing a Return on Investment (RoI) Toolkit for assets and infrastructure to become more resilient to disaster risks and climate change impacts, by building on the best available tools and methods. The cities of Toronto, Vancouver and Montreal have been identified as supporting partners to the project.

The purpose of this *Guide to Revise Base Model* is to provide municipalities and users with an overview of how the base model, the FEMA BCA Toolkit, is adapted to the Canadian context, what has been developed to achieve this, and the location of resources and other helpful information.

1.2 Glossary of Key Terms

For reference, a glossary of key terms is provided using definitions identified in the FEMA BCA Reference Guide.[1]

Benefits (returns): Future losses prevented or reduced by an adaptation project. The returns counted in the RoI are in the present value of the sum of the expected annual avoided damages over the adaptation project useful life.

Benefit-Cost Analysis (BCA): An analysis that estimates the potential positive effects of an adaptation measure and comparing them to the cost of the measure. With the FEMA BCA modules, the positive effect is a reduction in future damages from natural hazards; this is the benefit of adaptation.

Benefit-Cost Ratio (BCR): The ratio is the project benefits divided by the project cost. A BCR greater than 1.0 indicates the benefits are greater than the cost and the project is cost-effective.

Building Replacement Value (BRV): The cost to replace a building with a functionally equivalent building of the same size and quality, based on the current cost of labor and materials. The BRV is not the same as the current market value of the building.

Depth Damage Function (DDF): A way of expressing expected flood damages for various types of buildings, their contents, or their functions at different water depths. For floods, this relationship is expressed as depth versus percentage damage to the element being considered.

Displacement Costs: The costs when occupants (of residential, commercial, or public buildings) are displaced to temporary quarters while damage is repaired. These costs include rent and other monthly costs, such as furniture rental and utilities, and one-time costs, such as moving and utility hook-up fees.

Hazard: In the context of an adaptation project, a naturally occurring phenomenon that poses a risk of asset damages, economic losses, or casualties.

Hazard Adaptation: Reduction of the risk of natural hazards through the implementation of projects or procedures that reduce or prevent future damages.

Indirect Benefits: In the context of an adaptation project, the reduction in damages from natural hazard events that are not directly caused by the hazard itself.

[1] Federal Emergency Management Agency, Final BCA Reference Guide, June 2009. Retrieved https://www.fema.gov/sites/default/files/2020-04/fema_bca_reference-guide.pdf

Loss of Function Damages: Costs and direct economic impacts that occur when physical damages are severe enough to interrupt the function of a building or other facility.

Loss of Public Services: The cost of providing services, plus a continuity premium, for services that are critical to immediate disaster response and recovery.

Monetize: To express in terms of money to compare actions or results of actions that are not comparable in other terms.

Project Useful Life (PUL): The estimated amount of time that the adaptation project investment will be effective.

2. Adapting Base Model to Canadian Context

2.1 Introduction

The FEMA BCA Toolkit has been developed since the 1990s by the U.S. Federal Emergency Management Agency (FEMA) to estimate the future risk reduction benefits of a proposed hazard adaptation project. These estimated future benefits are then compared to the costs of a hazard adaptation project. The FEMA BCA Toolkit simplifies the effort necessary to prepare a BCA by providing a suite of methods and software for a range of major natural hazards in the United States of America. Some features of these methods and software have been modified in order to fit the Canadian context. An overview of elements of the FEMA BCA Toolkit that have been adapted and revised when developing the RoI Toolkit, as well as additional features that have been incorporated into the RoI Toolkit (e.g. climate change), include the following:

1) Adaptation project: Location, property structure type, hazard type, damage model selection, adaptation action type, adaptation measure, and climate change mode are required as the adaptation project description. The toolkit will link the property structure type to hazards, damages models and adaptation measures where applicable.

2) Hazard covered: Hazards with the highest impacts historically in Canada were selected or those that are increasing with climate change.

3) Impact models: Impacts for each hazard were estimated using the results of the latest models developed by Canadian experts.

4) Project useful life: The average expected useful lives of new municipally owned assets were estimated using published data by Statistics Canada.

5) Province/Territory Cost Index: A method was developed to estimate construction costs in each province and territory according on the size of their population centre (including rural areas).

6) Impact Categories: Similar to the FEMA BCA Toolkit, the RoI Toolkit will analyze impacts for the Economic, Social, Environmental categories but will also include a Cultural category.

7) Climate Change Impact Considerations: Unlike the FEMA BCA Toolkit, the RoI Toolkit will allow the users to take climate change projections into consideration for the hazards, if desired.

8) The Damage Frequency Assessment (DFA): Relationships were established between natural hazards that occurred in Canada in the past and the extent of damages or losses that occur as a result of these specified natural hazard events.

9) Adaptation Library: The adaptation measures within the RoI Toolkit were adapted to the Canadian reality by using Canadian standards, such as CSA standards, Fire Smart, etc.

The following sections present more detail about each of these 9 adaptations to the base model.

2.2 Adaptation Project Type

Table 2-1 shows the differences of adaptation project asset types between the RoI Toolkit and the FEMA BCA Toolkit. The FEMA BCA Toolkit's property asset types include Utilities, Roads & Bridges, Residential Buildings, Non-Residential Buildings, Critical Facility Buildings and other property asset types. The RoI Toolkit applied an asset classification approach which category assets into asset categories and asset sub-categories/types to best represents the majority of local government municipal assets across Canada to ensure the RoI Toolkit is applicable to the wider Canadian municipalities through reviewing multiple Canadian infrastructure frameworks (Task 4).

Table 2-1: Asset Hierarchy – Asset Category & Type

RoI Toolkit	FEMA BCA Toolkit
Asset Category	**Property Asset Type**
– Utilities	– Utilities
– Transportation	– Roads & Bridges
– Building and Facilities	– Residential Building – Non-Residential Building – Critical Facility Building
– Nature-Based Infrastructure	Nature-Based Infrastructure
– Other	– Other

2.3 Hazards Covered

The FEMA BCA Toolkit is used by state, local, territorial officials to estimate costs avoided and benefits resulting from hazard adaptation projects. The FEMA BCA Toolkit includes data on losses and damages to specific types of property asset types (or assets) due to 16 natural disasters (Table 2-2).

Initially, DRDC and PSC wanted the RoI Toolkit to consider not all the hazards covered by the FEMA BCA Toolkit but only the top five hazards in Canada, namely, flood, wildfire, wind, increasing extreme temperatures and ice storms (Table 2-2). These five hazards were selected on the following basis: flood, wildfire, ice storm and wind-related hazards have had the highest impacts historically in Canada (Task 2), while extreme temperature-related hazards are increasing with climate change and impacting not only health but also deteriorating infrastructure.

Table 2-2: Hazard covered into RoI Toolkit

Hazard	RoI Toolkit	FEMA BCA Toolkit
Riverine Flood	X	X
Pluvial Flood	X	
Coastal A Flood		X
Hurricane Wind / Strong wind	X	X
Tornado		X
Wildfire	X	X
Drought		X
Landslide		X
Seismic		X
Dam/Levee Break		X
Extreme Temperature	X	X
Infrastructure Failure		X
Severe Storm		X
Tsunami		X
Volcano		X
Winter storm		X
Ice Storm	X	

For each of the five natural hazards, the RoI Toolkit contains the calculations required to estimate the direct and indirect impacts. As a primary choice, the RoI Toolkit uses impact models developed for the Canadian context. When this was not possible, the RoI Toolkit includes a default calculation method, which will use the DFA option as long as a relationship can be established between the frequency of a natural hazard event and the damage or losses incurred as a result of the event.

Table 2-3 presents the impact modules that are used in the RoI Toolkit for each natural hazard. The FEMA BCA Toolkit have a very similar organisation, except for Ice Storm hazard which is a new feature of the ROI Toolkit.

Table 2-3: Impact models type for each category of asset in ROI Toolkit

Hazard	Riverine flood			Wildfire			Wind			Extreme Temperature			Ice Storm		
Asset	**Modeled damage**	**DFA - Buildings and Facilities**	**DFA – Road and Bridges**	**Modeled damage**	**DFA - Buildings and Facilities**	**DFA – Road and Bridges**	**Modeled damage**	**DFA - Buildings and Facilities**	**DFA – Road and Bridges**	**Modeled damage**	**DFA - Buildings and Facilities**	**DFA – Road and Bridges**	**Modeled damage**	**DFA - Buildings and Facilities**	**DFA – Road and Bridges**
Utilities			X			X			X			X			X
Transportation			X			X			X			X			X
Building and facilities	X	X		X	X		X	X		X	X		X	X	
Nature-Based infrastructure		X			X	X		X	X	X	X	X		X	X
Other		X			X	X		X	X		X	X		X	X

X: Features existing in both FEMA BCA and ROI Toolkit

X: New feature in ROI Toolkit

3. Impact Categories

For all three impact categories that will be analyzed—Economic, Social and Environmental, a distinction will be made from the direct or indirect relationship to the natural hazard affecting the selected asset. Also, each impact category described will be evaluated under the hazard exposed and the asset type selected. Not every category listed will be available or applicable to all hazards considered or asset types defined. The RoI Toolkit will match the potential and most likely category needed based on the information provided by the user. A detailed section discussing impact categories calculations is below. The standard data types and corresponding values and sources are summarized in Appendix A.

3.1 Economic Impact Calculation

As previously indicated, economic categories will be composed of the direct and indirect dollar losses resulting from the selected natural hazard. The distinction between direct and indirect depends on the proximity of time of the damage caused by the natural hazard event to the natural hazard event. Damages that are incurred during the hazard event, such as asset, content, or property damage, are typically directly related to the natural hazard impact when it occurs. On the other hand, loss of services, business interruption, or temporary service costs will be categorized as an indirect impact resulting from the selected natural hazard. For some hazards, such as wind or ice storms, the direct impacts will be the damages to the property or asset, but damages to contents will be considered indirect damages. This is based on the assumption that damaged façades or enclosed protection are primarily a result of the selected natural hazard, but the subsequent exposure to rainfall or other elements are primarily caused by damages to the contents of those assets.

Table 3-1 below summarizes the economic impact categories captured in the RoI Toolkit, and includes a summary of the calculation methods, affected asset categories, and applicable natural hazards.

Table 3-1: Economic Impact Categories

Economic Impact	Format	FEMA BCA	RoI	Calculation Method	Affected Asset Category	Hazard Covered
Asset Value	Present day dollar asset value.	Applicable to modeled damages module. Asset and content values are determined based off the BRV, a function of the area of the asset.	Applicable to modeled damages module. Asset and content values are determined based off the building replacement value.	Dollar value related to the damaged caused to the asset	All water, transportation, and building and facilities asset categories.	Flooding Wildfire Wind
Content Value	Present day dollar asset value.	Applicable to modeled damages module. Asset and content values are determined based off the BRV, a function of the area of the asset.	Applicable to modeled damages module. Asset and content values are determined based off the building replacement value.	Dollar value related to the damaged caused to the content equipment and furniture	Some water assets and all building and facilities asset categories.	Flooding Wildfire Wind

Economic Impact	Format	FEMA BCA	RoI	Calculation Method	Affected Asset Category	Hazard Covered
Loss of Service/ Function	Days to repair or loss of service. Number of people affected. AADT. Vehicle miles traveled. Road speed limits. Value of unit of service.	Benefits associated with avoiding loss of function are available for utilities (electrical, potable water, wastewater) and for transportation assets. For transportation infrastructure, Toolkit calculates based on additional distance (VMT) and time (VHT) per trip from road closure.	Benefits associated with avoiding loss of function are available for utilities (electrical, potable water, wastewater) and for transportation assets. For transportation infrastructure, Toolkit calculates based on additional distance (VMT) and time (VKT) per trip from road closure.	Estimated dollar value of the loss of service due to the damage caused. Population and service affected will vary depending on the asset type and hazard.	All water and transportation asset category. Some building and facility asset categories.	All
Business interruption	Days to repair or loss of service. Present day dollar values	Benefits associated with business loss are available for Non-Residential assets, classified as loss of function/loss of income.	Benefits associated with business loss are available for Non-Residential assets, classified as displacement costs.	Estimated dollar value of the loss of business operation due to the damage caused.	All building and facilities asset categories.	All

3.2 Social Impact Calculation

Only injuries and fatalities will be counted as direct social impacts. Mental health and anxiety, lost productivity, and displacement costs will be considered indirect impacts. The monetization of injuries and fatalities damage will be supported by user's historic safety record for the hazard and asset selected in the evaluation. The adaptation projects information will be encouraged to provide safety improvement, so safety hazard can be effectively reduced. Using provincial guidance on car accidents monetary impact for safety, the RoI Toolkit will apply those parameters in present day dollars values to compare and account the benefit of avoiding those potentially safety consequences. Displacement cost will require an additional level of calculation, as it will account not only for the people affected, either by the lack of an essential service or by inability to reside in a facility, but also the potential cost incurred by them for the time that a complete repair or restoration of service is achieved. Cost incurred will be standardized by a per diem rate set by the Canada Revenue Agency for meals, lodge, and incidentals allowances[2].

Health issues resulting from a natural hazard, such as mental health and anxiety and lost productivity, have become a major field of study in the last decade. FEMA has incorporated and developed a research program to cover mental stress and anxiety levels developed because of flooding and other natural hazard events. The RoI Toolkit will include the FEMA's [i]generated default values for mental stress and anxiety treatment[3]

[2] https://www.canada.ca/en/revenue-agency/corporate/about-canada-revenue-agency-cra/travel-directive/appendix-b-meals-allowances-oct-2020.html

[3] 2014, FEMA, Benefit Cost Analysis Toolkit Sustainment and Enhancement, *Updated Social Benefits Methodology Report – Final.*

coverage as default. FEMA provided values will be a good approximation of the benefits associated with avoided displacement of residents, including costs associated with mental health and anxiety and lost productivity. A Canadian study to update and expand in the subject is encouraged.

Table 3-2 below summarizes the main social impact, format, type of asset impacted, and impact calculation methods:

Table 3-2: Social Impact Categories

Social Impact	Format	FEMA BCA Toolkit	RoI Toolkit	Calculation Method	Affected Asset Category	Hazards Covered
Additional Living expenses	Number of people affected.	Based on number of households and number of residents (residential) and first floor area and building size (non-residential).	Based on number of households and number of residents (residential) and first floor area and building size (non-residential).	Calculated by applying standard per diem rates for lodging and meals and incidentals to households and residents displaced, respectively. Duration of displacement is a function of depth of inundation.	Water (people affected by the lack of service) and some building and facilities.	All
Injuries and Fatalities	Historic safety records.	Based on population at risk. Applicable to projects that address hazards that have little or no warning time.	Based on population at risk. Applicable to projects that address hazards that have little or no warning time for modeled damages module. Applicable to all hazards for DFA module.	Estimated historic number of people affected by injuries and fatalities caused by the hazard event, multiplied by the monetized values assigned for injuries or fatalities.	Some transportation assets and building and facilities.	All modules
Post Traumatic Stress Disorder	Number of people affected.	Based on number of residents and number of residents that work. Applicable to residential structures only.	Number of residents and number of employed residents affected.	Assigns an average cost to treat mental health and anxiety per individual affected and average lost productivity per employed individual affected.	Water (people affected by the lack of service) and some building and facilities.	All
Hospitalization cost	Number of people affected.	Not covered	Population affected	Using the attributable fraction per disease (Hypertension, Stroke, Coronary)	Nature-Based Solution	Extreme Heat

For the additional living expenses, use the NRCAN (2021) and Multihazard Mitigation Council (2019) assumption for the following benefits:

- Monthly rent 2023: Default value taken for an average of 30 Canadian cities in 2023 for 2 bedrooms on rental.ca;
- Storage: The US value of $500 value of Multihazard Mitigation Council (2019);
- Increase commuting cost: The Multihazard mitigation Council (2019) value of US $100 per month was adopted; and
- Hotel stay: The toolkit made the assumption that hotel stay is 50% for the first two weeks. The NRCAN 2021 value of 146$ was adopted.

It is worth mentioning that all the above referenced values are default values that could be overridden by the end-users.

AECOM adopts the Multihazard Mitigation council methodology (2019) for most of the social impact elements. For injuries and fatalities, AECOM uses the injury scale proposed by the Advancement of Automotive Medicine (AIS) calculated from the fraction of the Value of Statistical life (VSL) presented in Table 3-3. A Canadian VSL was calculated from the 2019 Transport Canada VSL of $10.01 M and adjusted to the year of analysis using the formula below, as proposed by Bergeron (2014):

$$VSL_{t2} = VSL_{t1} * (\frac{CPI_{t2}}{CPI_{t1}}) * (\frac{W_{t2}}{W_{t1}})^{e}$$

Where: t1= Time 1 reference date
t2 = Year of analysis
CPI = Consumer Price Index
W = Real Wage growth
e = Elasticity of real wages (0.6 recommended)

Table 3-3: Acceptable cost to avoid a statistical injury, with injuries measured by AIS.

AIS	Severity	Fraction of VSL
AIS 1	Minor	0.0020
AIS 2	Moderate	0.0155
AIS 3	Serious	0.0575
AIS 4	Severe	0.1875
AIS 5	Critical	0.7625
AIS 6	Fatal	1.0000

For the instance of PTSD, AECOM directly uses the Multihazard Mitigation Council (2019) value for an instance of PTSD. They assume that they consider direct treatment costs where treatment is about 10% of the overall costs of the incidence, and the other costs include things like lost wages, lost household productivity, and pain and suffering. They use $9,000 for direct treatment costs and $90,000 for the overall acceptable cost to avoid a statistical incidence of PTSD.

3.3 Environmental Impact Calculation

Environmental impacts assessed include benefits resulting from a change in land use, for certain adaptation measures. The ecosystem services and land cover categories selected for the tool are those used and described by FEMA[4]. FEMA unit values have been adapted to represent the Canadian context from various sources (see Appendix A). Table 3-4 presents the main environmental impact categories that can be triggered by certain nature-based adaptation measures. As an example, when acquiring land, reforestation or restoration actions, improvement, or creation of wooded or vegetated areas will allow the toolkit user to benefit from ecosystem benefits in the benefits-costs calculation.

Below is a summary of the environmental impact categories discussed, including their description, the calculation method, and the affected asset category. For all environmental impact categories listed, the estimated area affected by the project is subjected to the pre-calculated ecosystem service values to account for natural assets gained with adaptation project.

Table 3-4: Environmental Impact Categories

Environmental Impact	Description	FEMA BCA	RoI	Calculation Method	Affected Asset Category
Air quality	Removing air pollutants, such as particulate matter or ozone, from the atmosphere	Project area (in acres or square feet).	Project area (in square meters, hectares or number of urban trees)	Can be captured by certain large-scale nature-based adaptation measures that involve a change of land-cover (ha). Can be captured by urban green infrastructures.	- Forests - Green open spaces - Riparian areas - Green roofs - Bioretention - Urban trees
Climate regulation	Process of removing and storing carbon dioxide (CO2) from the atmosphere or by avoiding carbon emissions	Project area (in acres or square feet).	Project area (in square meters, hectares, or number of urban trees)	Can be captured by certain large-scale nature-based adaptation measures that involve a change of land-cover (ha). Can be captured by urban green infrastructures.	- Forests - Green open spaces - Riparian areas - Inland wetlands - Green roofs - Permeable pavements - Bioretention - Urban trees
Erosion control	Benefits and avoided costs related to erosion control	Project area (in acres or square feet).	Project area (in square meters or hectares)	Can be captured by certain large-scale nature-based adaptation measures that involve a change of land-cover (ha).	- Forests - Green open spaces - Riparian areas
Habitat	Providing shelter and refugia to maintain	Project area (in acres or square feet).	Project area (in square meters, hectares, or number of urban trees)	Can be captured by certain large-scale nature-based adaptation measures that	- Green open spaces - Riparian areas

[4] FEMA. (2022). Economic Benefit Values for Green Infrastructure. And FEMA. (2022). Ecosystem Service Value Updates.

Environmental Impact	Description	FEMA BCA	RoI	Calculation Method	Affected Asset Category
	biological diversity			involve a change of land-cover (ha). Can be captured by urban green infrastructures.	- Inland wetlands - Green roofs - Bioretention - Urban trees
Building energy savings	Reduction in energy use for heating and cooling by insulating buildings from large changes in temperature	Project area (in acres or square feet).	Project area (in square meters or number of urban trees)	Can be captured by urban green infrastructures.	- Green roofs - Urban trees
Drought risk reduction	Mitigating drought risk by increasing water supply through groundwater infiltration	Project area (in acres or square feet).	Project area (in square meters or number of urban trees)	Can be captured by urban green infrastructures.	- Permeable pavements - Bioretention - Urban trees
Heat risk reduction	Reducing the risk of human heat-related illness by reducing local temperatures through shade and evapotranspir ation	Project area (in acres or square feet).	Number of urban trees	Can be captured by urban green infrastructures.	Urban trees
Property value improvement	Increase in home sales price because of proximity to green infrastructure	Project area (in acres or square feet).	Project area (in square meters or number of urban trees)	Can be captured by urban green infrastructures.	- Green roofs - Bioretention - Urban trees
Reduction of stormwater volume and quality	Reducing the quantity of stormwater runoff and pollutant loading through increased infiltration	Project area (in acres or square feet).	Project area (in square meters, hectares, or number of urban trees)	Can be captured by certain large-scale nature-based adaptation measures that involve a change of land-cover (ha). Can be captured by urban green infrastructures.	- Forests - Green open spaces - Riparian areas - Inland wetlands - Green roofs - Permeable pavements - Bioretention - Urban trees

4. Modeled Damage

This section describes how the hazard probability parameter were incorporated in the toolkit as well as the assumptions taken to calculate direct impact estimates. The following sections provide details related to modeled damage specific for each hazard.

4.1 Flood

Input

The main input to the Riverine Flood Modules is the Water Surface Elevation. This input generally come from Hydrology and Hydraulic studies (H&H). The required inputs within the ROI Toolkit are similar to the inputs within the FEMA BCA Toolkit. While recurrence intervals modeled can vary, four recurrence intervals are necessary to correctly model the damage probability curve.

Modeled Damage

Direct damage estimation is made through the use of depth damage functions (DDFs). The RoI Toolkit includes three sets of DDFs in the current version of the prototype.

The FEMA BCA Toolkit offers the possibility of selecting a specific DDF to estimate damages to assets and contents from the following six sources of DDFs:

- USACE – Generic
- USACE – Galveston
- USACE – Chicago
- USACE – New Orleans
- USACE – St Paul
- USACE – Wilmington

An analysis was made to select the most appropriate DDF's. The only DDF's incorporated in the RoI Toolkit, coming from the FEMA BCA Toolkit was the USACE – Generic DDFs. Other DDFs have been rejected, because they have been calibrated regionally and are resultantly not applicable to a Canadian context.

AECOM has reviewed the DDFs available in Canadian context; specifically, DDFs offered by the software CanFlood[5]. The following sets of Canadian DDFs are available within CanFlood:

- ACRES 1968 (Ontario)
- Alberta Provincial assessment (IBI Group 2015)
- Fraser Valley (IBI Group 2020- British Columbia)
- Red River Basin (Manitoba 2000 – KGS Group)

For the first version of the RoI Toolkit, only the Alberta Provincial assessment DDFs have been incorporated from those available in CanFlood. The reason is that other DDFs are either old or do not have extensive coverage of the asset types included in the RoI Toolkit. Regarding the Fraser Valley DDFs, contact has been made with NRCAN to obtain more information for the application of the DDF's.

AECOM had also incorporated DDFs developed by the International Joint Mixed Commission (IJC) with collaboration from Fisheries and Ocean Canada (MPO) (Doyon et al, 2021 unpublished). Those DDFs were developed from the flooding of Richelieu River and Lake Champlain in 2011.

The following sections provide additional information on each set of DDFs included in the RoI Toolkit.

[5] IBI Group and Natural Resources Canada. 2021. Canflood 1.0 – User Manual. 139 pages.

USACE – GENERIC:

The USACE – Generic DDFs includes a wide variety of DDFs for Residential and Non-Residential assets. The USACE – Generic DDF separately estimates damages to assets and their contents, which are expressed as a percent of the building replacement value (BRV) and total content value, respectively. The damage point begins at the lowest finished floor (which could be a finished basement). Residential assets are separated by the presence/absence of basement and number of storeys. Structural damages are estimated using the BRV. The content value for each asset was estimated based on the asset's replacement value and the content-to-structure value ratio (CSVR) for the assigned asset type. The CSVR is applied (Table 4-1) from the BRV to calculate the content value for various types of assets, while Residential assets have a CSVR of 100%.

Table 4-1: Contents Value as a Percent of Asset Value

Asset	Engineered Building	Pre-engineered Building
Apartment	10%	12%
Clothing, Retail	29%	36%
Convenience Store	52%	62%
Correctional Facility	24%	27%
Electronics, Retail	65%	81%
Fast Food	15%	17%
Furniture, Retail	14%	18%
Grocery	85%	106%
Hospital	28%	30%
Hotel	15%	19%
Industrial Light	38%	47%
Medical Office	13%	15%
Non-Fast Food	23%	26%
Office One-Story	12%	14%
Other	There is no standard value and users must enter their own data, with documentation	There is no standard value and users must enter their own data, with documentation
Protective Services	69%	88%
Recreation	25%	30%
Religious Facilities	7%	8%
Schools	6%	7%
Service Station	66%	83%
Warehouse, Non-Refrigerated	37%	47%
Warehouse, Refrigerated	36%	43%

Alberta Provincial assessment (IBI Group 2015)

The IBI group[6] has produced a wide variety of DDFs for Residential and Non-Residential assets. The damage is calculated on dollar per square meters basis. The damage point starts at the first floor. The Residential DDF for both assets and contents are categorized by the floor area:

- 372 + m^2
- 223-271 m^2

[66] IBI Group and Golder Associates Ltd. 2015. Provincial Flood Damage Assessment Study. Prepared for Government of Alberta ESRD - Resilience and Mitigation. 117 pages.

- 112-223 m^2
- <112 m^2
- Mobile home typical 128 m^2
- Apartment typical 93 m^2
- Apartment typical 65 m^2

The Residential building curve is also separated by the presence/absence of a basement.

Regarding the Non-Residential assets, there is a total of 5 five DDFs for structures and 20 DDFs for contents. The list below identifies the Non-Residential structures DDF'S:

- Office/Retail
- Industrial/Warehouse
- Hotel/Motel
- High Rise
- Institution

The Non-Residential content DDFs are:

- General Office
- Medical
- Retail-Shoes
- Retail-Clothing
- Retail-Electronics
- Paper
- Hardware/Carpet
- Mics-Retail
- Furniture/Appliance
- Groceries
- Drugs
- Auto
- Hotels
- Restaurant
- Personal Services
- Financial
- Warehouse/industrial
- Theatres
- Institution
- Hospital

The Non-Residential building and apartment can integrate the presence of underground parking with a damage cost of 215$/per square metre[7].

The DDF's have been developed in Calgary and Edmonton. Damage has to be updated from 2014 to current year dollars. A City Cost index based on RSMeans have been developed to perform regional adjustments and transfer to other geographic location (see section 6).

IJC (Doyon et al 2021[8])

The IJC model is a set of 12 Residential DDFs of direct damage (combining structures and content). The damage point start at the first floor and the damage unit are in percent. A few elements differentiate their model from others such as curve that differentiated finished basement from non-finished. They also have set of curves that applied to rural, to include damage to sceptic tanks and individual water facilities. Residential Building are also separated by the number of storeys.

[7] IBI Group and Golder Associates Ltd. 2019. Provincial Flood Damage Assessment Study- Village of Carbon: Damage Estimates. Submitted to Alberta Environment and Parks. 32 pages.

[8] Unpublished

Modeled Damage after Adaptation Measures

Similar to the FEMA BCA Toolkit, for most of the adaptation measures an H&H study needs to be conducted accounting for the adaptation. For Elevation, Acquisition and Flood proofing measures no Water Surface Elevation after adaptation measures need to be input. For Elevation projects, the user must enter the height of the elevation while the tool will automatically calculate the damage point. For Flood proofing, the user needs to input the geodesic elevation of the Top Barrier. More information on adaptation measures can be found at section 7.6.

4.2 Wildfire

Input Data

The FEMA BCA Toolkit uses, as default value, the Fire Return interval coming from the LANDFIRE[9]. A similar Canada-Wide product is currently under development at NRCAN. NRCAN graciously handed over two probability maps (beta version) to the RoI project for two inhabited areas (Southern zones of Saskatchewan and Val d'Or in Quebec). It is important to note that NRCAN sent these maps to the RoI project to develop the prototype. Indeed, they were created at the beginning of their project, and they do not depict the real burn probability. NRCAN intended to publish their maps in Fall 2021, but it is still unpublished. The use might integrate the regional wildfire recurrence intervals coming from the work of Erni et al, (2020).

Erni, S., Wang, X., Taylor, S., Boulanger, Y., Swystun, T., Flannigan, M., and Parisien, M.A. (2020). Developing a two-level fire regime zonation system for Canada. Canadian Journal of Forest Research, 50, 259–273. https://cdnsciencepub.com/doi/10.1139/cjfr-2019-0191 [accessed December 7, 2020]

Bénichou N., Adelzadeh M., Singh J., Gomaa I., Elsagan N., Kinateder M., Ma C., Gaur A., Bwalya A., and Sultan M. (2021). National Guide for Wildland-Urban Interface Fires. National Research Council Canada: Ottawa, ON. 192 pp.

Modeled Damage

The FEMA BCA Toolkit assumed a 100% destruction of the assets and a damage-to-content ratio of 50% of the BRV. Recent work performs by Porter et al, (2021) suggest using a content ratio of 70% for BRV. The RoI Toolkit has been updated accordingly.

The FEMA toolkit gives an efficiency of 10% for building retrofit with ignition-resistant material and 20% when it is combined with a defensible space. Those findings are in contradiction with recent wildfire lessons learned, such as Fort McMurray in 2016, California Camp Fire of 2018, and 2021 Lytton Wildfire. The lessons learned have shown that the compliance with FireSmart principles are the dominating criteria between destroyed and preserved buildings. AECOM performed important updates on the toolkit based on the National research Council (NRC) risk assessment methodology and recommendation on retrofit and Construction class.

AECOM developed a module to guide the user for the evaluation of wildfire risk as recommended by the NRC. The first step involves the risk evaluation in each of the priority zone as displayed in Figure 4-1.

9 US Department of Interior and US Forest Service, 2021. Fire Return Interval. (Accessed 2021-09-23) https://landfire.gov/bps.php

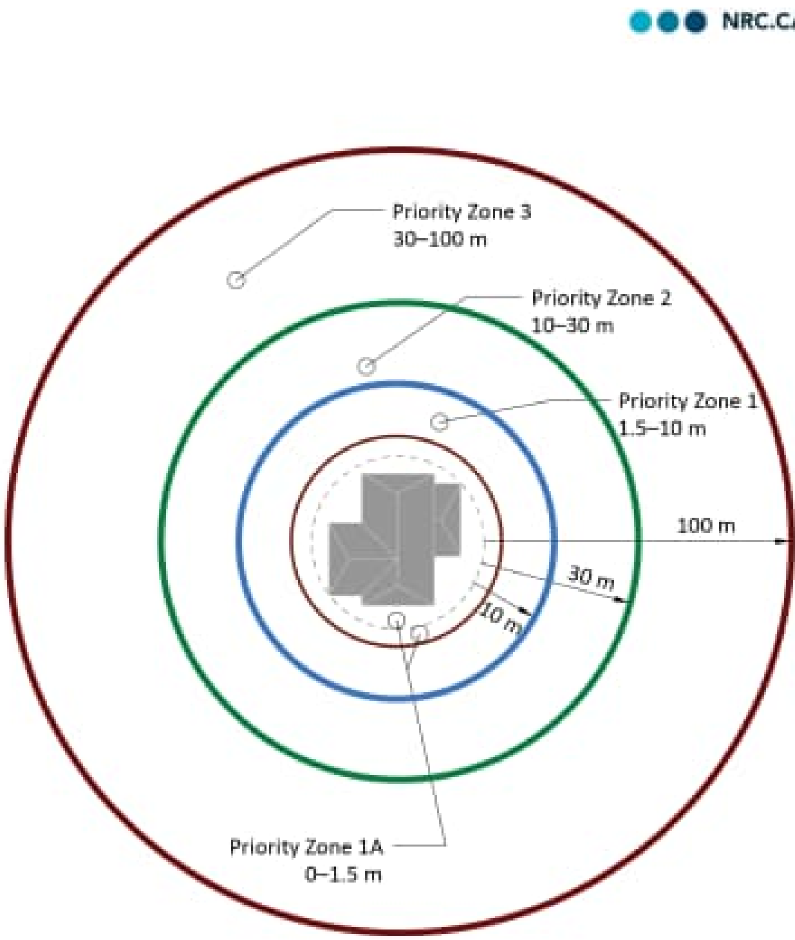

Figure 4-1: Structure Ignition Zone as Proposed by NRC

The user is then questioned on a series of question to assess the level of exposure in each of the priority zone. Based on that evaluation, a global level of risk is evaluated from exposure and hazard level as presented in Table 4-2.

Table 4-2: Global Wildfire risk Exposure

Hazard Level	Exposure			
	Nil	**Low**	**Moderate**	**High**
Nil-Very Low	Nil	Nil	Nil	Nil
Low	Nil	Low	Low	Moderate
Moderate	Nil	Low	Moderate	High
High	Nil	Low	Moderate	High

The different project possibilities are then presented based on the global level of risks in each priority zone as presented in Table 4-3. The user could then select between different option of construction classes mixed with forest fuel management, based on the level of risk. The owner has the choice to properly manage the fuel or use resistant construction material as recommended by NRC. The considered construction classes are the following:

- **Construction Class CC1**: Construction Class where, primarily through the use of non-combustible materials, a level of resistance to **direct flame** impingement and a **high level** of thermal irradiation and **burning embers;**
- **Construction Class CC2**: Construction Class where, through the use of a combination of non-combustible and ignition-resistant materials, a level of resistance to a **moderate level** of thermal irradiation and burning embers; and
- **Construction Class CC3**: Construction Class where, through the use of a combination of non-combustible materials, ignition-resistant materials, and other combustible materials, a **level of resistance to burning embers**.

Table 4-3: Recommended Construction Classes in Listed Priority Zones

Global Exposure Level	Recommended Construction Classes for Use with Mitigation Measures Applied in the Listed Priority Zones				
	None	1A	1A and 1	1A to 2	1A to 3
Low	*CC1*(FR)(1) Baseline	*CC1* *Option 2*	*CC3* *Option 5*	*CC3* *Option 5*	*CC3* *Option 6*
Moderate	*CC1*(FR)(1) Baseline	*CC1*(FR)(2) Option 1	*CC2* *Option 4*	*CC2* *Option 5*	*CC3* *Option 6*
High	*CC1*(FR)(1) Baseline	*CC1(FR)*(2) *Option 1*	*CC1* *Option 3*	*CC1* *Option 4*	*CC3* *Option 6*

Project effectiveness refers to the extent to which the project will reduce wildfire damages, losses, and casualties. It is not possible to assume that a wildfire adaptation project will eliminate wildfire damages and losses, but only reduce them. The toolkit by default that indicates the compliance with NRC Construction class recommendation assumes a 90% project efficiency.

The user can also use the option ‘property vulnerability’ which uses the odds ratio based on the 2018 campfire observation (Hawks, 2020) and implemented by Porter et al, (2021). The user can then select the construction material before and after retrofitting. It is worth mentioning that this approach complies with American standards, not with Canadian standards. For example, the Defensible Space is more an American concept in opposition to Fire Smart that uses a different approach.

Table 4-4: Property Vulnerability Function

Elements	Material	Odds Ratio
Elevated Deck or Porch	composite	0.5
	masonry or concrete	0.3
	none	0.5
	wood	2.5
Deck or Porch Grade	composite	0.3
	masonry or concrete	0.3
	none	2
	wood	2.7
Defensible Space	compliant	0.2
	non-compliant	5
Eaves	enclosed	0.8
	none	2
	unenclosed	1
Exterior Cladding	combustible	1.5
	ignition-resistant	0.6
Fence	combustible	1.8
	none	0.7
	non-combustible	1.1
Patio/Carport Cover	combustible	1.5
	none	0.7
	non-combustible	1.1
Roof	asphalt	0.9
	concrete	1.2
	metal	1.2
	tile	0.4
	wood	6
Vent Screen	mesh < 4mm	0.7
	mesh >4mm	1.2
	no vents	1.1
	no screen	1.5
Windows	multi-pane	0.4
	single pane	3

4.3 Wind

Input

The Wind speed data included in the RoI Toolkit come from The National Building Codes. The National Building Codes are developed by the Canadian Commission on Building and Fire Codes and published every five years by the National Research Council of Canada (NRCC). The latest edition was published in 2015 and presents historic data assuming a stationary climate, including wind speeds.

The wind speeds and corresponding velocity pressures used in the Code are regionally representative or reference values. The reference wind speeds are nominal one-hour averages of wind speeds representative of the 10 m height in flat open terrain. These values were plotted on maps, then analyzed and abstracted for several locations across the country in Table C-2 of the National Building Codes. The data from this table were extracted and included in the RoI Toolkit.

Modeled Damage

The wind damage function used in the RoI Toolkit came from Unanwa et al (2000)[10] while the FEMA BCA toolkit uses the Wind damage function from Hazus. Some challenge has been encountered, while trying to incorporate Hazus Wind damage function. One issue is that many wind scenarios refers to standard specific to the United State Building Code. Also, a total of 9000 Wind damage function are available in Hazus, combined with different wind modelling scenarios (Specific Terrain, building type, change to property type, adaptation strategy etc.), some parameters cannot be explicitly retrieved. AECOM has contacted the HAZUS helpdesk and will try to extract the most reliable information possible adapted to Canadian context in future version of the prototype.

The damage prediction model in the RoI toolkit uses the concept of wind damage bands. The damage band prediction methodology employs an objective weighting technique driven by building component cost factors, component fragilities, and location parameters to obtain upper and lower bounds to building damage thresholds. Damage bands are developed for Residential and Non-Residential assets of 1-3 story (low-rise) as well as 4-10 story (mid-rise) commercial buildings. The curve included in the RoI Toolkit depict the average damage bands taken for each of the asset type. A conversion was performed from one-hour wind coming from the National Building code to gust wind speed of sustained 1-minute wind speed[11].

To model the damage after adaptation techniques, the average decrease in average annual loss was taken from the Hazus hurricane model documentation[12]. The Table 4-5 illustrates the damage reduction factor applied to Residential assets for each adaptation technique.

Table 4-5: Wind Damage Residential Reduction Factor

Adaptation Action Type	Damage Reduction Factor (%)
Install Shutters	33%
Upgrade Roof	16%
Add secondary Water Resistance	12%
Install shutters and upgrade roof	59%
Install Shutters, Upgrade Roof, and add Secondary Water Resistance	68%
Upgrade Roof and Add Secondary Water Resistance	19%

For Non-Residential assets, Table 4-6 presents the aggregation of Non-Residential assets for some key attributes taken from Hazus.

[10] Unanwa et al. 2000. The development of wind damage bands for buildings. Journal of Wind Engineering and Industrial Aerodynamics 84: 119-149

[11] WMO (World Meteorological Organization), 2009. Guidelines for converting between various wind averaging periods in tropical cyclone conditions. Sixth Tropical Cyclone RSM Cs/TCWCs Technical Coordinating Meeting, Item 2.3, 2-5th November 2009.

[12] FEMA (Federal Emergency Management Agency), 2021. Hazus Hurricane Model Technical Manual – Hazus 4.2 Service Pack 3. 624 pages.

Table 4-6: Wind Damage Reduction Factor – Non-Residential Assets

Adaptation Action Type	Damage Reduction Factor (%)
Install Shutters	33%
Presence of Reinforced Masonry	9%
Presence of a Built-up membrane Roof Cover	11%
Strapped Roof-Wall Connection (applied to Wood Truss frame system)	74%
Superior Roof Deck Attachment (applied to steel joist frame system)	3.75%

4.4 Ice Storm

Modeled damage for an Ice Storm is a new feature of the current ROI platform that does not exist in the FEMA BCA Toolkit.

Input

Utility systems may be able to handle moderate ice accumulations, but stressed lines under wind forces are more likely to break. In that context, the RoI Toolkit includes the following inputs:

Ice Accretion

Three researchers at the Climate Research Division of Environment and Climate Change Canada published in 2019 a paper[13] that project changes to extreme ice loads for future periods of specified global mean temperature change (GMTC), relative to the recent 1986–2016 period over the entire country. These searchers graciously granted permission to copy, use and reproduce 20- and 50-year return level radial ice accretion data for baseline and future periods from their paper and incorporate into the RoI Toolkit.

Canadian Wind atlas

Environment and Climate Change Canadas Wind Atlas web site contains maps and data for wind energy over all of Canada at a resolution of 5 km[14]. This site also features colour maps representing the average wind velocity and power on the whole country, as well as corresponding geophysical characteristics. The wind velocity data from this web site were extracted and included in the RoI Toolkit to obtain the probability for different wind classes.

Modeled Damage

The RoI Toolkit estimated the economic impact for two main issues related to ice storm events of varying intensity: Business interruption during power outages and damages trees.

[13] Jeong, D.I., A.J. Cannon, and X. Zhang, 2019. Projected changes to extreme freezing precipitation and design ice loads over North America based on a large ensemble of Canadian regional climate model simulations. Natural Hazards and Earth System Sciences, 19:857-872. doi:10.5194/nhess-2018-395

[14] http://www.windatlas.ca/index-en.php

Business interruption during power outages

The economic impact due to business interruption during power outages is estimated using an extreme weather index known as the Sperry-Piltz Utility Ice Accumulation (SPIA) Damage Index[15]. This index categorizes damage potential in 5 levels through the use of radial ice thickness and wind speed (Table 4-7).

Table 4-7: Sperry-Piltz Utility Ice Accumulation Damage Index

Ice Index	Radial Ice Amount (mm)	Wind (km/h)	Damage and Impact Description
1	< 6.35	24-40	Some localized utility interruptions possible, typically lasting only 1 or 2 hours maximum.
	6.35 – 12.70	< 40	
2	< 6.35	≥ 40	Scattered utility interruptions expected, typically lasting less than 8-12 hours maximum.
	6.35 – 12.70	24 – 40	
	12.7 – 25.4	< 24	
3	6.35 – 12.70	≥ 40	Numerous utility interruption, with some damage to main feeder lines expected with outages lasting from 1-3 days.
	12.7 – 19.05	24 – 40	
	19.05 – 25.40	< 24	
4	12.7 – 19.05	≥ 40	Prolonged & widespread utility interruptions, with extensive damage to main distribution feeder lines and possibly some high voltage transmission lines. Outages expected to last more than 3 to 5 days.
	19.05 – 25.40	24 – 40	
	25.40 – 38.10	< 24	
5	19.05 – 25.40	≥ 40	Catastrophic damage to entire utility systems. Outages could last from one week to several weeks in some areas
	25.40 – 38.10	24– 40	
	> 38.10	< 24	

Source: McManus et al. 2009.

All the data from this table were converted in the metric system and included in the RoI Toolkit. The RoI Toolkit output the joint probability of Radial Ice combined with wind class probability.

The quantification of the damage after adaptation project is made through a user defined project efficiency value. For example, if a micro grid project is able to supplement power 80% of time during outage for 50% of the residents, the project efficiency should be set at 40%.

Tree Damage and associated clean-up

For the first version of the RoI Toolkit, a simplistic assumption was taken to quantify the amount of tree debris. The city street distance factor of 51.8 m^3 tree debris per km city street distance per cm ice thickness[16] at a cost of $13.85 per m^3. The tree removal and associated cleaning price per m^3 came from the aggregation of 26 cities in North Carolina after hurricane Isabel[17]. The cost will be updated in the future to correctly represent Canadian Forest distribution and corresponding clean up price.

The quantification of damage after adaptation only apply to Nature-Based Infrastructure project such as plantation of species tolerant to Ice Storm and tree Inspection and Pruning before winter. The project efficiency is also user entry.

[15] Piltz G.D., S.F., Sperry, S., McPherson, R.A., Gartside, A.D., McClain, D., Meyer, T., Fetsch, C., Shafer, M.A., 2009. Development and testing of an ice accumulation algorithm. August 2008 Conference: 17th Conference on Applied Climatology, American Meteorological Society at: Whistler, B.C.

[16] Hauer, Richard J et al.2011. Rapid Assessment of Tree Debris Following Urban Forest Ice Storms. Arboriculture & Urban Forestry: 236-246.

[17] Federal Emergency Management Agency (FEMA) 2021. Hazus Hurricane Model Technical Manual – Hazus 4.2 Service Pack 3. 624 pages.

4.5 Extreme Temperature

The extreme heat modules did not exist in the FEMA BCA toolkit. The approach and methodology have been largely inspired by the Canadian Institute of Climate Choices (BOYD et al, 2020).

Input Data

For the purpose of temperature modelling, the regional climate simulations used are statistically downscaled climate simulations whereby the Bias Correction/Constructed Analogues with Quantile delta mapping reordering (BCCAQV2) method was used by the Pacific Climate Impacts Consortium (PCIC)[18]. For each location, the Weibull distribution of mean and max temperatures have been extracted from 1980 to 2100. Those distribution will be used to calculate the number of days above optimum temperatures with implications on mortality and morbidity and for workers with high-risk occupations.

Modeled Damage

Fatality

To quantify mortality impacts attributable to high temperatures, an exposure-response function (ERF) coefficients have been obtained from Gasparrini et al. (2015). The coefficients estimated excess deaths attributable to heat for 384 locations globally, including 21 Canadian cities. Excess deaths were defined as deaths attributable to mean daily temperatures above (heat) the “optimum temperature” (i.e., the mean daily temperature between the 2.5th and 97.5th percentiles that corresponded to the minimum daily mortality rate).

Table 4-8: Attributable Mortality Fraction for Heat- Exposures above the Minimum Mortality Temperature

City	Minimum Mortality Temperature	Minimum Mortality Percentile	Fraction of All Cause Mortality (%)
Abbotsford	16.4	79	0.21
Calgary	14.7	82	0.21
Edmonton	15.6	81	0.46
Halifax	16.4	80	0.43
Hamilton	18.2	79	0.52
Kingston	18	79	0.56
Kitchener-Waterloo	18.1	82	0.57
London	18.5	80	0.6
Montreal	18.9	81	0.68
Ottawa	18.3	80	0.62
Regina	16.6	82	0.49
Sudbury	16.7	81	0.59
Saint Johns (NB)	15.6	83	0.28

[18] (PCIC, Statistically Downscaled Climate Scenarios, 2019). https://www.pacificclimate.org/data/statistically-downscaled-climate-scenarios.

City	Minimum Mortality Temperature	Minimum Mortality Percentile	Fraction of All Cause Mortality (%)
St. Johns (NFLD)	16.5	90	0.48
Saskatoon	16.1	82	0.53
Thunder Bay	15.4	82	0.57
Toronto	18.9	80	0.72
Victoria	15.7	82	0.18
Vancouver	16.7	82	0.31
Windsor	20.2	78	0.55
Winnipeg	17.2	81	0.54
Canada	**17.6**	**81**	**0.54**

Morbidity

Bai et al. (2016 and 2017) investigated the relationship between ambient air temperatures and hospitalizations for coronary heart disease, acute myocardial infarction, hemorrhagic stroke, ischaemic stroke, hypertensive diseases, diabetes, and arrhythmia in Ontario between 1996 and 2013. For each disease, a non-linear model was estimated to measure the cumulative effect of temperatures on hospitalizations over a 21-day lag period. Excess hospitalizations were defined as admissions attributable to mean daily temperatures above (heat) the "optimum temperature" (i.e., the mean daily temperature between the 2.5th and 97.5th percentiles that corresponded to the minimum daily hospitalization rate).

Table 4-9: Minimum Morbidity Temperatures, Attributable Fractions, and Attributable Numbers for Heat Effects on Hospitalizations for Four Diseases in Ontario, 1996-2013

	Coronary Heart Diseases	Stroke	Diabetes	Hypertension
Hospitalization Rate (per 100000)	1.81	0.46	0.42	0.07
Mild Heat	1.04	1.63	10.55	1.12
Extreme Heat	0.16	0.19	0.57	0.31
Total Heat	1.2	1.82	11.12	1.43
Mild Heat	18.00	16.60		18.60
Extreme Heat	24.80	24.80	24.80	24.80
Total Heat	18.00	16.60		18.60

Business Interruption

Using a panel data set created from the American Time-Use Survey, Zivin and Neidell (2014) examined the response of labour to daily maximum temperature across 5°F (»2.8°C) bins, from >25°F (-3.9°C) to 105°F (40.6°C). They found that days with extreme temperatures are associated with significant changes in the time allocated to labour by individuals. On days when maximum temperatures exceeded 37.8°C (100°F), workers in industries with relatively high exposure to weather reduced time allocated to labour by nearly one hour compared to temperatures in the 24.4-26.7°C range, which represents a 14% reduction in labour supply for the day.11 However, they found no statistically significant temperature-labour supply effects in other industries that are less exposed to weather (e.g., non-manufacturing, indoor occupations).

Table 4-10: Exposure response functions for relationship between maximum daily temperature and time allocation (change in minutes allocated to labour at each temperature bin relative to 24.4°C - 26.7°C

Max Daily Temperatures		High-risk Occupations (mins / worker / day)
from	to	
29.4	32.2	-5.053
32.2	35	-17.4
35	37.8	-41.417
>37.8		-58.032

The business interruption has been calculated in terms of reduction of labour productivity on an hourly basis. High-risk industries considered are: (NAICS 11) Agriculture, Forestry, Fishing, and Hunting; (NAICS 21) Mining, Quarrying, and Oil and Gas Extraction; (NAICS 22) Utilities; (NAICS 23) Construction; (NAICS 31-33) Manufacturing; and (NAICS 48-49) Transportation and Warehousing.

5. Historical Damage - DFA

The DFA module assesses adaptation projects based on damages avoided. The DFA approach is applicable to all natural hazard types as long as a relationship can be established between how often the natural hazards occur and the extent of damages or losses that occur as a result of each natural hazard event. The DFA module requires historical damage data for two or more natural hazard events in addition to the recurrence interval, or estimated annual probability, of natural hazard event recorded.

The DFA module is applicable to all asset types, including building and facilities, transportation, and water. The DFA module requires the following inputs to evaluate adaptation projects in the building and facilities asset category:

- Historical damages to buildings and contents before the implementation of the adaptation project, including the damage year, recurrence interval, and material damage costs.
- Injuries and fatalities resulting from each event recorded in the DFA.
- Number of volunteers and volunteer days necessary for response activities following each event recorded in the DFA.
- Number of residents displaced, and number of employed residents displaced following each event recorded in the DFA.

After adjusting historical damages to present dollars, the DFA module uses historical damages to estimate average annual damages before the implementation of the selected adaptation project. The DFA module for the building and facilities asset category provides the user the opportunity to enter area of new habitat created, in hectares, for adaptation projects that restore natural habitat and result in Nature-Based Infrastructure.

The DFA module requires the following inputs to evaluate adaptation projects in the transportation asset category:

- Road and bridge properties, including the estimated number of one-way trips per day and additional one-way detour time (in minutes) and one-way detour distance (in kilometers) in the event the road or bridge under evaluation is washed out. These inputs estimate historical damages associated with loss of function in the event of a service disruption.
- Historical damages to roads and bridges before the implementation of the adaptation project, including the damage year, recurrence interval, and material damage costs.

In addition, the DFA module in the transportation asset category requires the user to enter injuries and fatalities resulting from each event recorded in the DFA.

After adjusting historical damages to present dollars, the DFA module uses historical damages to estimate average annual damages before the implementation of the selected adaptation project. The DFA module for the transportation asset category provides the user the opportunity to enter area of new habitat created, in hectares, for adaptation projects that restore natural habitat and result in Nature-Based Infrastructure.

The DFA module requires the following inputs to evaluate adaptation projects in the water asset category:

- Type of service provided, and number of customers served. These inputs estimate historical damages associated with loss of function in the event of a service disruption.
- Historical damages to water assets before the implementation of the adaptation project, including the damage year, recurrence interval, and material damage costs.

In addition, the DFA module in the water asset category requires the user to enter injuries and fatalities resulting from each event recorded in the DFA.

After adjusting historical damages to present dollars, the DFA module uses historical damages to estimate average annual damages before the implementation of the selected adaptation project. The DFA module for the water asset category provides the user the opportunity to enter area of new habitat created, in hectares, for adaptation projects that restore natural habitat and result in Nature-Based Infrastructure.

The DFA module in the RoI Toolkit is similar to the DFA module incorporated in the FEMA BCA Toolkit, though several differences exist. The DFA module in the RoI Toolkit estimates damages associated with historical injuries and fatalities for all asset types (buildings and facilities, transportation, and water) and all hazards. A subtle difference between the RoI Toolkit DFA and the FEMA BCA Toolkit DFA is how historical damages before the adaptation project are presented and calculated. Historical damages before the adaptation project are aggregated per event to capture all benefit categories in the FEMA BCA Toolkit. In the RoI Toolkit, historical damages before the adaptation project are calculated separately by impact category.

6. Province/Territory Cost Index

6.1 Overview

The damage impact costs adopted in this project are based on the costs associated with the City of Edmonton. Province/City Cost index “the index” is introduced as a factor to assist in converting the outputs of damage impact models from one city to another making the model scalable and applicable in different geographical locations across the country.

The indexes are used in accordance with the RSMeans database which is one of the most reliable published data sources in the construction industry. It is mainly used in the predesign and design stages in order to complete conceptual or detailed estimates, respectively. It is adopted when actual costs or historical data are not available in-house to complete cost estimates in various locations. It includes a significant number of construction models (apartments, banking institutions, garages, court houses, libraries, etc.) that a user can specify to approximately estimate costs of projects. RSMeans comprises a number of unit costs of materials, tools, and other construction resources that can be applied to project quantities and prepare detailed schedule of values.

All unit costs and approximate estimates can be adjusted based on a project location a user specifies. These adjustments are based on city cost indices that RSMeans calculated across North America. Albeit the data source is mostly articulated to suit the United States, it accounts for number of city(ies) per province in Canada (except Nunavut). The total number of Canadian cities RSMeans cover is 74, where the highest number of cities available in RSMeans can be found in Quebec (17 cities) and Ontario (20 cities).

6.2 Asset Hierarchy – Level 3 Province/Territory Cost Index Methodology

Several steps have been considered along with a number of assumptions to conclude the indices values under the Building and Facilities group of the asset hierarchy presented as part of Appendix A of Task 3 Report:

1. RS Means publication of Year 2021 – Quarter 1 is used (This is the latest available data at the time of preparing this document and damage impact models).

To align with the asset hierarchy proposed in this project (refer to Task 3 Report Appendix A), number of representative RSMeans models have been used to derive a cost index. These models assist in providing an approximate total cost along with an overall calculated unit cost.

2. Table 6-1 lists the RSMeans models that best represent Asset Hierarchy Level 3 of this project. There are many other RSMeans models that could be applicable, but the main purpose is not to derive a unit cost to calculate the project costs but rather a representative a cost index that could be applied at Asset Hierarchy Level 3 for the damage impact models. In addition to the municipal assets identified in Asset Hierarchy Level 3, commercial facilities have been also considered in the methodology to increase the number of facilities analyzed.

Table 6-1: Asset Hierarchy Level 3 and Associated RSMeans Models

Asset Hierarchy Level 3 *i*	RSMeans Model *j*	Unit cost ($/Sq.ft) Example in Calgary, Alberta	Unit cost ($/Sq.ft) Example in Edmonton, Alberta
Indoor Recreation Facilities (M1)	1: Rink, Hockey/Indoor Soccer; Concrete Block/Rigid Steel	$214.65	$217.18
	2: Swimming Pool, Enclosed; Concrete Block/Precast Concrete	$355.07	$358.24
Outdoor Recreation Facilities (M2)	There are not available models in RSMeans that could relate to Outdoor Recreation Facilities. As construction resources would most likely be relevant to Indoor Recreation Facilities, the same derived indices of the latter are used.		
Cultural Buildings (M3)	1: Auditorium; Concrete Block/Bearing Walls	$205.64	$207.38
	2: Community Center; Decorative Concrete Block/Bearing Wall	$166.20	$167.41
	3: Library; Face Brick & Concrete Block/Reinforced Concrete	$207.55	$209.18
Educational Buildings (M4)	1: College, Classroom, 2-3 Story; Brick Veneer/ Reinforced Concrete	$207.31	$208.97
	2: College Dormitory, 4-8 Story; Brick Veneer/Reinforced Concrete	$221.00	$222.74
	3: School, Elementary; Brick Veneer/Reinforced Concrete	$215.24	$216.95
	4: School, High, 2-3 Story; Brick Veneer / Reinforced Concrete	$244.05	$228.59
Essential Facilities (M5)	1: Hospitals,4-8 Story; Brick Veneer/Reinforced Concrete	$334.54	$336.0
	2: Medical Office,2 Story; Brick Veneer/Reinforced Concrete	$262.05	$263.32
	3: Nursing Home; Face Brick & Concrete Block/Bearing Walls	$237.93	$239.46
	4: Police Station; Decorative Concrete Block/Bearing Walls	$274.96	$276.55
	5: Fire Station, 2 Story; Decorative Concrete Block/Precast Concrete	$227.63	$229.38
Housing (M6)	1: Apartment, 1-3 Story; Brick Veneer/Reinforced Concrete	$216.98	$218.03
	2: Assisted-Senior Living; Brick Veneer & Concrete Block/Bearing Walls	$256.72	$259.69
Commercial (M7)	1: Store, Retail; Brick Veneer/Reinforced Concrete	$189.21	$191.03

3. Unit costs for all considered RSMeans models were calculated per city. In total, 1406-unit costs were identified. Each unit cost was converted to an index ranging between 0 to greater than 100 (considering Edmonton's unit costs as the baseline). The index is calculated according to the following:

$$Index\ City_{cij} = \frac{Unit\ Cost_{cij}}{Unit\ Cost_{Edmonton\_ij}} x100, \text{ Equation 1}$$

where i is the Assets under Building and Facilities (e.g. Indoor Reaction Facilities); j is the RSMeans model per i; c is any city within the cities in RSMeans. For example, the value of model 11 (M11), in Table 6-1, is $214.64 in Calgary and $217.18 in Edmonton. Using Equation 1, the calculated index would be 98.8.

4. The average value of RSMeans models' indices per Asset Hierarchy - Level 3, including Commercial, for each city is calculated using Equation 2.

$$Index\ City_{ci} = \frac{\sum_{j=1}^{n} Index\ City_{cij}}{n}, \text{ Equation 2}$$

For example and considering the indices of the City of Calgary for M11 (98.8) and M12 (99.1), the index for Indoor Recreation Facilities would be 99.0.

5. RSMeans lacks any information regarding Nunavut. Housing costs information comparing Yellowknife with Iqaluit is collected from a construction magazine dated in 2012 (Northern News Services 2012)[19]. The housing index calculated for Northwestern Territories was used to interpolate the Housing index for Nunavut considering the unit costs reported in that article. The calculation of the remaining asset hierarchy in Level 3, including Commercial, are based on the difference percentages per asset in Level 3 computed in Northwestern Territories (Table 6-2).

Table 6-2: Nunavut Calculated Indices from Northwestern Territories

Province/Territory	M1	M2	M3	M4	M5	M6	M7
Northwestern Territory	100.0	100.0	100.1	101.0	99.8	99.0	98.3
Nunavut	84.9	84.9	84.9	$(\frac{101.0 - 99.0}{99.0})\% = 2.08\%$ $Index = 84.0(1 + 2.08\%) = 85.7$	$(\frac{99.8 - 99.0}{99.0})\% = 0.83\%$ $Index = 84.0(1 + 0.83\%) = 84.7$	84.0 (interpolated using the article information)	83.4

6.3 Results – Province/Territory Cost Index

Based on the methodology and the assumptions, Table 6-3 lists the indices that can be applied to the impact models. These indices are prepared considering the city of Edmonton as a baseline.

[19] Northern News Services. 2012. “Numbers show a different Picture”. http://nbsnorth.com/assets/construction-info-in-yellowknife-(facts).pdf

Table 6-3: Calculated Province/Territory Cost Index

Province	City	Indoor Recreation Facilities	Outdoor Recreation Facilities	Cultural Buildings	Educational Buildings	Essential Facilities	Housing	Commercial
Alberta	Calgary	99.0	99.0	99.2	101.1	99.4	99.2	99.0
Alberta	Edmonton	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Alberta	Fort MacMurray	97.7	97.7	97.0	98.3	97.2	95.8	95.9
Alberta	Lethbridge	94.9	94.9	94.4	96.1	95.1	93.7	93.0
Alberta	Lloydminster	90.9	90.9	90.7	92.3	91.9	90.0	88.9
Alberta	Medicine Hat	90.7	90.7	90.5	92.0	91.5	90.0	88.9
Alberta	Red Deer	90.9	90.9	90.8	92.3	91.7	90.6	89.4
British Columbia	Kamloops	91.1	91.1	91.1	93.1	92.7	90.9	90.5
British Columbia	Prince George	91.3	91.3	91.3	96.0	92.6	90.6	90.6
British Columbia	Vancouver	98.8	98.8	99.2	99.5	99.2	99.4	98.4
British Columbia	Victoria	94.1	94.1	94.3	96.3	95.2	94.2	94.5
Manitoba	Brandon	89.5	89.5	89.0	90.1	90.4	87.7	86.0
Manitoba	Portage La Prairie	84.9	84.9	83.6	84.5	85.3	82.3	80.1
Manitoba	Winnipeg	91.0	91.0	89.8	90.7	90.3	89.1	87.5
New Brunswick	Bathurst	81.6	81.6	80.0	80.9	82.0	78.7	76.7
New Brunswick	Dalhousie	81.5	81.5	80.3	81.2	82.3	79.4	77.4
New Brunswick	Fredericton	88.9	88.9	88.2	89.5	89.5	87.5	84.9
New Brunswick	Moncton	87.9	87.9	87.5	89.3	89.0	86.8	83.9
New Brunswick	Newcastle	81.9	81.9	80.4	81.4	82.4	79.3	77.1
New Brunswick	Saint John	89.2	89.2	88.9	90.7	90.2	88.1	85.2
Newfoundland	Corner Brook	90.6	90.6	90.3	91.3	91.5	89.1	89.0
Newfoundland	St John	98.4	98.4	98.3	99.8	98.0	97.9	97.4
Northwestern Territories	Yellowknife	100.0	100.0	100.1	101.0	99.8	99.0	98.3
Nova Scotia	Bridgewater	85.4	85.4	84.1	85.2	85.9	83.0	81.4
Nova Scotia	Dartmouth	90.0	90.0	89.4	90.4	90.9	88.1	87.4
Nova Scotia	Halifax	95.6	95.6	95.8	98.0	96.4	96.2	94.3

Province	City	Indoor Recreation Facilities	Outdoor Recreation Facilities	Cultural Buildings	Educational Buildings	Essential Facilities	Housing	Commercial
Nova Scotia	New Glasgow	89.1	89.1	88.5	89.5	90.1	87.2	86.3
Nova Scotia	Sydney	88.1	88.1	87.6	88.9	89.5	86.6	85.3
Nova Scotia	Truro	85.2	85.2	84.0	85.0	85.7	82.7	81.2
Nova Scotia	Yarmouth	89.1	89.1	88.5	89.5	90.0	87.2	86.3
Ontario	Barrie	94.8	94.8	94.4	96.1	95.3	93.4	92.4
Ontario	Brantford	94.6	94.6	94.8	96.7	95.4	94.3	93.6
Ontario	Cornwall	93.1	93.1	93.5	95.3	94.4	92.9	91.5
Ontario	Hamilton	99.2	99.2	100.1	102.8	100.4	100.4	98.5
Ontario	Kingston	93.5	93.5	94.0	95.8	94.9	93.3	92.1
Ontario	Kitchener	93.8	93.8	93.8	96.5	94.7	93.8	91.7
Ontario	London	98.8	98.8	99.3	101.8	99.5	99.3	98.0
Ontario	North Bay	96.6	96.6	97.2	99.0	97.9	96.5	95.8
Ontario	Oshawa	96.0	96.0	96.4	98.7	96.7	96.4	94.8
Ontario	Ottawa	100.2	100.2	101.2	101.9	101.1	101.5	98.8
Ontario	Owen Sound	94.1	94.1	93.7	95.3	94.6	92.5	91.5
Ontario	Peterborough	93.1	93.1	93.2	94.9	94.1	92.5	91.5
Ontario	Sarnia	94.7	94.7	95.3	97.4	96.4	94.9	93.7
Ontario	Sault Ste. Marie	91.3	91.3	91.4	93.9	92.9	91.5	89.6
Ontario	St Catharine	93.2	93.2	93.2	95.9	94.1	93.6	92.0
Ontario	Sudbury	92.0	92.0	92.0	94.7	93.1	92.2	90.5
Ontario	Thunder Bay	93.6	93.6	93.7	96.3	94.4	93.9	91.3
Ontario	Timmins	92.5	92.5	92.3	94.1	93.3	91.7	90.5
Ontario	Toronto	102.0	102.0	103.2	104.3	103.3	103.8	101.7
Ontario	Windsor	93.4	93.4	93.5	96.2	94.3	93.8	91.7
Prince Edward Island	Charlottetown	86.3	86.3	84.6	84.8	85.4	83.4	81.6
Prince Edward Island	Summerside	84.8	84.8	84.0	84.5	85.7	82.4	81.6
Quebec	Cap-de-madeleine	88.8	88.8	88.7	90.3	90.2	88.0	86.0

Province	City	Indoor Recreation Facilities	Outdoor Recreation Facilities	Cultural Buildings	Educational Buildings	Essential Facilities	Housing	Commercial
Quebec	Charlesbourg	88.8	88.8	88.7	90.3	90.2	88.0	86.0
Quebec	Chicoutimi	92.8	92.8	93.0	95.3	94.0	93.0	90.8
Quebec	Gatineau	88.7	88.7	88.3	90.0	89.9	87.7	85.7
Quebec	Granby	88.8	88.8	89.2	90.0	89.9	87.7	85.8
Quebec	Hull	88.8	88.8	88.4	90.0	89.9	87.8	85.8
Quebec	Joliette	88.9	88.9	88.7	90.3	90.2	88.1	86.1
Quebec	Laval	89.1	89.1	88.8	90.4	90.3	88.2	86.2
Quebec	Montreal	98.7	98.7	98.4	100.6	98.6	98.4	96.8
Quebec	Quebec	98.8	98.8	98.7	100.9	98.8	98.7	97.3
Quebec	Rimouski	92.7	92.7	93.0	95.3	94.1	93.1	91.1
Quebec	Rouyn-Noranda	88.7	88.7	88.3	89.9	89.9	87.7	85.7
Quebec	Saint Hyacinthe	88.4	88.4	87.9	89.6	89.4	87.4	85.5
Quebec	Sherbrooke	88.9	88.9	88.5	90.0	90.0	87.8	85.9
Quebec	Sorel	88.9	88.9	88.7	90.3	90.2	88.1	86.1
Quebec	Saint Jerome	88.7	88.7	88.3	90.0	89.9	87.7	85.8
Quebec	Trois Rivieres	93.2	93.2	93.7	95.3	94.9	93.0	91.5
Saskatchewan	Moose Jaw	81.3	81.3	79.9	80.8	82.0	78.7	76.4
Saskatchewan	Prince Albert	80.3	80.3	78.7	79.7	80.8	77.7	75.5
Saskatchewan	Regina	99.9	99.9	99.9	99.9	99.6	99.9	98.9
Saskatchewan	Saskatoon	91.3	91.3	91.5	93.7	92.7	91.6	89.8
Yukon	Whitehorse	94.2	94.2	93.6	94.1	93.8	92.1	91.6
Nunavut	Iqaluit	84.9	84.9	84.9	85.7	84.7	84.0	83.4

6.4 Cost Modifier and Adjusted Impact Cost

The indices presented in Table 6-3 provides an opportunity to observe the expected variations in costs across the considered cities. Cities with indices greater in value than others will generate higher costs. For example, in Edmonton, the indices are set at 100. Any index exceeding 100 will generate a cost greater than in Edmonton. Further, and since indices represent the cost variations across cities, a known cost (baseline cost) of City A along with known indices of City A and B can aid in calculating the approximate unknown cost of City B.

This principle has been adopted to determine the damage impact cost from one city to another through the Cost Multiplier (Equation 3) and Adjusted Damage Impact Cost (Equation 4). Cost Multipliers less than 1 will generate Adjusted Damage Impact Cost less than the baseline cost.

$Cost\ Multiplier = \frac{Index_c}{Index_y}$, Equation 3

where y is the index of a city with a known damage impact cost (baseline cost).

$Adjusted\ Damage\ \ Cost_c\ =\ Cost\ Multiplier_c * Damage\ Cost_y$, Equation 4

Example 1 and 2 shows two hypothetical examples where Equation 3 and 4 are applied for illustration.

Example 1 – Impact cost of Indoor Recreation (M1) Facilities in Edmonton, Alberta = $50,000

To calculate an impact cost of the same asset level in Iqaluit, consider the following:

1. Edmonton is located in Alberta. the index is equal to 100.
2. Iqaluit is located in Nunavut; the index is equal to 84.9.
3. The damage impact cost on Indoor Recreation Facilities in Iqaluit = $\$50{,}000\left(\frac{84.9}{100}\right)$ = $42,450

Example 2 – Impact cost of Essential Facilities (M5) in Montreal, Quebec = $250,000

To calculate an impact cost of the same asset level in Toronto, Ontario, consider the following:

1. Montreal is located in Quebec; the index is equal to 98.6.
2. Toronto is located in Ontario; the index is equal to 103.3.
3. The damage impact cost on Essential Facilities in Toronto = $\$250{,}000\left(\frac{103.3}{98.6}\right)$ = $261,917.

7. Climate Change Impact Considerations

The effects of widespread warming are evident in many parts of Canada and are projected to intensify in the future[20]. This means that Canadian cities can expect to be confronted more often with natural hazards. In that context, a module was added in the RoI Toolkit for each hazard in order to help cities to test their resilience and help them adapt to the new climatic conditions. Climate change is a new feature that is not available into FEMA BCA Toolkit.

Climate projections are based on assumptions regarding the evolution of GHG emissions. These are referred to as Representative Concentration Pathways (RCP) and are named after their associated level of radiative forcing or difference between sunlight absorbed on Earth and what is radiated back to space. For instance, RCP 2.6, RCP 4.5, RCP 6 and RCP 8.5 correspond to 2.6, 4.5, 6 and 8.5 W/m² of radiative forcing, respectively for each scenario. Projected carbon dioxide (CO2) concentration levels are predicted from the anticipated growth in population and energy demand (the type of energy is an important factor), as well as by the anticipated changes vegetation cover and type.3 High level descriptions of the RCPs are below in Table 7-1.

Table 7-1: RCPs Scenario

RCP	Description
RCP 2.6	Stringent mitigation scenario; representative of a scenario that aims to keep global warming likely below 2 degrees Celsius (°C) increase above preindustrial temperatures. Ambitious reduction of GHG emissions peak around 2020, then decline and become net negative before 2100.
RCP 4.5	Intermediate mitigation scenario consistent with relatively ambitious emissions reductions and GHG emissions increasing slightly before starting to decline ~2040. This falls short of the 2°C limit agreed upon in the Paris Agreement.
RCP 6.0	High to intermediate emissions scenario with emissions peaking in 2060 and declining for the rest of the century.
RCP 8.5	Very high GHG emissions; consistent with no policy changes to reduce emissions (current policies or business as usual).

Source: IPCC, 2014[4]

The high carbon future (RCP 8.5) scenario was selected as default Climate Change mode in the RoI Toolkit as it represents the worst-case scenario, which would overestimate the associated risk. The RCP 8.5 has been chosen in the toolkit, because it will depict the upper damage band. The user can perform an analysis with and without climate change to quantify damage associated to the magnitude of Climate Change uncertainty.

Table 7-2: The year at which the indicated global mean warming ∆T relative to 1986-2016 reference period[21]

Δ Temperature	Year
+ 1.0°C	2035
+ 1.5°C	2047
+ 2.0°C	2059
+ 2.5°C	2069
+ 3.0°C	2080
+ 3.5°C	2090

[20] Bush, E. and Lemmen, D.S., editors (2019): Canada's Changing Climate Report; Government of Canada, Ottawa, ON. 444 p.
[21] Source: Cannon et al. 2020. Climate-resilient buildings and core public infrastructure 2020 : an assessment of the impact of climate change on climatic design data in Canada. 106 pages.

The most relevant timeframe for each of the assets evaluated has been identified in the RoI Toolkit. For example, the most appropriate timeframe to carry out an assessment to may be 2080 for a newly constructed infrastructure as we are expecting its life expectancy to be several decades. On the contrary, a shorter timeframe (e.g., 2035) may be appropriate for an infrastructure whose replacement is planned shortly. The default climate change mode automatically selects the appropriate timeframe based on the expected construction end combined with the project useful life.

Specific climate models will be used for flood and wildfire risks, the following subsections present data requirements for each climate hazard.

7.1 Riverine Flood

For Stormwater and pluvial project user is encouraged to use the intensity-duration-frequency(IDF) tool of the university of Western Ontario[22].

The user can override any-time the default mode with the availability of better data accounting for climate change.

7.2 Wildfire

The updated Burn Probability with regards to climate change are supposed to be included in the upcoming NRCAN project (see section 4.2). For now, the approach of Wotton et al, (2020) depicting the increase in burn area over time, will be used to evaluate climate change based on the following regression:

$$f1(t) = a * (t - 2000)^b$$

where: a=0.562

b=0.2436

t=target year

7.3 Wind

Cannon et al.(2020) projected wind speed value for 675 locations across Canada for 6 global mean temperature change level above the baseline, namely 0.5°C; 1°C, 1.5°C, 2°C, 2.5°C, 3°C and 3.5°C. Briefly, the authors used the wind speed values presented in the Table C-2 of the 2015 National Code of Building as baseline level and projected the variation of these baseline values for two return periods (10 and 50-year) by using the Canadian Regional Climate Model Large Ensemble (CanRCM4). Results from this modeling were downloaded (https://climate-scenarios.canada.ca) and included in the RoI Toolkit.

7.4 Ice Storm

As stated in section 2.3.3., the three searchers from the Climate Research Division of Environment and Climate Change Canada graciously grant permission to the RoI project to copy, use and reproduce 20- and 50-year return level radial ice accretion data for future periods from their paper[13]. They used a global mean temperature change level (0.0°C to 3.5°C) above the baseline. The Sperry-Piltz Radial Ice accretion indices (see section was generated for each climate change scenarios.

7.5 Extreme Temperature

Using gridded observations of the historical climate for the calibration of the downscaling method (i.e., a combination of several statistical methods), regional variations are derived from the coarser global climate simulations. Consequently, the projection for the period 2010-2023 will be computed as a baseline period to closely aligned with the observations and compared to a future period ranging from 2071 to 2100.

[22] ICLR (Institute of Catastrophic Loss), FIDS - Western University – 2021. https://www.idf-cc-uwo.ca/. Accessed 2021-09-24.

From the 27 available climate models and the three emission scenarios (RCP2.6, RCP4.5, and RCP8.5), 12 models and one scenario (RCP8.5) have been selected for the analyses (Table 7-3 and These simulations represent the full range and uncertainty of the climate simulations.

Table 7-3: Selected Global Climate Models (GCMs) for which downscaled climate data were obtained for this CCVA (PCIC, 2019)

Global climate models		
ACCESS1-0	CSIRO-mk3-6-0	IPSL-CM5A-MR
CanESM2	GFDL-CM3	MIROC5
CCSM4	GFDL-EMSM2G	MPI-ESM-LR
CNRM-CM5	inmcm4	MRI-CGCM3

Table 7-4: Short description of the different Representative Concentration Pathways (RCPs) (IPCC, 2001)[23]

RCP	Description
RCP2.6	**Stringent mitigation scenario**: representative of a scenario that aims to keep global warming likely below a 2°C increase above preindustrial temperatures. Ambitious reduction of GHG emissions required for this scenario for emissions to peak around 2020, then decline, and become net negative before 2100.
RCP4.5	**Intermediate mitigation scenario** consistent with relatively ambitious emissions reductions. The GHG emissions increase before starting to decline between 2040 and 2050. This scenario will likely fall short of the 2°C limit agreed upon in the Paris Agreement.
RCP6.0	**Intermediate to high emissions scenario** with emissions peaking in 2080 and declining for the rest of the century.
RCP8.5	**Very high GHG emissions**: consistent with no policy changes to reduce emissions.

7.6 Adaptation Library

The RoI Toolkit hosts a default adaptation project inventory for each type of hazard; therefore, options will depend on the Hazard Type selection (flooding, wildfires, wind, extreme temperatures and ice storms). The table below presents the adaptation measure library. The adaptation projects library classifies the adaptation according to the type of hazard, the components that are targeted by the adaptations and the different stakeholders that could be involved. The adaptations are also classified according to three categories: Design, Operation and Maintenance and Policy.

The Design category refers to structural measures or projects to adapt the asset so that it withstands future climate conditions, while the operation and maintenance and policy categories are non-structural measures that refer to planning additional operations and maintenance measures or projects or the development of policies to ensure resiliency to future climate change impacts.

The adaptation projects within the RoI Toolkit are adapted to the Canadian reality and Canadian standards, such as CSA standards, Fire Smart, etc. The calculation of adaptation project costs will be undertaken for structural projects within the RoI Toolkit by considering their costs and the project or asset's useful life. For non-structural projects, it is hard to establish default costs, therefore the user will have to input their own data for non-structural measure costs.

[23] IPCC (2001). https://www.ipcc.ch/2001/

FLOODING (RIVERINE)				
Scale	Stakeholders	Examples of Adaptation Projects		
		Design (Structural)	Operation and Maintenance (Non-Structural)	Policy (Non-Structural)
Roads	Local transportation authorities and transportation agencies	• Use appropriate materials to prevent cracking of the surface layer of roads • Use pavement materials that are well sealed and less susceptible to moisture • Increase base strength (thickness and/or quality) to increase protection of subgrade layers • Use subgrade materials that withstand higher moisture content and/or use hydraulic binding agents in road foundation • If possible, raise road surface level to reduce flood damage and ensure continued access during flood event	• Increase crack sealing, especially prior to flooding season	
Bridges and Culverts	Local transportation authorities and transportation agencies	• Raise bridge decks to accommodate increase in flood volumes • Reinforce bridge piers and abutments and strengthen foundation to protect from erosion risks. • Incorporate design requirements from the CSA S6-18 Canadian Highway Bridge Design Code in order to increase resiliency of bridges to erosion caused by flooding • Culvert design should account for the possibility of partial blockage by debris and sediments (CSA W204:19)	• Cleaning out debris from clogged culverts and increase its frequency • Inspect bridges for erosion before and after flooding events	
River Basin	Local, regional, provincial, and territorial governments AND landowners	• Floodplain and stream restoration (FSR): Land purchase of flood prone areas by the government in order to relocate on safer grounds and restore the land to natural floodplain functions	• Monitor water level to assess the risk or flooding during heavy rainfall (see TRCA's real-time flood monitoring website and Calgary's flood and rive monitoring program)	
	Local, regional, provincial, and territorial governments AND watercourse experts	• Watercourse alteration: o Channel relocation o Widening or straightening o Culvert replacement o Stream bank stabilization	• Keep floodplain information and maps up to date and make sure they are accessible • Develop an operational and maintenance plan that identifies potential areas of risk related to flooding of riverine zones and specify measures and procedures to address any such risks	
Buildings	Architects, developers, builders, and renovation specialists and building owners	• Dry floodproofing • Wet floodproofing • Elevation of assets • Flood barriers • Levees • Floodwalls • Anti-return valve • Site-grading	• Ensure proper testing and maintenance of sump pump and backwater valve systems • Residential buildings should conduct sewer connection inspections, maintenance, repairs, or replacements when appropriate (CSA Z800-18) • Proper construction should be conducted during pre-construction, construction, and post	• Increase minimum building elevations during development and construction

FLOODING (RIVERINE)				
Scale	**Stakeholders**	**Examples of Adaptation Projects**		
		Design (Structural)	**Operation and Maintenance (Non-Structural)**	**Policy (Non-Structural)**
		• Use flood-damage-resistant building materials (CSA Z800-18) • Ensure that buildings are not located in flood prone areas and prioritize sites that are at lower risks of flooding when choosing sites • Residential Building Retrofit • Non-Residential Building Retrofit • Public Building Retrofit • Historic Building Retrofit	construction phases in order to prevent erosion as per CSA W202-18	
	Homeowners and building owners		• Increase routine and proactive maintenance measures that should be regularly completed by homeowners to reduce water damage and flood risk (CSA Z800-18)	
Critical Infrastructure	Local, regional, provincial, and territorial governments AND engineers	• Drainage improvement by: o Retention ponds o By-pass channels o Higher capacity storm sewers o Separating storm sewers and sanitary sewers o Improve pumping capacity of drainage systems • Sewer backwater protection by never directing downspout, foundation drain and sump pump discharge toward the sanitary sewers (CSA W204:19) • Stormwater system should be designed according to a dual drainage concept, taking into account the minor and major system • As per CSA W204:19: o Minor and major drainage systems should be designed concurrently to a minimum 1-in-100-year major storm design event. o Minor drainage systems should be designed to convey runoff for the 1-in-2-year to 1-in-10-year return period flows and more frequent rainfall events. o Major drainage systems should be designed to convey runoff for rainfall events, which exceed the capacity of the minor system and serve up to the major design storm	• Designated authorities shall develop an operational and maintenance plan that identifies potential areas of risk to proper system functioning and specify measures and procedures to address any such risks. (CSA W204:19) • Clear drainage systems of debris (e.g.: objects, leaves, etc.) to prevent flooding and sewer backup • Increase regular inspections and maintenance of drainage systems	• Implement a flood emergency response plan to manage facilities impacted during flood events (CSA W204:19)

FLOODING (RIVERINE)				
Scale	**Stakeholders**	**Examples of Adaptation Projects**		
		Design (Structural)	**Operation and Maintenance (Non-Structural)**	**Policy (Non-Structural)**
	Local, regional, provincial, and territorial governments AND engineers AND the energy/electricity sector	• Require elevation of electrical panels above the ground or ensure the ability to disconnect power above ground • Incorporate the use of water sensors in basements to shut off power and/or isolate connections • Consider using stainless steel transformers to avoid and delay corrosion	• Increase regular inspections and maintenance after heavy rainfall events and introduce more guidance on monitoring and maintenance of critical assets	
City	Local, regional, provincial, and territorial governments AND	• In high-risk areas, build community-scale structural flood adaptation works (such as berms and dikes) to supplement other flood-proofing measures • Relocate critical energy infrastructure outside of areas at risk of flooding or erosion now or within the infrastructure's lifetime		• Implement flood forecasting and warning systems protocols • Implement emergency response protocols
Community	Neighborhood associations and local community groups			• Flood prevention/preparedness education • Teach about local flood forecasting and warning systems and help residents prepare emergency plans and emergency kits
Landscape	Landscapers and landowners	• Incorporate low impact development practices or nature-based solutions to manage stormwater runoff and prevent flood damages. Some examples include, bioretention platers, bioswales, etc. o The strategic use of natural infrastructure, low impact development measures and grey infrastructure to manage flood risk in new residential communities should be considered in the planning and design (CSA W204:19) o Natural infrastructure should be assessed at the watershed/sub-watershed level as well as the site level (CSA W204:19) o Measures should be planned and designed to retain, infiltrate, evapotranspiration, or filter runoff close to its source and in the conveyance system so that discharges from frequent events are treated and runoff volumes are minimized (CSA W204:19) o Adaptable configurations of natural infrastructure and LID measures should		

FLOODING (RIVERINE)				
Scale	**Stakeholders**	**Examples of Adaptation Projects**		
		Design (Structural)	**Operation and Maintenance (Non-Structural)**	**Policy (Non-Structural)**
		be spatially distributed through the watershed to ensure redundancy and increase resilience of the systems (CSA W204:19)		
	Local, regional, provincial, and territorial governments AND landowners AND landscapers	• Avoid encroachment on riparian buffers	• Proactively manage vegetation and maintain riparian buffer zones along water coursers, including debris removal	

WILDFIRE				
Scale	**Stakeholder**	**Examples of Adaptation Projects**		
		Design (Structural)	**Operation and Maintenance (Non-Structural)**	**Policy (Non-Structural)**
Community	Local, regional, provincial, and territorial governments, architects, developers, builders, and renovation specialists	• Minimize development where fire risk is high and prioritize the selection of areas at lower risk • Create a defensible fuel break around vulnerable areas • Bury the electrical grid to avoid damage from extreme heat and fire • Design community with good and proper access to helps emergency responders arrive in a timely manner • Non-Residential Building Retrofit • Public Building Retrofit • Historic Building Retrofit		• Develop and follow guidelines for development such as those presented in Development Permit Areas for hazards in British Columbia • Implement evacuation planning and prepare community to properly handle emergencies • Make sure that emergency plans are current and that people responsible for the implementation of the plans are emergency-ready
	Neighborhood associations and local community groups			• Implement public awareness, engagement and community participation to risk reduction activities
	Architects, developers and builders	• Consider the location of developments or of a building on flat or rising ground. Avoid slopes because fire will burn more rapidly uphill than on a flat or level surface		

Individual Assets	Homeowners, architects, developers, builders, and renovation specialists	• Use ignition-resistant construction
		  o Fire resistant roofing (metal, clay tiles and asphalt shingles)
		  o Exterior walls made of stucco, metal, brick, and concrete
		  o Metal railings or tempered glass
		  o Non-combustible patio furniture
		• Clearing all combustibles in the safety zone surrounding the asset
		• Installing non-combustible ground surfaces within 1.5m of the house (mineral soil, rock, concrete or stone)
		• Create a 15cm ground-to-siding non-combustible clearance (cement board or metal skirting)
		• Residential Building Retrofit		

	Residents, homeowners, and tenants		• Maintain roof cleanliness by making sure gutters are unclogged and there is no accumulation of combustible materials and debris • Increase frequency of clearing roofs of overhanging trees or vegetation that can provide fuel for airborne sparks and embers	

WILDFIRE				
Scale	**Stakeholder**	**Examples of Adaptation Projects**		
		Design (Structural)	**Operation and Maintenance (Non-Structural)**	**Policy (Non-Structural)**
			• Firewood must be stored at least 50 feet from the home and any other asset • Keep vegetation cleared well back of all electrical lines, propane tanks and other fuel supplies • It is recommended that pea gravel, lava rock or other non-combustible material be used as ground cover rather than bark mulch • Replace worn or missing weather stripping on all doors, including garage doors	
Landscape	Landowners and landscapers	• Minimizing the volume of vegetation • Remove conifer trees that are within 10m of the house Replacing flammable vegetation with less flammable species o Avoid cedar, juniper, pine, tall grass and spruce because they have high flammability	• Vegetation management or the removal of vegetative fuels that, if ignited, pose significant threat to human life and property • Vegetation clearing or thinning • Slash removal • Vertical clearing of tree branches • Mow the lawn under 10cm and plant low-growing, well-spaced shrubs and other vegetation *FireSmart Canada Guidelines to Landscaping provides information on appropriate plant selection and landscaping practices to reduce wildfire threat	
	Community, landowners and local utility companies		• Power lines should be clear of branches and other vegetation. Contact your local utility company to discuss removing any branches or vegetation around overhead electrical installations.	

WIND				
Scale	**Stakeholder**	**Examples of Adaptation Projects**		
		Design (Structural)	**Operation and Maintenance (Non-Structural)**	**Policy (Non-Structural)**
Landscape	Landscapers, landowners	• Incorporate windbreaks (e.g.: vegetation) in the landscape design		
Buildings	Architects, developers, builders, and renovation specialists	• Retrofit window and door protection to prevent damage and injury from debris • Retrofit project to transfer wind loads from the roof to the foundation • Retrofit project to secure the building envelope and integrity during a wind event • Avoid building elevation forms that are thinner at the bottom and wider at the top • Buildings supported on columns in their first story should have these columns stiffened by bracing • A hip-roofed home of a cubical form is considered as one of the best configurations to use in high wind or hurricane prone areas • Residential Building Retrofit • Non-Residential Building Retrofit • Public Building Retrofit • Historic Building Retrofit • Roof Diaphragm Retrofit - Roof hardening and roof clips		
	Local, regional, provincial, and territorial governments			• Establish new code to upgrade building requirements for strong wind/hurricane resistance
Critical Infrastructure	Local, regional, territorial government, and energy authorities	• Install a generator to ensure minimal power loss to the building before, during and after a power outage • Burying electrical lines when possible to prevent vulnerability to winds and power outages in areas that are not vulnerable to flooding. • Incorporate a range of clean energy technologies such as renewable energy, energy storage, and distributed generation • Roof Diaphragm Retrofit - Roof hardening and roof clips		• Provincial and federal policymakers should adopt and strengthen programs that support the timely expansion of renewable energy and energy efficiency measures, such as renewable electricity standards.

WIND				
Scale	**Stakeholder**	**Examples of Adaptation Projects**		
		Design (Structural)	**Operation and Maintenance (Non-Structural)**	**Policy (Non-Structural)**
Roads	Local transportation authorities and transportation agencies	• Construct strategic wind breaks • Design roadside infrastructure and bridges to withstand higher wind speed	• Increase clearing of sidewalks and roads of debris or objects that may be blown away.	
	Landscapers and Local, regional, provincial, and territorial governments and transportation agencies	• Put “snow fences” which are rows of trees, to reduce impacts of blowing snow or blowing rain on roadway visibility		
Community	Construction workers		• Increase clearing of all types of construction sites of debris that can be blown away. Tie down materials, debris and objects from construction sites that can potentially be blown away and considered as projectiles	• Establish new codes and standards for construction zones where debris and objects that can be blown away are properly tied down and stored away.

EXTREME TEMPERATURE/ HEAT WAVES				
Scale	Stakeholder	Examples of Adaptation Projects		
		Design (Structural)	Operation and Maintenance (Non-Structural)	Policy (Non-Structural)
Roads	Local transportation authorities and transportation agencies	• Use heat resistant paving materials with higher solar reflectance to reduce damages (e.g.: potholes and cracks) and UHI effect. • Solar heating reflective coating layer • Using white materials (e.g., pigments, binders, light aggregates, white topping, reflective paints) for surface layer of road pavement • consider use of additives in asphalt mix to reduce shoving/rutting • Increase roadside vegetation and trees to increase shade and decrease exposure	• Increase frequency of inspections of pavement surfaces to ensure cracks are properly sealed	• Implement proactive traffic management plans to reduce risk of rutting
Bridges	Local transportation authorities and transportation agencies	• Use more durable materials for bridge deck, including reinforced concrete	• Replace bridge expansion joints and ensure joints can accommodate thermal expansion • Conduct more frequent inspections and maintenance	
Landscape	Landscapers, landowners	• Consider nature-based solutions, such as planting local species that have a greater heat tolerance or are drought resistant, retaining water.		
Buildings	Architects, developers, builders, and renovation specialists	• Use materials that are resistant to or limit the accumulation of heat, such as light-colored materials such as white (high albedo) • Building retrofit and plan building designs that promote electricity and energy conservation, such as passive cooling systems, window shading and insulation • Incorporated heat island reduction strategies such as green roofs or cool roofs. • Install window shades • Residential Building Retrofit • Non-Residential Building Retrofit • Public Building Retrofit • Historic Building Retrofit	• Upgrade ventilation system	
	Inspectors, building managers and owners		• Weekly monitoring of energy demand on mechanical HVAC and cooling systems, during the high temperature periods in July/August • Increase monitoring of HVAC cooling demand during heat wave periods to avoid overheating of the systems.	

EXTREME TEMPERATURE/ HEAT WAVES				
Scale	**Stakeholder**	**Examples of Adaptation Projects**		
		Design (Structural)	**Operation and Maintenance (Non-Structural)**	**Policy (Non-Structural)**

Critical infrastructure	Local, regional, provincial, and territorial governments and energy sector stakeholders	• Consider electricity mix diversification by having centralised and decentralised options and by promoting an increase in renewable energy. Diversification minimises the magnitude of impacts and makes electricity systems less prone to failures
		• Bury the electrical grid to avoid damage from extreme heat
		• Improving the electricity grid by retrofitting current assets and introducing new technologies and new design asset
		  o Replacing overhead lines with underground cables
		  o Supplementary transmission lines to re-route electricity in case of failure
		  o Invest in smart grids, microgrids and circular grids
		• Aquifer Storage and recovery project
				• Policymakers should adopt and strengthen programs that support the timely expansion of renewable energy and energy efficiency measures

City	Local, regional, provincial, and territorial governments		• Track impacts of extreme heat to identify "hot-spots" that may require an increased rate of inspection. • Regularly evaluate de local forecast and monitor heat	• Implement urban planning standards and adaptation such as tree cover minimums, green spaces standards, fresh air corridor standards, etc. • Implement formal systems for notifying the public of heat waves which would include the communication of its arrival, duration and severity
Community	Neighborhood associations and local community groups	• Planting trees and other vegetation to create shade in urban and open spaces		• During prolonged episodes of extreme temperatures and heat waves, establish a secure area where the community and vulnerable populations can cool off • Educate the community on best practices in urban greening
	Local, regional, provincial, and territorial governments and workers		• Improve or develop outreach strategies for communication risks to vulnerable communities • Training employers and workers in industries where work is conducted outside, including water availability, shade, rest breaks and training on heat risks	• Implement strategies to increase community resilience by improving social infrastructure, such as places and organizations that foster cohesion and support • Improve, promote and implement coordination by government, local agencies, industries, schools, clinics, hospitals for better worker protection measures

EXTREME TEMPERATURE/ HEAT WAVES				
Scale	Stakeholder	Examples of Adaptation Projects		
		Design (Structural)	Operation and Maintenance (Non-Structural)	Policy (Non-Structural)
ICE STORM				
Scale	Stakeholder	Examples of Adaptation Projects		
		Design (Structural)	Operation and Maintenance (Non-Structural)	Policy (Non-Structural)
Roads	Local transportation authorities and transportation agencies		• Increase maintenance of pavement surfaces to monitor the accumulation of ice and the formation of black ice • Spread de-icing agents to eliminate icy road hazardous conditions	
Buildings	Architects, developers, builders, and renovation specialists	• Add a back-up generator or battery backup system and check-up regularly to provide emergency power • Add solar panels accompanied of a power storage source (e.g.: battery) as an alternative source of power • Residential Building Retrofit • Non-Residential Building Retrofit • Public Building Retrofit • Historic Building Retrofit	• Upgrade insulation at building corners to reduce heat loss; seal joints between panels to address insulation discontinuity issues	
	Inspectors, building owners		• Increase the frequency of wall condition monitoring in critical areas • Regular inspection of snow/ice removal on building roofs	
Critical Infrastructure	Architects, developers, builders, and renovation specialists AND engineers AND energy/electricity sector	• Add a back-up generator or battery backup system and check-up regularly to provide emergency power so that operations and services are not disrupted during an outage • Improving the electricity grid by retrofitting current assets and introducing new technologies and new design asset o Replacing overhead lines with underground cables o Supplementary transmission lines to re-route electricity in case of failure		• Policymakers should adopt and strengthen programs that support the timely expansion of renewable energy and energy efficiency measures

EXTREME TEMPERATURE/ HEAT WAVES				
Scale	Stakeholder	Examples of Adaptation Projects		
		Design (Structural)	Operation and Maintenance (Non-Structural)	Policy (Non-Structural)
		• Invest in smart grids, microgrids and circular grids • Add solar panels accompanied of a power storage source (e.g.: battery) as an alternative source of power • Burying power lines when possible, in areas that are not vulnerable to flooding. • Use thicker overhead wires in areas prone to severe icing		
Landscape	Landscapers, landowners,	• Use vegetation that have a higher resilience to ice storms. For example, some tree species are more prone to having ice accumulate on the entire branches, while others will only see the tip of the branches covered in ice and tend to perform better during ice storms. This will minimize the number of tree branches falling on power lines and roads.	• Increased maintenance for tree cover (trimming tree branches) to minimize ice incrusted branches that fall on power lines • Offer clients advice of adequate vegetation coverage to prevent and/or minimize risk associated with ice storms	
City	Local, regional, provincial, and territorial governments		• Regularly evaluate de local forecast and increase its frequency • Regular review and increase frequency of updating ice loading maps and loading criteria	• Implement a storm preparedness plan • Implement emergency response protocols • Establishing reception centre sites across the city • Make sure that emergency plans are current and that people responsible for the implementation of the plans are emergency-ready
Community				• Educate the community on best practices and how to prepare for ice storms

FLOODING (RIVERINE)				
Scale	**Stakeholders**	**Examples of Projects**		
		Design (Structural)	**Operation and Maintenance (Non-Structural)**	**Policy (Non-Structural)**
Roads	Local transportation authorities and transportation agencies	• Use appropriate materials to prevent cracking of the surface layer of roads • Use pavement materials that are well sealed and less susceptible to moisture • Increase base strength (thickness and/or quality) to increase protection of subgrade layers • Use subgrade materials that withstand higher moisture content and/or use hydraulic binding agents in road foundation • If possible, raise road surface level to reduce flood damage and ensure continued access during flood event	• Seal crack on a regular basis, especially prior to flooding season	
Bridges and Culverts	Local transportation authorities and transportation agencies	• Raise bridge decks to accommodate increase in flood volumes • Reinforce bridge piers and abutments and strengthen foundation to protect from erosion risks. • Incorporate design requirements from the CSA S6-18 Canadian Highway Bridge Design Code in order to increase resiliency of bridges to erosion caused by flooding • Culvert design should account for the possibility of partial blockage by debris and sediments (CSA W204:19)	• Cleaning out debris from clogged culverts and increase its frequency • Inspect bridges for erosion before and after flooding events	
River Basin	Local, regional, provincial, and territorial governments AND landowners	• Floodplain and stream restoration (FSR): Land purchase of flood prone areas by the government in order to relocate on safer grounds and restore the land to natural floodplain functions	• Monitor water level to assess the risk or flooding during heavy rainfall (see TRCA's real-time flood monitoring website and Calgary's flood and rive monitoring program)	
	Local, regional, provincial, and territorial governments AND watercourse experts	• Watercourse alteration: o Channel relocation o Widening or straightening o Culvert replacement o Stream bank stabilization	• Keep floodplain information and maps up to date and make sure they are accessible • Develop an operational and maintenance plan that identifies potential areas of risk related to flooding of riverine zones and specify measures and procedures to address any such risks	
Buildings	Architects, developers, builders, and renovation specialists and building owners	• Dry floodproofing • Wet floodproofing • Elevation of assets • Flood barriers • Levees • Floodwalls • Anti-return valve	• Ensure proper testing and maintenance of sump pump and backwater valve systems • Residential buildings should conduct sewer connection inspections, maintenance, repairs, or replacements when appropriate (CSA Z800-18) • Proper construction should be conducted during pre-construction, construction, and post	• Increase minimum building elevations during development and construction

FLOODING (RIVERINE)				
Scale	Stakeholders	Examples of Projects		
		Design (Structural)	Operation and Maintenance (Non-Structural)	Policy (Non-Structural)
		• Site-grading • Use flood-damage-resistant building materials (CSA Z800-18) • Ensure that buildings are not located in flood prone areas • Residential Building Retrofit • Non-Residential Building Retrofit • Public Building Retrofit • Historic Building Retrofit	construction phases in order to prevent erosion as per CSA W202-18	
	Homeowners and building owners		• Routine and proactive maintenance measures that should be regularly completed by homeowners to reduce water damage and flood risk (CSA Z800-18)	

Critical Infrastructure	Local, regional, provincial, and territorial governments AND engineers	• Drainage improvement by:
		  o Retention ponds
		  o By-pass channels
		  o Higher capacity storm sewers
		  o Separating storm sewers and sanitary sewers
		  o Improve pumping capacity of drainage systems
		• Sewer backwater protection by never directing downspout, foundation drain and sump pump discharge toward the sanitary sewers (CSA W204:19)
		• Stormwater system should be designed according to a dual drainage concept, taking into account the minor and major system
		• As per CSA W204:19:
		  o Minor and major drainage systems should be designed concurrently to a minimum 1-in-100-year major storm design event.
		  o Minor drainage systems should be designed to convey runoff for the 1-in-2-year to 1-in-10-year return period flows and more frequent rainfall events.
		  o Major drainage systems should be designed to convey runoff for rainfall events, which exceed the capacity of the minor system and serve up to the major design storm
			• Designated authorities shall develop an operational and maintenance plan that identifies potential areas of risk to proper system functioning and specify measures and procedures to address any such risks. This shall include a flood emergency response plan to manage facilities impacted during flood events (CSA W204:19)
			• Clear drainage systems of debris (e.g.: objects, leaves, etc.) to prevent flooding and sewer backup
			• Increase regular inspections and maintenance of drainage systems
				• Implement a flood emergency response plan to manage facilities impacted during flood events

FLOODING (RIVERINE)				
Scale	Stakeholders	Examples of Projects		
		Design (Structural)	Operation and Maintenance (Non-Structural)	Policy (Non-Structural)
	Local, regional, provincial, and territorial governments AND engineers AND the energy/electricity sector	• Require elevation of electrical panels above the ground or ensure the ability to disconnect power above ground • Incorporate the use of water sensors in basements to shut off power and/or isolate connections • Consider using stainless steel transformers to avoid and delay corrosion	• Increase regular inspections and maintenance after heavy rainfall events and introduce more guidance on monitoring and maintenance of critical assets	
City	Local, regional, provincial, and territorial governments AND	• In high-risk areas, build community-scale structural flood adaptation works (such as berms and dikes) to supplement other flood-proofing measures • Relocate critical energy infrastructure outside of areas at risk of flooding or erosion now or within the infrastructure's lifetime		• Implement flood forecasting and warning systems • Implement emergency response protocols
Community	Neighborhood associations and local community groups			• Flood prevention/preparedness education • Teach about local flood forecasting and warning systems and help residents prepare emergency plans and emergency kits
Landscape	Landscapers and landowners	• Incorporate low impact development practices or nature-based solutions to manage stormwater runoff and prevent flood damages. Some examples include, bioretention platers, bioswales, etc. o The strategic use of natural infrastructure, low impact development measures and grey infrastructure to manage flood risk in new residential communities should be considered in the planning and design (CSA W204:19) o Natural infrastructure should be assessed at the watershed/sub-watershed level as well as the site level (CSA W204:19) o Measures should be planned and designed to retain, infiltrate, evapotranspiration, or filter runoff close to its source and in the conveyance system so that discharges from frequent events are treated and runoff volumes are minimized (CSA W204:19) o Adaptable configurations of natural infrastructure and LID measures should		

FLOODING (RIVERINE)				
Scale	Stakeholders	Examples of Projects		
		Design (Structural)	Operation and Maintenance (Non-Structural)	Policy (Non-Structural)
		be spatially distributed through the watershed to ensure redundancy and increase resilience of the systems (CSA W204:19)		
	Local, regional, provincial, and territorial governments AND landowners AND landscapers	• Avoid encroachment on riparian buffers	• Proactively manage vegetation and maintain riparian buffer zones along water coursers, including debris removal	

WILDFIRE				
		Examples of Adaptation Projects		
Scale	**Stakeholder**	**Design (Structural)**	**Operation and Maintenance (Non-Structural)**	**Policy (Non-Structural)**
Community	Local, regional, provincial, and territorial governments, architects, developers, builders, and renovation specialists	• Minimize development where fire risk is high • Create a defensible fuel break around vulnerable areas • Bury the electrical grid to avoid damage from extreme heat and fire • Design community with good and proper access to helps emergency responders arrive in a timely manner • Non-Residential Building Retrofit • Public Building Retrofit • Historic Building Retrofit	• Make sure that emergency plans are current and that people responsible for the implementation of the plans are emergency-ready	• Develop and follow guidelines for development such as those presented in Development Permit Areas for hazards in British Columbia • Implement evacuation planning and prepare community to properly handle emergencies
	Neighborhood associations and local community groups			• Implement public awareness, engagement and community participation to risk reduction activities
	Architects, developers and builders	• Consider the location of developments or of a building on flat or rising ground. Avoid slopes because fire will burn more rapidly uphill than on a flat or level surface		

Individual Assets	Homeowners, architects, developers, builders, and renovation specialists	• Use ignition-resistant construction
		  o Fire resistant roofing (metal, clay tiles and asphalt shingles)
		  o Exterior walls made of stucco, metal, brick, and concrete
		  o Metal railings or tempered glass
		  o Non-combustible patio furniture
		• Clearing all combustibles in the safety zone surrounding the asset
		• Installing non-combustible ground surfaces within 1.5m of the house (mineral soil, rock, concrete or stone)
		• Create a 15cm ground-to-siding non-combustible clearance (cement board or metal skirting)
		• Residential Building Retrofit		

	Residents, homeowners, and tenants		• Maintain roof cleanliness by making sure gutters are unclogged and there is no accumulation of combustible materials and debris • Clear roof of overhanging trees or vegetation that can provide fuel for airborne sparks and embers • Firewood must be stored at least 50 feet from the home and any other asset	

WILDFIRE				
Scale	**Stakeholder**	**Examples of Adaptation Projects**		
		Design (Structural)	**Operation and Maintenance (Non-Structural)**	**Policy (Non-Structural)**
			• Keep vegetation cleared well back of all electrical lines, propane tanks and other fuel supplies • It is recommended that pea gravel, lava rock or other non-combustible material be used as ground cover rather than bark mulch • Replace worn or missing weather stripping on all doors, including garage doors	
Landscape	Landowners and landscapers	• Minimizing the volume of vegetation • Remove conifer trees that are within 10m of the house Replacing flammable vegetation with less flammable species o Avoid cedar, juniper, pine, tall grass and spruce because they have high flammability	• Vegetation management or the removal of vegetative fuels that, if ignited, pose significant threat to human life and property • Vegetation clearing or thinning • Slash removal • Vertical clearing of tree branches • Mow the lawn under 10cm and plant low-growing, well-spaced shrubs and other vegetation *FireSmart Canada Guidelines to Landscaping provides information on appropriate plant selection and landscaping practices to reduce wildfire threat	
	Community, landowners and local utility companies		• Power lines should be clear of branches and other vegetation. Contact your local utility company to discuss removing any branches or vegetation around overhead electrical installations.	

WIND				
Scale	**Stakeholder**	**Examples of Adaptation Projects**		
		Design (Structural)	**Operation and Maintenance (Non-Structural)**	**Policy (Non-Structural)**
Landscape	Landscapers, landowners	• Incorporate windbreaks (e.g.: vegetation) in the landscape design		
Buildings	Architects, developers, builders, and renovation specialists	• Retrofit window and door protection to prevent damage and injury from debris • Retrofit project to transfer wind loads from the roof to the foundation • Retrofit project to secure the building envelope and integrity during a wind event • Avoid building elevation forms that are thinner at the bottom and wider at the top • Buildings supported on columns in their first story should have these columns stiffened by bracing • A hip-roofed home of a cubical form is considered as one of the best configurations to use in high wind or hurricane prone areas • Residential Building Retrofit • Non-Residential Building Retrofit • Public Building Retrofit • Historic Building Retrofit • Roof Diaphragm Retrofit - Roof hardening and roof clips		
	Local, regional, provincial, and territorial governments			• Establish new code to upgrade building requirements for strong wind/hurricane resistance
Critical Infrastructure	Local, regional, territorial government, and energy authorities	• Install a generator to ensure minimal power loss to the building before, during and after a power outage • Burying electrical lines when possible to prevent vulnerability to winds and power outages in areas that are not vulnerable to flooding. • Incorporate a range of clean energy technologies such as renewable energy, energy storage, and distributed generation • Roof Diaphragm Retrofit - Roof hardening and roof clips		• Provincial and federal policymakers should adopt and strengthen programs that support the timely expansion of renewable energy and energy efficiency measures, such as renewable electricity standards.

WIND				
Scale	**Stakeholder**	**Examples of Adaptation Projects**		
		Design (Structural)	**Operation and Maintenance (Non-Structural)**	**Policy (Non-Structural)**
Roads	Local transportation authorities and transportation agencies	• Construct strategic wind breaks • Design roadside infrastructure and bridges to withstand higher wind speed	• Clear sidewalks and roads of debris or objects that may be blown away.	
	Landscapers and Local, regional, provincial, and territorial governments and transportation agencies	• Put “snow fences” which are rows of trees, to reduce impacts of blowing snow or blowing rain on roadway visibility		
Community	Construction workers		• Clear all types of construction sites of debris that can be blown away. Tie down materials, debris and objects from construction sites that can potentially be blown away and considered as projectiles	• Establish new codes and standards for construction zones where debris and objects that can be blown away are properly tied down and stored away.

EXTREME TEMPERATURE/ HEAT WAVES				
Scale	Stakeholder	Examples of Adaptation Projects		
		Design (Structural)	Operation and Maintenance (Non-Structural)	Policy (Non-Structural)
Roads	Local transportation authorities and transportation agencies	• Use heat resistant paving materials with higher solar reflectance to reduce damages (e.g.: potholes and cracks) and UHI effect. • Solar heating reflective coating layer • Using white materials (e.g., pigments, binders, light aggregates, white topping, reflective paints) for surface layer of road pavement • consider use of additives in asphalt mix to reduce shoving/rutting • Increase roadside vegetation and trees to increase shade and decrease exposure	• Conduct frequent inspections of pavement surfaces to ensure cracks are properly sealed	• Implement proactive traffic management plans to reduce risk of rutting
Bridges	Local transportation authorities and transportation agencies	• Use more durable materials for bridge deck, including reinforced concrete	• Replace bridge expansion joints and ensure joints can accommodate thermal expansion • Conduct more frequent inspections and maintenance	
Landscape	Landscapers, landowners	• Consider nature-based solutions, such as planting local species that have a greater heat tolerance or are drought resistant, retaining water.		
Buildings	Architects, developers, builders, and renovation specialists	• Use materials that are resistant to or limit the accumulation of heat, such as light-colored materials such as white (high albedo) • Building retrofit and plan building designs that promote electricity and energy conservation, such as passive cooling systems, window shading and insulation • Incorporated heat island reduction strategies such as green roofs or cool roofs. • Install window shades • Residential Building Retrofit • Non-Residential Building Retrofit • Public Building Retrofit • Historic Building Retrofit	• Upgrade ventilation system	
	Inspectors, building managers and owners		• Weekly monitoring of energy demand on mechanical HVAC and cooling systems, during the high temperature periods in July/August • Increase monitoring of HVAC cooling demand during heat wave periods to avoid overheating of the systems.	

EXTREME TEMPERATURE/ HEAT WAVES				
Scale	Stakeholder	Examples of Adaptation Projects		
		Design (Structural)	Operation and Maintenance (Non-Structural)	Policy (Non-Structural)
Critical infrastructure	Local, regional, provincial, and territorial governments and energy sector stakeholders	• Consider electricity mix diversification by having centralised and decentralised options and by promoting an increase in renewable energy. Diversification minimises the magnitude of impacts and makes electricity systems less prone to failures • Bury the electrical grid to avoid damage from extreme heat • Improving the electricity grid by retrofitting current assets and introducing new technologies and new design asset o Replacing overhead lines with underground cables o Supplementary transmission lines to re-route electricity in case of failure o Invest in smart grids, microgrids and circular grids • Aquifer Storage and Recovery project		• Policymakers should adopt and strengthen programs that support the timely expansion of renewable energy and energy efficiency measures
City	Local, regional, provincial, and territorial governments		• Track impacts of extreme heat to identify "hot-spots" that may require an increased rate of inspection. • Regularly evaluate de local forecast and monitor heat	• Implement urban planning standards and adaptation such as tree cover minimums, green spaces standards, fresh air corridor standards, etc. • Implement formal systems for notifying the public of heat waves which would include the communication of its arrival, duration and severity
Community	Neighborhood associations and local community groups	• Planting trees and other vegetation to create shade in urban and open spaces		• During prolonged episodes of extreme temperatures and heat waves, establish a secure area where the community and vulnerable populations can cool off • Educate the community on best practices in urban greening
	Local, regional, provincial, and territorial governments and workers		• Improve or develop outreach strategies for communication risks to vulnerable communities • Training employers and workers in industries where work is conducted outside, including water availability, shade, rest breaks and training on heat risks	• Implement strategies to increase community resilience by improving social infrastructure, such as places and organizations that foster cohesion and support • Improve, promote and implement coordination by government, local agencies, industries, schools, clinics, hospitals for better worker protection measures

EXTREME TEMPERATURE/ HEAT WAVES				
Scale	**Stakeholder**	**Examples of Adaptation Projects**		
		Design (Structural)	**Operation and Maintenance (Non-Structural)**	**Policy (Non-Structural)**

ICE STORM				
Scale	**Stakeholder**	**Examples of Adaptation Projects**		
		Design (Structural)	**Operation and Maintenance (Non-Structural)**	**Policy (Non-Structural)**
Roads	Local transportation authorities and transportation agencies		• Increase maintenance of pavement surfaces to monitor the accumulation of ice and the formation of black ice • Spread de-icing agents to eliminate icy road hazardous conditions	
Buildings	Architects, developers, builders, and renovation specialists	• Add a back-up generator or battery backup system and check-up regularly to provide emergency power • Add solar panels accompanied of a power storage source (e.g.: battery) as an alternative source of power • Residential Building Retrofit • Non-Residential Building Retrofit • Public Building Retrofit • Historic Building Retrofit	• Upgrade insulation at building corners to reduce heat loss; seal joints between panels to address insulation discontinuity issues	
	Inspectors, building owners		• Increase the frequency of wall condition monitoring in critical areas • Regular inspection of snow/ice removal on building roofs	

Critical Infrastructure	Architects, developers, builders, and renovation specialists AND engineers AND energy/electricity sector	• Add a back-up generator or battery backup system and check-up regularly to provide emergency power so that operations and services are not disrupted during an outage
		• Improving the electricity grid by retrofitting current assets and introducing new technologies and new design asset
		  o Replacing overhead lines with underground cables
		  o Supplementary transmission lines to re-route electricity in case of failure
				• Policymakers should adopt and strengthen programs that support the timely expansion of renewable energy and energy efficiency measures

EXTREME TEMPERATURE/ HEAT WAVES				
Scale	Stakeholder	Examples of Adaptation Projects		
		Design (Structural)	Operation and Maintenance (Non-Structural)	Policy (Non-Structural)
		• Invest in smart grids, microgrids and circular grids • Add solar panels accompanied of a power storage source (e.g.: battery) as an alternative source of power • Burying power lines when possible, in areas that are not vulnerable to flooding. • Use thicker overhead wires in areas prone to severe icing		
Landscape	Landscapers, landowners,	• Use vegetation that have a higher resilience to ice storms. For example, some tree species are more prone to having ice accumulate on the entire branches, while others will only see the tip of the branches covered in ice and tend to perform better during ice storms. This will minimize the number of tree branches falling on power lines and roads.	• Increased maintenance for tree cover (trimming tree branches) to minimize ice incrusted branches that fall on power lines • Offer clients advice of adequate vegetation coverage to prevent and/or minimize risk associated with ice storms	
City	Local, regional, provincial, and territorial governments		• Regularly evaluate de local forecast • Regular review and update ice loading maps and loading criteria • Make sure that emergency plans are current and that people responsible for the implementation of the plans are emergency-ready	• Implement a storm preparedness plan • Implement emergency response protocols • Establishing reception centre sites across the city
Community				• Educate the community on best practices and how to prepare for ice storms

FLOODING (RIVERINE)				
Scale	**Stakeholders**	**Examples of Adaptation Projects**		
		Design (Structural)	**Operation and Maintenance (Non-Structural)**	**Policy (Non-Structural)**
Roads	Local transportation authorities and transportation agencies	• Use appropriate materials to prevent cracking of the surface layer of roads • Use pavement materials that are well sealed and less susceptible to moisture • Increase base strength (thickness and/or quality) to increase protection of subgrade layers • Use subgrade materials that withstand higher moisture content and/or use hydraulic binding agents in road foundation • If possible, raise road surface level to reduce flood damage and ensure continued access during flood event	• Increase crack sealing, especially prior to flooding season	
Bridges and Culverts	Local transportation authorities and transportation agencies	• Raise bridge decks to accommodate increase in flood volumes • Reinforce bridge piers and abutments and strengthen foundation to protect from erosion risks. • Incorporate design requirements from the CSA S6-18 Canadian Highway Bridge Design Code in order to increase resiliency of bridges to erosion caused by flooding • Culvert design should account for the possibility of partial blockage by debris and sediments (CSA W204:19)	• Cleaning out debris from clogged culverts and increase its frequency • Inspect bridges for erosion before and after flooding events	
River Basin	Local, regional, provincial, and territorial governments AND landowners	• Floodplain and stream restoration (FSR): Land purchase of flood prone areas by the government in order to relocate on safer grounds and restore the land to natural floodplain functions	• Monitor water level to assess the risk or flooding during heavy rainfall (see TRCA's real-time flood monitoring website and Calgary's flood and rive monitoring program)	
	Local, regional, provincial, and territorial governments AND watercourse experts	• Watercourse alteration: o Channel relocation o Widening or straightening o Culvert replacement o Stream bank stabilization	• Keep floodplain information and maps up to date and make sure they are accessible • Develop an operational and maintenance plan that identifies potential areas of risk related to flooding of riverine zones and specify measures and procedures to address any such risks	
Buildings	Architects, developers, builders, and renovation specialists and building owners	• Dry floodproofing • Wet floodproofing • Elevation of assets • Flood barriers • Levees • Floodwalls • Anti-return valve	• Ensure proper testing and maintenance of sump pump and backwater valve systems • Residential buildings should conduct sewer connection inspections, maintenance, repairs, or replacements when appropriate (CSA Z800-18) • Proper construction should be conducted during pre-construction, construction, and post	• Increase minimum building elevations during development and construction

FLOODING (RIVERINE)				
Scale	**Stakeholders**	**Examples of Adaptation Projects**		
		Design (Structural)	**Operation and Maintenance (Non-Structural)**	**Policy (Non-Structural)**
		• Site-grading • Use flood-damage-resistant building materials (CSA Z800-18) • Ensure that buildings are not located in flood prone areas • Residential Building Retrofit • Non-Residential Building Retrofit • Public Building Retrofit • Historic Building Retrofit	construction phases in order to prevent erosion as per CSA W202-18	
	Homeowners and building owners		• Increase routine and proactive maintenance measures that should be regularly completed by homeowners to reduce water damage and flood risk (CSA Z800-18)	

Critical Infrastructure	Local, regional, provincial, and territorial governments AND engineers	• Drainage improvement by:
		  o Retention ponds
		  o By-pass channels
		  o Higher capacity storm sewers
		  o Separating storm sewers and sanitary sewers
		  o Improve pumping capacity of drainage systems
		• Sewer backwater protection by never directing downspout, foundation drain and sump pump discharge toward the sanitary sewers (CSA W204:19)
		• Stormwater system should be designed according to a dual drainage concept, taking into account the minor and major system
		• As per CSA W204:19:
		  o Minor and major drainage systems should be designed concurrently to a minimum 1-in-100-year major storm design event.
		  o Minor drainage systems should be designed to convey runoff for the 1-in-2-year to 1-in-10-year return period flows and more frequent rainfall events.
		  o Major drainage systems should be designed to convey runoff for rainfall events, which exceed the capacity of the minor system and serve up to the major design storm
			• Designated authorities shall develop an operational and maintenance plan that identifies potential areas of risk to proper system functioning and specify measures and procedures to address any such risks. (CSA W204:19)
			• Clear drainage systems of debris (e.g.: objects, leaves, etc.) to prevent flooding and sewer backup
			• Increase regular inspections and maintenance of drainage systems
				• Implement a flood emergency response plan to manage facilities impacted during flood events (CSA W204:19)

FLOODING (RIVERINE)				
		Examples of Adaptation Projects		
Scale	**Stakeholders**	**Design (Structural)**	**Operation and Maintenance (Non-Structural)**	**Policy (Non-Structural)**
	Local, regional, provincial, and territorial governments AND engineers AND the energy/electricity sector	• Require elevation of electrical panels above the ground or ensure the ability to disconnect power above ground • Incorporate the use of water sensors in basements to shut off power and/or isolate connections • Consider using stainless steel transformers to avoid and delay corrosion	• Increase regular inspections and maintenance after heavy rainfall events and introduce more guidance on monitoring and maintenance of critical assets	
City	Local, regional, provincial, and territorial governments AND	• In high-risk areas, build community-scale structural flood adaptation works (such as berms and dikes) to supplement other flood-proofing measures • Relocate critical energy infrastructure outside of areas at risk of flooding or erosion now or within the infrastructure's lifetime		• Implement flood forecasting and warning systems protocols • Implement emergency response protocols
Community	Neighborhood associations and local community groups			• Flood prevention/preparedness education • Teach about local flood forecasting and warning systems and help residents prepare emergency plans and emergency kits

Landscape	Landscapers and landowners	• Incorporate low impact development practices or nature-based solutions to manage stormwater runoff and prevent flood damages. Some examples include, bioretention platers, bioswales, etc.
		  o The strategic use of natural infrastructure, low impact development measures and grey infrastructure to manage flood risk in new residential communities should be considered in the planning and design (CSA W204:19)
		  o Natural infrastructure should be assessed at the watershed/sub-watershed level as well as the site level (CSA W204:19)
		  o Measures should be planned and designed to retain, infiltrate, evapotranspiration, or filter runoff close to its source and in the conveyance system so that discharges from frequent events are treated and runoff volumes are minimized (CSA W204:19)
		  o Adaptable configurations of natural infrastructure and LID measures should		

FLOODING (RIVERINE)				
Scale	Stakeholders	Examples of Adaptation Projects		
		Design (Structural)	Operation and Maintenance (Non-Structural)	Policy (Non-Structural)
		be spatially distributed through the watershed to ensure redundancy and increase resilience of the systems (CSA W204:19)		
	Local, regional, provincial, and territorial governments AND landowners AND landscapers	• Avoid encroachment on riparian buffers	• Proactively manage vegetation and maintain riparian buffer zones along water coursers, including debris removal	

WILDFIRE				
Scale	**Stakeholder**	**Examples of Adaptation Projects**		
		Design (Structural)	**Operation and Maintenance (Non-Structural)**	**Policy (Non-Structural)**
Community	Local, regional, provincial, and territorial governments, architects, developers, builders, and renovation specialists	• Minimize development where fire risk is high and prioritize the selection of areas at lower risk • Create a defensible fuel break around vulnerable areas • Bury the electrical grid to avoid damage from extreme heat and fire • Design community with good and proper access to helps emergency responders arrive in a timely manner • Non-Residential Building Retrofit • Public Building Retrofit • Historic Building Retrofit		• Develop and follow guidelines for development such as those presented in Development Permit Areas for hazards in British Columbia • Implement evacuation planning and prepare community to properly handle emergencies • Make sure that emergency plans are current and that people responsible for the implementation of the plans are emergency-ready
	Neighborhood associations and local community groups			• Implement public awareness, engagement and community participation to risk reduction activities
	Architects, developers and builders	• Consider the location of developments or of a building on flat or rising ground. Avoid slopes because fire will burn more rapidly uphill than on a flat or level surface		
Individual Assets	Homeowners, architects, developers, builders, and renovation specialists	• Use ignition-resistant construction o Fire resistant roofing (metal, clay tiles and asphalt shingles) o Exterior walls made of stucco, metal, brick, and concrete o Metal railings or tempered glass o Non-combustible patio furniture • Clearing all combustibles in the safety zone surrounding the asset • Installing non-combustible ground surfaces within 1.5m of the house (mineral soil, rock, concrete or stone) • Create a 15cm ground-to-siding non-combustible clearance (cement board or metal skirting) • Residential Building Retrofit		
	Residents, homeowners, and tenants		• Maintain roof cleanliness by making sure gutters are unclogged and there is no accumulation of combustible materials and debris	

WILDFIRE				
Scale	Stakeholder	Examples of Adaptation Projects		
		Design (Structural)	Operation and Maintenance (Non-Structural)	Policy (Non-Structural)
			• Increase frequency of clearing roofs of overhanging trees or vegetation that can provide fuel for airborne sparks and embers • Firewood must be stored at least 50 feet from the home and any other asset • Keep vegetation cleared well back of all electrical lines, propane tanks and other fuel supplies • It is recommended that pea gravel, lava rock or other non-combustible material be used as ground cover rather than bark mulch • Replace worn or missing weather stripping on all doors, including garage doors	
Landscape	Landowners and landscapers	• Minimizing the volume of vegetation • Remove conifer trees that are within 10m of the house Replacing flammable vegetation with less flammable species o Avoid cedar, juniper, pine, tall grass and spruce because they have high flammability	• Vegetation management or the removal of vegetative fuels that, if ignited, pose significant threat to human life and property • Vegetation clearing or thinning • Slash removal • Vertical clearing of tree branches • Mow the lawn under 10cm and plant low-growing, well-spaced shrubs and other vegetation *FireSmart Canada Guidelines to Landscaping provides information on appropriate plant selection and landscaping practices to reduce wildfire threat	
	Community, landowners and local utility companies		• Power lines should be clear of branches and other vegetation. Contact your local utility company to discuss removing any branches or vegetation around overhead electrical installations.	

WIND				
		Examples of Adaptation Projects		
Scale	**Stakeholder**	**Design (Structural)**	**Operation and Maintenance (Non-Structural)**	**Policy (Non-Structural)**
Landscape	Landscapers, landowners	• Incorporate windbreaks (e.g.: vegetation) in the landscape design		
Buildings	Architects, developers, builders, and renovation specialists	• Retrofit window and door protection to prevent damage and injury from debris • Retrofit project to transfer wind loads from the roof to the foundation • Retrofit project to secure the building envelope and integrity during a wind event • Avoid building elevation forms that are thinner at the bottom and wider at the top • Buildings supported on columns in their first story should have these columns stiffened by bracing • A hip-roofed home of a cubical form is considered as one of the best configurations to use in high wind or hurricane prone areas • Residential Building Retrofit • Non-Residential Building Retrofit • Public Building Retrofit • Historic Building Retrofit • Roof Diaphragm Retrofit - Roof hardening and roof clips		
	Local, regional, provincial, and territorial governments			• Establish new code to upgrade building requirements for strong wind/hurricane resistance
Critical Infrastructure	Local, regional, territorial government, and energy authorities	• Install a generator to ensure minimal power loss to the building before, during and after a power outage • Burying electrical lines when possible to prevent vulnerability to winds and power outages in areas that are not vulnerable to flooding. • Incorporate a range of clean energy technologies such as renewable energy, energy storage, and distributed generation • Roof Diaphragm Retrofit - Roof hardening and roof clips		• Provincial and federal policymakers should adopt and strengthen programs that support the timely expansion of renewable energy and energy efficiency measures, such as renewable electricity standards.

WIND				
Scale	**Stakeholder**	**Examples of Adaptation Projects**		
		Design (Structural)	**Operation and Maintenance (Non-Structural)**	**Policy (Non-Structural)**
Roads	Local transportation authorities and transportation agencies	• Construct strategic wind breaks • Design roadside infrastructure and bridges to withstand higher wind speed	• Increase clearing of sidewalks and roads of debris or objects that may be blown away.	
	Landscapers and Local, regional, provincial, and territorial governments and transportation agencies	• Put “snow fences” which are rows of trees, to reduce impacts of blowing snow or blowing rain on roadway visibility		
Community	Construction workers		• Increase clearing of all types of construction sites of debris that can be blown away. Tie down materials, debris and objects from construction sites that can potentially be blown away and considered as projectiles	• Establish new codes and standards for construction zones where debris and objects that can be blown away are properly tied down and stored away.

EXTREME TEMPERATURE/ HEAT WAVES				
Scale	Stakeholder	Examples of Adaptation Projects		
		Design (Structural)	Operation and Maintenance (Non-Structural)	Policy (Non-Structural)
Roads	Local transportation authorities and transportation agencies	• Use heat resistant paving materials with higher solar reflectance to reduce damages (e.g.: potholes and cracks) and UHI effect. • Solar heating reflective coating layer • Using white materials (e.g., pigments, binders, light aggregates, white topping, reflective paints) for surface layer of road pavement • consider use of additives in asphalt mix to reduce shoving/rutting • Increase roadside vegetation and trees to increase shade and decrease exposure	• Increase frequency of inspections of pavement surfaces to ensure cracks are properly sealed	• Implement proactive traffic management plans to reduce risk of rutting
Bridges	Local transportation authorities and transportation agencies	• Use more durable materials for bridge deck, including reinforced concrete	• Replace bridge expansion joints and ensure joints can accommodate thermal expansion • Conduct more frequent inspections and maintenance	
Landscape	Landscapers, landowners	• Consider nature-based solutions, such as planting local species that have a greater heat tolerance or are drought resistant, retaining water.		
Buildings	Architects, developers, builders, and renovation specialists	• Use materials that are resistant to or limit the accumulation of heat, such as light-colored materials such as white (high albedo) • Building retrofit and plan building designs that promote electricity and energy conservation, such as passive cooling systems, window shading and insulation • Incorporated heat island reduction strategies such as green roofs or cool roofs. • Install window shades • Residential Building Retrofit • Non-Residential Building Retrofit • Public Building Retrofit • Historic Building Retrofit	• Upgrade ventilation system	
	Inspectors, building managers and owners		• Weekly monitoring of energy demand on mechanical HVAC and cooling systems, during the high temperature periods in July/August • Increase monitoring of HVAC cooling demand during heat wave periods to avoid overheating of the systems.	

EXTREME TEMPERATURE/ HEAT WAVES				
		Examples of Adaptation Projects		
Scale	**Stakeholder**	**Design (Structural)**	**Operation and Maintenance (Non-Structural)**	**Policy (Non-Structural)**

Critical infrastructure	Local, regional, provincial, and territorial governments and energy sector stakeholders	• Consider electricity mix diversification by having centralised and decentralised options and by promoting an increase in renewable energy. Diversification minimises the magnitude of impacts and makes electricity systems less prone to failures
		• Bury the electrical grid to avoid damage from extreme heat
		• Improving the electricity grid by retrofitting current assets and introducing new technologies and new design asset
		  o Replacing overhead lines with underground cables
		  o Supplementary transmission lines to re-route electricity in case of failure
		  o Invest in smart grids, microgrids and circular grids
		• Aquifer Storage and recovery project
				• Policymakers should adopt and strengthen programs that support the timely expansion of renewable energy and energy efficiency measures

City	Local, regional, provincial, and territorial governments		• Track impacts of extreme heat to identify "hot-spots" that may require an increased rate of inspection. • Regularly evaluate de local forecast and monitor heat	• Implement urban planning standards and adaptation such as tree cover minimums, green spaces standards, fresh air corridor standards, etc. • Implement formal systems for notifying the public of heat waves which would include the communication of its arrival, duration and severity
Community	Neighborhood associations and local community groups	• Planting trees and other vegetation to create shade in urban and open spaces		• During prolonged episodes of extreme temperatures and heat waves, establish a secure area where the community and vulnerable populations can cool off • Educate the community on best practices in urban greening
	Local, regional, provincial, and territorial governments and workers		• Improve or develop outreach strategies for communication risks to vulnerable communities • Training employers and workers in industries where work is conducted outside, including water availability, shade, rest breaks and training on heat risks	• Implement strategies to increase community resilience by improving social infrastructure, such as places and organizations that foster cohesion and support • Improve, promote and implement coordination by government, local agencies, industries, schools, clinics, hospitals for better worker protection measures

EXTREME TEMPERATURE/ HEAT WAVES				
Scale	**Stakeholder**	**Examples of Adaptation Projects**		
		Design (Structural)	**Operation and Maintenance (Non-Structural)**	**Policy (Non-Structural)**

ICE STORM				
Scale	**Stakeholder**	**Examples of Adaptation Projects**		
		Design (Structural)	**Operation and Maintenance (Non-Structural)**	**Policy (Non-Structural)**
Roads	Local transportation authorities and transportation agencies		• Increase maintenance of pavement surfaces to monitor the accumulation of ice and the formation of black ice • Spread de-icing agents to eliminate icy road hazardous conditions	
Buildings	Architects, developers, builders, and renovation specialists	• Add a back-up generator or battery backup system and check-up regularly to provide emergency power • Add solar panels accompanied of a power storage source (e.g.: battery) as an alternative source of power • Residential Building Retrofit • Non-Residential Building Retrofit • Public Building Retrofit • Historic Building Retrofit	• Upgrade insulation at building corners to reduce heat loss; seal joints between panels to address insulation discontinuity issues	
	Inspectors, building owners		• Increase the frequency of wall condition monitoring in critical areas • Regular inspection of snow/ice removal on building roofs	

Critical Infrastructure	Architects, developers, builders, and renovation specialists AND engineers AND energy/electricity sector	• Add a back-up generator or battery backup system and check-up regularly to provide emergency power so that operations and services are not disrupted during an outage
		• Improving the electricity grid by retrofitting current assets and introducing new technologies and new design asset
		  o Replacing overhead lines with underground cables
		  o Supplementary transmission lines to re-route electricity in case of failure
				• Policymakers should adopt and strengthen programs that support the timely expansion of renewable energy and energy efficiency measures

EXTREME TEMPERATURE/ HEAT WAVES				
Scale	Stakeholder	Examples of Adaptation Projects		
		Design (Structural)	Operation and Maintenance (Non-Structural)	Policy (Non-Structural)
		• Invest in smart grids, microgrids and circular grids • Add solar panels accompanied of a power storage source (e.g.: battery) as an alternative source of power • Burying power lines when possible, in areas that are not vulnerable to flooding. • Use thicker overhead wires in areas prone to severe icing		
Landscape	Landscapers, landowners,	• Use vegetation that have a higher resilience to ice storms. For example, some tree species are more prone to having ice accumulate on the entire branches, while others will only see the tip of the branches covered in ice and tend to perform better during ice storms. This will minimize the number of tree branches falling on power lines and roads.	• Increased maintenance for tree cover (trimming tree branches) to minimize ice incrusted branches that fall on power lines • Offer clients advice of adequate vegetation coverage to prevent and/or minimize risk associated with ice storms	
City	Local, regional, provincial, and territorial governments		• Regularly evaluate de local forecast and increase its frequency • Regular review and increase frequency of updating ice loading maps and loading criteria	• Implement a storm preparedness plan • Implement emergency response protocols • Establishing reception centre sites across the city • Make sure that emergency plans are current and that people responsible for the implementation of the plans are emergency-ready
Community				• Educate the community on best practices and how to prepare for ice storms

FLOODING (RIVERINE)				
Scale	Stakeholders	Examples of Adaptation Projects		
		Design (Structural)	Operation and Maintenance (Non-Structural)	Policy (Non-Structural)
Roads	Local transportation authorities and transportation agencies	• Use appropriate materials to prevent cracking of the surface layer of roads • Use pavement materials that are well sealed and less susceptible to moisture • Increase base strength (thickness and/or quality) to increase protection of subgrade layers • Use subgrade materials that withstand higher moisture content and/or use hydraulic binding agents in road foundation • If possible, raise road surface level to reduce flood damage and ensure continued access during flood event	• Seal crack on a regular basis, especially prior to flooding season	
Bridges and Culverts	Local transportation authorities and transportation agencies	• Raise bridge decks to accommodate increase in flood volumes • Reinforce bridge piers and abutments and strengthen foundation to protect from erosion risks. • Incorporate design requirements from the CSA S6-18 Canadian Highway Bridge Design Code in order to increase resiliency of bridges to erosion caused by flooding • Culvert design should account for the possibility of partial blockage by debris and sediments (CSA W204:19)	• Cleaning out debris from clogged culverts and increase its frequency • Inspect bridges for erosion before and after flooding events	
River Basin	Local, regional, provincial, and territorial governments AND landowners	• Floodplain and stream restoration (FSR): Land purchase of flood prone areas by the government in order to relocate on safer grounds and restore the land to natural floodplain functions	• Monitor water level to assess the risk or flooding during heavy rainfall (see TRCA's real-time flood monitoring website and Calgary's flood and rive monitoring program)	

	Local, regional, provincial, and territorial governments AND watercourse experts	• Watercourse alteration:
		  o Channel relocation
		  o Widening or straightening
		  o Culvert replacement
		  o Stream bank stabilization
			• Keep floodplain information and maps up to date and make sure they are accessible
			• Develop an operational and maintenance plan that identifies potential areas of risk related to flooding of riverine zones and specify measures and procedures to address any such risks	

Buildings	Architects, developers, builders, and renovation specialists and building owners	• Dry floodproofing • Wet floodproofing • Elevation of assets • Flood barriers • Levees • Floodwalls • Anti-return valve	• Ensure proper testing and maintenance of sump pump and backwater valve systems • Residential buildings should conduct sewer connection inspections, maintenance, repairs, or replacements when appropriate (CSA Z800-18) • Proper construction should be conducted during pre-construction, construction, and post	• Increase minimum building elevations during development and construction

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  o Separating storm sewers and sanitary sewers
  o Improve pumping capacity of drainage systems
• Sewer backwater protection by never directing downspout, foundation drain and sump pump discharge toward the sanitary sewers (CSA W204:19)
• Stormwater system should be designed according to a dual drainage concept, taking into account the minor and major system

• As per CSA W204:19:
  o Minor and major drainage systems should be designed concurrently to a minimum 1-in-100-year major storm design event.
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FLOODING (RIVERINE)				
Scale	Stakeholders	Examples of Adaptation Projects		
		Design (Structural)	Operation and Maintenance (Non-Structural)	Policy (Non-Structural)
	Local, regional, provincial, and territorial governments AND engineers AND the energy/electricity sector	• Require elevation of electrical panels above the ground or ensure the ability to disconnect power above ground • Incorporate the use of water sensors in basements to shut off power and/or isolate connections • Consider using stainless steel transformers to avoid and delay corrosion	• Increase regular inspections and maintenance after heavy rainfall events and introduce more guidance on monitoring and maintenance of critical assets	
City	Local, regional, provincial, and territorial governments AND	• In high-risk areas, build community-scale structural flood adaptation works (such as berms and dikes) to supplement other flood-proofing measures • Relocate critical energy infrastructure outside of areas at risk of flooding or erosion now or within the infrastructure's lifetime		• Implement flood forecasting and warning systems • Implement emergency response protocols
Community	Neighborhood associations and local community groups			• Flood prevention/preparedness education • Teach about local flood forecasting and warning systems and help residents prepare emergency plans and emergency kits
Landscape	Landscapers and landowners	• Incorporate low impact development practices or nature-based solutions to manage stormwater runoff and prevent flood damages. Some examples include, bioretention platers, bioswales, etc. o The strategic use of natural infrastructure, low impact development measures and grey infrastructure to manage flood risk in new residential communities should be considered in the planning and design (CSA W204:19) o Natural infrastructure should be assessed at the watershed/sub-watershed level as well as the site level (CSA W204:19) o Measures should be planned and designed to retain, infiltrate, evapotranspiration, or filter runoff close to its source and in the conveyance system so that discharges from frequent events are treated and runoff volumes are minimized (CSA W204:19) o Adaptable configurations of natural infrastructure and LID measures should		

FLOODING (RIVERINE)				
Scale	Stakeholders	Examples of Adaptation Projects		
		Design (Structural)	Operation and Maintenance (Non-Structural)	Policy (Non-Structural)
		be spatially distributed through the watershed to ensure redundancy and increase resilience of the systems (CSA W204:19)		
	Local, regional, provincial, and territorial governments AND landowners AND landscapers	• Avoid encroachment on riparian buffers	• Proactively manage vegetation and maintain riparian buffer zones along water coursers, including debris removal	

WILDFIRE				
		Examples of Adaptation Projects		
Scale	Stakeholder	Design (Structural)	Operation and Maintenance (Non-Structural)	Policy (Non-Structural)
Community	Local, regional, provincial, and territorial governments, architects, developers, builders, and renovation specialists	• Minimize development where fire risk is high • Create a defensible fuel break around vulnerable areas • Bury the electrical grid to avoid damage from extreme heat and fire • Design community with good and proper access to helps emergency responders arrive in a timely manner • Non-Residential Building Retrofit • Public Building Retrofit • Historic Building Retrofit	• Make sure that emergency plans are current and that people responsible for the implementation of the plans are emergency-ready	• Develop and follow guidelines for development such as those presented in Development Permit Areas for hazards in British Columbia • Implement evacuation planning and prepare community to properly handle emergencies
	Neighborhood associations and local community groups			• Implement public awareness, engagement and community participation to risk reduction activities
	Architects, developers and builders	• Consider the location of developments or of a building on flat or rising ground. Avoid slopes because fire will burn more rapidly uphill than on a flat or level surface		

Individual Assets	Homeowners, architects, developers, builders, and renovation specialists	• Use ignition-resistant construction
		  o Fire resistant roofing (metal, clay tiles and asphalt shingles)
		  o Exterior walls made of stucco, metal, brick, and concrete
		  o Metal railings or tempered glass
		  o Non-combustible patio furniture
		• Clearing all combustibles in the safety zone surrounding the asset
		• Installing non-combustible ground surfaces within 1.5m of the house (mineral soil, rock, concrete or stone)
		• Create a 15cm ground-to-siding non-combustible clearance (cement board or metal skirting)
		• Residential Building Retrofit		

	Residents, homeowners, and tenants		• Maintain roof cleanliness by making sure gutters are unclogged and there is no accumulation of combustible materials and debris • Clear roof of overhanging trees or vegetation that can provide fuel for airborne sparks and embers	

WILDFIRE				
Scale	Stakeholder	Examples of Adaptation Projects		
		Design (Structural)	Operation and Maintenance (Non-Structural)	Policy (Non-Structural)
			• Firewood must be stored at least 50 feet from the home and any other asset • Keep vegetation cleared well back of all electrical lines, propane tanks and other fuel supplies • It is recommended that pea gravel, lava rock or other non-combustible material be used as ground cover rather than bark mulch • Replace worn or missing weather stripping on all doors, including garage doors	
Landscape	Landowners and landscapers	• Minimizing the volume of vegetation • Remove conifer trees that are within 10m of the house Replacing flammable vegetation with less flammable species o Avoid cedar, juniper, pine, tall grass and spruce because they have high flammability	• Vegetation management or the removal of vegetative fuels that, if ignited, pose significant threat to human life and property • Vegetation clearing or thinning • Slash removal • Vertical clearing of tree branches • Mow the lawn under 10cm and plant low-growing, well-spaced shrubs and other vegetation *FireSmart Canada Guidelines to Landscaping provides information on appropriate plant selection and landscaping practices to reduce wildfire threat	
	Community, landowners and local utility companies		• Power lines should be clear of branches and other vegetation. Contact your local utility company to discuss removing any branches or vegetation around overhead electrical installations.	

WIND				
Scale	**Stakeholder**	**Examples of Adaptation Projects**		
		Design (Structural)	**Operation and Maintenance (Non-Structural)**	**Policy (Non-Structural)**
Landscape	Landscapers, landowners	• Incorporate windbreaks (e.g.: vegetation) in the landscape design		
Buildings	Architects, developers, builders, and renovation specialists	• Retrofit window and door protection to prevent damage and injury from debris • Retrofit project to transfer wind loads from the roof to the foundation • Retrofit project to secure the building envelope and integrity during a wind event • Avoid building elevation forms that are thinner at the bottom and wider at the top • Buildings supported on columns in their first story should have these columns stiffened by bracing • A hip-roofed home of a cubical form is considered as one of the best configurations to use in high wind or hurricane prone areas • Residential Building Retrofit • Non-Residential Building Retrofit • Public Building Retrofit • Historic Building Retrofit • Roof Diaphragm Retrofit - Roof hardening and roof clips		
	Local, regional, provincial, and territorial governments			• Establish new code to upgrade building requirements for strong wind/hurricane resistance
Critical Infrastructure	Local, regional, territorial government, and energy authorities	• Install a generator to ensure minimal power loss to the building before, during and after a power outage • Burying electrical lines when possible to prevent vulnerability to winds and power outages in areas that are not vulnerable to flooding. • Incorporate a range of clean energy technologies such as renewable energy, energy storage, and distributed generation • Roof Diaphragm Retrofit - Roof hardening and roof clips		• Provincial and federal policymakers should adopt and strengthen programs that support the timely expansion of renewable energy and energy efficiency measures, such as renewable electricity standards.

WIND				
Scale	Stakeholder	Examples of Adaptation Projects		
		Design (Structural)	Operation and Maintenance (Non-Structural)	Policy (Non-Structural)
Roads	Local transportation authorities and transportation agencies	• Construct strategic wind breaks • Design roadside infrastructure and bridges to withstand higher wind speed	• Clear sidewalks and roads of debris or objects that may be blown away.	
	Landscapers and Local, regional, provincial, and territorial governments and transportation agencies	• Put “snow fences” which are rows of trees, to reduce impacts of blowing snow or blowing rain on roadway visibility		
Community	Construction workers		• Clear all types of construction sites of debris that can be blown away. Tie down materials, debris and objects from construction sites that can potentially be blown away and considered as projectiles	• Establish new codes and standards for construction zones where debris and objects that can be blown away are properly tied down and stored away.

EXTREME TEMPERATURE/ HEAT WAVES				
		Examples of Adaptation Projects		
Scale	**Stakeholder**	**Design (Structural)**	**Operation and Maintenance (Non-Structural)**	**Policy (Non-Structural)**
Roads	Local transportation authorities and transportation agencies	• Use heat resistant paving materials with higher solar reflectance to reduce damages (e.g.: potholes and cracks) and UHI effect. • Solar heating reflective coating layer • Using white materials (e.g., pigments, binders, light aggregates, white topping, reflective paints) for surface layer of road pavement • consider use of additives in asphalt mix to reduce shoving/rutting • Increase roadside vegetation and trees to increase shade and decrease exposure	• Conduct frequent inspections of pavement surfaces to ensure cracks are properly sealed	• Implement proactive traffic management plans to reduce risk of rutting
Bridges	Local transportation authorities and transportation agencies	• Use more durable materials for bridge deck, including reinforced concrete	• Replace bridge expansion joints and ensure joints can accommodate thermal expansion • Conduct more frequent inspections and maintenance	
Landscape	Landscapers, landowners	• Consider nature-based solutions, such as planting local species that have a greater heat tolerance or are drought resistant, retaining water.		
Buildings	Architects, developers, builders, and renovation specialists	• Use materials that are resistant to or limit the accumulation of heat, such as light-colored materials such as white (high albedo) • Building retrofit and plan building designs that promote electricity and energy conservation, such as passive cooling systems, window shading and insulation • Incorporated heat island reduction strategies such as green roofs or cool roofs. • Install window shades • Residential Building Retrofit • Non-Residential Building Retrofit • Public Building Retrofit • Historic Building Retrofit	• Upgrade ventilation system	
	Inspectors, building managers and owners		• Weekly monitoring of energy demand on mechanical HVAC and cooling systems, during the high temperature periods in July/August • Increase monitoring of HVAC cooling demand during heat wave periods to avoid overheating of the systems.	

EXTREME TEMPERATURE/ HEAT WAVES				
		Examples of Adaptation Projects		
Scale	**Stakeholder**	**Design (Structural)**	**Operation and Maintenance (Non-Structural)**	**Policy (Non-Structural)**

Critical infrastructure	Local, regional, provincial, and territorial governments and energy sector stakeholders	• Consider electricity mix diversification by having centralised and decentralised options and by promoting an increase in renewable energy. Diversification minimises the magnitude of impacts and makes electricity systems less prone to failures
		• Bury the electrical grid to avoid damage from extreme heat
		• Improving the electricity grid by retrofitting current assets and introducing new technologies and new design asset
		  o Replacing overhead lines with underground cables
		  o Supplementary transmission lines to re-route electricity in case of failure
		  o Invest in smart grids, microgrids and circular grids
		• Aquifer Storage and Recovery project
				• Policymakers should adopt and strengthen programs that support the timely expansion of renewable energy and energy efficiency measures

City	Local, regional, provincial, and territorial governments		• Track impacts of extreme heat to identify "hot-spots" that may require an increased rate of inspection. • Regularly evaluate de local forecast and monitor heat	• Implement urban planning standards and adaptation such as tree cover minimums, green spaces standards, fresh air corridor standards, etc. • Implement formal systems for notifying the public of heat waves which would include the communication of its arrival, duration and severity
Community	Neighborhood associations and local community groups	• Planting trees and other vegetation to create shade in urban and open spaces		• During prolonged episodes of extreme temperatures and heat waves, establish a secure area where the community and vulnerable populations can cool off • Educate the community on best practices in urban greening
	Local, regional, provincial, and territorial governments and workers		• Improve or develop outreach strategies for communication risks to vulnerable communities • Training employers and workers in industries where work is conducted outside, including water availability, shade, rest breaks and training on heat risks	• Implement strategies to increase community resilience by improving social infrastructure, such as places and organizations that foster cohesion and support • Improve, promote and implement coordination by government, local agencies, industries, schools, clinics, hospitals for better worker protection measures

EXTREME TEMPERATURE/ HEAT WAVES				
Scale	Stakeholder	Examples of Adaptation Projects		
		Design (Structural)	Operation and Maintenance (Non-Structural)	Policy (Non-Structural)

ICE STORM				
Scale	Stakeholder	Examples of Adaptation Projects		
		Design (Structural)	Operation and Maintenance (Non-Structural)	Policy (Non-Structural)
Roads	Local transportation authorities and transportation agencies		• Increase maintenance of pavement surfaces to monitor the accumulation of ice and the formation of black ice • Spread de-icing agents to eliminate icy road hazardous conditions	
Buildings	Architects, developers, builders, and renovation specialists	• Add a back-up generator or battery backup system and check-up regularly to provide emergency power • Add solar panels accompanied of a power storage source (e.g.: battery) as an alternative source of power • Residential Building Retrofit • Non-Residential Building Retrofit • Public Building Retrofit • Historic Building Retrofit	• Upgrade insulation at building corners to reduce heat loss; seal joints between panels to address insulation discontinuity issues	
	Inspectors, building owners		• Increase the frequency of wall condition monitoring in critical areas • Regular inspection of snow/ice removal on building roofs	
Critical Infrastructure	Architects, developers, builders, and renovation specialists AND engineers AND energy/electricity sector	• Add a back-up generator or battery backup system and check-up regularly to provide emergency power so that operations and services are not disrupted during an outage • Improving the electricity grid by retrofitting current assets and introducing new technologies and new design asset o Replacing overhead lines with underground cables o Supplementary transmission lines to re-route electricity in case of failure		• Policymakers should adopt and strengthen programs that support the timely expansion of renewable energy and energy efficiency measures

EXTREME TEMPERATURE/ HEAT WAVES				
Scale	**Stakeholder**	**Examples of Adaptation Projects**		
		Design (Structural)	**Operation and Maintenance (Non-Structural)**	**Policy (Non-Structural)**
		• Invest in smart grids, microgrids and circular grids • Add solar panels accompanied of a power storage source (e.g.: battery) as an alternative source of power • Burying power lines when possible, in areas that are not vulnerable to flooding. • Use thicker overhead wires in areas prone to severe icing		
Landscape	Landscapers, landowners,	• Use vegetation that have a higher resilience to ice storms. For example, some tree species are more prone to having ice accumulate on the entire branches, while others will only see the tip of the branches covered in ice and tend to perform better during ice storms. This will minimize the number of tree branches falling on power lines and roads.	• Increased maintenance for tree cover (trimming tree branches) to minimize ice incrusted branches that fall on power lines • Offer clients advice of adequate vegetation coverage to prevent and/or minimize risk associated with ice storms	
City	Local, regional, provincial, and territorial governments		• Regularly evaluate de local forecast • Regular review and update ice loading maps and loading criteria • Make sure that emergency plans are current and that people responsible for the implementation of the plans are emergency-ready	• Implement a storm preparedness plan • Implement emergency response protocols • Establishing reception centre sites across the city
Community				– Educate the community on best practices and how to prepare for ice storms

EXTREME TEMPERATURE/ HEAT WAVES				
		Examples of Adaptation Projects		
Scale	**Stakeholder**	**Design (Structural)**	**Operation and Maintenance (Non-Structural)**	**Policy (Non-Structural)**
Roads	Local transportation authorities and transportation agencies	• Use heat resistant paving materials with higher solar reflectance to reduce damages (e.g.: potholes and cracks) and UHI effect. • Solar heating reflective coating layer • Using white materials (e.g., pigments, binders, light aggregates, white topping, reflective paints) for surface layer of road pavement • consider use of additives in asphalt mix to reduce shoving/rutting • Increase roadside vegetation and trees to increase shade and decrease exposure	• Conduct frequent inspections of pavement surfaces to ensure cracks are properly sealed	• Implement proactive traffic management plans to reduce risk of rutting
Bridges	Local transportation authorities and transportation agencies	• Use more durable materials for bridge deck, including reinforced concrete	• Replace bridge expansion joints and ensure joints can accommodate thermal expansion • Conduct more frequent inspections and maintenance	
Landscape	Landscapers, landowners	• Consider nature-based solutions, such as planting local species that have a greater heat tolerance or are drought resistant, retaining water.		
Buildings	Architects, developers, builders, and renovation specialists	• Use materials that are resistant to or limit the accumulation of heat, such as light-colored materials such as white (high albedo) • Building retrofit and plan building designs that promote electricity and energy conservation, such as passive cooling systems, window shading and insulation • Incorporated heat island reduction strategies such as green roofs or cool roofs. • Install window shades • Residential Building Retrofit • Non-Residential Building Retrofit • Public Building Retrofit • Historic Building Retrofit	• Upgrade ventilation system	
	Inspectors, building managers and owners		• Weekly monitoring of energy demand on mechanical HVAC and cooling systems, during the high temperature periods in July/August • Increase monitoring of HVAC cooling demand during heat wave periods to avoid overheating of the systems.	

EXTREME TEMPERATURE/ HEAT WAVES				
		Examples of Adaptation Projects		
Scale	**Stakeholder**	**Design (Structural)**	**Operation and Maintenance (Non-Structural)**	**Policy (Non-Structural)**
Critical infrastructure	Local, regional, provincial, and territorial governments and energy sector stakeholders	• Consider electricity mix diversification by having centralised and decentralised options and by promoting an increase in renewable energy. Diversification minimises the magnitude of impacts and makes electricity systems less prone to failures • Bury the electrical grid to avoid damage from extreme heat • Improving the electricity grid by retrofitting current assets and introducing new technologies and new design asset o Replacing overhead lines with underground cables o Supplementary transmission lines to re-route electricity in case of failure o Invest in smart grids, microgrids and circular grids • Aquifer Storage and Recovery project		• Policymakers should adopt and strengthen programs that support the timely expansion of renewable energy and energy efficiency measures
City	Local, regional, provincial, and territorial governments		• Track impacts of extreme heat to identify "hot-spots" that may require an increased rate of inspection. • Regularly evaluate de local forecast and monitor heat	• Implement urban planning standards and adaptation such as tree cover minimums, green spaces standards, fresh air corridor standards, etc. • Implement formal systems for notifying the public of heat waves which would include the communication of its arrival, duration and severity
Community	Neighborhood associations and local community groups	• Planting trees and other vegetation to create shade in urban and open spaces		• During prolonged episodes of extreme temperatures and heat waves, establish a secure area where the community and vulnerable populations can cool off • Educate the community on best practices in urban greening
	Local, regional, provincial, and territorial governments and workers		• Improve or develop outreach strategies for communication risks to vulnerable communities • Training employers and workers in industries where work is conducted outside, including water availability, shade, rest breaks and training on heat risks	• Implement strategies to increase community resilience by improving social infrastructure, such as places and organizations that foster cohesion and support • Improve, promote and implement coordination by government, local agencies, industries, schools, clinics, hospitals for better worker protection measures

EXTREME TEMPERATURE/ HEAT WAVES				
Scale	Stakeholder	Examples of Adaptation Projects		
		Design (Structural)	Operation and Maintenance (Non-Structural)	Policy (Non-Structural)

ICE STORM				
Scale	Stakeholder	Examples of Adaptation Projects		
		Design (Structural)	Operation and Maintenance (Non-Structural)	Policy (Non-Structural)
Roads	Local transportation authorities and transportation agencies		• Increase maintenance of pavement surfaces to monitor the accumulation of ice and the formation of black ice • Spread de-icing agents to eliminate icy road hazardous conditions	
Buildings	Architects, developers, builders, and renovation specialists	• Add a back-up generator or battery backup system and check-up regularly to provide emergency power • Add solar panels accompanied of a power storage source (e.g.: battery) as an alternative source of power • Residential Building Retrofit • Non-Residential Building Retrofit • Public Building Retrofit • Historic Building Retrofit	• Upgrade insulation at building corners to reduce heat loss; seal joints between panels to address insulation discontinuity issues	
	Inspectors, building owners		• Increase the frequency of wall condition monitoring in critical areas • Regular inspection of snow/ice removal on building roofs	

Critical Infrastructure	Architects, developers, builders, and renovation specialists AND engineers AND energy/electricity sector	• Add a back-up generator or battery backup system and check-up regularly to provide emergency power so that operations and services are not disrupted during an outage
		• Improving the electricity grid by retrofitting current assets and introducing new technologies and new design asset
		  o Replacing overhead lines with underground cables
		  o Supplementary transmission lines to re-route electricity in case of failure
				• Policymakers should adopt and strengthen programs that support the timely expansion of renewable energy and energy efficiency measures

EXTREME TEMPERATURE/ HEAT WAVES				
Scale	Stakeholder	Examples of Adaptation Projects		
		Design (Structural)	Operation and Maintenance (Non-Structural)	Policy (Non-Structural)
		• Invest in smart grids, microgrids and circular grids • Add solar panels accompanied of a power storage source (e.g.: battery) as an alternative source of power • Burying power lines when possible, in areas that are not vulnerable to flooding. • Use thicker overhead wires in areas prone to severe icing		
Landscape	Landscapers, landowners,	• Use vegetation that have a higher resilience to ice storms. For example, some tree species are more prone to having ice accumulate on the entire branches, while others will only see the tip of the branches covered in ice and tend to perform better during ice storms. This will minimize the number of tree branches falling on power lines and roads.	• Increased maintenance for tree cover (trimming tree branches) to minimize ice incrusted branches that fall on power lines • Offer clients advice of adequate vegetation coverage to prevent and/or minimize risk associated with ice storms	
City	Local, regional, provincial, and territorial governments		• Regularly evaluate de local forecast • Regular review and update ice loading maps and loading criteria • Make sure that emergency plans are current and that people responsible for the implementation of the plans are emergency-ready	• Implement a storm preparedness plan • Implement emergency response protocols • Establishing reception centre sites across the city
Community				– Educate the community on best practices and how to prepare for ice storms

8.

9. Project Useful Life

The PUL is the estimated amount of time (in years) that the adaptation action will be effective. It is one of the important parameters in the calculation because it establishes the timeframe to calculate benefits. Project maintenance cost may also be calculated using the project useful life if assuming the number of maintenance years is the same value as the project useful life.

Table 9-1 presents the differences between the PUL input for the FEMA BCA Toolkit and the RoI Toolkit. FEMA BCA Toolkit provides the Standard Values for hazard and project types including capital projects (CAPEX) and operation and maintenance projects (OPEX) for each hazard type. While the RoI Toolkit's database adopted the average expected useful lives of new municipally owned assets published by Statistics Canada 2018 for capital adaptation project. The data was collected from Canada's Core Public Infrastructure Survey that aims to collect statistical information on the core public infrastructure assets owned or leased by various levels of the Canadian government, which makes it an ideal data source considering wilder Canadian municipalities may use this RoI Toolkit to evaluate the effectiveness of adaptation projects.

In the RoI Toolkit, there are more OPEX adaptation project types available in the adaptation library compared to the FEMA BCA Toolkit. There is a user input setting for the PUL of the OPEX projects allowing flexibility of the selection of project types considering local conditions.

It is noticeable that FEMA BCA Toolkit has an acceptable limit setting. Higher PUL values extend the duration over which benefits are calculated, resulting in a higher BCR. Therefore, the acceptable limit setting in the FEMA BCA Toolkit helps create a good limit setting with regards to grant administration. For the RoI Toolkit, there is no pre-set limit, but it is recommended that documentation and justification be required if the PUL value is significantly higher than the average expected useful life provided.

Table 9-1: Project Useful Life Input

	RoI Toolkit	FEMA BCA Toolkit
Project Useful Life Input	• CAPEX: – User's experience – average expected useful life of new municipally owned assets – Average expected useful life value for different provinces – Available for both urban and rural area – No acceptable limit setting • OPEX: – User's experience (allow flexibility to include more types of adaptation projects) – FEMA BCA standard value available for users to choose (limited type of projects) – No acceptable limit setting	• User's experience • Standard Values for hazard and project types (including specific CAPEX and OPEX projects) • Acceptable Limits Setting (as the FEMA BCA is for grant application purpose)

Both tools allow users to enter the PUL based on their local experience for both tools. In the RoI Toolkit, a PUL database is available for users to choose values for urban and rural areas in different Canadian provinces. The RoI Toolkit also provides the FEMA BCA Standard Values (Table 9-2) for various adaptation project types for users. The average asset expected useful lives for Canadian new municipally owned assets are presented in Appendix B.

Table 9-2: FEMA BCA Toolkit Standard Value for Hazard and Project Types

Project Type	Project Useful Life		Comment
	Standard Value	**Acceptable Limits**	
Flood			
Acquisition / Relocation			
Acquisition / Relocation	100	100	
Building Elevation			
Residential Building	30	30-50	
Non-Residential Building	25	25-50	
Public Building	50	50-100	
Historical Building	50	50-100	
Adaptation Reconstruction			
Adaptation Reconstruction	50	50	
Infrastructure Project			
Major Infrastructure (dams, levees)	50	35-100	
Concrete infrastructure, flood walls, roads, bridges, major drainage system	50	35-50	
Culverts (concrete, PVC, CMP, HDPE, etc.	30	25-50	Culvert with end treatment (i.e. wing, walls, end sections, head walls, etc.)
	10	5-20	Culvert without end treatment (i.e. wing, walls, end sections, head walls, etc.)
Pump Stations, substations, wastewater systems, or equipment such as generators	50	50	Major (power lines, cable, hardening gas, water, sewer lines, etc.)
	5	5-30	Minor (backflow valves, downspout disconnect, etc.)
Other Flood Adaptation Project Types			
Floodplain and Stream Restoration	30		Higher values acceptable
Flood Diversion and Storage	30		Higher values acceptable
Tornado and Hurricane Safe Room			
Tornado Safe Room - Residential	30	30	Retrofit or Small Community safe room ≤ 16 people (30 yr.), New (50 yr.)
Tornado Safe Room - Community	30	30-50	
Hurricane Safe Room	30	30-50	
Hurricane Wind			
Roof Diaphragm Retrofit	30	30	Roof hardening and roof clips
Hurricane Storm Shutters	15	15-30	Depends on type of storm shutter
Wildfire			
Defensible Space/Hazardous Fuels Reduction (Vegetation Management)	4	1-4	Brush - Depends on drought conditions
	1	1	Grass - Depends on geographic location and precipitation
	20	3-20	Forest Canopy - Must be maintained every 3 years
Ignition Resistant Construction	10	10-30	Depends on type of construction and materials used.
Building Retrofit Projects			
Residential Building Retrofit	30	30	
Non-Residential Building Retrofit	25	25-50	

Project Type	Project Useful Life		Comment
	Standard Value	**Acceptable Limits**	
Public Building Retrofit	50	50-100	
Historic Building Retrofit	50	50-100	
Utility Adaptation Projects			
Utility **Adaptation** Projects	50	50-100	Major (power lines, cable, hardening gas, water, sewer lines, etc.)
	5	5-30	Minor (backflow values, downspout disconnect, etc.)
Generators and Miscellaneous Equipment			
Equipment Purchases	2	2-10	Small, portable equipment (e.g., computer)
	30	5-30	Heavy equipment
Generators	19		The Project Useful Life may be altered based on manufacturer warranty or other documentation that can demonstrate that the generator life may be able to provide service longer than 19 years.

10. Resources

10.1 Download FEMA BCA Tool

FEMA BCA Toolkit 6.0 is available to download for free. Users can use the Toolkit in Excel Desktop or in Excel Online. Below are the directions for using the FEMA BCA Toolkit from FEMA BCA Toolkit 6.0 Installation Instructions.

Excel Desktop

To download the FEMA BCA software, visit the Benefit-Cost Analysis page and following directions are for using FEMA BCA Toolkit 6.0 in the desktop version of Excel. (Excel 2013 or newer is required.)

1. Click the “Download the FEMA BCA Toolkit Version 6.0” button on the Benefit-Cost Analysis page and open the Excel file.
2. (FEMA computers should skip this step) In the Insert tab, in the Add-ins section, click on My Add-ins. Select the Store option and search for FEMA Benefit-Cost Analysis Calculator. Click Add.
3. On the Home tab, you should now see the FEMA BCA V6.0 icon in the upper righthand ribbon.
4. Click on the FEMA BCA V6.0 icon. A sidebar will open.
5. Click Open Calculator to begin your BCA.
6. The add-in window will open and take you to the home screen. From here you can start a new project by clicking Add Project.
7. To save your work, click "Finish" on the second screen, close the add-in window, and save the Excel file, renaming it as desired.

Excel Online

The following directions are for using the FEMA BCA Toolkit 6.0 in Excel Online. Excel Online works best in Firefox and Chrome browsers.

1. Click the “Download the FEMA BCA Toolkit Version 6.0” button on the Benefit-Cost Analysis page and save the Excel file to your machine or OneDrive.
2. If you do not already have one, create a free Office 365 account.
3. Once logged in, open Excel Online by clicking on the Excel icon under Apps.
4. Open the file BCA_Toolkit_6.xlsx in Excel Online by clicking Upload a Workbook.
5. In the Insert tab, click Office Add-ins. Select the Store option and search for FEMA Benefit-Cost Analysis Calculator. Click Add. (If you get a message saying Microsoft 365 has been configured to prevent individual acquisition of Office Add-ins, you can sign out and sign in using a personal account.)
6. You should now see the FEMA BCA button in the top righthand side in the Home tab.
7. To launch the Toolkit, click on the FEMA BCA button. A sidebar will open.
8. Click Open Calculator. You may be asked if you want to allow your browser to open another window. Click Allow.
9. The add-in window will open and take you to the Home screen. From here you can start a new project by clicking Add Project.
10. To save your work, click “Finish” on the second screen and close the add-in window. IMPORTANT: You must make sure to save a copy of the file to your local machine by clicking File, Save As, Download a Copy, and choosing the “Open with Microsoft Excel” option. Once the file opens, click File, Save As,

and save a copy to your local machine. To reopen the file in Excel Online, click Upload a Workbook and navigate to the file on your local machine.

10.2 Specific Hazard Resources

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10.3 Project Useful Life resources

Statistics Canada. Table 34-10-0199-01 Average expected useful life of new municipally owned potable water assets, by urban and rural, and population size, Infrastructure Canada

Statistics Canada. Table 34-10-0229-01 Average expected useful life of new municipally owned wastewater assets, by urban and rural, and population size, Infrastructure Canada.

Statistics Canada. Table 34-10-0217-01 Average expected useful life of new municipally owned stormwater assets, by urban and rural, and population size, Infrastructure Canada

Statistics Canada. Table 34-10-0073-01 Average expected useful life of new municipally owned road assets, by urban and rural, and population size, Infrastructure Canada

Statistics Canada. Table 34-10-0170-01 Average expected useful life of new municipally owned bridge and tunnel assets, Infrastructure Canada

Statistics Canada. Table 34-10-0255-01 Average expected useful life of new municipally owned public transit assets, by urban and rural, and population size, Infrastructure Canada

Statistics Canada. Table 34-10-0183-01 Average expected useful life of new municipally owned culture, recreation and sport facilities, by urban and rural, and population size, Infrastructure Canada

10.4 Adaptation Library Resources

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Appendix A: Standard Data Types and Corresponding Values and Sources

Table A1: Standard Data Types and Corresponding Values and Sources

Data Type	FEMA Value	RoI	Source
Discount Rate	3.5%	User entry (default at 3.5%)	
BCA Parameters for Utility Services			
Electrical (US$/Person/Day)	US$ 174	$221	FEMA Benefit-Cost Analysis Toolkit Version 6.0
Potable Water (US$/Person/Day)	US$ 114	$145	FEMA Benefit-Cost Analysis Toolkit Version 6.0
Wastewater (US$/Person/Day)	US$ 58	$74	FEMA Benefit-Cost Analysis Toolkit Version 6.0
Vehicle Occupancy and Unit Cost for Time Parameters			
Passenger Vehicle (Occupancy)	1.67	1.7	Alberta Transportation Benefit Cost Model – Version 201811120.
Time value of money work travel (per hour)	US$ 27.90	$ 26.00	Alberta Transportation Benefit Cost Model – Version 201811120.
Time value of money leisure travel (per hour)	US$ 16.50	$ 13.00	Alberta Transportation Benefit Cost Model – Version 201811120.
Safety Parameters			
Cost of fatality	7,500,000	$11.80M	Multihazard Mitigation Council (2019) VSL from Bergeron (2014)
Cost of serious injury	N/A	$4.4M	
Cost of minor injury	N/A	$66,109	
FEMA value of a hospitalization (2021$)	US$ 2,300,000	N/A	
FEMA value of treat & release (2021$)	US$ 61,000	N/A	
FEMA value of self-treatment (2021$)	US$ 14,000	N/A	
Wildfire casualty rate	8.94 death per million	0.009 per person	Calfire database
Wildfire injury rate	NA	0.033	Calfire database
Flood minor injury rate per households		0.1275	Multihazard Mitigation Council 2019
Flood moderate injury rate per households		0.04	Multihazard Mitigation Council 2019
Flood death rate per house per households		0.0008	Multihazard Mitigation Council 2019
Mental Health Parameters			
Treatment Cost per Person (per event)	US$ 2,443	$90,000	FEMA BCA Help, "How are mental health treatment costs and productivity losses calculated?"

Data Type	FEMA Value	RoI	Source
Instance of PTSD		0.15 per person	Multihazard Mitigation Council 2019
Loss of Productivity Parameters			
Productivity loss per Person (per event)	US$ 8,736	$15,634	FEMA BCA Help, "How are mental health treatment costs and productivity losses calculated?"
Average number of workers per household	1.22	User entry	
Ecosystem Services Parameters (Value per acre per year [U.S.]/hectare per year [Can])			
Forest	US$ 554	$8,814.35	Multiple sources
Urban Green Open Space	US$ 8,308	$20,496.85	Multiple sources
Rural Green Open Space		$7,824.03	Multiple sources
Riparian	US$ 39,545	$51,599.56	Multiple sources
Inland wetland	US$ 6,010	$4,559.37	Multiple sources
Volunteer Costs			
Volunteer costs per person per day	US$ 198	N/A	FEMA Benefit-Cost Analysis Toolkit Version 6.0

Table A2: Standard Data Types and Corresponding Values of Ecosystem Services (Urban Green Infrastructure)

Data Type	Green Roofs	Permeable Pavements	Bioretention	Urban Trees
Avoided carbon emissions	$0.0065 m^{-2}	$0.05 m^{-2}	$0.23 m^{-2}	$0.19 tree^{-1}
Carbon sequestration	$0.0023 m^{-2}	-	$74.45 m^{-2}	$28.65 tree^{-1}
Carbon sequestration and avoided emissions	$0.0088 m^{-2}	$0.05 m^{-2}	$74.67 m^{-2}	$28.84 tree^{-1}
Building energy cost savings	$1.98 m^{-2}	-	-	$31.19 tree^{-1}
Drought risk reduction	-	$0.10 m^{-2}	$0.41 m^{-2}	$4.41 tree^{-1}
Habitat	$0.04 m^{-2}	-	$0.09 m^{-2}	$32.05 tree^{-1}
Heat risk reduction	-	-	-	$726.19 tree^{-1}
Property value improvement	$0.15 m^{-2}	-	$0.32 m^{-2}	$42.40 tree^{-1}
Removal of air pollutants	$0.01 m^{-2}	-	$0.076 m^{-2}	$6.78 m^{-2} tree^{-1}
Stormwater volume and quality	$0.52 m^{-2}	$4.37 m^{-2}	$18.10 m^{-2}	$14.89 tree^{-1}

Table A3: Standard Data Types and Corresponding Values of Ecosystem Services (per Land Cover)

Data Type	Forests	Urban Green Open Space	Rural Green Open Space	Riparian	Inland Wetland
Air quality	$909.63 ha^{-1}	$760.23 ha^{-1}	-	$597.80 ha^{-1}	-
Climate regulation	$623.03 ha^{-1}	$167.26 ha^{-1}	$238.50 ha^{-1}	$297.35 ha^{-1}	$173.45 ha^{-1}
Erosion Control	$5,178.85 ha^{-1}	$241.60 ha^{-1}	$241.60 ha^{-1}	$42,815.34 ha^{-1}	-
Flood and storm hazard reduction	$2,093.84 ha^{-1}	$978.78 ha^{-1}	-	$18,745.46 ha^{-1}	$3,915.11 ha^{-1}
Habitat	-	$18,243.68 ha^{-1}	$6,259.84 ha^{-1}	$7,889.07 ha^{-1}	$4,385.92 ha^{-1}
Pollination	-	$1,084.09 ha^{-1}	$1,084.09 ha^{-1}	-	-

Appendix B: Average Expected Useful Life for Publicly Owned New Assets

Table B1: RoI Toolkit - Average Expected Useful Life of New Publicly Owned Potable Water Assets[1,2]

Geography	Type of municipality by population size	Water Treatment Facilities	Water Reservoirs (including dams) before intake[3]	Storage Tanks after Intake not part of a Treatment Plant	Water Pump Stations[4]	Local Water Pipes (diameter less than 416 mm)[5]	Transmission Pipes (diameter greater than or equal to 416 m)[6]	Pipes of unknown diameter
Canada	All municipalities	37	38	41	33	54	62	44
	All urban municipalities	41	44	45	37	63	71	57
	All rural municipalities	35	35	38	32	50	51	38
Newfoundland and Labrador	All municipalities	26	35	29	27	39	54	38
	All urban municipalities	37	47	36	38	50	57	43
	All rural municipalities	25	33	27	25	38	54	38
Prince Edward Island	All municipalities	36	22	28	30	55	89	10
	All urban municipalities	55	40	47	52	84	89	100
	All rural municipalities	32	20	21	25	51	NA[7]	NA
Nova Scotia	All municipalities	38	50	38	36	58	62	16
	All urban municipalities	36	44	47	40	64	66	20
	All rural municipalities	45	58	31	44	58	69	NA
New Brunswick	All municipalities	36	42	39	36	53	67	44
	All urban municipalities	37	40	38	36	59	72	68
	All rural municipalities	36	44	39	36	49	62	36
Quebec	All municipalities	38	38	41	NA	NA	60	46
	All urban municipalities	43	43	47	38	68	76	53
	All rural municipalities	37	37	40	34	51	46	45
Ontario	All municipalities	46	46	49	42	67	72	63
	All urban municipalities	49	46	51	49	71	75	69
	All rural municipalities	44	48	46	39	64	64	56
Manitoba	All municipalities	36	36	35	32	47	43	32
	All urban municipalities	39	33	46	35	52	87	67
	All rural municipalities	35	37	28	32	45	35	25
Saskatchewan	All municipalities	34	30	38	28	44	51	30
	All urban municipalities	39	43	42	37	59	67	43
	All rural municipalities	33	26	36	26	40	44	27
Alberta	All municipalities	35	38	40	32	53	58	44
	All urban municipalities	38	42	39	35	53	63	54
	All rural municipalities	33	34	39	29	53	49	36

Geography	Type of municipality by population size	Water Treatment Facilities	Water Reservoirs (including dams) before intake[3]	Storage Tanks after Intake not part of a Treatment Plant	Water Pump Stations[4]	Local Water Pipes (diameter less than 416 mm)[5]	Transmission Pipes (diameter greater than or equal to 416 m)[6]	Pipes of unknown diameter
British Columbia	All municipalities	38	48	46	35	68	71	63
	All urban municipalities	40	49	49	34	71	74	65
	All rural municipalities	36	46	42	38	65	71	58
Yukon	All municipalities	47	45	45	NA	57	NA	NA
	All urban municipalities	45	45	45	NA	75	NA	NA
	All rural municipalities	48	NA	NA	NA	49	NA	NA
Northwest Territories	All municipalities	26	27	NA	24	31	15	NA
	All urban municipalities	27	27	NA	24	31	15	NA
	All rural municipalities	25	NA	NA	NA	NA	NA	NA
Nunavut	All municipalities	36	45	20	37	75	75	20
	All urban municipalities	40	45	20	37	75	75	NA
	All rural municipalities	33	NA	NA	NA	NA	NA	20

Note:

1. *Expected useful life of an asset refers to the service life or the productive life of the asset at the time of its acquisition regardless of their lives reported for income tax purposes.*
2. *Estimates for 2018 may not be comparable to those for 2016 due to improved coverage and definitions as well as changes in survey methodology.*
3. *Reservoir: A pond, lake, or basin (natural or artificial) that stores, regulates, or controls water. Includes the number of reservoirs and water towers within the distribution, transmission, or integrated system.*
4. *Pump stations include pump stations within the non-linear potable water system.*
5. *Local water pipes include all connecting pipes, of diameter less than 416 mm, between pump stations, rechlorination facilities and storage facilities if these are located within the distribution system.*
6. *Transmission pipes include all connecting pipes, of diameter greater than or equal to 416mm, between pump stations, rechlorination facilities and storage facilities when located between the source and the treatment plant or between the treatment plant and the distribution system.*
7. *Not available for a specific reference period*

Table B2: RoI Toolkit - Average Expected Useful Life of New Publicly Owned Wastewater Assets[1,2]

Geography	Type of municipality by population size	Wastewater Treatment Plants (includes sludge handling plants)	Lagoon Systems	Wastewater Pump Stations	Wastewater Lift Stations	Wastewater Storage Tanks	Sewer pipes (diameter: less than 450 mm)	Sewer Pipes (diameter: greater than or equal to 450 mm to less than 1,500 mm)	Sewer Pipes (diameter: greater than or equal to 1,500 mm)	Sewer Pipes (of unknown diameter)	Sanitary Forcemains
Canada	All municipalities	34	42	35	32	42	53	61	52	54	55
	All urban municipalities	36	44	38	34	53	62	65	67	64	62
	All rural municipalities	33	42	34	31	40	50	53	38	50	51
Newfoundland and Labrador	All municipalities	24	54	31	22	34	40	46	62	67	44
	All urban municipalities	26	51	60	31	NA[3]	47	45	NA	83	52
	All rural municipalities	22	60	28	21	34	39	50	62	58	41
Prince Edward Island	All municipalities	37	31	24	27	NA	53	68	NA	72	52
	All urban municipalities	37	30	30	38	NA	74	64	NA	72	67
	All rural municipalities	37	31	23	27	NA	51	75	NA	NA	49
Nova Scotia	All municipalities	36	48	34	31	35	48	56	NA	53	43
	All urban municipalities	37	56	28	29	28	50	65	NA	40	42
	All rural municipalities	35	45	38	32	41	47	25	NA	75	44
New Brunswick	All municipalities	36	38	36	35	45	56	48	31	57	51
	All urban municipalities	35	39	48	34	NA	61	75	85	75	59
	All rural municipalities	36	38	35	36	45	55	27	10	50	48
Quebec	All municipalities	33	44	35	30	46	56	60	47	58	55
	All urban municipalities	35	46	35	32	76	65	65	54	62	64
	All rural municipalities	33	44	34	29	44	54	54	42	57	51
Ontario	All municipalities	37	52	42	38	53	67	70	74	63	64
	All urban municipalities	39	59	45	41	55	73	73	74	75	70
	All rural municipalities	36	50	40	37	51	63	66	NA	54	61
Manitoba	All municipalities	30	36	26	30	50	38	41	42	39	42
	All urban municipalities	37	35	25	31	NA	50	63	75	75	50
	All rural municipalities	26	36	27	29	50	33	26	20	34	36

Geography	Type of municipality by population size	Wastewater Treatment Plants (includes sludge handling plants)	Lagoon Systems	Wastewater Pump Stations	Wastewater Lift Stations	Wastewater Storage Tanks	Sewer pipes (diameter: less than 450 mm)	Sewer Pipes (diameter: greater than or equal to 450 mm to less than 1,500 mm)	Sewer Pipes (diameter: greater than or equal to 1,500 mm)	Sewer Pipes (of unknown diameter)	Sanitary Forcemains
Saskatchewan	All municipalities	26	42	29	34	25	40	52	36	35	52
	All urban municipalities	34	43	40	36	43	52	62	75	52	60
	All rural municipalities	22	41	26	33	21	36	29	29	34	47
Alberta	All municipalities	36	41	33	33	33	48	61	76	49	54
	All urban municipalities	35	46	45	35	51	53	63	76	51	56
	All rural municipalities	39	37	20	32	26	44	55	NA	47	53
British Columbia	All municipalities	34	48	32	36	37	64	62	60	61	62
	All urban municipalities	36	37	32	34	38	68	62	74	60	67
	All rural municipalities	32	58	31	39	37	58	63	50	61	54
Yukon	All municipalities	NA	0	NA	NA	NA	38	45	45	NA	35
	All urban municipalities	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	All rural municipalities	NA	0	NA	NA	NA	38	45	45	NA	35
Northwest Territories	All municipalities	NA	32	NA	24	NA	40	NA	NA	NA	40
	All urban municipalities	NA	35	NA	24	NA	40	NA	NA	NA	40
	All rural municipalities	NA	30	NA	NA	NA	NA	NA	NA	NA	NA
Nunavut	All municipalities	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	All urban municipalities	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	All rural municipalities	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Note:

1. *Expected useful life of an asset refers to the service life or the productive life of the asset at the time of its acquisition regardless of their lives reported for income tax purposes.*
2. *Estimates for 2018 may not be comparable to those for 2016 due to improved coverage and definitions as well as changes in survey methodology.*
3. *Not available for a specific reference period*

Table B3: RoI Toolkit - Average Expected Useful Life of New Publicly Owned Stormwater Assets[1,2]

Geography	Type of municipality by population size	Stormwater Drainage Pump Stations[3]	Stormwater Management Facilities, Stormwater Management Ponds and Stormwater Wetlands[4]	Stormwater Management Facilities all other Permitted, End-of-Pipe Facilities[5]	Culverts (diameter less than 3 metres)	Open Ditches	Stormwater pipes (diameter: less than 450 mm)	Stormwater Pipes (diameter: greater than or equal to 450 mm to less than 1,500 mm)	Stormwater Pipes (diameter: greater than or equal to 1,500 mm)	Stormwater Pipes (of unknown diameter)
Canada	All municipalities	45	56	42	39	45	56	59	73	52
	All urban municipalities	47	57	48	46	51	63	65	79	60
	All rural municipalities	43	55	36	36	43	51	53	60	47
Newfoundland and Labrador	All municipalities	44	57	39	29	37	48	45	51	32
	All urban municipalities	45	56	42	34	49	51	47	68	53
	All rural municipalities	44	59	30	28	33	46	43	43	25
Prince Edward Island	All municipalities	NA[6]	50	NA	28	28	51	50	61	66
	All urban municipalities	NA	50	NA	23	28	62	50	61	66
	All rural municipalities	NA	NA	NA	30	27	50	NA	NA	NA
Nova Scotia	All municipalities	30	42	37	45	47	48	52	64	42
	All urban municipalities	30	43	50	44	49	61	48	70	38
	All rural municipalities	NA	41	30	47	45	39	56	50	54
New Brunswick	All municipalities	44	67	24	40	41	52	52	57	56
	All urban municipalities	40	76	20	49	52	57	56	62	58
	All rural municipalities	45	58	25	39	38	51	51	52	56
Quebec	All municipalities	43	57	43	40	37	58	61	89	54
	All urban municipalities	44	62	49	53	40	74	80	98	71
	All rural municipalities	41	53	38	37	37	53	52	71	51
Ontario	All municipalities	48	56	50	42	52	60	64	73	63
	All urban municipalities	51	51	54	53	63	67	70	76	76
	All rural municipalities	42	59	45	38	48	57	59	68	56
Manitoba	All municipalities	36	48	39	31	47	44	49	40	40
	All urban municipalities	34	52	45	38	42	52	54	75	44
	All rural municipalities	38	44	35	29	50	36	45	18	37

Geography	Type of municipality by population size	Stormwater Drainage Pump Stations[3]	Stormwater Management Facilities, Stormwater Management Ponds and Stormwater Wetlands[4]	Stormwater Management Facilities all other Permitted, End-of-Pipe Facilities[5]	Culverts (diameter less than 3 metres)	Open Ditches	Stormwater pipes (diameter: less than 450 mm)	Stormwater Pipes (diameter: greater than or equal to 450 mm to less than 1,500 mm)	Stormwater Pipes (diameter: greater than or equal to 1,500 mm)	Stormwater Pipes (of unknown diameter)
Saskatchewan	All municipalities	48	56	24	34	54	48	50	57	32
	All urban municipalities	48	64	28	38	55	53	51	70	38
	All rural municipalities	48	50	21	32	54	46	48	20	30
Alberta	All municipalities	46	56	37	37	51	52	56	67	51
	All urban municipalities	46	55	37	41	53	56	59	67	52
	All rural municipalities	46	59	38	32	48	45	45	66	49
British Columbia	All municipalities	49	55	57	47	55	64	65	68	65
	All urban municipalities	52	56	57	50	54	68	69	72	69
	All rural municipalities	34	46	60	44	57	58	60	40	52
Yukon	All municipalities	25	40	20	53	75	60	50	75	41
	All urban municipalities	NA	NA	NA	30	75	60	50	75	50
	All rural municipalities	25	40	20	75	NA	NA	NA	NA	32
Northwest Territories	All municipalities	NA	NA	NA	30	40	27	27	30	22
	All urban municipalities	NA	NA	NA	30	40	27	27	30	22
	All rural municipalities	NA	NA	NA	NA	NA	NA	NA	NA	NA
Nunavut	All municipalities	NA	NA	NA	30	30	49	NA	NA	46
	All urban municipalities	NA	NA	NA	NA	NA	NA	NA	NA	NA
	All rural municipalities	NA	NA	NA	30	30	49	NA	NA	46

Note:

1. *Expected useful life of an asset refers to the service life or the productive life of the asset at the time of its acquisition regardless of their lives reported for income tax purposes.*
2. *Estimates for 2018 may not be comparable to those for 2016 due to improved coverage and definitions as well as changes in survey methodology.*
3. *Stormwater drainage pump stations include stormwater drainage pump stations that are connected to drainage swales, ditches and storm sewers. Exclude combined pump stations which convey combined sewage/stormwater to wastewater treatment plants.*
4. *Stormwater management facilities – Stormwater management ponds and stormwater wetlands:includes engineered end-of-pipe facilities that have received a permit or approval to operate and which may provide peak flow control, runoff quality control, runoff control for downstream erosion, runoff volume control, etc. Includes dry ponds, wet ponds, and stormwater wetlands etc.*
5. *Stormwater management facilities – All other permitted end-of-pipe facilities includes engineered end-of-pipe facilities that have received a permit or approval to operate and which are not stormwater ponds or wetlands (e.g. oil-grit separators, etc.).*
6. *Not available for a specific reference period*

Table B4: RoI Toolkit - Average Expected Useful Life of New Publicly Owned Road Assets

Geography	Type of municipality by population size	Highways[3]	Rural Highways[4]	Arterial Roads[5]	Collector Roads[6]	Local Roads[7]	Lanes and Alleys	Sidewalks
Canada	All municipalities	28	35	30	31	31	31	31
	All urban municipalities	28	35	30	30	31	30	34
	All rural municipalities	28	35	30	31	31	31	29
Newfoundland and Labrador	All municipalities	30	16	22	20	22	30	24
	All urban municipalities	NA[8]	NA	23	20	21	24	24
	All rural municipalities	30	16	20	15	22	32	24
Prince Edward Island	All municipalities	NA	NA	15	17	23	NA	34
	All urban municipalities	NA	NA	15	17	25	NA	33
	All rural municipalities	NA	NA	NA	NA	23	NA	34
Nova Scotia	All municipalities	28	28	26	25	28	33	27
	All urban municipalities	NA	25	23	25	30	20	29
	All rural municipalities	28	29	32	25	27	40	25
New Brunswick	All municipalities	29	22	31	36	28	34	26
	All urban municipalities	NA	33	38	31	26	15	29
	All rural municipalities	29	20	25	39	28	37	26
Quebec	All municipalities	25	26	28	27	29	32	28
	All urban municipalities	30	32	29	28	31	28	32
	All rural municipalities	20	26	26	27	29	33	27
Ontario	All municipalities	25	32	31	32	30	30	35
	All urban municipalities	25	26	33	35	36	31	37
	All rural municipalities	25	33	27	28	28	30	34
Manitoba	All municipalities	35	36	34	35	38	31	30
	All urban municipalities	30	25	36	33	35	30	33
	All rural municipalities	40	37	33	37	39	31	28
Saskatchewan	All municipalities	25	44	34	36	37	33	31
	All urban municipalities	24	25	27	25	30	34	36
	All rural municipalities	26	45	37	40	38	32	29
Alberta	All municipalities	32	30	30	31	32	26	29
	All urban municipalities	30	33	28	30	29	24	30
	All rural municipalities	35	29	32	32	35	28	29
British Columbia	All municipalities	33	58	30	32	34	31	39
	All urban municipalities	32	86	31	32	35	36	43
	All rural municipalities	40	50	26	32	34	25	34

Geography	Type of municipality by population size	Highways[3]	Rural Highways[4]	Arterial Roads[5]	Collector Roads[6]	Local Roads[7]	Lanes and Alleys	Sidewalks
Yukon	All municipalities	NA	NA	NA	NA	NA	NA	NA
	All urban municipalities	NA	NA	NA	NA	NA	NA	NA
	All rural municipalities	NA	NA	NA	NA	NA	NA	NA
Northwest Territories	All municipalities	NA	NA	25	25	32	25	23
	All urban municipalities	NA	NA	25	25	25	25	23
	All rural municipalities	NA	NA	NA	NA	40	NA	NA
Nunavut	All municipalities	NA	NA	NA	NA	23	NA	NA
	All urban municipalities	NA	NA	NA	NA	30	NA	NA
	All rural municipalities	NA	NA	NA	NA	20	NA	NA

Note:

1. *Expected useful life of an asset refers to the service life or the productive life of the asset at the time of its acquisition regardless of their lives reported for income tax purposes.*
2. *Estimates for 2018 may not be comparable to those for 2016 due to improved coverage and definitions as well as changes in survey methodology.*
3. *As of 2018, highways are defined as roads that move high volumes of traffic and have controlled entrance and exit, a dividing strip between the traffic in opposite directions, and typically two or more lanes in each direction. Highways do not provide access to property, and generally do not accommodate cyclists or pedestrians.*
4. *As of 2018, rural highways are defined as roads that move varied traffic volumes depending on location, are medium to high speed, and are usually one, but sometimes two lanes in each direction. These highways usually have no dividing strip and allow for direct access from adjacent developments.*
5. *As of 2018, arterial roads are defined as roads that move moderate to high traffic volumes over moderate distances between principal areas of traffic generation, and gather traffic from collector roads and local roads and move it to the highway system. Arterial roads are generally designed for medium speed, have capacity for 2 to 6 lanes, and may be divided, with limited or controlled direct access from adjacent developments and with on-street parking discouraged.*
6. *As of 2018, collector roads are defined as roads that move low to moderate traffic volumes within specific areas of a municipality and collect local traffic for distribution to the arterial or highway system. Collector roads are generally designed for medium speed, have capacity for 2 to 4 lanes, are usually undivided, with direct access from adjacent development permitted but usually controlled, and with controlled on-street parking usually permitted.*
7. *As of 2018, local roads are defined as roads that provide for low volumes of traffic and access to private properties; local roads are designed for low speeds, have capacity for 2 undivided lanes of traffic; through traffic is discouraged and parking is usually permitted though often controlled.*
8. *Not available for a specific reference period*

Table B5: RoI Toolkit - Average Expected Useful Life of New Publicly Owned bridge and Tunnel Assets[1,2]

Geography	Type of municipality by population size	Highway Bridges[3]	Rural Highway Bridges[4]	Arterial Bridges[5]	Collector Bridges[6]	Local Bridges[7]	Foot Bridges	Culverts diameter greater than or equal to 3 metres	Tunnels
Canada	All municipalities	55	46	56	56	48	40	39	65
	All urban municipalities	52	41	56	57	49	45	55	68
	All rural municipalities	57	47	57	54	47	35	34	50
Newfoundland and Labrador	All municipalities	50	NA[8]	50	..	41	10	15	..
	All urban municipalities	..	..	50	..	42	..	..	..
	All rural municipalities	50	..	..	..	35	10	15	..
Prince Edward Island	All municipalities	NA	NA	NA	NA	NA	NA	NA	NA
	All urban municipalities	NA	NA	NA	NA	NA	NA	NA	NA
	All rural municipalities	NA	NA	NA	NA	NA	NA	NA	NA
Nova Scotia	All municipalities	NA	NA	48	NA	50	NA	NA	NA
	All urban municipalities	NA	NA	48	NA	NA	NA	NA	NA
	All rural municipalities	NA	NA	NA	NA	50	NA	NA	NA
New Brunswick	All municipalities	NA	20	NA	NA	70	NA	NA	NA
	All urban municipalities	NA	NA	NA	NA	NA	NA	NA	NA
	All rural municipalities	NA	20	NA	NA	70	NA	NA	NA
Quebec	All municipalities	NA	99	30	30	46	NA	59	70
	All urban municipalities	NA	NA	NA	NA	NA	NA	55	70
	All rural municipalities	NA	99	30	30	46	NA	62	NA
Ontario	All municipalities	75	57	65	65	63	46	46	50
	All urban municipalities	NA	40	63	63	59	46	76	NA
	All rural municipalities	75	62	75	75	65	46	41	50
Manitoba	All municipalities	NA	40	35	72	37	37	32	NA
	All urban municipalities	NA	NA	NA	NA	NA	25	NA	NA
	All rural municipalities	NA	40	35	72	37	40	32	NA
Saskatchewan	All municipalities	75	42	75	75	39	40	33	NA
	All urban municipalities	75	NA	75	75	20	40	48	NA
	All rural municipalities	NA	42	NA	NA	40	NA	31	NA

Geography	Type of municipality by population size	Highway Bridges[3]	Rural Highway Bridges[4]	Arterial Bridges[5]	Collector Bridges[6]	Local Bridges[7]	Foot Bridges	Culverts diameter greater than or equal to 3 metres	Tunnels
Alberta	All municipalities	NA	41	56	56	51	45	22	NA
	All urban municipalities	NA	41	30	NA	NA	35	10	NA
	All rural municipalities	NA	NA	63	56	51	50	26	NA
British Columbia	All municipalities	44	NA	57	46	47	39	55	67
	All urban municipalities	44	NA	54	51	51	49	61	67
	All rural municipalities	NA	NA	75	25	35	27	25	NA
Yukon	All municipalities	NA	NA	NA	NA	NA	NA	NA	NA
	All urban municipalities	NA	NA	NA	NA	NA	NA	NA	NA
	All rural municipalities	NA	NA	NA	NA	NA	NA	NA	NA
Northwest Territories	All municipalities	NA	NA	NA	40	NA	30	40	NA
	All urban municipalities	NA	NA	NA	40	NA	30	40	NA
	All rural municipalities	NA	NA	NA	NA	NA	NA	NA	NA
Nunavut	All municipalities	NA	NA	NA	NA	NA	NA	NA	NA
	All urban municipalities	NA	NA	NA	NA	NA	NA	NA	NA
	All rural municipalities	NA	NA	NA	NA	NA	NA	NA	NA

Note:

1. *Expected useful life of an asset refers to the service life or the productive life of the asset at the time of its acquisition regardless of their lives reported for income tax purposes.*
2. *Estimates for 2018 may not be comparable to those for 2016 due to improved coverage and definitions as well as changes in survey methodology.*
3. *As of 2018, highways are defined as roads that move high volumes of traffic and have controlled entrance and exit, a dividing strip between the traffic in opposite directions, and typically two or more lanes in each direction. Highways do not provide access to property, and generally do not accommodate cyclists or pedestrians.*
4. *As of 2018, rural highways are defined as roads that move varied traffic volumes depending on location, are medium to high speed, and are usually one, but sometimes two lanes in each direction. These highways usually have no dividing strip and allow for direct access from adjacent developments.*
5. *As of 2018, arterial roads are defined as roads that move moderate to high traffic volumes over moderate distances between principal areas of traffic generation and gather traffic from collector roads and local roads and move it to the highway system. Arterial roads are generally designed for medium speed, have capacity for 2 to 6 lanes, and may be divided, with limited or controlled direct access from adjacent developments and with on-street parking discouraged.*
6. *As of 2018, collector roads are defined as roads that move low to moderate traffic volumes within specific areas of a municipality and collect local traffic for distribution to the arterial or highway system. Collector roads are generally designed for medium speed, have capacity for 2 to 4 lanes, are usually undivided, with direct access from adjacent development permitted but usually controlled, and with controlled on-street parking usually permitted.*
7. *As of 2018, local roads are defined as roads that provide for low volumes of traffic and access to private properties; local roads are designed for low speeds, have capacity for 2 undivided lanes of traffic; through traffic is discouraged and parking is usually permitted though often controlled.*
8. *Not available for a specific reference period*

Table B6: RoI Toolkit - Average Expected Useful Life of New Publicly Owned Public Transit Assets[1,2]

Geography	Type of municipality by population size	Diesel Buses	Bio-diesel Buses	Hybrid Buses (includes diesel, biodiesel and natural gas)	Heavy Railcars (subway)[3]	Commuter Railcars (locomotives and passenger)[4]	Light Railcars[5]	Specialized Transit (para or handi transpo and dial a ride)[6]	Passenger Stations/ Terminals	Transit Shelters	Exclusive rights-of-ways[7]	Parking Lots (park and ride)[8]	Passenger Drop-off Facilities (kiss and Ride)
Canada	All municipalities	15	x[9]	15	x	x	30	10	41	22	21	19	23
	All urban municipalities	x	x	15	x	x	30	9	41	x	21	19	x
	All rural municipalities	x	NA[10]	17	NA	NA	NA	10	38	x	NA	20	x
Newfoundland and Labrador	All municipalities	20	NA	NA	NA	NA	NA	NA	NA	30	NA	NA	NA
	All urban municipalities	20	NA	NA	NA	NA	NA	NA	NA	30	NA	NA	NA
	All rural municipalities	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Prince Edward Island	All municipalities	10	NA	NA	NA	NA	NA	NA	NA	23	NA	NA	NA
	All urban municipalities	10	NA	NA	NA	NA	NA	NA	NA	26	NA	NA	NA
	All rural municipalities	10	NA	NA	NA	NA	NA	NA	NA	20	NA	NA	NA
Nova Scotia	All municipalities	11	NA	NA	NA	NA	NA	10	30	20	NA	NA	NA
	All urban municipalities	12	NA	NA	NA	NA	NA	NA	30	10	NA	NA	NA
	All rural municipalities	10	NA	NA	NA	NA	NA	10	NA	25	NA	NA	NA
New Brunswick	All municipalities	18	NA	NA	NA	NA	NA	8	NA	19	NA	16	15
	All urban municipalities	17	NA	NA	NA	NA	NA	8	NA	19	NA	16	15
	All rural municipalities	20	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Quebec	All municipalities	23	x	16	x	x	NA	9	33	29	15	20	17
	All urban municipalities	x	x	16	x	x	NA	8	33	x	15	22	x
	All rural municipalities	x	NA	NA	NA	NA	NA	10	NA	x	NA	19	x
Ontario	All municipalities	14	16	13	30	NA	30	8	50	21	25	19	25
	All urban municipalities	13	16	13	30	NA	30	8	50	21	25	18	25
	All rural municipalities	14	NA	NA	NA	NA	NA	9	50	23	NA	20	NA

Geography	Type of municipality by population size	Diesel Buses	Bio-diesel Buses	Hybrid Buses (includes diesel, biodiesel and natural gas)	Heavy Railcars (subway)[3]	Commuter Railcars (locomotives and passenger)[4]	Light Railcars[5]	Specialized Transit (para or handi transpo and dial a ride)[6]	Passenger Stations/ Terminals	Transit Shelters	Exclusive rights-of-ways[7]	Parking Lots (park and ride)[8]	Passenger Drop-off Facilities (kiss and Ride)
Manitoba	All municipalities	14	NA	NA	NA	NA	NA	10	25	30	25	20	60
	All urban municipalities	16	NA	NA	NA	NA	NA	5	25	30	25	20	60
	All rural municipalities	10	NA	NA	NA	NA	NA	11	NA	NA	NA	NA	NA
Saskatchewan	All municipalities	13	NA	16	NA	NA	NA	11	22	24	25	NA	NA
	All urban municipalities	13	NA	16	NA	NA	NA	10	22	24	25	NA	NA
	All rural municipalities	13	NA	NA	NA	NA	NA	11	NA	NA	NA	NA	NA
Alberta	All municipalities	16	NA	17	NA	NA	30	8	24	24	NA	20	23
	All urban municipalities	15	NA	NA	NA	NA	30	8	24	24	NA	20	20
	All rural municipalities	16	NA	17	NA	NA	NA	8	25	23	NA	20	25
British Columbia	All municipalities	11	10	NA	NA	NA	NA	13	48	18	25	20	30
	All urban municipalities	12	10	NA	NA	NA	NA	13	48	19	25	20	30
	All rural municipalities	10	NA	NA	NA	NA	NA	NA	NA	13	NA	20	NA
Yukon	All municipalities	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	All urban municipalities	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	All rural municipalities	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Northwest Territories	All municipalities	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	All urban municipalities	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	All rural municipalities	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Nunavut	All municipalities	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	All urban municipalities	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	All rural municipalities	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Note:

1. *Expected useful life of an asset refers to the service life or the productive life of the asset at the time of its acquisition regardless of their lives reported for income tax purposes.*
2. *Estimates for 2018 may not be comparable to those for 2016 due to improved coverage and definitions as well as changes in survey methodology.*

3. *Heavy rail (subways): Heavy rail (subways) usually operate in tunnels but may also operate at grade. Includes rail or guided tire based heavy rail (subways) owned by an organization, as well as all heavy rail (subways) leased by an organization through a capital lease agreement and used for revenue service.*
4. *Commuter rail (locomotive and passenger): Commuter rail (locomotive and passenger) link regional centres with outlaying communities and may operate along some of the same corridors and track used by freight and inter-city passenger rail services. Includes commuter rail (locomotive and passenger) owned by an organization, as well as all the commuter rail (locomotive and passenger) leased by an organization through a capital lease agreement and used for revenue service.*
5. *Light rail transit (LRT)/Advanced light rail transit (ALRT): LRT/ALRT usually operates above ground in their own rights-of-way, however, some systems are operated in tunnels and on elevated guideways. Includes LRT/ALRT owned by an organization, as well as all the assets leased by an organization through a capital lease agreement and used for revenue service.*
6. *Specialized transit services are transit services for persons with disabilities.*
7. *Exclusive right-of-way includes roadways reserved at all times for transit use and/or other high occupancy vehicles only. Exclude transit exclusive lanes that are only transit exclusive during rush hour.*
8. *Park and ride parking lots: Park and ride parking lots provided parking spaces with direct connections to the transit system that allow commuters to leave their personal vehicle and transfer to transit. Includes park and ride parking lots owned by an organization, as well as all park and ride parking spaces leased by an organization through a capital lease agreement.*

Table B7: RoI Toolkit - Average Expected Useful Life of New Publicly Owned Culture, Recreation and Sport Facilities

Geography	Type of municipality by population size	Indoor ice arenas, single pad	Indoor ice arenas: multiple pads (two or more)	Indoor ice arenas: Performance/spectator	Outdoor ice arenas	Curling rinks	Indoor pools, 25 metres	Indoor pools, 50 metres or longer	Indoor pools, leisure pools 3	Outdoor pools	Outdoor spray parks/splash pads/wading pools	Galleries	Libraries	Museums and archives	Presentation and performance spaces	Indigenous culture facilities	Community centres (senior and youth centres)	Indoor gymnasiums	Indoor racquet courts	Indoor walking/jogging tracks	Indoor fitness areas	Indoor fields	Outdoor speciality areas	Playgrounds	Outdoor tennis and/or pickleball courts	Ball diamonds	Rectangular sports fields (natural turf)	Artificial turf sports fields	Paved pathways	Trails (non-paved)
Canada	All	36	44	39	27	36	37	46	36	27	23	41	37	35	36	x	40	34	31	34	29	32	28	22	21	28	30	20	25	29
	All urban	38	44	40	26	38	36	x	x	30	25	45	40	38	42	x	43	35	31	36	33	35	31	21	23	27	30	21	26	30
	All rural	36	43	38	27	35	38	x	x	25	22	37	35	33	33	x	39	33	31	32	28	29	26	22	21	28	29	19	24	28
Newfoundl and and Labrador	All	39	55	18	28	37	26	NA	40	21	23	51	24	31	68	NA	38	23	51	29	19	NA	26	23	24	36	30	37	38	29
	All urban	30	55	18	15	29	22	NA	NA	60	25	55	27	29	55	NA	41	36	52	28	68	NA	30	20	20	26	34	43	50	30
	All rural	42	NA	NA	30	40	46	NA	40	18	20	50	23	32	77	NA	38	21	50	29	14	NA	25	24	25	38	29	20	33	29
Prince Edward Island	All	30	50	32	22	50	50	NA	NA	30	33	36	23	22	31	NA	37	26	50	52	27	NA	20	22	19	25	24	29	25	26
	All urban	46	50	50	50	NA	50	NA	NA	40	46	50	50	50	NA	NA	61	75	50	61	50	NA	50	39	39	41	46	50	39	43
	All rural	29	NA	30	17	50	50	NA	NA	25	30	35	22	20	31	NA	36	20	NA	50	25	NA	19	21	18	24	21	15	22	26
Nova Scotia	All	31	NA	23	38	20	40	NA	NA	18	16	23	36	47	35	NA	34	33	10	27	39	NA	37	19	15	35	39	20	15	33
	All urban	25	NA	25	25	NA	50	NA	NA	25	21	NA	45	31	50	NA	33	38	10	25	50	NA	38	18	16	39	42	NA	15	32
	All rural	32	NA	20	45	20	35	NA	NA	17	12	23	34	53	27	NA	35	31	NA	28	35	NA	36	19	15	32	37	20	15	34
New Brunswick	All	36	40	38	25	38	40	25	25	23	21	43	46	28	31	NA	40	37	30	31	30	NA	38	20	19	24	18	17	21	28
	All urban	35	40	35	24	40	44	25	25	30	24	42	44	48	36	NA	40	45	30	41	35	NA	48	18	22	20	21	14	27	33
	All rural	37	NA	43	25	37	34	NA	NA	20	19	44	47	20	26	NA	41	32	NA	29	27	NA	33	20	17	27	17	30	16	27

Geography	Type of municipality by population size	Indoor ice arenas, single pad	Indoor ice arenas: multiple pads (two or more)	Indoor ice arenas: Performance/spectator	Outdoor ice arenas	Curling rinks	Indoor pools, 25 metres	Indoor pools, 50 metres or longer	Indoor pools, leisure pools 3	Outdoor pools	Outdoor spray parks/splash pads/wading pools	Galleries	Libraries	Museums and archives	Presentation and performance spaces	Indigenous culture facilities	Community centres (senior and youth centres)	Indoor gymnasiums	Indoor racquet courts	Indoor walking/jogging tracks	Indoor fitness areas	Indoor fields	Outdoor speciality areas	Playgrounds	Outdoor tennis and/or pickleball courts	Ball diamonds	Rectangular sports fields (natural turf)	Artificial turf sports fields	Paved pathways	Trails (non-paved)
Quebec	All	37	42	46	26	32	34	37	35	27	24	34	37	35	31	x	39	37	32	31	29	31	25	24	22	29	29	21	28	28
	All urban	42	41	43	28	31	36	x	x	31	25	32	40	35	35	x	43	34	38	30	27	35	32	25	24	27	28	21	29	27
	All rural	35	44	48	26	34	31	x	x	23	24	35	37	35	30	x	39	38	27	31	30	30	22	24	21	29	30	20	27	29
Ontario	All	44	48	45	29	40	40	52	41	34	23	53	45	47	51	40	49	41	32	35	35	24	28	20	22	26	30	21	25	29
	All urban	47	49	46	33	42	39	48	37	34	23	56	50	51	52	40	52	35	31	37	35	28	25	20	21	25	28	21	25	25
	All rural	43	45	44	28	40	44	63	52	33	23	44	43	45	51	NA	48	46	33	33	34	20	30	19	22	27	31	23	25	32
Manitoba	All	32	40	36	26	35	32	50	NA	18	24	29	30	30	26	9	34	29	NA	26	23	47	40	20	19	22	23	10	24	29
	All urban	31	33	NA	24	36	40	50	NA	19	28	10	37	42	39	NA	37	33	NA	35	29	50	53	23	22	22	23	10	22	27
	All rural	32	47	36	28	34	21	NA	NA	17	20	38	27	26	20	9	34	27	NA	22	22	45	35	19	16	22	23	NA	26	29
Saskatchewan	All	32	35	37	25	34	38	40	38	26	19	29	29	28	25	74	35	27	35	35	28	27	29	21	21	28	37	10	21	27
	All urban	33	29	37	22	32	36	40	38	25	22	29	31	26	26	22	33	28	30	37	29	28	31	18	23	26	34	NA	17	22
	All rural	32	50	36	30	35	40	NA	NA	26	16	NA	29	29	23	99	36	27	40	32	27	25	28	23	19	28	40	10	28	30
Alberta	All	35	41	36	23	36	36	47	32	28	27	39	36	35	37	42	40	35	27	34	30	41	28	19	21	24	29	15	22	23
	All urban	37	39	41	23	40	35	47	32	32	27	39	39	35	39	63	41	37	29	34	34	45	28	20	22	28	31	20	22	26
	All rural	34	48	24	23	30	40	NA	NA	22	25	38	32	34	36	33	40	31	20	35	27	33	28	17	18	20	24	10	21	19

Geography	Type of municipality by population size	Indoor ice arenas, single pad	Indoor ice arenas: multiple pads (two or more)	Indoor ice arenas: Performance/spectator	Outdoor ice arenas	Curling rinks	Indoor pools, 25 metres	Indoor pools, 50 metres or longer	Indoor pools, leisure pools 3	Outdoor pools	Outdoor spray parks/splash pads/wading pools	Galleries	Libraries	Museums and archives	Presentation and performance spaces	Indigenous culture facilities	Community centres (senior and youth centres)	Indoor gymnasiums	Indoor racquet courts	Indoor walking/jogging tracks	Indoor fitness areas	Indoor fields	Outdoor speciality areas	Playgrounds	Outdoor tennis and/or pickleball courts	Ball diamonds	Rectangular sports fields (natural turf)	Artificial turf sports fields	Paved pathways	Trails (non-paved)
British Columbia	All	35	40	39	34	42	36	52	26	37	22	53	35	39	48	60	45	36	24	38	31	27	28	21	25	26	34	20	27	36
	All urban	38	45	40	34	42	39	52	26	31	24	55	37	42	49	NA	47	34	20	38	31	27	30	20	25	26	35	18	31	41
	All rural	31	33	35	34	42	31	NA	NA	46	19	42	32	29	43	60	43	44	50	40	31	NA	24	23	24	25	32	29	15	28
Yukon	All	20	NA	NA	NA	10	NA	NA	24	NA	NA	NA	NA	NA	NA	NA	21	22	19	NA	10	NA	NA	5	NA	10	NA	NA	NA	25
	All urban	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	All rural	20	NA	NA	NA	10	NA	NA	24	NA	NA	NA	NA	NA	NA	NA	21	22	19	NA	10	NA	NA	5	NA	10	NA	NA	NA	25
Northwest Territories	All	31	45	NA	28	35	30	NA	NA	NA	NA	NA	30	NA	NA	NA	27	NA	NA	50	25	45	36	21	14	32	NA	NA	50	26
	All urban	50	45	NA	28	50	30	NA	NA	NA	NA	NA	30	NA	NA	NA	50	NA	NA	50	NA	45	36	30	20	45	NA	NA	50	38
	All rural	21	NA	NA	NA	15	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	21	NA	NA	NA	25	NA	NA	15	10	15	NA	NA	NA	10
Nunavut	All	45	NA	NA	NA	20	NA	NA	30	NA	NA	NA	27	40	10	30	23	24	NA	10	30	NA	NA	16	15	34	20	15	NA	28
	All urban	40	NA	NA	NA	20	NA	NA	30	NA	NA	NA	30	NA	NA	30	26	50	NA	NA	30	NA	NA	17	15	36	NA	NA	NA	35
	All rural	50	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	25	40	10	NA	21	18	NA	10	NA	NA	NA	15	NA	30	20	15	NA	25

Table B8: RoI Toolkit - Average Expected Useful Life of New Municipally Owned Social and Affordable Housing Assets

Geography	Type of municipality by population size	Single Detached House[3]	Semi-detached House[4]	Row House[5]	Apartment Building (fewer than five storeys)[6]	Apartment Building (five or more storeys)[7]
Canada	All municipalities	65	NA[8]	65	42	80
	All urban municipalities	NA	NA	65	40	80
	All rural municipalities	65	NA	NA	45	NA
Newfoundland and Labrador	All municipalities	NA	NA	NA	NA	NA
	All urban municipalities	NA	NA	NA	NA	NA
	All rural municipalities	NA	NA	NA	NA	NA
Prince Edward Island	All municipalities	NA	NA	NA	NA	NA
	All urban municipalities	NA	NA	NA	NA	NA
	All rural municipalities	NA	NA	NA	NA	NA
Nova Scotia	All municipalities	NA	NA	NA	NA	NA
	All urban municipalities	NA	NA	NA	NA	NA
	All rural municipalities	NA	NA	NA	NA	NA
New Brunswick	All municipalities	NA	NA	NA	NA	NA
	All urban municipalities	NA	NA	NA	NA	NA
	All rural municipalities	NA	NA	NA	NA	NA
Quebec	All municipalities	NA	NA	NA	NA	NA
	All urban municipalities	NA	NA	NA	NA	NA
	All rural municipalities	NA	NA	NA	NA	NA
Ontario	All municipalities	NA	NA	65	38	NA
	All urban municipalities	NA	NA	65	38	NA
	All rural municipalities	NA	NA	NA	NA	NA
Manitoba	All municipalities	NA	NA	NA	NA	NA
	All urban municipalities	NA	NA	NA	NA	NA
	All rural municipalities	NA	NA	NA	NA	NA
Saskatchewan	All municipalities	NA	NA	NA	NA	NA
	All urban municipalities	NA	NA	NA	NA	NA
	All rural municipalities	NA	NA	NA	NA	NA
Alberta	All municipalities	65	NA	NA	45	NA
	All urban municipalities	NA	NA	NA	45	NA
	All rural municipalities	65	NA	NA	NA	NA
British Columbia	All municipalities	NA	NA	NA	45	80
	All urban municipalities	NA	NA	NA	NA	80
	All rural municipalities	NA	NA	NA	45	NA

Geography	Type of municipality by population size	Single Detached House[3]	Semi-detached House[4]	Row House[5]	Apartment Building (fewer than five storeys)[6]	Apartment Building (five or more storeys)[7]
Yukon	All municipalities	NA	NA	NA	NA	NA
	All urban municipalities	NA	NA	NA	NA	NA
	All rural municipalities	NA	NA	NA	NA	NA
Northwest Territories	All municipalities	NA	NA	NA	NA	NA
	All urban municipalities	NA	NA	NA	NA	NA
	All rural municipalities	NA	NA	NA	NA	NA
Nunavut	All municipalities	NA	NA	NA	NA	NA
	All urban municipalities	NA	NA	NA	NA	NA
	All rural municipalities	NA	NA	NA	NA	NA

Note:

1. *Expected useful life of an asset refers to the service life or the productive life of the asset at the time of its acquisition regardless of their lives reported for income tax purposes.*
2. *Public social and affordable housing estimates for Canada were produced excluding Quebec.*
3. *Single-detached house: A single dwelling not attached to any other dwelling or structure (except its own garage or shed). A single-detached house has open space on all sides and has no dwellings either above it or below it. A mobile home fixed permanently to a foundation is also classified as a single-detached house.*
4. *One of two dwellings attached side by side (or back-to-back) to each other, but not attached to any other dwelling or structure (except its own garage or shed). A semi-detached dwelling has no dwellings either above it or below it, and the two units together have open space on all sides.*
5. *Row house: One of three or more dwellings joined side by side (or occasionally side to back), such as a townhouse or garden home, but not having any other dwellings either above or below. Townhouses attached to a high-rise building are also classified as row houses. A set of row houses represents one structure.*
6. *Apartment building (fewer than five storeys): A high-rise apartment building which has five or more storeys.*
7. *Apartment building (five or more storeys): A building that has fewer than five storeys.*
8. *Public social and affordable housing data for Quebec are not available.*
9. *Not available for a specific reference period*

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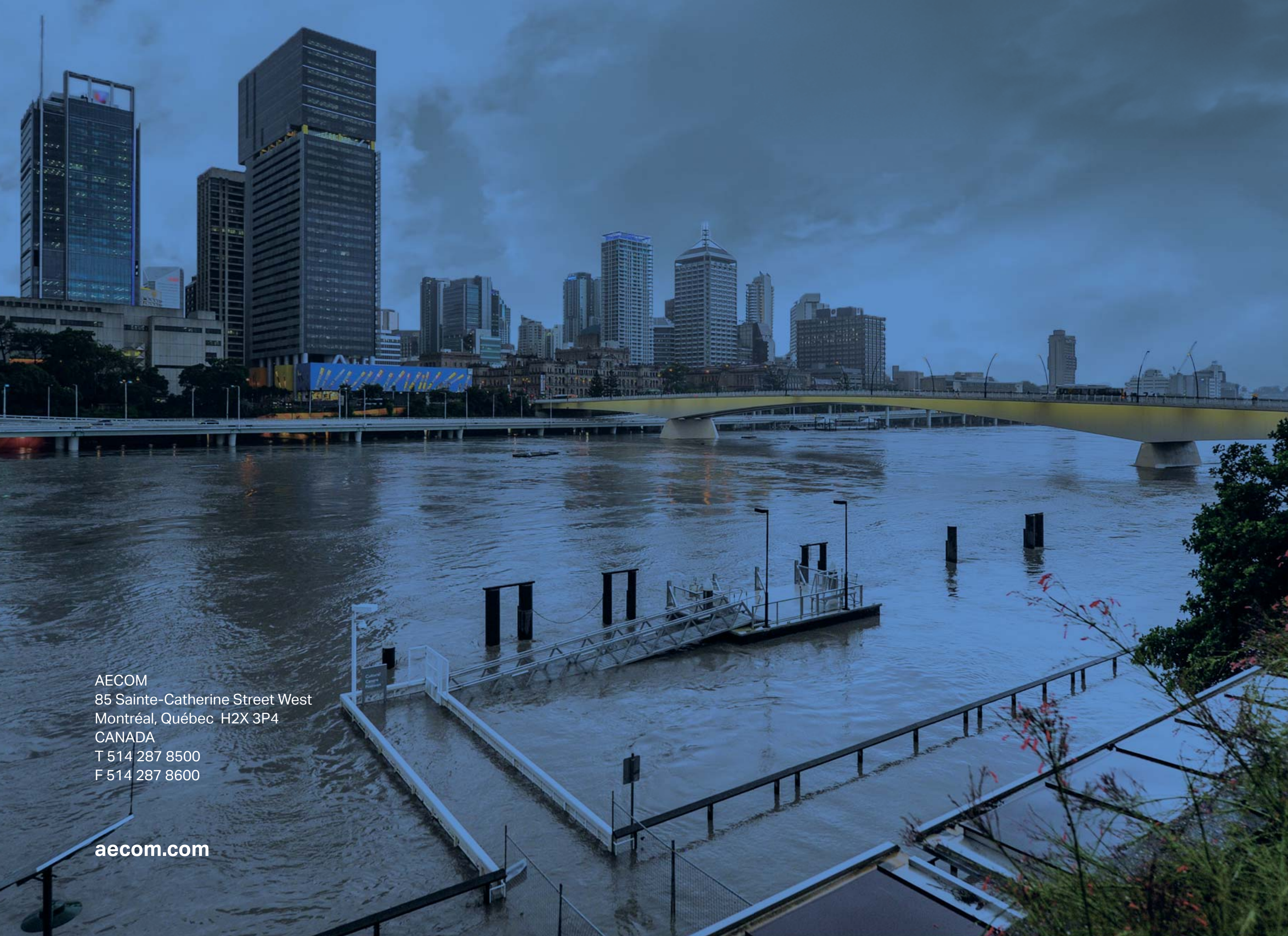

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