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Climate Change Adaptation and Canadian Infrastructure

A review of the literature

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Written by Jessica Boyle, Maxine Cunningham and Julie Dekens

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Acronyms

CSA	Canadian Standards Association
CSRI	Codes, Standards and Related Instruments
IPCC	Intergovernmental Panel on Climate Change
NEPA	National Environmental Policy Act (US)
NISI	Northern Infrastructure Standardization Initiative
NWT	Northwest Territories
PIEVC	Public Infrastructure Engineering Vulnerability Committee
RAC	Regional Adaptation Collaborative
SCC	Standards Council of Canada

Executive Summary

Climate events in Canada in recent years have provided insight into what continued climatic change might mean for built infrastructure throughout the country: floods affecting management and road systems, degradation of permafrost threatening the integrity of building structures, more extreme weather events inundating coastlines and disrupting essential services. As climate change impacts continue to be felt amidst other economic, social and environmental stressors, the difficulty of maintaining robust and resilient infrastructure systems is increasing across the country. It is becoming increasingly clear that actions must be taken to not only reduce generation of the greenhouse gases spurring climate change, but also to address the present and future negative impacts of climate change through adaptation. This process requires building on the relatively nascent shift of reacting to the adverse impacts of climatic events to an anticipatory approach that secures the sustainability of critical sectors through the implementation of planned adaptation measures.

This literature review is intended to serve as a stimulus for further discussions around planned adaptation to climate change in Canada, particularly with respect to ensuring the viability of critical built infrastructure. It explores the following:

- The complex relationship between climate and infrastructure in Canada.
- Climate impacts and risks for key infrastructure in Canada, including differentiation by region and types of infrastructure.
- Exposure and vulnerability of such infrastructure to climate hazards.
- Tools, approaches and mechanisms to support climate risk management, including: (1) current government policy responses and related tools, (2) codes, standards and related instruments (3) markets, financial incentives and liability rules and (4) responses by key actors in the cement and concrete industry.

Based on this exploration, four general conclusions are identified:

- **Climate change has the potential to substantially affect the effectiveness and lifespan of infrastructure in Canada, particularly transportation, buildings, marine and water management infrastructure**. The exposure and vulnerability of these different types of infrastructure varies greatly. Collectively, though, substantial economic costs have already been attributed to the impact of climate hazards on such infrastructure, and these costs are only expected to increase in the future.
- **Adaptive measures can be taken to limit costs and strengthen the resiliency of infrastructure**. A number of key policy, regulatory and financial tools have been identified as "enabling factors" in supporting the deeper integration of climate change considerations into infrastructure decision-making, design and maintenance.
- **While a great deal of research and planning has been done, most supporting policies and regulatory changes remain nascent, and investments have not yet fundamentally shifted**. Despite notable progress in recent years, many adaptation responses remain elusive or underutilized, and investment decisions are not yet being substantially driven by the need to reduce vulnerability to the impacts of climate change. While the scale of response is not yet commensurate with the challenges posed by climate change, there is an ever-growing recognition of the need to rethink investment choices to further incentivize adaptation and capture the benefits of low-carbon, climate-resilient development.

- **The current state-of-play provides a key opportunity for industry actors to engage in the further development and implementation of effective approaches to support climate-resilient development.** Adaptation is a dynamic, context-specific and often long-term process that requires sustained efforts from a variety of actors. Recent events have further galvanized calls for action at the local, regional and national levels, and a number of points of entry into the discussion can be identified across various sectors.

1.0 Introduction

Climate change and its associated impacts are now unavoidable. A growing body of scientific literature provides unequivocal evidence that "climate change will continue for many decades, and even centuries, regardless of the success of global initiatives to reduce greenhouse gas emissions" (Natural Resources Canada, 2007, p 4). The process of climate change, with its projected changes in temperatures, precipitation patterns, wind conditions and the occurrence of extreme weather events, have clear implications for Canada's built infrastructure. However, as noted by the Intergovernmental Panel on Climate Change (IPCC), "detailed analyses of potential and projected damages are limited to a few countries (e.g., Australia, Canada, the United States), infrastructure types (e.g., power lines), and sectors (e.g., transport, tourism)" (2012, p. 248).

Climate variability (short term) and climate change (long term) already threaten critical national infrastructure and the Canadian economy. Climate events in recent years have offered insight into what continued changes might mean for infrastructure: floods affecting management and road systems, degradation of permafrost threatening the integrity of building structures, more extreme weather events inundating coastlines and disrupting essential services.

Adapting to climate change is critical to avoid breakdowns in the essential services delivered by key infrastructures in the face of extreme events, as well as to ensure resilience in the face of more incremental, but potentially cumulative impacts. Climatic changes are not taking place in a vacuum; as impacts continue to be felt amidst other economic, social and environmental stressors, the difficulty of maintaining robust and resilient infrastructure systems increases. Given the interdependencies, this also means that resilient infrastructure can have positive impacts on those same economic, social and environmental factors, such as human health or household energy costs.

In recent years, many government, private sector and civil society actors in Canada have taken actions to address the cause of climate change (mitigation); but in comparison, limited efforts have been made to address the present and future negative impacts of climate change and to maximize potential benefits (adaptation). There is a pressing need to shift towards forward-looking, long-term planning and investment decision-making that strengthens adaptive capacity and builds resiliency across a number of sectors.

Of course, such a shift is much easier said than done. It requires consideration of the planning, design, construction, maintenance, performance and cost of infrastructure under uncertain circumstances. However, failure to take proactive measures and make necessary investments now will likely only necessitate continued reactive and more costly measures in the future.

This report focuses on climate impacts and risk on infrastructures in Canada. Risk from climate variability and change (i.e., climate risk) on infrastructure refers to the probability of harmful consequences or expected loss (e.g., degradation or destruction of infrastructures and associated loss of life and injury) resulting from interactions between climate hazards, exposure of infrastructures to these hazards and vulnerable conditions (United Nations Office for Disaster Risk Reduction, 2011). Figure 1 outlines our definition of climate risk for the purposes of this review.

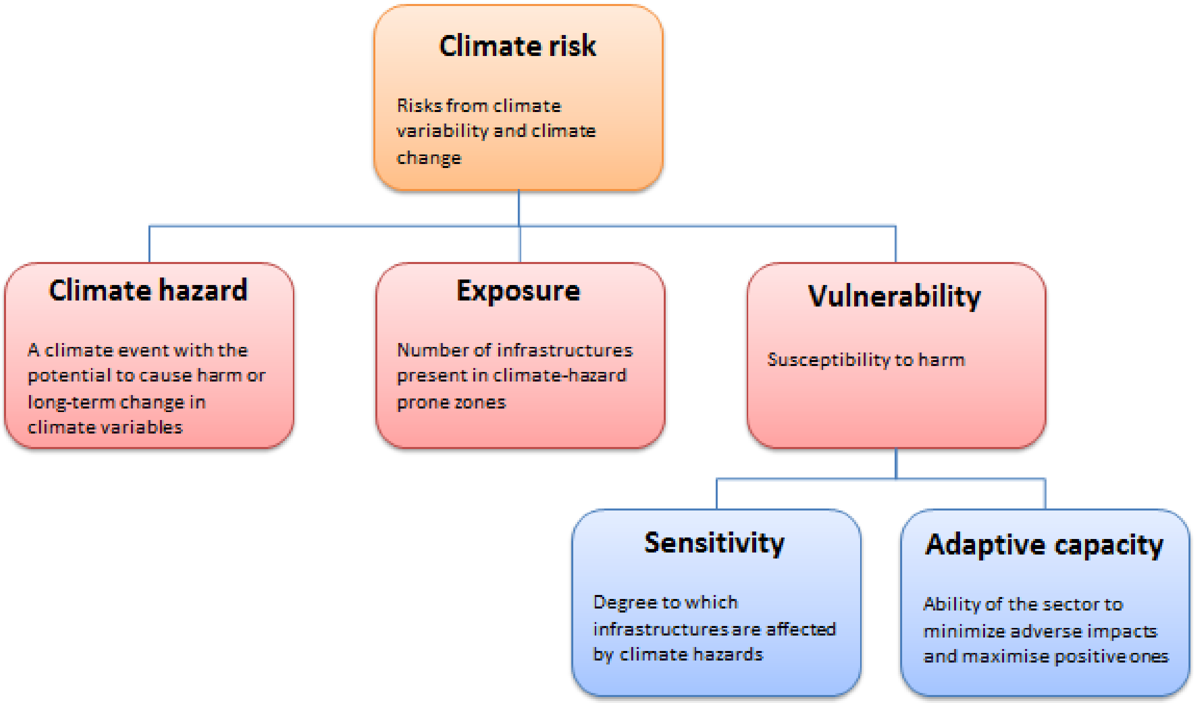

FIGURE 1: DEFINITION OF CLIMATE RISK

Source: Authors

The exposure and the vulnerability of infrastructure systems to climate hazards are understood as follows:

- A **climate hazard** refers to a climatic event with the potential to cause harm (e.g., floods, wildfires, hurricanes) or long-term changes in climate variables that have negative consequences over time (e.g., rising temperatures, changing rainfall patterns).
- **Exposure** of infrastructures to climate risk refers to the presence of infrastructures in climate-hazard prone areas.
- **Vulnerability** of infrastructure systems to climate events is understood as the susceptibility of those infrastructures to harm from climate hazards. The vulnerability of particular infrastructures depends on the **sensitivity** of infrastructures to climate risk (i.e., the predisposition of infrastructures to be affected due to at least three factors: the age, the composition and the design of infrastructure) and the capacity of the sector to adapt (**adaptive capacity**) by minimizing negative impacts and/or maximizing positive ones.

An additional concept that helps to inform efforts to manage climate risk is **resilience**, which is defined by the IPCC as the "ability of a system and its counterparts to anticipate, absorb, accommodate or recover from the effects of a hazardous event in a timely and efficient manner" (2012, p. 563). In the context of infrastructure, climate resilience refers to the capacity to adapt to changing conditions without catastrophic loss of form or function (Concrete Sustainability Hub, 2013).

An effective strategy to managing climate risk typically involves a combination of responses focusing on technical aspects (e.g., modifying the design of infrastructures to make them more resistant to the increased intensity of floods), policy and legal aspects (e.g., new building codes), financial aspects (e.g., specific funds allocated to support the maintenance of infrastructure), socioeconomic aspects (e.g., relocation or abandonment of infrastructures, change in habits and behavioral patterns associated with the use of infrastructures) and institutional aspects (e.g., awareness raising and capacity building of the infrastructure sector on climate adaptation).

This literature review is intended to serve as a stimulus for further discussions around adaptation in Canada, particularly related to critical infrastructure. The review is based on an analysis of existing knowledge, drawn from the published scientific and technical literature, policy documents and expert knowledge.

Section 2 provides an overview of the climate impacts and risks for key infrastructures in Canada, including impacts differentiated by region and types of infrastructures. It also explores the exposure and vulnerability of infrastructure to climate change. Section 3 explores the potential adaptive capacity of various sectors on the basis of key tools, policies and mechanisms that can support climate resiliency. It also includes an overview of responses from key players in the cement and concrete industry outside of Canada (the United States and Europe), given their important role in infrastructure development and maintenance and the applicability of similar responses in Canada. Section 4 concludes by highlighting some of the key take-away messages from the review.

2.0 Climate Impacts and Risks for Key Infrastructures

This section describes the current and future potential consequences of climate hazards on infrastructure in Canada in the context of climate variability and change. It first highlights the complexity of the relationship between climate and infrastructure and then summarizes climate impacts by region and types of infrastructure based on the available literature.

2.1 Climate and Infrastructure in Canada: A Complex Relationship

The geographical and socioeconomic diversity of Canada makes it difficult to generalize current and future potential climate impacts on infrastructures. First, the climate and weather of Canada vary greatly spatially (across regions) and temporally (from one season to the other). Climate change projections for Canada (see summary, Box 1) foresee some common trends across the country, such as increased average summer temperatures and average precipitation, but with significant geographical variations. For example, temperature increases are projected to be more significant in the North than anywhere else. Annex I provides an overview of the likelihood of future trends in climate extremes globally. While it is not possible to state with exact certainty how or when climatic conditions will change in the decades to come (due in part to uncertainty about future levels of greenhouse gas emissions and the imperfect capacity of global climate models), it is projected that there will be continued "increases in the occurrence of heat waves, forest fires, storm-surge flooding, coastal erosion, and other climate-related hazards" in Canada, according to Natural Resources Canada (2007).

BOX 1: CLIMATE CONTEXT IN CANADA

According to Canada's 2010 *National Communication to the United Nations Convention on Climate Change,* climate change projections include the following key findings (Government of Canada, 2010):

- Average summer temperatures are likely to rise by 2˚C to 4˚C over the next 50 years. The most significant impact will be in the Arctic, which could see increases of up to 4˚C by 2020 and 8˚C by 2050. In general, there will be more warming in the winter, on a daily basis, with nights warming more than days.
- Average precipitation is expected to increase, but is not expected to be evenly distributed geographically. Generally, there will be significant changes in precipitation between the seasons, with winters becoming wetter and summers becoming drier.
- Accelerated sea-level rise is expected. Extreme water levels under storm conditions, combined with wave and ice impacts, are likely to be exacerbated by rising sea levels, leading to higher frequency of flooding. Coastal erosion rates are also expected to accelerate with rising sea levels and less ice and more open water during the fall or winter.

Second, significant socioeconomic differences exist across Canada. Some communities have more capacity to adapt to the impact of climate change due to greater wealth, higher levels of education, more diverse skill sets and easier access to technology and institutions. Conversely, other communities have less diversified economies, limited economic resources and limited access to services. The design, materials, size and maintenance of infrastructure systems can reflect these differences between communities and, as a result, different communities can be affected differently by climate change. Understanding of how climate change will place additional stress on Canadian infrastructure also varies between locations, as there is less understanding of the specific impacts climate change could have on smaller communities who may lack key infrastructure data (Canada Council of Professional Engineers, 2008).

In addition, the role of non-climatic factors and interdependencies within the infrastructure sector further increase the complexity of the relationship between infrastructure and climate in Canada as elsewhere in the world. Non-climatic factors such as rising wealth, demographic shifts to coastal areas, rising demand for waterfront property and development land, increasing urbanization in storm-prone areas, land-use changes and population growth can contribute to, exacerbate or attenuate the negative impacts of climate hazards on infrastructure. Very little research has been conducted in Canada to date on how climate change could influence these various non-climatic factors and, in turn, the interdependent infrastructure systems. However, many municipalities and large cities are playing a leading role in this area, which is of particular importance given the context-specific nature of these relationships.

Further complicating the picture is that fact that very few, if any, public infrastructure systems function in total isolation. Many are co-located and interdependent. For instance, power cables are often laid below roads, adjacent to water, gas mains and sewers. Consequently, a failure in one area can lead to a failure in another, ultimately increasing the associated economic costs of various extreme weather events. Between 1996 and 2006, the economic costs resulting from extreme weather events in Canada were greater than for all previous recorded years combined (Natural Resources Canada, 2007). Table 1 provides examples of severe weather events in Canada (excluding drought) and their impacts on infrastructure, along with estimated costs.

Though estimates remain very preliminary, several weather events in 2013 continue to illustrate the dramatic costs associated with singular events, largely due to the strong interdependencies between different infrastructure systems. In July 2013 more than a month's worth of rain fell in Toronto over the course of two hours. Initial estimates put damages in the CAD$600 million range.[1] Around the same time, Southern and Central Alberta experienced the most severe flooding in the province's history. Costs have been broadly estimated at between $3 billion and $5 billion, with recovery efforts ongoing.[2] Consistent with projections that the frequency and severity of extreme weather events are likely to increase in most parts of Canada in the future due to climate change, it can be anticipated that the economic costs associated with such events will also only grow in the absence of planned adaptation efforts.

[1] All currency is in Canadian funds unless otherwise indicated. Cost estimates are based on initial estimates from the Insurance Bureau of Canada. See: http://www.theglobeandmail.com/news/national/cost-of-floods-in-toronto-likely-to-exceed-the-600-million-price-tag-of-2005-storm/article13094764/?cmpid=rss1

[2] Based on very preliminary estimates from BMO Nesbitt Burns and ATB Financial. See http://www.theglobeandmail.com/news/national/costs-mount-devastation-rises-the-flood-in-numbers/article12792247/

TABLE 1: EXAMPLES OF COSTLY CLIMATE IMPACTS ON INFRASTRUCTURE IN CANADA

CLIMATE HAZARDS	REGION	ESTIMATED COSTS (CAD)	INFRASTRUCTURE DAMAGED
Toronto Flood, August 19, 2005	Ontario	>$500 million	• Collapse of Finch avenue (a major arterial street) • Damage to two high-pressure gas mains, and a portable water main • Damage to telephone, hydro and cable service lines
Southern Alberta floods, 2005	Prairies	>$400 million	• Sewer backup • Roads, parks, sewers, bridges, buildings, agriculture
Peterborough Flood, July 15, 2004	Ontario	$200 million	• 500 homes were flooded • 1,000 homes had gas lines disconnected • Sewer systems and roads were inundated
B.C. Wildfires, 2003	British Columbia	$700 million	• Destroyed 334 homes and many businesses
Hurricane Juan, 2003	Atlantic	$200 million	• Homes, businesses, energy systems, roads, pipelines
Ice storm, 1998	Ontario, Quebec, Atlantic Canada	$5.4 billion	• Power lines causing loss of electricity for more than 4 million people • 1,000 steel electrical pylons, and 35,000 wooden utility poles were crushed by the weight of the ice • Approximately $790 million damage to homes, cars and other property
Saguenay flood, 1996	Quebec	$1.7 billion	• Roads, bridges, railways, aqueduct and sewage networks needed complete restoration • Pumping stations were completely wiped out • 20 businesses destroyed and another 25 damaged
Calgary hailstorm, 1991	Prairies	$884 million	• Roof and building damage • Aircraft and automobile damage

Sources: Government of British Columbia (2003); Environment Canada (2005); Public Safety Canada (2005)

The trend lines in the United States are perhaps even more telling of the costs of extreme weather events. Figure 2 clearly demonstrates a significant increase since 1980, both in the number of events responsible for generating billions of dollars in damage and in the total cost of these events.[3] The significantly increased costs in recent years (i.e., since 2009) are likely the result of a number of factors. These include a number of non-climatic elements such as the overall increased value of the built environment, new infrastructure and higher levels of insurance coverage.

While these extreme weather events dramatically illustrate the potential economic risk of climate change, it is important to note that incremental costs will also be incurred due to cumulative climate impacts, such as progressive increases in mean annual temperatures, greater exposure to freeze-thaw cycles and the melting of permafrost. These costs can also be significant, particularly if regular maintenance or retrofitting of infrastructure is not undertaken over time.

[3] For a recent analysis of projected economic impacts see also Cunningham, N. and Parillo, D. (May 2013). *Protecting the Homeland: The Risking Costs of Inaction on Climate Change.* American Security Project. Available at: http://americansecurityproject.org/featured-items/2013/protecting-the-homeland-the-rising-costs-of-inaction-on-climate-change/

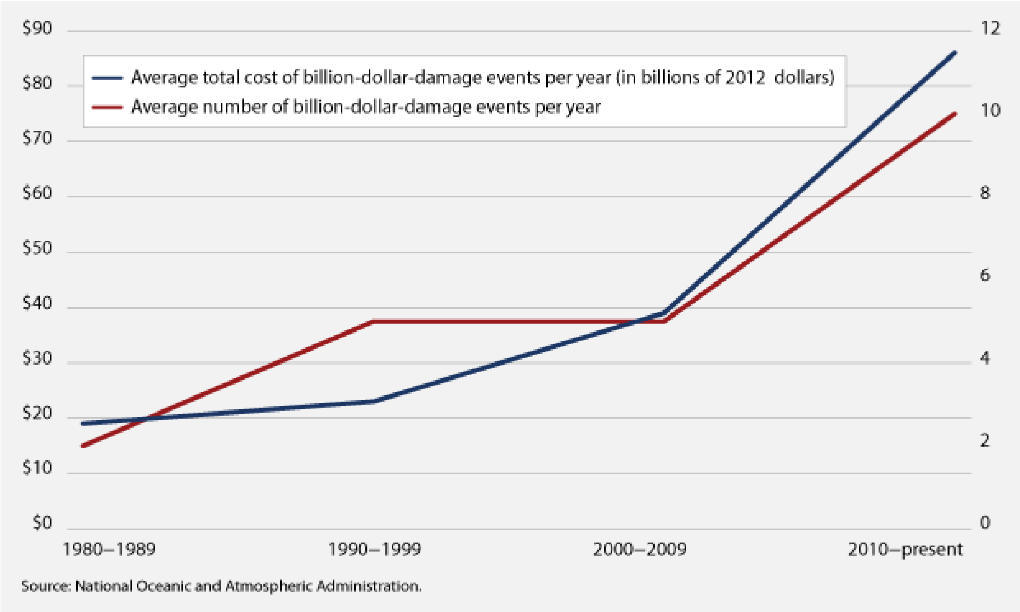

FIGURE 2: BILLIONS OF DOLLARS IN DAMAGES FROM INCREASING FREQUENCY OF EXTREME WEATHER EVENTS IN THE UNITED STATES BETWEEN 1980 AND 2012

Source: Weiss & Weidman (2013)

Finally, climate change may also bring some benefits to the infrastructure sector in specific areas. For example, warmer weather can reduce the duration of frost on highways, leading to an increased lifespan of southern highways, a decrease in the cost of maintenance and a decrease in the cost of construction. These savings are expected to increase in the long term, as less and less frost is expected to damage southern roads. While climate change is likely to continue to have generally negative impacts throughout Canada, the need to harness any potential benefits is important as well.

2.2 Climate Impacts on Infrastructure by Region

A number of studies have been done in Canada to identify current and potential future climate impacts on key infrastructure sectors. A challenge has been to pinpoint more precisely the differentiated impacts of climate change on various types of infrastructure (Canada Council of Professional Engineers, 2008). The following section provides the current state of knowledge based on available literature.

2.2.1 North

In the past few decades, the average temperature in the Arctic has increased almost twice as fast as that if the rest of the world (Government of Canada, 2010). A number of studies based on past climate records and indigenous observations have documented issues of permafrost degradation, rising sea levels, alterations in sea-ice dynamics and increased frequency of freeze-thaw cycles as a result of temperature increase (Natural Resources Canada, 2007). These changes are having adverse impacts on infrastructure systems such as airstrips, pipelines, roads, railways, water facilities and building foundations—a trend that is expected to continue in the future (Defra, 2013).

One of the greatest climate change concerns regarding northern infrastructure is the thawing of permafrost (Government of the Northwest Territories [NWT], 2008). As permafrost thaws and the soil sinks, structures built on or within the soil can be severely damaged. Transportation networks, pipelines and building foundations have already shown signs of failure, deterioration and, in some instances, buildings have become uninhabitable and roads impassable (Government of the NWT, 2008). The observable rising sea level creates risks of flooding and increased erosion in the northern coastal zone. Cultural heritage sites, coastal communities and municipal infrastructures have already been affected by rising sea levels. Increased frequencies in freeze-thaw cycles are also leading to greater weathering of infrastructure materials such as concrete and pavement. These more frequent freeze-thaw cycles are expected to continue (Government of the NWT, 2008).

2.2.2 East and West Coasts

Major shifts in climate variability and extremes are inherent to both the East and West coasts due to their close proximity to the Atlantic and Pacific oceans. More than 80 per cent of Canada's coastline is submerging due to rising sea levels and even areas where the sea level is stable are at risk because of the greater frequency of storms. Of greatest concern are highly developed areas, such as the lower mainland of British Columbia, many of which have already experienced extensive property, transportation and wastewater treatment damage (Natural Resources Canada, 2007). Although the phenomenon is nationwide, it affects regions in different ways: the West Coast is more prone to changes in both the frequency and patterns of storms, while the East Coast is more prone to rising sea levels, storm surges, accelerated coastal erosion and hurricanes (Government of Canada, 2011a).[4] Some coastal communities have also started experiencing saltwater intrusion in their groundwater supply as a result of rising sea levels, threating community's water quality and water infrastructure (Prince Edward Island Department of Environment, Labour and Justice, 2011).

2.2.3 Prairies

Increased drought and excessive moisture risks are some of the most problematic impacts expected due to climate change for the Prairie region (IISD, 2012). More specifically, Alberta and Saskatchewan are more prone to increased water scarcity as a result of rising temperatures and increased evapotranspiration, whereas Manitoba is more vulnerable to excess moisture (IISD, 2012; Kharin and Zwiers, 2000). Climate-related disruptions to critical infrastructure, including water treatment and distribution systems, energy generation and transmission, and transportation have already occurred in all Prairie provinces and are likely to become increasingly frequent in the future (Government of Canada, 2010). It is predicted that future water scarcity could lead to abandonment and/or underutilization of major infrastructure (canals, pipelines, dams and reservoirs) worth billions of dollars (Natural Resources Canada, 2007). At the same time, climate change is also projected to result in greater risk of excess moisture events, including flooding. Recent severe flooding in southern Canada has also disrupted transportation and communication lines, with damages and costs associated with individual events exceeding $500 million (Government of Canada, 2010)

[4] It should be noted that tsunamis and storm patterns are not directly climate-related, but the potential for increasing frequency and severity of such events may be attributable to climate change.

2.2.4 Ontario and Quebec

Ontario and Quebec are prone to climate hazards such as drought, intense rainfall, ice and windstorms, and heat waves. Disruptions to critical infrastructure, including water treatment and distribution systems, energy generation and transmission, and transportation as a result of these climate hazards have already occurred in all parts of these provinces (Natural Resources Canada, 2007). Water shortages and lowering of water levels in the Great Lakes historically have compromised shipping routes and reduced hydroelectricity output by more than 1,100 megawatts (Natural Resources Canada, 2007). It is expected that increased shoreline erosion along the Gulf of St. Lawrence, where most of the subregion's socioeconomic activity is currently concentrated, will cause adverse effects on building infrastructure, potentially causing more evacuations. In the past, flooding associated with severe weather has disrupted transportation and communication lines, with damage costs exceeding $500 million (Natural Resources Canada, 2007).

2.3 Climate Impacts by Type of Infrastructure

Different types of infrastructure may be affected by climate hazards similarly and differently. This section focuses on five categories of critical infrastructure: land transportation, buildings, wastewater management, marine infrastructure and water resources. Summary tables below provide an overview of events and processes likely caused by climate change and their infrastructure impacts, based on past and currently observed impacts.

2.3.1 Land Transportation (Roads, Railways, Airports, Runaways and Bridges)

By far, public funding is most heavily invested in highways and roads. The approximate worth of this investment was $170.1 billion in 2007 (Canadian Council of Professional Engineers, 2008). Recent warm winters have adversely affected this infrastructure, such as by shortening the ice road season by several weeks and by enhancing freeze-thaw cycles that, in turn, accelerate the deterioration of transportation infrastructure (including roads, ramps and bridges). Many cities have started to invest in the design and fine tuning of new pavement equipment in light of this increase in freeze-thaw cycles (Natural Resources Canada, 2007). Further, increases in the frequency of hot days during the summer is leading to pavement softening, rutting and bleeding of liquid asphalt (Lemmen & Warren, 2004) and thermal expansion of railway infrastructure (Nelson, Anisimov, & Shiklomanov, 2002). In coastal regions, changes in water levels are increasing the frequency of inundation and damage to causeways, bridges and low-lying roads. Permafrost degradation has resulted in heaving, thawing, sinkholes, potholes and settlement issues, all of which are affecting roads, bridges, runways, and railways in Northern Canada (IMG-Golder Corporation, 2012).

TABLE 2: CLIMATE CHANGE AND INFRASTRUCTURE IMPACTS: LAND TRANSPORTATION

CLIMATE HAZARD AND/OR WEATHERING PROCESS LIKELY AFFECTED BY A CHANGING CLIMATE	POTENTIAL INFRASTRUCTURE IMPACTS
Permafrost degradation and greater frequency of freeze-thaw cycles in winter months	• Soil instability, ground movement and slope instability • Triggered instability of embankments and pavement structures (ditches, culverts, drains, street hardware, bridges, tunnels) • Increased frequency, duration and severity of: thermal cracking, rutting, frost heave and thaw weakening
Hotter, drier summers	• Pavement softening • Reduction in the maximum loads that can be safely transported • Asphalt-covered surfaces are more susceptible to damage during heat waves • Increase in flushing or bleeding of older pavement • Shortened ice road seasons by several weeks • Change in the timing and duration of seasonal load restrictions and winter weight premiums • Increased challenges in pavement construction process • Shortened life expectancy of highways, roads and rail • Drier conditions affecting the life cycle of bridges and culverts • Increased flow of streams and rivers, which increases need to replace ice bridges • Augmentation of Urban Heat Island Effect
Milder winters	• Longer construction season, fewer pothole repairs • Less frost damage for southern roads • Decreased damage from fewer freeze-thaw cycles • Changes to maintenance schedules
Sea-level rising, increased frequency of storm surges, higher tides and flooding	• Capacity of culverts and storm sewer systems are more frequently exceeded; road damage, bridge washouts, underpass and basement flooding, increased repair bills and insurance costs • Causeways, bridges and low-lying roads have a high risk of being inundated or damaged. • Coastal roads may be required to be moved or be rebuilt at higher elevation to avoid or reduce flooding.

Sources: Government of the NWT (2008); Governments of Nunavut, Northwest Territories and Yukon (2009); Government of Nunavut (2012); Lemmen & Warren (2004); Nelson et al. (2002); Lemmen & Warren (2004); Natural Resources Canada (2007)

2.3.2 Building Infrastructure (Public and Private Buildings)

Climate hazards can have wide-ranging consequences for exterior and interior surfaces of public and private buildings. Increased snowfall in Ontario, Quebec and the Atlantic has led to numerous incidences of the structural collapse of public and private building structures (Natural Resources Canada, 2007). There have also been incidences of severe wind damage on all three of Canada's coasts, and building subsidence due to the melting of permafrost in Canada's North (Natural Resources Canada, 2007). Increased precipitation has reduced the structural integrity of many buildings, accelerated the deterioration of building facades, caused premature weathering of input material, increased surface leaching and, in some instances, decreased the integrity of engineered berms as a result of slope instability (Infastructure Canada, 2006). Greater incidences of flooding have led to extensive commercial and property damage and basement flooding, which have reduced the functionality and service life of building foundations (Natural Resources Canada, 2007).

TABLE 3: CLIMATE CHANGE AND INFRASTRUCTURE IMPACTS: BUILDINGS

CLIMATE HAZARD AND/OR WEATHERING PROCESS LIKELY AFFECTED BY A CHANGING CLIMATE	INFRASTRUCTURE IMPACTS
Permafrost degradation	• Soil subsidence and buckling can damage a property's foundation infrastructure. • Loss of strength in buildings, which can cause them to become uninhabitable • Reduced strength and reliability of containment structures and other physical infrastructure
Hotter, drier summers and heat waves	• Building damage has sometimes been observed when clay soils dry out. • Forest fires can damage entire homes and businesses. • Premature weathering • Increased indoor air temperature and reliance on cooling systems
Increased precipitation	• Reduced structural integrity of building components through mechanical, chemical and biological degradation • Accelerated deterioration of building facades • Premature weathering of input materials • Increased fractures and spalling in building foundations • Decreased durability of materials • Increased efflorescence and surface leaching concerns • Increased corrosion • Increased mold growth
Increase rainfall, storm surges and higher tides	• Damaged or flooded structures • Slope stability and integrity of engineered berms are also vulnerable to extreme precipitation. • Coastal infrastructure inducted • Wharves to be rebuilt, moved or raised to avoid inundation • Increased risk of basement and localized flooding • Increased corrosion in metals or deterioration in concrete
Hurricanes, tornadoes, hail, windstorms and ice storms	• Property destruction • Damage building infrastructure • Reduction of design safety margins • Reduced service life and functionality of components and systems • Increased risk for catastrophic failure • Increased repair, maintenance, reserve fund contingencies and energy costs

Sources: Government of British Columbia (2003); Infastructure Canada (2006); Lemmen & Warren (2004); Natural Resources Canada (2007)

2.3.3 Water Infrastructure (Dams, Reservoirs, Aquifers, Hydroelectric Generators)

Climate change affects the function and operation of existing water infrastructure, which is frequently cited as one of most vulnerable types of infrastructure to climate impacts (Natural Resources Canada, 2004). As a result of increases in temperatures, sea levels and the variability of precipitation patterns, incidents of water infrastructure failure, insufficient supply, inadequate protection from floods and unacceptable water quality have all been experienced across Canada (Simonovic, 2008). Shallow, unconfined aquifers are frequently running dry during drought periods in many Canadian regions (Government of Canada, 2011a). The failure of these shallow aquifers increases the demand for water storage and water diversion. Studies also suggest that the potential for hydroelectric generation will likely rise in northern regions and decrease in the south, due to projected changes in annual runoff volume (Natural Resources Canada, 2007). Sea-level rise and changing precipitation patterns are also influencing the incidence of saltwater intrusion in Atlantic Canada, which is rendering water undrinkable (Prince Edward Island Department of Environment, Labour and Justice, 2011).

TABLE 4: CLIMATE CHANGE AND INFRASTRUCTURE IMPACTS: WATER INFRASTRUCTURE

CLIMATE HAZARD AND/OR WEATHERING PROCESS LIKELY AFFECTED BY A CHANGING CLIMATE	INFRASTRUCTURE IMPACTS
Drought	• Increased water demands and pressure on infrastructure • Water apportion issues • Loss of potable water • Increased water quality problems • Increased risk of flooding • Dam failures
Permafrost degradation	• Rupture of drinking water lines • Rupture of water storage tanks • Increased turbidity and sediment loads in drinking water
Rising sea level	• Saltwater intrusion in groundwater aquifers
Flooding	• Water-borne health effects from increased flooding • Volatilization of toxic chemicals • Summer taste/odour problems in municipal water supply

Sources: Government of Canada (2011a); Lemmen & Warren (2004); Natural Resources Canada (2007); Simonovic (2011); Prince Edward Island Department of Environment, Labour and Justice (2011)

2.3.4 Marine Infrastructure (Ports, Canals, Docks, Wharves, Piers, Seawalls)

Diminishing sea ice, particularly in Hudson Bay and the Beaufort Sea, and a lengthened summertime shipping season associated with warming will increase opportunities for shipping and passage within Canadian Arctic waters (Natural Resources Canada, 2007). This will likely lead to the development and expansion of marine ports, buildings and all-season road networks on the northern mainland and Arctic islands, particularly to access natural resources whose development has previously been uneconomical (Natural Resources Canada, 2007). Rising sea levels are of particular concern on Canada's East and West coasts, as they increase the exposure of existing marine infrastructure to storm surges, erosion and saltwater intrusion.

TABLE 5: CLIMATE CHANGE AND INFRASTRUCTURE IMPACTS: MARINE INFRASTRUCTURE

CLIMATE HAZARD AND/OR WEATHERING PROCESS LIKELY AFFECTED BY A CHANGING CLIMATE	INFRASTRUCTURE IMPACTS
Less ice cover; remaining ice is more mobile and wave action is more intense	• Marine infrastructure becomes more vulnerable to storm surges and extreme weather • Accelerated erosion and sedimentation of marine infrastructure • Affects the future design and operation of near shore and shore infrastructures • Increased construction of marine infrastructure, expansion of ports, associated with higher and less seasonal marine traffic as Arctic Sea melt continues
Flooding, coastal erosion, storm surges	• More extensive coastal inundation; flooding of marine infrastructure • Increased force exerted on docks • Saltwater intrusion into freshwater aquifers • Coastal erosion makes coastal infrastructure unstable • Land-based installations, such as oil storage reservoirs or storage facilities must be protected with seawalls to avoid damage
Low water levels	• Cargo ships unable to access marine infrastructure during low tide

Sources: Government of Canada (2011a); Lemmen & Warren (2004); Natural Resources Canada (2007)

2.3.5 Wastewater Infrastructure (Treatment Facilities, Culverts, Sewers, Storm Drains, Pipes)

Increases in periods of heavy rainfall will put drainage systems under stress, thereby increasing the risk of flooding. Floods will damage both water supply and waste systems by overwhelming the system. Several cities in Canada have identified situations in which stormwater management facilities have become completely inundated during severe rainfall and are now paying several millions of dollars to retrofit their infrastructure (Natural Resources Canada, 2007). Issues with wastewater infrastructure in Canada are likely to be compounded by the poor status of most wastewater infrastructure and growing populations in many urban centres. According to Canada's first report card on municipal wastewater infrastructure, 40.3 per cent of wastewater plans, pumping stations and storage tanks scored "fair" to "very poor" condition, and 30.1 per cent of pipes in "fair" to "very poor" condition (UMA Engineering Ltd., 2005).

TABLE 6: CLIMATE CHANGE AND INFRASTRUCTURE IMPACTS: WASTEWATER INFRASTRUCTURE

EXAMPLES OF WEATHERING PROCESSES LIKELY AFFECTED BY THE CHANGING CLIMATE	INFRASTRUCTURE IMPACTS
Permafrost degradation	• New containment structures in continuous permafrost zone may need to be built • Potential rupture of drinking water and sewage lines, sewage storage tanks • Potential seepage from sewage storage • Failure of frozen-core dams on tailing ponds due to thawing and differential settlement
Hotter, drier summers and heat waves	• Increased demand for water delivery and collection systems
Increase in rainfall	• Stormwater infrastructure more frequently exceeded • Require increased capacity on wastewater treatment facilities • Urban drainage systems could fail, causing problems such as sewer backups and basement flooding
Increased frequency of storm surges and higher tides	• Implications for large urban drainage systems • Potential impact on the strength in wastewater systems • Sinking of land surfaces • Buildings, tankage, housed process equipment affected by flooding • Overtaxing of drainage facilities • Pipeline ruptures

Sources: Government of Canada (2011a); Infastructure Canada (2006); Lemmen & Warren (2004); Natural Resources Canada (2007)

2.4 Exposure and Vulnerability of Infrastructure to Climate Hazards

As previously mentioned, the sensitivity of infrastructure to climate hazards is shaped by a number of factors (both climatic and non-climatic), which often vary both within and between regions. A review of the literature shows that while some research and data on the exposure and vulnerability of infrastructure exists at the local and municipal levels in Canada, there is a need to map such dynamics at a provincial and/or national level to better understand levels of sensitivity to climate hazards.

With this in mind, it is evident that at least three main factors influence the sensitivity of infrastructure to climate hazards, namely: age, composition and design. Of course, these three elements are also interdependent and influenced by other social and economic factors.

Age. Old and overextended infrastructure is likely to be more susceptible to the negative impacts of climate change. Older infrastructure is most vulnerable in general; that is to say that, all other factors remaining constant, a new building will be less affected by climate hazards than an older building that has aged and deteriorated over time. As of 2005, 31 per cent of Canada's infrastructure was between 40 and 80 years old, and 28 per cent was between 80 and 100 years (Federation of Canadian Municipalities, 2005). Further to this, it has been estimated that 50 per cent of existing public infrastructure will reach the end of its service life by 2027 (Infrastructure Canada, 2006). In 2012, Canada's first report on municipal infrastructure estimated that the replacement cost of infrastructure ranked as being "fair" to "very poor" required a total of $171.8 billion nationally (Felio, 2012).[5] The high costs associated with aging infrastructure maintenance and replacement in Canada will likely only increase in the face of climate change. With so much of Canada's infrastructure reaching the end of its life in the very near future, there are opportunities for investments to be rethought and life-cycle costs to be taken into greater consideration. If targeted effectively, new infrastructure investments can significantly improve the long-term resilience of Canada's infrastructure in the face of climate change.

Composition. The materials used in the construction and maintenance of various types of infrastructure also play a key role in influencing the sensitivity of said infrastructure to climate hazards. The extent to which materials are susceptible to natural breakdown and weathering over time can be compounded in the context of climate variability and change. For example, wood and other flammable materials are obviously much more susceptible to damage from wildfires in drought conditions. Similarly, the exposure of infrastructure to more incremental climatic changes is also affected by the types of material used in their construction. For example, the ability of structures to provide passive cooling in increasing average temperatures varies from one conventional building material to the next.

Design. Most infrastructure continues to be designed on the basis of historical climate data and assumptions, generally meaning they do not account for an expected increase in frequency and intensity of climate hazards or new climate hazards. For example, storm pipes and drainage infrastructure may need to be larger to accommodate increased water flow or seawalls built higher to protect against storm surges and sea-level rise. Climate considerations in design are important not only to improving resilience to climate hazards and incremental climate change, but can also positively contribute to reducing greenhouse gas emissions. For example, green roofs can contribute to the passive cooling of buildings and more effective rainwater management while simultaneously reducing energy usage and costs. Though often representing higher upfront costs, investments in more resilient design can help avoid larger future costs (in terms of maintenance, repair and replacement). As discussed further in Section 3, though climate change is being incorporated into infrastructure design to some degree (particularly in Canada's North), significant changes to building codes or other standards have not yet been broadly applied.

The vulnerability of the infrastructure sector to climate change is also defined by the capacity of the particular sector to adapt by minimizing adverse impacts and maximizing positive ones (i.e., the sector's adaptive capacity). Various policies, regulations, standards and market mechanisms play a key role in defining this adaptive capacity, as discussed in detail in Section 3. Of course, building resilience requires much more than just policy, legal or market responses. However, for the purposes of this review, we have chosen to focus on those "enabling conditions" and tools most relevant to incentivizing significant adaptation actions across Canada.

[5] The report offered an assessment of the state of road, wastewater, drinking water and stormwater infrastructure in 123 municipalities across Canada.

3.0 Tools, Approaches and Mechanisms to Support Climate Resiliency

Based on the literature, it is clear that action is needed at a number of levels to help address the challenges that climate change poses for key infrastructure. Given the diversity of impacts discussed in Section 2, along with the wide range of potential responses from various sectors, it is difficult to generalize as to the types of tools and approaches that can help improve the resiliency of Canada's built infrastructure to the impacts of climate change. For example, Box 2 provides a broad overview of the range of tools and techniques that may be used to support the integration of climate change considerations in infrastructure planning and underscores the range of actors involved in creating the enabling environment for such actions.

BOX 2: EXAMPLES OF TOOLS AND TECHNIQUES TO SUPPORT THE INTEGRATION OF CLIMATE RESILIENCE INTO INFRASTRUCTURE PLANNING

A 2012 survey of Canadian Infrastructure Engineers suggested a number of tools and techniques for responding and/or adapting to climate change based on the latest thinking and literature. The main themes are certainly applicable to the cement sector:

- Increase the magnitude of design parameters or safety factors
- Perform a formal risk assessment and carry out risk management
- Review existing practices and use entirely new solutions
- Develop contingency plans for infrastructure failure
- Identify infrastructure that is at risk because of a changing climate and retrofit priority assets
- Consider increased deterioration rates in design and maintenance plans
- Consider different climate change scenarios or models for design, maintenance or planning
- Identify locations that may be vulnerable to climate change impacts and avoid them altogether or modify designs accordingly

A great deal of thinking has been done in recent years by governments and private sector actors, who are beginning to more fully understand not only the potential costs associated with climate change and the necessity for adaptation, but also the broader opportunities for and co-benefits that could be associated with proactive measures. It is becoming clear to many that the adaptive capacity of various infrastructure is directly shaped by the extent to which policies, regulations and other market mechanisms support and incentivize actions that build climate resilience. Though relatively nascent, these tools are beginning to shift from being reactionary in nature to having a stronger focus on ensuring the longer-term adaptive capacity of critical sectors.

Through a consideration of the literature we have identified four key levers of action:

1. **Current Government Policy Responses and Related Tools.** This includes a review of the status of enabling adaptation frameworks and funding at the federal level in Canada, as well as in the North, Atlantic Region, Quebec, Ontario, Prairies and B.C. Additional examples from outside of Canada are also provided given their potential relevance in the Canadian context.
2. **Codes, Standards and Related Instruments (CSRIs)**. We consider the extent to which national building codes and other standards support climate resiliency. Also considered is the development of other important tools

and resources, such as the Public Infrastructure Engineering Vulnerability Committee (PIEVC) Protocol and the Canadian Standards Council Northern Infrastructure Standardization Initiative, that support the integration of climate considerations into infrastructure planning.

3. **Markets, Financial Incentives and Liability Rules.** The private sector, and in particular the insurance (and reinsurance) industry, also has a key role to play. Here we identify the most recent thinking and potential tools available in this respect.
4. **Industry Responses.** Finally, we explore actions taken by key cement/concrete industry actors in shaping responses to sustainability challenges more broadly, and the linkages being made to adaptation and climate resilience specifically.

3.1 Current Government Policy Responses and Related Tools

Across Canada (and internationally), there has been an upsurge in the development of climate change action plans in recent years. Recognizing that adapting to the negative consequences of climate change is as necessary as mitigating the causes of climate change, several jurisdictions have initiated processes to develop additional adaptation frameworks and/or integrate adaptation more closely into existing action plans and ministry mandates. Current activities are largely focused on laying the groundwork for implementable action plans through capacity building, coordination, research and priority-setting. Given that many of the existing policy frameworks have yet to be translated into action plans and associated budgets, discrete funding for adaptation and climate resilience remains limited at present.

Nonetheless, substantial developments have taken place in recent years and investments are beginning to be made, with much more expected to come in the near future. Below is a review of key enabling adaptation policy and funding frameworks across Canada, with additional examples from the United States and the United Kingdom. A particular focus has been placed on elements related to infrastructure and ensuring climate resilience of the built environment.

3.1.1 Canadian Federal Government

As the overarching policy outlining a federal approach to sustainable development, Canada's Federal Sustainable Development Strategy first cycle (2010–2013) (Environment Canada, 2010) included very few indicators focused on adaptation, and nothing of significance related to climate resilience in infrastructure. The final draft of the second-cycle framework *Planning for a Sustainable Future* (2013–2016) notably includes a new target focused on climate change adaptation and proposes support for resilient infrastructure (buildings and transportation) in Canada's North.[6] While adaptation and infrastructure requirements are most acute in the North, it is noteworthy that the only infrastructure-related adaptation targets are regionally focused, and there are no broader strategies to address climate impacts on infrastructure elsewhere in Canada. This is also reflected in federal funding for adaptation more broadly. While in 2011, the government committed nearly $150 million (over five years) to support adaptation, only $14.5 million of that amount is going towards the previously mentioned Northern infrastructure projects; no other funding is directly committed to infrastructure and adaptation projects in other parts of Canada.[7]

[6] Public consultations on the draft document ended in June 2013 and a final version is expected to be published in fall 2013. For further details, see http://www.ec.gc.ca/dd-sd/default.asp?lang=En&n=F7780ED7-1

[7] This funding is to be used as follows: $3.5 million for Industry Canada and Aboriginal Affairs and Northern Development Canada, for Integrating Adaptation into Codes and Standards for Northern Infrastructure and $10.99 million for Transport Canada's Northern Transportation Adaptation Initiative. See http://ec.gc.ca/default.asp?lang=En&n=2D1D6FA7-1&news=B67A7995-A1CA-4DE3-89D2-E4E3C0E24BFB

A second high-level strategy, the *Federal Adaptation Policy Framework* has recently been developed. The document signals the government's intentions to mainstream adaptation into federal priorities and notes that the "costs associated with future climate-related failures in infrastructure could potentially be avoided by changing current infrastructure design protocols to become more resilient to predicted future changes in climate" (Government of Canada, 2011b). However, the strategy's impact is likely to be limited given it does not include any action points and is not a monitoring or implementation framework (Canadian Press, 2012).

The federal government has also supported the development of several tools and knowledge platforms in recent years. Most notably, Natural Resource Canada's *Adaptation Platform*[8] was launched in March 2012, with the goal of bringing together key groups from government, industry and professional organizations to collaborate on adaptation priorities. The online platform includes tools and guides of relevance to infrastructure adaptation.[9]

From 2009 to 2012, the federal government was also engaged in the establishment of six *Regional Adaptation Collaboratives* (RACs).[10] The $30 million dollar, cost-shared federal program established six distinct RACs in British Columbia,[11] the Prairies,[12] Ontario,[13] Quebec,[14] Atlantic Canada[15] and Northern Canada.[16] The work undertaken was instrumental in expanding knowledge bases and policy process and each RAC produced various reports, guidance documents and capacity-building tools. Natural Resources Canada is continuing to support adaptation efforts in Canada through its *Enhancing Competitiveness in a Changing Climate* program, which focuses on challenges related to selected economic sectors. The program also continues to provide some funding to the provincial RACs.

3.1.2 North

As the region of Canada where climate change impacts are among the most observable and dramatic—and where existing economic and infrastructure challenges act to enhance vulnerability to such impacts—adaptation to climate change is of particular importance in Canada's North.[17] The *Pan-Territorial Adaptation Strategy*[18] prepared in 2009 sets out a political commitment to reduce the risks posed by climate change on Northern infrastructure and economies, as well as human health and safety, ecosystems and traditional cultures (Governments of Nunavut, Northwest Territories and Yukon, 2009). As the strategy does not include a specific policies or funding decisions, its implementation is supported by policies and action plans at the territorial level, as below.

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[8] See http://www.nrcan.gc.ca/earth-sciences/climate-change/community-adaptation/platform/11958

[9] These include: a number of municipal and community-level risk screening tools and adaptation guidebooks, including one developed by the International Council for Local Environmental Initiatives, Local Governments for Sustainability, Canada; a handbook outlining tools for small Canadian communities looking to mainstream climate change considerations into their planning processes; and a number of sector-specific tools related to water resource management, including a *Water Balance Model and Water Conservation Calculator* intended to support scenario analysis of future water management needs at the drainage site, development and watershed levels.

[10] See http://www.nrcan.gc.ca/earth-sciences/climate-change/community-adaptation/regional-collaborative/48

[11] See http://www.nrcan.gc.ca/earth-sciences/climate-change/community-adaptation/regional-collaborative/636

[12] See http://www.nrcan.gc.ca/earth-sciences/climate-change/community-adaptation/regional-collaborative/175

[13] See http://www.nrcan.gc.ca/earth-sciences/climate-change/community-adaptation/regional-collaborative/189

[14] See http://www.nrcan.gc.ca/earth-sciences/climate-change/community-adaptation/regional-collaborative/768

[15] See http://www.nrcan.gc.ca/earth-sciences/climate-change/community-adaptation/regional-collaborative/204

[16] See http://www.nrcan.gc.ca/earth-sciences/climate-change/community-adaptation/regional-collaborative/171

[17] For a comprehensive analysis of climate change and infrastructure in Canada's North, see the National Roundtable on Environment and Economy report *True North: Adapting Infrastructure to Climate Change in Northern Canada* (2009). Available at: http://collectionscanada.gc.ca/webarchives2/20130322143509/http://nrtee-trnee.ca/climate/true-north

[18] See http://www.anorthernvision.ca/documents/Pan-TerritorialAdaptationStrategyEN.pdf

In the Northwest Territories, its *Climate Change Impacts and Adaptation Report*[19] outlines the impacts of climate change on key infrastructures—most notably the impacts of melting permafrost on buildings and roads, as well as the impacts of permafrost erosion along waterways that threatens dikes, bridges and culverts (Government of the Northwest Territories, 2008). Following the report's release, plans were announced to develop a Northwest Territories Adaptation Plan, though it has not yet been published. A number of communities have developed adaptation action plans, processes that could be scaled up or build on in a jurisdiction-wide approach.[20]

Also in 2008, the Yukon developed a *Climate Change Action Plan*,[21] which included several infrastructure-relevant adaptation actions, including to complete an infrastructure risk and vulnerability assessment and determine adaptation strategies needed in response and regulate and enforce "best practice" building standards. A 2012 status report called *Yukon Government Climate Change Action Plan: Progress Report* noted that progress had been made insofar as a risk assessment of Yukon government buildings in areas where permafrost is thawing was completed (Yukon Government, 2012). A broader assessment has not yet been completed. The report also noted that some building standards had been improved (mainly related to energy efficiency), but that changes to building codes to address climate impacts had not yet been made (Yukon Government, 2012).

The Nunavut Climate Change Partnership was formed in 2008 to build capacity for adaptation planning.[22] The *Setting the Course* report[23] (2011) outlined the impacts of climate change on various elements of infrastructure and highlighted general objectives to address some of the issues (including ensuring that climate change considerations are integrated into land-use planning), but no specific policy measures were included. An additional report, *Climate Change Adaptation Planning: A Nunavut Toolkit*[24] (2011), details the steps to developing Climate Change Action Plans at the community level. However, similar to NWT, an overarching action plan at the territorial level has not yet been implemented.

3.1.3 Atlantic Canada

In 2008 the Atlantic Environment Ministers agreed to a strategic regional approach to climate change adaptation, as outlined in *Climate Change Adaptation Strategy for Atlantic Canada*.[25] Similar to regional coordination in Northern Canada, the strategy's implementation is dependent on action plans at the provincial level.

Nova Scotia's *Climate Change Action Plan* (2009)[26] includes a strong focus on adaptation. The province intended to ensure that design standards for public infrastructure reflect projected climate trends, not just historical records, by 2010; this does not appear to have been achieved to date. The plan also established a small *Climate Change Adaptation Fund*—which in 2013–2014 has $25,000 available to support community projects. Given the relative size of the fund, previous support has focused on research and capacity-building activities as opposed to hard infrastructure projects.

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[19] See http://www.enr.gov.nt.ca/_live/documents/content/NWT_Climate_Change_Impacts_and_Adaptation_Report.pdf
[20] For example, the community of Paulatuk, in collaboration with ArcticNorth Consulting and with support from AANDC's Climate Change Adaptation Program, have developed a multi-sectoral action plan. See http://arctic-north.com/wp-content/uploads/pdfs/Paulatuk/Paulatuk_Adaptation_Plan.pdf
[21] See http://www.env.gov.yk.ca/publications-maps/documents/YG_Climate_Change_Action_Plan.pdf
[22] The partnership includes the Government of Nunavut, the Canadian Institute of Planners, and the Government of Canada (Natural Resources Canada & AANDC).
[23] See http://env.gov.nu.ca/sites/default/files/3154-315_climate_english_sm.pdf
[24] See http://www.planningforclimatechange.ca/wwwroot/Docs/Library/CIPReports/NUNAVUT%20TOOLKIT%20FINAL.PDF
[25] See http://www2.gnb.ca/content/dam/gnb/Departments/env/pdf/Climate-Climatiques/ClimateChange%20AdaptationStrategyAtlanticCanada.pdf
[26] See http://www.exec.gov.nl.ca/exec/cceeet/publications/climate_change.pdf

The province also released a *State of Nova Scotia's Coast*[27] report in 2009, which is intended to serve as the basis for a Sustainable Coastal Development Strategy, which has not yet been released. The province has also invested in the development of a number of adaptation tools[28] in recent years, including a *Developer's Guide to Considering Climate Change in Project Development in Nova Scotia*.[29]

Newfoundland and Labrador's *Climate Change Action Plan* (2011)[30] similarly included a number of infrastructure-relevant investments, including $700,000 over three years to establish flood-risk mapping and alert systems, as well as a coastal erosion monitoring and mapping program. The government had previously included consideration of climate change implications (e.g., potential for flooding) in the site selection and design of provincial government buildings and infrastructure and planned to extend these considerations to all infrastructure receiving public funding. It is unclear based on the literature whether or not this measure has been introduced.

New Brunswick's *Climate Change Action Plan* (2007–2012)[31] similarly included plans to enhance provincial adaptation planning with special emphasis on coastal regions. Key actions include incorporation of vulnerability considerations into cross-governmental decision making, and the implementation of a regulatory framework to help protect the coastal environment, infrastructure and public and private property. Similar to Nova Scotia, the province established an *Environmental Trust Fund*, which has funded some 50 projects related to mapping vulnerabilities and engaging stakeholders in adaptation planning (Government of New Brunswick, 2012). The latest progress report on the action plan's implementation does not make reference to the progress relative to infrastructure, beyond research and capacity building completed under the Atlantic RAC.[32]

Finally, Prince Edward Island's *Climate Change Strategy* (2008)[33] outlined that province's plans to create an interdepartmental approach to incorporating climate change considerations into environmental assessments, land-use plans, land-use bylaws, road and bridge construction, wharves, marinas and other infrastructure. Hazard mapping and monitoring, particularly related to sea-level rise, was also identified by the strategy and undertaken though the previously mentioned Atlantic RAC. It also referenced plans for a working group co-chaired by the Environment and Public Works ministries to oversee the development of a climate change adaptation strategy; no subsequent references to progress on this strategy have been found.

3.1.4 Quebec

Building on government actions taken as part of the 2006–2012 Climate Change Action Plan, Quebec's *Government Strategy for Climate Change Adaptation* (2013–2020)[34] outlines a number of specific actions and funding initiatives of relevance to the infrastructure sector, including to "Modify land use and manage risks to reduce vulnerabilities" and "Improve the safety and durability of buildings and infrastructure" (Government of Quebec, 2012). The plan commits

[27] See . http://www.gov.ns.ca/coast/documents/state-of-the-coast/WEB_SummaryReport.pdf. Two of six priority areas directly relate to infrastructure, namely working waterfronts and sea level rise and storm events.
[28] See http://climatechange.gov.ns.ca/content/tools
[29] See http://climatechange.gov.ns.ca/files/02/66/Development_CC_Guide1.pdf
[30] See http://www.exec.gov.nl.ca/exec/cceeet/publications/climate_change.pdf
[31] See http://www2.gnb.ca/content/dam/gnb/Departments/env/pdf/Climate-Climatiques/2007-2012ClimateChangeActionPlan%20.pdf. The province's next action plan for 2013 onwards has not yet been released.
[32] See http://www2.gnb.ca/content/dam/gnb/Departments/env/pdf/Climate-Climatiques/ClimateChangeProgressReportSummary2011-2012.pdf
[33] See http://www.gov.pe.ca/environment/ccstrategy
[34] See http://www.mddefp.gouv.qc.ca/changements/plan_action/stategie-adaptation2013-2020-en.pdf

over $120 million to actions to reduce vulnerability and improve community adaptive capacity. It further commits $45 million for adaptation research, and $11.5 million to strengthening the durability and safety of buildings by revising infrastructure design criteria and management and maintenance methods. Funding for the adaptation strategy comes mainly from carbon pricing revenues, which is an innovative approach to combining mitigation and adaptation actions.

Additional actions include the drafting of a strategy for the protection of drinking water sources, revaluating the positioning of some water intakes, and improving the management of supply and distribution networks as climate conditions change. New requirements for rainwater management measures, including the reduction of rainfall runoff volumes and limiting of overflows, are also being considered. So too are modifications to public dam management plans to ensure they reflect climate change impacts on water volumes rather than historical data. Adaptation of northern transportation infrastructure is also identified as a priority action area.

3.1.5 Ontario

Like Quebec, Ontario also has a standalone adaptation strategy corresponding with a climate change action plan and approach to mainstreaming adaptation considerations across various government ministries. As the most densely populated province, the first goal of Ontario's *Adaptation Strategy and Action Plan* (2011–2014)[35] is to "avoid loss and unsustainable investment, and take advantage of new economic opportunities" (p. 26). This is intended to be done through actions such as considering climate change impacts in building codes, undertaking infrastructure vulnerability assessments, building climate change adaptation into Ontario's 10-year infrastructure plan, developing guidance for stormwater management and strengthening the winter road network. The plan proposed the establishment of a *Climate Change Adaptation Directorate* to help guide the implementation of 37 actions across government. The Environmental Commissioner of Ontario has pointed to the lack of prioritization within the numerous actions outlined in the strategy, along with a lack of quantitative or qualitative targets and absence of specific timelines for delivery as potential shortcomings in the plan's implementation (Environmental Comissioner of Ontario, 2012).

3.1.6 Prairies

Saskatchewan does not have a formal climate change plan or explicit adaptation strategy, and it is not clear whether or not the province's forthcoming greenhouse gas framework will have an adaptation component.[36]

Manitoba's most recent *Green Plan* (2012)[37] and forthcoming *Green Prosperity Act*[38] lay out a phased approach to the development of an adaptation strategy, but there are no specific actions or clear implementation plans included. The province has outlined plans to improve flood management and related infrastructure, including through modernization of its regulatory approach to water management. A recent task force report on the floods of 2011 includes reference to building an additional control structure out of Lake Manitoba to enhance capacity to regulate water levels within this lake (Manitoba 2011 Flood Review Task Force, 2013)

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[35] See http://www.ene.gov.on.ca/stdprodconsume/groups/lr/@ene/@resources/documents/resource/ stdprod_085423.pdf

[36] See http://www.finance.gov.sk.ca/PlanningAndReporting/2012-13/EnvironmentPlan1213.pdf for further details. In 2011–2012, climate change accounted for only 3 per cent of the Ministry of Environment's budget.

[37] See http://www.gov.mb.ca/conservation/tomorrownowgreenplan/pdf/tomorrowNowBook.pdf

[38] See http://www.gov.mb.ca/conservation/greenprosperity/index.html

In Alberta, the province's *Climate Change Strategy* (2008)[39] called for the development of a provincial climate change adaptation strategy with a key focus on the water, biodiversity, energy, municipal infrastructure, agriculture and forestry sectors. This strategy is currently being finalized by the government. In the next three years, the government plans to review its climate change strategy, which may provide an additional opportunity for the inclusion of infrastructure adaptation priorities—including in the completion of regional land-use frameworks (Alberta Environment and Sustainable Resource Development, 2013). In 2010 the province released a *Climate Change Adaptation Framework*[40] as "a tool for organizations to assess vulnerabilities to climate change impacts…and identify options to respond" (Alberta Sustainable Resource Development, 2010). The tool includes infrastructure as one of the determinants of adaptive capacity but does not have a particular focus on infrastructure per se.

3.1.7 British Columbia

British Columbia adopted a high-level adaptation strategy[41] in 2010, the third pillar of which focuses on conducting risk assessments for infrastructure sectors known to be sensitive to climate change and to review and update existing policies and operational approaches on the basis of these assessments. The step-wise approach and lack of timelines in the strategy means awareness-raising and capacity building are likely to be priority actions in the near term, as opposed to significant policy changes.

The province is also working to plan for sea-level rise and storm surges by conducting extensive research and developing a number of planning tools, including commissioning a sea-level rise adaptation primer.[42] In 2011 the Ministry of Forests, Lands and Natural Resource Operations published draft technical guidelines for the design of sea dikes and coastal land use, making provisions for a sea-level rise of 0.5 metres by 2050 and 2.0 metres by 2200 (Arlington Group Planning & Architecture Inc., 2013). In 2012 British Columbia has also supported the development of an adaptation planning guide for local government[43] and an implementation guide.[44]

3.1.8 Examples Outside of Canada

Catalyzed by a series of major climate events in recent years—including Hurricane Katrina in the Gulf, ongoing droughts in the Midwest and Hurricane Sandy along the Eastern Seaboard—discussions around increasing infrastructure resilience have spiked in the United States. A number of these discussions should be of interest to Canadian businesses and other actors, given the similarities in infrastructure systems and related policy and regulatory regimes in the two countries.

President Obama's "All of the Above" *climate action plan*,[45] released in June 2013, looks to fortify the country's climate resilience and begin to more deeply integrate adaptation into national planning process. Various federal agencies

[39] See http://environment.gov.ab.ca/info/library/7894.pdf
[40] See http://srd.alberta.ca/MapsPhotosPublications/Publications/ClimateChangeAdaptationFramework.aspx
[41] See http://www.env.gov.bc.ca/cas/adaptation/pdf/Adaptation_Strategy.pdf
[42] See http://www.env.gov.bc.ca/cas/adaptation/pdf/SLR-Primer.pdf. The primer includes tools relevance for all coastal areas in Canada; and includes a review of four planning tools, four regulatory tools, five land-use change or restriction tools, five structural tools (also known as flood protection works) and three non-structural tools (also known as soft armouring).
[43] See http://pics.uvic.ca/sites/default/files/uploads/publications/Adaptation_Resources_June2011.pdf . This guide also includes a comprehensive list of similar tools and guidance from other jurisdictions.
[44] See http://www.retooling.ca/_Library/docs/WCEL_climate_change_FINAL.pdf
[45] For full text of the President's Climate Action Plan, see: http://www.whitehouse.gov/sites/default/files/image/president27sclimateactionplan.pdf

have been directed to re-examine policies and programs to ensure they promote climate resiliency. A number of key departments have already been engaged in the development of Adaptation Plans and sector-specific research. For example, the Department of Energy recently released a report on the vulnerabilities of the energy sector to climate change and extreme weather, including power and fuel infrastructures.[46] The National Institute of Standards and Technology has also been directed to convene a panel of experts to develop disaster-resilience standards, as a "comprehensive, community-based resilience framework" (Executive Office of the President, 2013, p. 13), providing guidelines that can inform the further development of private-sector standards and codes (see Section 3.2 below).

Additional proposed expenditures include USD$2.7 billion for the *U.S. Global Change Research Program*, which serves as the coordinating body for federal research on climate change,[47] and USD$200 million in investments to support communities' transportation or infrastructure projects to increase resilience to climate change. These funds are "part of the administration's overall proposed increase in infrastructure investment grants to $480 million in fiscal year 2014 from $275 million in fiscal year 2012" (Fellow, 2013).

It is also possible that climate change considerations will be more deeply integrated into the environmental impact analysis of the *National Environmental Policy Act* (NEPA) moving forward. There is speculation that President Obama may enact changes to the NEPA process that will require all federal agencies to consider not only the greenhouse gas impacts of projects but also vulnerability to climate change impacts such as extreme weather events before projects are approved for funding (Nettler, 2013). It is expected that comprehensive reports would be required for facilities that emit 25,000 metric tonnes of carbon dioxide equivalent emissions or more per year. If enacted, the regulations could represent a significant shift in infrastructure planning and decision making, which could well have trickle-down impacts to other jurisdictions. Also in support of integrating resilience more broadly into planning processes, the U.S. Department of Homeland Security has developed risk modelling, resilience screening and target analysis tools to assess options for more resilient structures (Concrete Sustainability Hub, 2013).[48]

Various investments and planning to improve infrastructure resilience are also being made at the state and city levels in the United States. For example, Texas recently approved a USD$2 billion statewide water plan (total spending expected over the next 40 years is USD$53 billion) to address increasingly frequent droughts. The plan calls for the building of substantial new reservoirs and pipeline infrastructure, and similar discussions are underway in neighboring states (Buchele & Henry, 2013). Following Hurricane Sandy, New York City Mayor Michael Bloomberg appointed a task force to develop a "defence blueprint" against the future impacts of extreme weather and climate change. The group's final report (released in June 2013), made some 250 recommendations across a number of sectors, including buildings, insurance, utilities, liquid fuels, telecommunications, transportation and water/wastewater management. The plan suggests USD$20 billion in new spending and identifies community rebuilding and resiliency plans for all of the city's major boroughs.[49]

[46] See http://energy.gov/downloads/us-energy-sector-vulnerabilities-climate-change-and-extreme-weather

[47] See http://www.whitehouse.gov/omb/budget/factsheet/building-a-clean-energy-economy-improving-energy-security-and-addressing-climate-change for a full overview of proposed clean energy and climate investments.

[48] It should be noted that in this context, resilience refers to the ability of structures to withstand a variety of hazards (such as terrorist attacks or industrial accidents), not strictly those related to climate change.

[49] See: http://www.nyc.gov/html/sirr/html/report/report.shtml for the full text of the report.

A week after the New York report was released, a high-level framework, the *Resilient Communities for America Agreement* was signed by nearly 50 U.S. mayors. The move marks an important next step in cooperative action to support climate resilience at the city level and political recognition of the challenge.[50]

Experiences in the United Kingdom also hold relevance for Canada. The *U.K. Climate Change Act* of 2008 gives the Department of Environment, Food and Rural Affairs (Defra) *Adaptation Reporting Power*; that is to say, the authority to ask companies responsible for essential services (including key infrastructures like energy, water and transport) to report on the current and future predicted impacts of climate change on their organization (Defra, 2013). An independent analysis found that such requests were critical in providing a framework for greater consideration of climate change by several key infrastructure organizations and building capacity to assess and monitor climate risks across a variety of sectors. The reporting process also provided valuable information on organizations that were already taking steps to climate-proof new infrastructure and to modify design standards to accommodate future climate change (Cranfield University, 2012).[51]

From 2009–2011, the Government of the United Kingdom also undertook a comprehensive interdepartmental *Infrastructure and Adaptation Project* that examined the risks and potential solutions to improving the long-term resilience of new and existing infrastructure. The body of work produced through this project directly fed into the update of the National Infrastructure Plan in 2011, and subsequent updates.[52] Such a policy-making model could be adopted in Canada at either the provincial or federal levels, as a way of increasing consideration of climate change in existing and new infrastructure planning and identifying priority action areas.

3.2 Codes, Standards and Related Instruments

In addition to engaging in the policy responses outlined above to varying degrees, industry actors and governments have been instrumental in the development of approaches to strengthen climate risk considerations in existing infrastructure. However, the development, uptake and use of such approaches are still in early stages and no significant changes have been made to date (Sandink & McGillivary, 2012). A 2015 update of the *National Building Code of Canada* will represent an important opportunity to integrate future climate expectations into the climate data currently included in national codes and standards. To this end, Environment Canada and the Canadian Commission on Building and Fire Codes have been working to provide guidance on how to improve more than 6,000 specific climatic design values used in the national code, as well as many *Canadian Standards Association* (CSA) standards.[53]

Challenges in this respect are perhaps not surprising for a number of reasons. For example, there may be hesitance to support code changes or the introduction of new standards that could be seen to increase costs in competitive industries in the short term, while incorporating uncertain longer-term future climate impacts (Kelly, Kovacs, & Thistlewaite, 2012). These issues are more acute in the absence of other key drivers like policies or insurance to

[50] See vhttp://www.resilientamerica.org/wp-content/uploads/2013/06/Resilient_Communities_Agreement_Letter.pdf

[51] One such example was in the case of pavement design. The U.K. Highways Agency has already adopted French temperature standards for road surfaces. The report explains "this is an example of the Agency putting in place adaptation to ensure that design standards and operating practices can adapt to the changing climate expected over the lifetime and replacement cycle of the Agency's highways infrastructure" (Cranfield University, 2012, p 8).

[52] For a synthesis report, see *Climate Resilient Infrastructure: Preparing for a Changing Climate* available at: http://www.defra.gov.uk/publications/files/climate-resilient-infrastructure-full.pdf

[53] See http://www.ec.gc.ca/sc-cs/default.asp?lang=En&n=20CD1ADB-1

incentivize changes.[54] As well, the ability to take climate considerations into account in design codes and standards requires a baseline knowledge and understanding of relevant climate impacts, which may or may not be available depending on the assessment level and type of infrastructure. As such, any efforts to increase capacity and make tools (such as those discussed below) available to policy-makers, planners and engineers should be welcomed.

3.2.1 Public Infrastructure Engineering Vulnerability Committee (PIEVC) Protocol

From 2005–2012, Engineers Canada (with co-funding from Natural Resources Canada) undertook a series of activities, including publishing Canada's first *National Engineering Vulnerability Assessment* in 2008.[55] They also developed the *PIEVC Protocol* as a tool for evaluating the engineering vulnerability of infrastructure and the risks associated with the impacts of current and future climate change at a screening level. PIEVC was also to make recommendations concerning the review of infrastructure CSRI in the water, roads and buildings sectors, building on evidence from 22 case studies completed over the course of the project.

However, it appears that uptake of both the PIEVC Protocol and CSRI reviews have been relatively limited to date. In a survey of Canadian Infrastructure Engineers in May 2012, only seven per cent of engineers reported that they were somewhat or very familiar with the PIEVC Protocol, and only three percent said they had already used, or intend to use, the Protocol (CSA Group, 2012).[56] On the CSRI review, only recommendations related to water infrastructure have been made publicly available on the PIEVC website,[57] and those are very broad based as opposed to highlighting specific changes that could be made to particular codes or standards.

Similar to the RACs, federal funding for the project ended in 2012, and there is no clear indication of how the tools developed could support a broader process of CSRI revision in Canada. Engineers Canada, though, is seeking opportunities to complete case studies in other sectors (Engineers Canada, 2013).

3.2.2 Standards Council of Canada Northern Infrastructure Standardization Initiative

The Standards Council of Canada (SCC) has also been engaged in work to integrate adaptation considerations into codes and standards through the five-year (2012–2017), $3.5 million *Northern Infrastructure Standardization Initiative* (NISI).[58] The SCC, with federal funding, has identified likely priority areas including: the design, installation and maintenance of thermosyphon foundations; changing snow loads on roofs; management of the effects of permafrost degradation on existing buildings; and community drainage plans under climate change (SCC, 2012). By 2017, NISI intends to

[54] However, this is not to say that climate risks are not already being incorporated into infrastructure design even in the absence of strong policy signals. For example, during the design and construction of the Confederation Bridge in Prince Edward Island (over 15 years ago), sea-level rise was recognized as a principal concern. The bridge was built one metre higher than currently required to accommodate anticipated sea-level rise over its 100-year lifespan (Adger, 2007).

[55] See http://www.pievc.ca/e/doc_list.cfm?dsid=4

[56] That said, there is anecdotal evidence of successes in the application of the PIECV Protocol. For example, the community of Placentia, Newfoundland and Labrador, completed applied the PIEVC Protocol to complete a vulnerability assessment of the town's infrastructure, such as the breakwater, steel floodwall and a section of the Dunville highway damaged during Tropical Storm Chantal in 2007. The assessment identified vulnerabilities out to 2050 from changing climate events. As a result, the highway infrastructure was upgraded to handle more intense precipitation events and the area experienced minimal damage during Hurricane Igor in 2010 (Government of Newfoundland and Labrador, 2011).

[57] See http://www.pievc.ca/e/doc_list.cfm?dsid=45

[58] See http://www.scc.ca/sites/default/files/migrated_files/2011-12-22-NISI_ProgramBackgrounder_FinalDraft.pdf. The establishment of NISI was in response to recommendations from NRTEE's 2009 Report T*rue North: Adapting Infrastructure to Climate Change in Northern Canada.*

contribute to the development and application of several new standards reflective of climate impacts. Though the project is just getting underway, its outcomes will be of interest to both policy-makers and industry participants, not only for their potential impact in Northern Canada, but for their potential application to other jurisdictions.

3.2.3 Additional Tools and Resources

In partnership with the Federation of Canadian Municipalities, the CSA Group offers an online course entitled *Adapting Your Infrastructure to Climate Change*[59] for municipal staff, elected officials and service providers (CSA Group, 2011). Though the course does not advocate for changes to CSRIs per se, it is an important tool from one of the foremost standard-setting organizations directly targeted at practitioners and policy-makers. The CSA Group also offers a course on *Protecting Critical Infrastructure: Risk Management and Emergency Response Planning* focused on a number of vulnerabilities and interdependencies, including those related to natural disasters.[60]

The Canadian Institute of Planners has similarly developed a series of training modules and guides aimed at bringing adaptation strategies and tools to professional planners.[61] CIP has also recently developed a *Model Standard of Practice for Climate Change Planning* as an introduction to climate change planning and a framework for organizing an effective response.[62] The Federation of Canadian Municipalities also has a dedicated resource centre on adaptation relevant to infrastructure at the local level, including several adaptation planning guides, risk management and assessment tools, and case study examples, particularly those related to water management.[63]

3.3 Markets, Financial Incentives and Liability Rules

Though a review of the literature indicates that there is as yet only limited application of financial incentives to address risk and vulnerability in the context of climate change, insurance and liability changes (among other market mechanisms) are often cited as critical to incentivize adaptation; and thus merit brief discussion here.

The insurance (and re-insurance) industry has been active in efforts to quantify climate impacts in economic terms. For example, in March 2013 Swiss Re (2013) released its *Sigma* report on natural catastrophes and man-made disasters, detailing how large-scale weather events in the United States pushed the total global insured claims from natural catastrophes to USD$71 billion in 2012, making it the third most expensive year on record. The Insurance Bureau of Canada has been undertaking similar studies, releasing a 2012 report, *Telling the Weather Story*,[64] and continuing with efforts to quantify the economic impacts of climate change-related events. Additional climate modelling and research from the insurance industry has also been critical in providing data to substantiate policy changes in support of adaptation.[65]

[59] See http://shop.csa.ca/en/canada/infrastructure-solutions/adapting-your-infrastructure-to-climate-change/invt/2703207wt/

[60] See http://shop.csa.ca/en/canada/infrastructure-solutions/protecting-critical-infrastructure-risk-management-and-emergency-response-planning/invt/500523812011&bklist=icat,4,shop,learning-institute,infrastructuretrain

[61] See www.planningforclimatechange.ca

[62] See http://www.planningforclimatechange.ca/wwwroot/Docs/Library/CIPReports/CIP%20STANDARD%20OF%20PRACTICE(ENGLISH).PDF

[63] See http://www.fcm.ca/home/issues/environment/climate-change-adaptation/adaptation-resources.htm

[64] See http://www.ibc.ca/en/Natural_Disasters/documents/McBean_Report.pdf

[65] For example, Swiss Re's proprietary storm-surge model shows has also shown that, assuming a 10-inch rise in sea levels by 2050, the frequency of events like Hurricane Sandy are likely to increase in the future.

In Organisation for Economic Co-operation and Development countries with a well-established insurance and re-insurance sector, the industry also has an active role to play in incentivizing (or disincentivizing) certain actions, especially related to key infrastructure decisions. Intact Insurance funded the University of Waterloo's *Climate Change Adaptation Project*, which outlined various ways in which insurers can encourage risk-reducing behaviour by home and building owners, including: "adjusting the price charged for insurance coverage and deductibles, caps on the amount that policyholders will be paid for damage, excluding certain types of damages from insurance coverage, and cancelling insurance policies" (Sandink & McGillivary, 2012). It was also noted that insurers can offer premium discounts or apply other price signals to incentivize a range of adaptation practices, including, for example, the use of "better than code" construction materials/practices.

Similarly, the Institute for Catastrophic Loss Reduction (ICLR) was established by Canada's property and casualty insurance industry as an independent academic and policy institute. ICLR's work is focused on three programs: *RSVP* cities (resilient, sustainable, vibrant and prosperous cities);[66] *Designed…for Safer Living* (safer design and construction of buildings);[67] and Open for Business (disaster risk reduction for small business).[68] Through this work, ICLR aims to inform ongoing updates of provincial and national building codes, municipal bylaws and current construction practices.

Similar to insurance tools, taxation provides an opportunity to promote risk-reducing behaviour. Grants and other financial instruments could also be used, much the same way that existing programs like the *Green Home Program*[69] of the Canadian Mortgage and Housing Corporation provides loan insurance for buying an energy-efficient home or undertaking retrofits. Though these approaches have yet to be put to use within Canada to encourage adaptation to climate change (Sandink & McGillivary, 2012), this may well change in the coming years as a number of adaptation plans continue to be developed and implemented in various jurisdictions.

3.4 Industry Responses

A number of actors in the concrete industry outside of Canada have shown leadership in addressing adaptation issues, particularly within the context of broader sustainability initiatives. For industries that also have a strong role to play in reducing emissions, closely linking mitigation and adaptation (such as in the context of green buildings, energy-efficiency standards, and so forth) is beneficial to ensuring the potential co-benefits associated with a coordinated approach to low-carbon, climate-resilient development can be maximized. While a wide range of sectors are involved in the varied infrastructure reviewed in this report, this section focuses on the activities of the cement sector in particular. While many of the initiatives below are notable, much stronger connections can be made to foster adaptation in both policy and practice.

Internationally, the World Business Council for Sustainable Development's *Cement Sustainability Initiative*[70] has helped frame a dialogue around the role of the industry in contributing to sustainable development—most notably in terms of a sectoral approach to mitigation. A number of performance indicators have also been developed, ranging from emissions reporting to biodiversity and community engagement. Such a process provides an opportunity for additional indicators to be considered—including those related to climate resiliency—both in terms of the production and use of cement in various infrastructure.

[66] See http://www.iclr.org/communities/rsvpforcities.html
[67] See http://www.iclr.org/homeowners/newhomes.html
[68] See http://www.iclr.org/businesses/openforbusinesstm.html
[69] See http://www.cmhc.ca/en/co/moloin/moloin_008.cfm
[70] See http://www.wbcsdcement.org/

In Europe, a number of industry actors have been engaged in similar discussions, in many cases more discretely linking adaptation and climate resiliency. The Mineral Products Association has established the *Sustainable Concrete Forum*,[71] focusing on key areas of sustainable consumption and production, climate change and energy, natural resource protection and the creation of sustainable communities. This includes the development of a *Material and Resource Efficiency Programme* to inform best practice across the life cycle of concrete in the built environment, within which the climate resiliency of such infrastructures could be considered.

The *European Concrete Platform*[72] is similarly focused on several sustainability initiatives, including promoting the use of advanced building codes (such as EuroCode 2) and some adaptation considerations in the use of concrete, such as durability and robustness during extreme events.[73] The European Cement Association (Cembureau) has released a briefing note explicitly focused on adaptation and the role of cement therein.[74] It has also engaged in the policy-making process by providing public input on the development of the *EU Adaptation Strategy*.[75] The response noted that any policies should support long-term thinking and life-cycle analysis when considering solutions for infrastructure—an important consideration in the Canadian context as well.

In the United States, fewer direct links are being made to adaptation in industry responses, though some space has been made nonetheless. US Concrete has focused on elements of sustainable construction in its outreach, including related to water management and durability in cases of extreme events. The Portland Cement Association has also produced materials on the *Top 10 Reasons to Use Concrete in Sustainable Design*,[76] though, similarly, no explicit links to adaptation have been made. The association has also produced a number of technical briefs on resiliency-relevant topics, including stormwater management through the use of pervious concrete, permeable paver systems and green roofs.

Finally, the US Green Concrete Council has produced the *Sustainable Concrete Guide—Strategies and Examples*,[77] which provides an overview on specific strategies for the best use of concrete in high-performance and long-lasting green buildings. The guide includes chapters on resiliency to climate change and compatibility with other sustainability strategies. Other related sustainability protocols, such as LEED Certifications, can also have positive impacts in terms of sensitizing industries to the potential climate resiliency benefits of sustainable materials.

[71] See http://www.sustainableconcrete.org.uk/
[72] See http://www.europeanconcrete.eu/
[73] See http://www.europeanconcrete.eu/images/stories/publications/Executive_Summary.pdf?phpMy Admin=16bbb563ca 43adfed14bd78eb7d8cd8a
[74] See http://www.cembureau.eu/sites/default/files/documents/CC.pdf
[75] See http://www.cembureau.be/cembureau-response-eu-adaptation-strategy
[76] See http://www.cement.org/newsroom/AIA08/Top_Ten.htm
[77] See http://www.usgreenconcretecouncil.com/

4.0 Conclusions

Based on this review of the vulnerability of Canada's built infrastructure to climate change and actions that are being taken by governments and industry representatives to mitigate these risks, four general conclusions are identified:

- **Climate change has the potential to substantially affect the effectiveness and lifespan of infrastructure in Canada, particularly in transportation, buildings, marine and water management infrastructure**. The exposure and vulnerability of these different types of infrastructure varies greatly. Collectively, though, substantial economic costs have already been attributed to the impact of climate hazards on such infrastructure, and these costs are only expected to increase in the future.
- **Adaptive measures can be taken to limit costs and strengthen the resiliency of infrastructure**. A number of key policy, regulatory and financial tools have been identified as "enabling factors" in supporting the deeper integration of climate change considerations into infrastructure decision-making, design and maintenance.
- **While a great deal of research and planning has been done, most supporting policies and regulatory changes remain nascent, and investments have not yet fundamentally shifted**. Despite notable progress in recent years, many adaptation responses remain elusive or underutilized, and investment decisions are not yet being substantially driven by the need to reduce vulnerability to the impacts of climate change. While the scale of response is not yet commensurate with the challenges posed by climate change, there is an ever-growing recognition of the need to rethink investment choices to further incentivize adaptation and capture the benefits of low-carbon, climate-resilient development.
- **The current state-of-play provides a key opportunity for industry actors to engage in the further development and implementation of effective approaches to support climate-resilient development**. Adaptation is a dynamic, context-specific and often long-term process that requires sustained efforts from a variety of actors. Recent events have further galvanized calls for action at the local, regional and national levels; and a number of points of entry into the discussion can be identified across various sectors.

Works Cited

Adger, W. A. (2007). Assessment of adaptation practices, options, constraints and capacity. In M. C. Parry, *Climate change 2007: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (pp. 717–743). Cambridge: Cambridge University Press.

Alberta Environment and Sustainable Resource Development. (2013). *Business plan 2013–2016 Accountability statement*. Edmonton: Government of Alberta.

Arlington Group Planning & Architecture Inc., e. a. (2013). *Sea level rise adaptation primer: A toolkit to build adaptive capacity on Canada's south coasts*. Victoria: British Columbia Ministry of the Environment.

Buchele, M. & Henry, T. (2013, May 14). New movement on funding state water plan. *StateImpact: Texas*. Retrieved from http://stateimpact.npr.org/texas/2013/05/14/new-movement-on-funding-state-water-plan/

Canada Council of Professional Engineers. (2008). *Adapting to climate change: Canada's first national engineering vulnerability assessment of public infrastructure*. Retrieved from http://www.pievc.ca/e/Adapting_to_climate_Change_Report_Final.pdf

Canadian Press. (2012, July 29). Climate change plan easy for bureaucrats to ignore. *CBC News*. Retrieved from http://www.cbc.ca/m/touch/politics/story/2012/07/29/pol-environment-canada-bureaucrats-climate-change-plan.html

Concrete Sustainability Hub. (2013). *Life cycle assessment research brief: Quantitative assesment of resilience in Residential Building Envelope System*. Cambridge, MA: MIT.

Cranfield University. (2012). *Evaluating the risk assessment of adaptation reports under the adaptation reporting power: Final summary*. Cranfield: Centre for Environmental Risks and Futures.

CSA Group. (2011). *Adapting your infrastructure to climate change*. Retrieved from http://shop.csa.ca/en/canada/infrastructure-solutions/adapting-your-infrastructure-to-climate-change/invt/2703207wt/

CSA Group. (2012). *National survey of Canada's infrastructure engineers about climate change*. Toronto: CSA Group for Engineers Canada.

Defra. (2013, May 7). *Adapting to climate change*. From Adaptation Reporting Power. Retrieved from https://www.gov.uk/government/policies/adapting-to-climate-change/supporting-pages/adaptation-reporting-power

Engineers Canada. (2013). *Infrastructure climate risk assessment backgrounder.* Ottawa: Engineers Canada.

Environment Canada (2005): Adjusted historical Canadian climate data. Environment Canada, Meteorological Service of Canada, Climate Research Branch. Retrieved from http://www.cccma.bc.ec.gc.ca/hccd/

Environment Canada. (2010, October). *Planning for a sustainable future: A federal sustainability development strategy for Canada*. Retrieved from http://www.ec.gc.ca/dd-sd/default.asp?lang=En&n=F93CD795-1

Environmental Comissioner of Ontario. (2012). *Ready for change? An assessment of Canada's climate change adaptation strategy.* Toronto: ECO.

Executive Office of the President. (2013). *The president's climate action plan*. Retrieved from http://www.whitehouse.gov/sites/default/files/image/president27sclimateactionplan.pdf

Federation of Canadian Municipalities. (2005). *Managing infrastructure assets*. Ottawa: FCM.

Felio, G. (2012). *Canadian infrastructure report card. Volume 1: Municipal roads and water systems.* Published jointly by the Canadian Construction Association, Canadian Public Works Association, Canadian Society for Civil Engineering and Federation of Canadian Municipalities. Retrieved from http://www.fcm.ca/Documents/reports/Canadian_Infrastructure_Report_Card_EN.pdf

Fellow, A. (2013, April 12). Obama budget would help prepare for climate impacts. *Bloomberg*. Retrieved from http://www.bloomberg.com/news/2013-04-12/obama-budget-would-help-prepare-for-climate-impacts-.html

Government of British Columbia. (2003). *Firestorm report*. Retrieved from http://bcwildfire.ca/History/ReportsandReviews/2003/FirestormReport.pdf

Government of Canada. (2010). *Fifth National Communication on Climate Change*. Retrieved from http://unfccc.int/resource/docs/natc/can_nc5.pdf

Government of Canada. (2011a). *Canada's ongoing commitment to climate change adaptation*. Gatineau: Environment Canada.

Government of Canada. (2011b). *Federal adaptation policy framework*. Gatineau: Environment Canada.

Government of New Brunswick. (2012). *New Brunswick and climate change: Solid foundation in climate change action.* Fredericton, New Brunswick.

Government of Newfoundland and Labrador. (2011). *Climate change action plan*. St John's, NL: Office of Climate Change, Energy Efficiency and Emissions Trading.

Government of the Northwest Territories. (2008). *NWT climate change impacts and adaptation report.* Yellowknife, NWT: Environment and Natural Resources.

Governments of Nunavut, Northwest Territories and Yukon. (2009). *Pan-territorial adaptation strategy*. Governments of Nunavut, Northwest Territories and Yukon.

Government of Quebec. (2012). 2013-2020 *government strategy for climate change adaptation*. Retrieved from http://www.mddefp.gouv.qc.ca/changements/plan_action/stategie-adaptation2013-2020-en.pdf.

IISD. (2012). *Adaptive policy analysis of drought and excess moisture programmes in Manitoba: 2012 pilot application.* Report Prepared for the Manitoba Government Prairie Regional Adaptation Collaborative. Retrieved from http://www.parc.ca/rac/fileManagement/upload/MB_DEM_Adaptive_Policy_AnalysisSummary_Report_June_2012.pdf

IMG-Golder Corporation Environmental Consulting. (2012, March). *Nunavut Regional Adaptation Collaborative: Vulnerability assessment of the mining sector to climate change*. Task 1 Report No. 11-1334-0020. Retrieved from: http://www.nwtclimatechange.ca/sites/default/files/Vulnerability_Assessment_Nunavut_Mining.pdf

Infastructure Canada. (2006). *Adapting infrastructure to climate change in Canada's cities and communities*. Ottawa: Government of Canada.

Institute for Catastophic Loss Reduction. (2012). *Telling the weather story*. Toronto: Insurance Bureau of Canada.

Intergovernmental Panel on Climate Change. (2012). Glossary of terms. In Field et al. (Eds), *Managing the risks of extreme events and disasters to advance climate change adaptation.* A special report of Working Groups I and II of the Intergovernmental Panel on Climate Change (IPCC) (pp. 555–564). New York: Cambridge University Press.

Kelly, G., Kovacs, P. & Thistlewaite, J. (2012). Insurance: Adapting building codes for climate change. In B. Feltmate, & J. Thistlewaite (Eds.), *Climate change adaptation: A priorities plan for Canada*. Report of the Climate Change Adaptation Project. Waterloo: University of Waterloo.

Kharin, V. V. & Zwiers, F. W. (2000). Changes in extremes in an ensemble of transient climate simulations with a coupled atmosphere-ocean GCM. *Journal of Climate, 13*, 21, 3760–3788.

Lemmen, D. & Warren, F. (Eds.) (2004). *Climate change impacts and adaptation: A Canadian perspective.* Ottawa: Natural Resources Canada.

Manitoba 2011 Flood Review Task Force (2013). *Final Report to the Minister of Infrastructure and Transportation*. Retrieved from: http://www.gov.mb.ca/asset_library/en/2011flood/flood_review_task_force_report.pdf

Natural Resources Canada. (2007). *From impacts to adaptation: Canada in a changing climate*. Ottawa: Government of Canada.

Nelson, F. E., Anisimov, O. A. & Shiklomanov, N. I. (2002). Climate change and hazard zonation in the circum-Arctic permafrost regions. *Natural Hazards, 26*, 3, 203–225.

Nettler, J. (2013, March 16). Obama to expand NEPA reviews to consider climate change. *Planetizen*. Retrieved from http://www.planetizen.com/node/61252

NYC Office of the Mayor. (2013). Mayor Bloomberg, HUD Secretary Donovan and Senator Schumer announce federal approval of city's plan for nearly $1.8 billion in Hurricane Sandy Recovery Initiatives. Press Release. Retrieved from http://www.nyc.gov/portal/site/nycgov/menuitem.c0935b9a57bb4ef3daf2f1c701c789a0/index.jsp?pageID=mayor_press_release&catID=1194&doc_name=http%3A%2F%2Fwww.nyc.gov%2Fhtml%2Fom%2Fhtml%2F2013a%2Fpr159-13.html&cc=unused1978&rc=1194&ndi=1

Prince Edward Island Department of Environment, Labour and Justice. (2011). *Saltwater intrusion and climate change: A primer for local and provincial decision-makers*. Retrieved from http://atlanticadaptation.ca/sites/discoveryspace.upei.ca.acasa/files/Saltwater%20Intrusion%20and%20Climate%20Change%20in%20Atlantic%20Canada.pdf

Public Safety Canada (2005): Canadian disaster database. Retrieved from http://www.ps-sp.gc.ca/res/em/cdd/search-en.asp.

Sandink, D. & McGillivary. (2012). Insurance: Tools to promote adaptation by existing homeowners. In B. Feltmate, & J. Thistlewaite (Eds), *Climate change adaptation: A priorities plan for Canada. Final Report of the Climate Change Adaptation Project.* Waterloo: University of Waterloo.

Simonovic, S. P. (2011). *The City of London: Vulnerability of infrastructure to climate change*. London, ON: University of Western Ontario.

Standards Council of Canada. (2012). *The Northern Infrastructure Standardization Initiative (NISI): Integrating adaptation into codes and standards for Northern infrastructure*. Ottawa: SCC.

UMA Engineering Ltd. (2005). *City of Peterborough flood reduction master plan*. Engineering Report. Retrieved from http://www.peterborough.ca/Assets/City+Assets/Flood+Reduction/Documents/Flood+Documents/Flood+Reduction+Master+Plan.pdf

United Nations Office for Disaster Risk Reduction. (2011). *Global assessment report on disaster risk reduction*. New York: United Nations .

Weiss, D. & Weidman, J. (2013). *Disastrous spending: Federal disaster-relief expenditures rise amid more extreme weather.* Washington, D.C.: Center for American Progress.

Yukon Government. (2012). *Yukon Government Climate Change Action Plan: Progress report*. Retrieved from http://www.env.gov.yk.ca/publications-maps/documents/ccap_progressreport_eng_2012.pdf

Annex I: Likelihood of Future Trends in Climate Extremes

PHENONMENON AND DIRECTION OF TREND	LIKELIHOOD THAT TREND OCCURRED IN 20TH CENTURY (TYPICALLY POST-1960)	LIKELIHOOD OF FUTURE TRENDS FOR THE 21ST CENTURY BASED ON PROJECTIONS USING IPCC SCENARIOS
Warmer and fewer cold days and nights over most land areas	Very likely	Virtually certain
Warmer and more frequent hot days and nights over most land areas	Very likely	Virtually certain
Warm spells/heat waves: frequency increases over most land areas	Likely	Very likely
Heavy precipitation events: frequency increases over most areas	Likely	Very likely
Area affected by droughts increases	Likely in some regions since 1970s	Likely
Increased incidence of extreme high sea level (excludes tsunamis)	Likely	Likely

Source: Institute for Catastrophic Loss Reduction (2012)

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