CHAPTER 9: **ADAPTATION: LINKING RESEARCH AND PRACTICE**

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KEY FINDINGS

Since 2008, climate change adaptation research and practice in Canada has been characterized by increasing engagement, diversity and complexity. Understanding of the adaptation process has improved, more groups are involved in adaptation discussions and a growing number of adaptation activities are documented. This progress leads to the following conclusions:

- Adaptation is being undertaken in Canada to achieve a range of goals, such as increasing capacity to adapt, improving resilience to specific climate events (especially extremes), and enhancing ability to thrive under different climate conditions. Among sectors, those with a demonstrated high sensitivity and exposure to climate and weather are generally most active in taking steps to understand, assess and manage vulnerability and risk related to climate change.
- Adaptation is not solely a local issue, although examples from the municipal level still predominate. There are examples of action by all levels of government, as well as community groups and industry, many of which represent collaborative initiatives.
- Understanding of the barriers and challenges to adaptation has improved, with recognition that factors beyond the basic determinants of adaptive capacity need to be addressed in order to increase the will to adapt and the success of adaptation measures. These include consideration of values and risk perception in framing problems and identifying solutions. As a result, understanding of how to overcome key barriers and enable adaptation has improved.
- At present, undertaking planning and policy exercises, building capacity and raising awareness comprise much of the adaptation action documented, with relatively few examples of implementation of specific changes to reduce vulnerability to future climate change, or take advantage of potential opportunities. As such, adaptation implementation in Canada is still in its early stages.
- Several factors can help accelerate the transition between awareness and action, including strong leadership and effective champions, targeted awareness-raising and supportive strategies or policies. Experiencing extreme events, as well as observing impacts of gradual changes (e.g. sea level rise) also stimulate adaptation.

1. INTRODUCTION

The concept of adaptation has evolved since it was first recognized as a potential response to climate change in the 1990s, and attitudes have shifted such that adaptation is now viewed as an essential complement to the reduction of greenhouse gas emissions (Klein et al., 2007; Lemmen et al., 2008). Within the research community, focus has expanded beyond biophysical impacts, accompanied by lists of possible adaptation options, to studies that investigate the process of adaptation from a variety of perspectives (e.g. social, environmental, economic and psychological; e.g. Burch and Robinson, 2007; Jantarasami et al., 2010; Berang-Ford et al., 2011; Gifford, 2011; Brisley et al., 2012; O'Brien, 2012). In Canada, several organizations have specific mandates to generate and deliver adaptation knowledge, and all levels of government are beginning to develop and implement adaptation strategies, plans and policy frameworks (e.g. City of Toronto, 2007; Government of Canada, 2011; Government of Quebec, 2012). Engagement has broadened to encompass government, industry, non-governmental organizations and individuals, with mounting recognition that all have responsibility for adaptation action.

Despite these advances, there are few documented examples of adaptation being implemented specifically to reduce vulnerability to future climate conditions. Over recent years, a growing body of research has examined the barriers and challenges to adaptation that are preventing or constraining action. These barriers stem from issues such as information, resources, governance and values. At the same time, knowledge has increased on how to facilitate effective adaptation by enhancing awareness and the will to adapt, building capacity and creating an enabling environment.

This chapter examines the current status of adaptation in Canada with respect to both research and practice, based on scientific and grey literature. Section 2 examines where we were in 2007, at the time of the last assessment (Lemmen et al., 2008), while Section 3 presents a review of international approaches to adaptation. Section 4 examines how we have progressed in Canada since 2007, through discussion of changes in research, engagement, action on adaptation and understanding of barriers. Overcoming barriers and facilitating action are discussed in Section 5. Case studies are incorporated throughout the chapter to expand on a range of issues.

2. PREVIOUS ASSESSMENTS

'From Impacts to Adaptation: Canada in a Changing Climate 2007' (Lemmen et al., 2008) concluded that although still in early stages, adaptation was occurring, to differing degrees, in every region of the country. Although the definition of adaptation was broad – encompassing any activity, initiative or intention to enhance resilience to current or future climate variability or change – the assessment did demonstrate the growing importance of adaptation for different groups, including communities, higher levels of government (provincial/territorial and federal), industry (associations and companies) and professional organizations. A high potential to adapt was evident for Canada as a whole, although regional disparities relating to differing levels of exposure, sensitivity and capacity were highlighted, as was the observation that high adaptive capacity does not always translate to effective adaptation. Similar conclusions were drawn in the IPCC Fourth Assessment Report (Field et al., 2007).

For the most part, Lemmen et al. (2008) discussed adaptation in the context of potential options, strategies or needs, but it also included examples of adaptation initiatives deployed in response to a climate-related event or a current or perceived risk. For example, the City of Regina introduced drought contingency plans after experiencing the impacts of the 1988 drought (Sauchyn and Kulshreshtha, 2008), while the city of Toronto developed a Hot Weather Response Plan in response to more frequently occurring heat waves (Chiotti and Lavender, 2008). In Quebec, design criteria for electrical transmission facilities were revised after the 1998 ice storm in order to reduce vulnerability to severe weather events (Bourque and Simonet, 2008). Observations of changing risks also led to adaptation; for instance, elevating buildings on pylons in coastal regions to reduce damages from storm surge flooding (Vasseur and Catto, 2008), and winter tourism operators on the Prairies diversifying their activities to add summer recreational opportunities (Sauchyn and Kulshreshtha, 2008). These examples demonstrated that

adaptation to climate change does not necessarily involve detailed consideration of changes in climate parameters or precise predictions. Instead, it can be based on simple assumptions that climate-related events (e.g. storms, floods and droughts), temperature increases, and sea-level rise impacts (erosion and flooding) will recur, continue and/or increase in frequency and severity in the future.

The 2008 Assessment also highlighted the role of detailed climate projections as requirements for some types of adaptation implementation. Useable and accessible data on future climate (e.g. temperature, precipitation) and sea level are often required by engineers and resource managers, for example, to determine timely, appropriate and cost-effective adaptation. For instance, data of past trends and future climate projections may be needed to inform decisions on upgrading and replacing infrastructure (such as pipelines, culverts and structures for shoreline protection), planning for hydroelectric facility placement and renovation, and selecting tree species for forestry operations. Lack of availability of such information was identified by practitioners as a barrier to adaptation.

There were many examples of initiatives that served to enhance overall resilience, or build capacity to adapt, while not addressing impacts from specific changes in climate. Often referred to as 'no-regrets' or 'win-win' options designed to bring benefits regardless of climate outcomes, examples include improving water- and energy-use efficiency, diversifying economic activities in resource-dependent communities, and addressing underlying issues that make populations vulnerable (e.g. poverty, poor health status, and limited access to information and education).

Adaptation was being considered and undertaken by many different actors, including individuals and households, business and industry, community organizations, and governments at all levels (municipal, provincial, territorial, federal) (*see* Table 2 in Burton, 2008). Municipal governments appeared to be the most active on adaptation (Field et al., 2007; Lemmen et al., 2008), with action primarily triggered by observed damages from past climate-related events (e.g. floods, droughts, heat waves) and also by policy initiatives from higher levels of government that encouraged or required the development of adaptation plans or strategies. Examples of adaptation by industry and business were limited, with climate change adaptation just starting to appear on the agendas of industry and professional organizations (Burton, 2008) and some evidence of investments in adaptation being made (Field et al., 2007). For industry, motivation for adaptation included protecting investments, reducing risks and enhancing corporate reputation (Burton, 2008).

Although many of the chapters in the 2008 Assessment recommended that adaptation be mainstreamed, evidence of this occurring was limited. Mainstreaming refers to integrating climate change into existing decision-making processes, with the goal that climate change be considered in all decisions that are sensitive to climate. Mainstreaming is also sometimes referred to as 'policy integration'. Risk management approaches were also often recommended in the 2008 report. These approaches include a series of steps, ranging from preliminary analysis, to risk estimation and evaluation, to risk controls, then action and monitoring (Bruce et al., 2006), and were presented as an effective approach to decision making under the uncertainty inherent in climate change.

3. INTERNATIONAL CONTEXT

An exploration of the research on the status of adaptation at the international level provides important context for assessing the situation in Canada. Several papers have examined international adaptation policies and approaches by analyzing, for example, the types of adaptation being considered (Ford et al., 2011), the existence and role of adaptation plans and strategies (Biesbroek et al., 2010; Preston et al., 2010; Bauer et al., 2012) and trends in adaptation planning and implementation (Gagnon-Lebrun and Agrawala, 2007).

From this research, a common conclusion can be drawn: adaptation implementation is in the early stages in most, if not all, developed countries. Research and understanding of adaptation policies, plans and strategies have advanced considerably over the last 5 to 10 years, yet relatively few examples of adaptation implementation have been documented (Biesbroek et al., 2010; Lesnikowski et al., 2011; Bauer et al., 2012; Webb and Beh, 2013). Common challenges associated with moving adaptation from the planning to the implementation stage include dealing with uncertainties, coordinating adaptation effectively across sectors and different levels of government, and making adaptation a priority for decision makers (OECD, 2012). Inadequate funding and budgets for adaptation were also cited as key implementation challenges (Bauer et al., 2011). The paucity of examples of adaptation implementation may, in part,

reflect lag times between action, research and publication, and the lack of established, standard mechanisms for monitoring and measuring adaptation progress (OECD, 2012).

Many countries, including Australia, Germany, the UK and Norway have developed national adaptation strategies, which are generally non-binding frameworks that guide public adaptation policies. National adaptation strategies tend to focus on advancing adaptation by promoting the production and dissemination of data and information, and by identifying priorities for adaptation. Mechanisms to support framework priorities include guidelines for coordination among government departments, a centralized coordination body for developing and implementing the framework, a commitment to improve scientific knowledge integration (e.g. through assessments), and a standing scientific advisory committee that can provide ongoing information and advice to policy decision making (Bauer et al., 2012). Although lacking national adaptation strategies, the OECD (2012) identifies Canada, New Zealand, Slovenia, Sweden and United States as developed countries active on adaptation.

In a review of 7 European adaptation strategies, Biesbroek et al. (2010) concluded that the strategies are useful in that they signal a political commitment on the issue of climate change, but have not yet necessarily translated to adaptation implementation. This is supported by the European Commission itself, which states that although 15 Member States have developed national adaptation strategies, and others are in development, there are "relatively few concrete [adaptation] measures on the ground" (European Commission, 2013). The European Union has now developed a European adaptation strategy, which encompasses all Member States, and complements the national-level strategies.

Although legislated mandates for climate change adaptation are rare, some examples exist. The United Kingdom's Climate Change Act provides for an Adaptation Sub-Committee within the larger climate change scientific advisory committee, and requires that climate change risk assessments and the National Adaptation Programme be renewed every 5 years (Committee on Climate Change, n.d.). As a result, all departments in the UK have a departmental adaptation plan and the UK Treasury provides guidance on climate change adaptation. The government is also able to require reporting on adaptation initiatives by suppliers of public services (e.g. potable water, electricity), with almost 90 organizations providing reports during the first round (Committee on Climate Change, n.d.). Even with legislated requirements for adaptation, the transition from planning to implementation is constrained by challenges, such as evaluation and funding (Boyd et al., 2011). Other examples include the Delta Act of the Netherlands, which requires adaptation initiatives related to water management (e.g. flood safety and freshwater supply) (Delta Programme Commissioner, n.d.) and Norway's requirement that municipalities include climate change risk and vulnerability analysis in their spatial planning. The European Commission has indicated that if progress on adaptation action is not sufficient by 2017, they will consider a legally binding instrument (European Commission, 2013).

4. STATUS OF ADAPTATION IN CANADA

In Canada, engagement on adaptation by different groups has increased significantly since the 2008 Assessment. For the most part, however, the many initiatives being undertaken to build Canadians' capacity to adapt have yet to be evaluated or their lessons synthesized in scientific literature. Agreed-upon methods to track and measure actions taken to reduce climate change risk and vulnerability do not yet exist, which prevents meaningful comparisons across sectors. Nevertheless, by linking research and practice, an improved understanding of adaptation as a process is emerging.

4.1 RESEARCH AND PRACTICE

Adaptation is increasingly becoming a subject of scientific research and applied analysis. Canadian research on adaptation is being undertaken by a growing number of academic disciplines, exploring a range of sectors and problems (*see* Box 1). Knowledge for adaptation also comes from government-sponsored regional and sectoral assessments of impacts, vulnerability and climate-related risk (e.g. Séguin, 2008; Williamson et al., 2009; Desjarlais and Blondlot, 2010; Crawford and MacNair, 2012), from organizations with the specific mandate to produce this knowledge (e.g. Ouranos, Pacific Climate Impacts Consortium, Ontario Centre for Climate Impacts and Adaptation Resources and the Prairie Adaptation Research Collaborative) and from government programs (e.g. Natural Resources Canada, 2012, Environment Canada, 2013). University research groups and private consulting firms are filling an emerging demand for applied analysis, including undertaking targeted climate change risk assessments (OCCIAR, 2013) and developing compendia of case studies and tools (Nelitz et al., 2013).

Although efforts to understand climate impacts and vulnerabilities remain important, discussions on adaptation

BOX 1

TRENDS IN CANADIAN ADAPTATION RESEARCH

Many research disciplines contribute to generating information and knowledge that support adaptation planning. To identify broad trends in adaptation research between 2000 and 2012, a structured review of academic articles published by researchers from Canadian research bodies was undertaken, using methods in MacLellan (2008). An initial database search resulted in 743 articles of potential relevance, subsequently narrowed to 428 articles of direct relevance to climate change adaptation planning. Articles were categorized according to five factors: (1) sectors; (2) climate hazards addressed; (3) academic disciplines; (4) theory and methods employed (e.g. climate and impact modeling, vulnerability assessment, participatory methods, cost benefit analysis); and (5) geographic or ecosystem focus. Analysis led to the following conclusions:

- The rate of publication on climate change adaptation has grown exponentially. Between 2000 and 2012, the number of climate change adaptation articles published by researchers associated with Canadian institutions increased almost tenfold, exceeding trends in overall publication rates in all fields of study.
- Research publications on climate change adaptation are increasingly diverse, as suggested by the number of journals publishing articles about adaptation for the first time. In 2007, 13 journals published articles on climate change adaptation by researchers associated with Canadian institutions for the first time; the number of journals doing so in 2012 was 32.
- Sectoral coverage of adaptation research is also increasing. Figure 1 shows the distribution of research articles by sector for two time periods. Between 2000 and 2007, the top three sectors studied were water management, agriculture and the forest sector. After 2007, publications addressing health adaptation increased significantly; this sector is now among the top three studied. Coverage of all sectors, except for water management and transport, increased from one period to another.
- The Arctic has been a major focus of adaptation research. Further, research associated with the Arctic picked up significantly after 2005, likely a combined effect of the generation and dissemination of research for the Arctic Climate Impact Assessment (ACIA, 2005) and subsequent research investments through the International Polar Year (e.g. Kulkarni et al., 2012) and ArcticNet[1].

Trends in research methods are difficult to discern, as they are discipline and sector-specific. Three general points are worth noting from the analysis:

1. Adaptation research in the Arctic stands out as being highly inter-disciplinary, integrative and participatory. Subsistence and natural resource harvesting predominates as a research focus (40% of Arctic articles with a sectoral focus), followed by health (23%) and ecosystem conservation (10%). Arctic research also makes heavy use of surveys and participatory methodologies, and integrates social and cultural aspects of climate change adaptation with impacts modeling.
2. Although many articles refer to funding and financial resources as important in adaptation planning, fewer than 10 articles specifically analyzed the costs and benefits of adaptation (e.g. Crowe and Parker, 2008; Samarawickrema and Kulshreshtha, 2008; Lantz et al., 2012; Ochuodho et al., 2012). A direct focus on the assessment and selection of adaptation options using economic tools was absent.
3. An increase is apparent in the number of studies using quantitative methods, such as citation analysis and content analysis, to integrate and analyze research. Seven percent of all articles we assessed could be considered systematic reviews, some of which have direct relevance to specific policy questions (e.g. Hewitt et al., 2011).

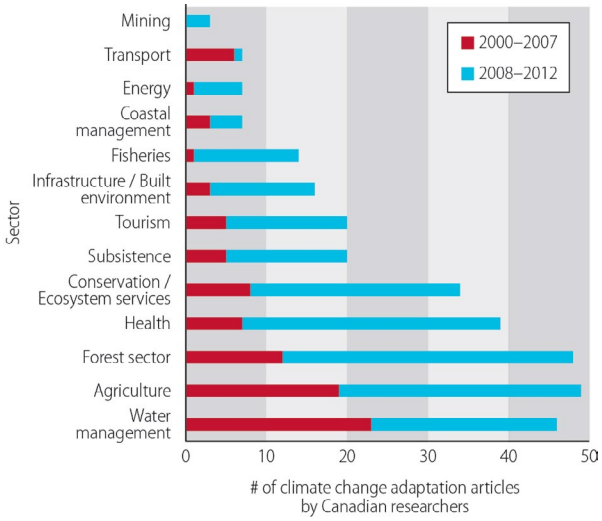

FIGURE 1: Number of climate change adaptation articles by Canadian researchers by sector (2000-2012).

This analysis is limited by its focus on the volume of academic literature. Despite this limitation, it does provide a snapshot of the evolving research capacity in support of adaptation in Canada. Expanding trend analysis to include grey literature and consideration of research uptake by decision makers would be useful.

have evolved from whether to adapt, to how to adapt. Building on pioneering work on adaptation policy and decision-making frameworks (e.g. Willows and Connell, 2003; Lim and Spanger-Siegfried, 2005), numerous Canadian guides and templates describing the adaptation process are now available (e.g. Quebec Ministry of Public Security, 2008; Natural Resources Canada, 2009; Jackson et al., 2011; CREXE, 2012), some of which are highly context-specific (Gleeson et al., 2011). Based on broad patterns across existing frameworks, along with observed adaptation activities undertaken by Canadian organizations, a generic adaptation process of awareness, preparation, implementation and iterative learning is proposed (*see* Box 2). Governments, often on a partnered basis, have implemented a range of initiatives to understand how adaptation occurs among different groups and to encourage further action. These include pilot activities (e.g. surveillance systems for heat-related illnesses; Chapter 7 – Human Health, Rodgers and Behan, 2012, Regional Adaptation Collaboratives Program, Natural Resources Canada, 2013a), case studies and best practices

BOX 2

THE ADAPTATION PROCESS

Like any process involving changes in thinking and practice, adapting to a changing climate involves deepening levels of engagement (phases) and actions that can be taken in support of decision making (steps). Figure 2 summarizes these phases and steps, which integrate observations on how adaptation is occurring in Canada with common elements of several adaptation planning frameworks. Although presented as a linear process, organizations may take different pathways as they transition and iterate through these phases and steps.

Phases in the adaptation process include awareness, preparation, implementation and iterative learning.

The seven steps are:

1. **Awareness of climate change:** the adaptation process begins once an individual or organization becomes aware of a changing climate as a threat or opportunity.
2. **Awareness of the need to adapt:** an awareness of the magnitude of the problem helps to identify adaptation as a solution.
3. **Mobilizing resources:** awareness can lead individuals and organizations to dedicate human and/or financial resources to help clarify the nature of threats or opportunities.
4. **Building capacity to adapt:** involves applying scientific information, financial resources, and skills to focused activities such as issue screening, risk assessment and in-depth analysis to generate the understanding needed for informed decision making.
5. **Implementing targeted adaptation actions:** concrete actions are put in place to reduce vulnerability (risk or exposure) to climate change and/or to take advantage of opportunities.

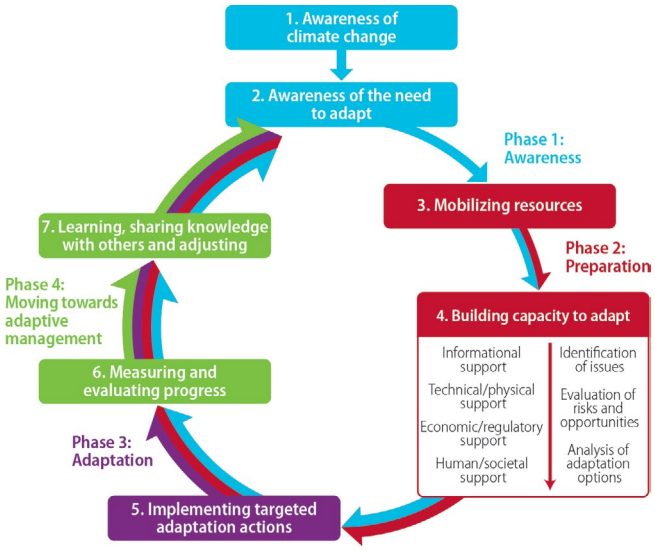

FIGURE 2: Stages and steps in the adaptation process.

6. **Measuring and evaluating progress:** measuring and evaluating the effectiveness of adaptation actions and related assumptions and uncertainties provides the feedback necessary for improved management.
7. **Learning, sharing knowledge with others and adjusting:** the last step leads to refinements in the adaptation actions implemented and transfer of lessons to future adaptation.

This Assessment highlights numerous examples of Canadian adaptation activities suggesting that, for the groups involved, steps 1 and 2 have been surpassed. Evidence of having reached steps 3 and 4 is also available, in the form of strategies or adaptation plans at provincial/territorial levels and within some local governments, as well as adaptation programs and initiatives supported by governments but implemented on a partnered basis. The creation of organizations with the specific mandate to generate knowledge for adaptation (e.g. Natural Resources Canada's Adaptation Platform, Ouranos, Pacific Climate Impacts Consortium, Ontario Centre for Climate Impacts and Adaptation Resources and Prairie Adaptation Research Collaborative) indicates high levels of activity intended to build capacity to adapt. Less progress is evident along the remaining three steps, although some examples of implementation of targeted actions are documented (*see* Table 1).

(e.g. PIEVC, 2012, NRTEE, 2012a; Rodgers and Behan, 2012, Fraser and Strand, 2011) and several initiatives promoting knowledge-sharing.

Policy and research communities also demonstrate an emerging interest in tracking and evaluating progress on adaptation (e.g. Leclerc, 2012; Ford et al. 2013). Survey research has explored patterns of awareness of climate change impacts and engagement on adaptation among groups, including businesses (e.g. Environics Research Group, 2010; NRTEE, 2012b), municipalities (Robinson and Gore, 2011; Carmin et al., 2012), and individuals, including public servants (e.g. BC Stats, 2012), members of professional associations (Davidson and Bowron, 2012) and households (e.g. Berry et al., 2009). Among other uses, evidence from these surveys serves to set baselines and informs future policy and program design. A lack of consistent characterizations of adaptation – and specifically of 'successful' adaptation – are among the current challenges to monitoring and evaluating adaptation progress (e.g. Ford et al., 2013) and to comparing results across studies (Dupuis and Biesbrock, *in press*).

In practice, Canada's approach to adaptation over the past few years reflects a focus on enabling local and regional (e.g. watershed-level) action (Mullan et al., 2013), although an overall rise in engagement by groups across sectors and levels of decision making has occurred (UNFCCC, 2011). Chapters 3 through 8 of this Assessment provide a number of examples of adaptation activities by governments, industry and non-governmental organizations (*see* Table 1). These include activities that build capacity for future adaptation, as well as the implementation of targeted activities to reduce vulnerability to climate risks or to exploit opportunities (Smit and Wandel, 2006; UKCIP, 2010).

		Type of adaptation activity	
Examples	Chapter	Build capacity to adapt	Implement actions
Government			
The communities of Cambridge and Milton, ON, are assessing the economic impacts of climate change on the design of drainage infrastructure in flood-prone areas	8	X	
The region of Durham, ON, is integrating climate change considerations into local planning documents	8	X	
The cities of Toronto and Windsor, ON, and Winnipeg, MB, have used outputs of heat-health vulnerability assessments to develop or update their heat alert and response systems (HARS)	7	X	X
Quebec city is over-designing culverts to account for the increasing frequency and intensity of rain events	8		X
The city of Calgary, AB, has increased water conservation efforts to maintain 2003 removal levels	8		X
British Columbia, Quebec, Yukon and Northwest Territories undertook sector-specific assessments of vulnerability, risks and opportunities (agriculture, northern transportation systems)	4, 8	X	
British Columbia is establishing an assisted migration adaptation trial for 15 commercial tree species in sites ranging from central Yukon to southern Oregon	3	X	
British Columbia, Alberta and Quebec are modifying seed transfer guidelines for reforestation to take shifting climate conditions ideal for tree growth into account	3	X	
As part of the Lake Simcoe Protection Plan, Ontario is requiring the development of a climate change adaptation strategy for the watershed	6	X	
Drawing on scientific, traditional and local knowledge, Yukon's land use plan for the Peel Watershed will integrate climate change considerations	6	X	
British Columbia is developing a range of policy guidance to mainstream adaptation into coastal zone management and land-use planning	8	X	
Manitoba is protecting winter habitat for the Qamanirjuaq barren-ground caribou herd in the transition zone between boreal and tundra ecosystems	6		X
The federal government has undertaken several activities to raise awareness of health-related risks from climate change among public health and medical practitioners and the public itself	7	X	
The federal government is considering adjusting biosecurity policies to adapt to the effects of changing climate on invasive alien species	4	X	

Table 1 continued on next page

		Type of adaptation activity	
Examples	Chapter	Build capacity to adapt	Implement actions
The federal government is developing tools to guide public health managers on vector-borne disease surveillance and control methods	7	X	
The federal government is taking into account the continued melt of glaciers in Banff and Jasper National Parks in the siting of new viewing locations and interpretive centres	5		X
The federal government is establishing ecologically-based regions for bluetongue control, a viral disease mainly affecting ruminants, in anticipation of shifts in prevalence of the disease	4		X
A range of intergovernmental initiatives to raise adaptation on the policy agenda and facilitate knowledge-sharing	3, 4	X	
Industry			
Industry associations in British Columbia are developing a tourism action plan to respond to Mountain Pine Beetle damage	3, 5	X	
An oil and gas company is developing and implementing a water strategy that includes engagement at policy levels and working with local stakeholders on site-specific water issues	3	X	
Quebec's hydro-electric corporation is integrating climate change considerations in demand forecasts, to inform rate adjustments and procurement plans	3	X	
Actors in the agro-industry sector are adopting real-time monitoring and other technologies to help increase efficiencies in irrigated agriculture	4	X	X
Maple syrup producers are adjusting start times for tapping sugar maple trees and installing more efficient collection systems	4		X
Some property insurers are adjusting insurance coverage (e.g. no longer offering sewer back up insurance in communities with recurring losses) to better align with exposure to climate risk	5		X
Mining companies operating in the North are applying techniques to protect northern infrastructure from permafrost warming (e.g. deeper pile foundations, adjustable foundations)	3		X
Tourism operators are improving management of impacts from current climate variability (e.g. snowmaking, irrigation, fire smart landscaping, seasonal diversification and insurance and financial products such as snow or sunshine guarantees)	5		X
Non-governmental organizations			
The Canadian Medical Association issued a policy statement as a call to action on climate change adaptation by health authorities	7	X	
The Canadian Standards Association has issued a technical guide for building infrastructure on permafrost including potential effects of future climate on permafrost	3	X	
Engineers Canada has undertaken a range of initiatives to equip engineering professionals with tools and information to adapt (e.g. a vulnerability assessment protocol, case studies, training workshops)	8	X	

TABLE 1: Selected examples of adaptation from the sectoral chapters.

A few observations can be drawn from the examples of adaptation documented in this assessment. First, direct experience with climate-related events and recognition of weather and climate sensitivity remain important triggers for adaptation in public and private sectors alike. For example, the 2011 Manitoba flood led to an expanded consideration of health impacts in disaster planning and recovery efforts (Chapter 7 – Human Health; Case Study 3); whereas an increasing trend of damage to homes and businesses caused by severe weather such as heavy rains, wind and wildfire in Canada and abroad has led Canadian insurers to consider adaptation (Chapter 5 – Industry). Other drivers of adaptation include regulatory compliance, reputational concerns and the desire to retain access to international markets (Chapters 3 – Natural Resources, 4 – Food Production and 8 – Water and Transportation Infrastructure). Government roles in protecting societies' most vulnerable individuals and preserving public health and safety provide the impetus for undertaking activities to understand risks and vulnerabilities, and to implement targeted measures (Chapters 7 – Human Health and 8 – Water and Transportation Infrastructure).

Second, examples of adaptation actions to proactively manage risks from future climate are limited. Of the 63 examples of adaptation actions compiled overall, 60 percent involve the following: research; monitoring climate impacts; assessing vulnerabilities, risks and opportunities; developing stand-alone adaptation strategies; and mainstreaming adaptation within existing policies and planning. The balance comprises activities implemented to prevent or offset harm from current climate-related risks, including operational changes to address impacts of current climate variability and of observed gradual changes such as permafrost degradation. Beyond trials for assisted migration of tree species (*see* Case study 2 in Chapter 3 – Natural Resources), evidence of novel actions taken to manage risks associated with potentially unfamiliar, large-scale or step changes in climate conditions is lacking.

Third, collaboration is occurring across sectors, with objectives including acquiring knowledge for adaptation and expanding the range of options to adapt. For instance, the Ontario government established a research partnership with the University of Guelph to help augment understanding of animal diseases related to climate change (Chapter 4 – Food Production). Partnerships to help build a case for adaptation have also been observed. The Co-operators Insurance Group, together with the Institute for Catastrophic Loss Reduction, undertook an initiative to demonstrate the technical and economic feasibility of building climate-resilient homes (Chapter 5 – Industry). Implementation of adaptation can also require collaboration. For example, a partnership between the Chaplin mine in Saskatchewan and the conservation group Ducks Unlimited Canada helped the mine to gain access to secondary water sources to offset effects of dry years (Chapter 3 – Natural Resources).

Engagement and action on adaptation differ among stakeholder groups, and so the following sections discuss advances in adaptation by governments (federal, provincial/territorial and local) and industry, including their roles, objectives and approaches.

4.1.1 FEDERAL GOVERNMENT

The federal government plays an important role in delivering scientific information on climate change impacts and adaptation, and in adaptation mainstreaming (OAG, 2010). This is consistent with emerging understanding of the roles of government as adaptors and facilitators of adaptation (e.g. NRTEE, 2009; Cimato and Mullan, 2010; Hallegatte et al., 2011). As facilitators, government agencies are responsible for removing barriers and creating incentives so that people and organizations across society are more inclined to proactively adapt. As adaptors, government agencies are responsible for adjusting policy, programming and operational decisions to account for changing climate.

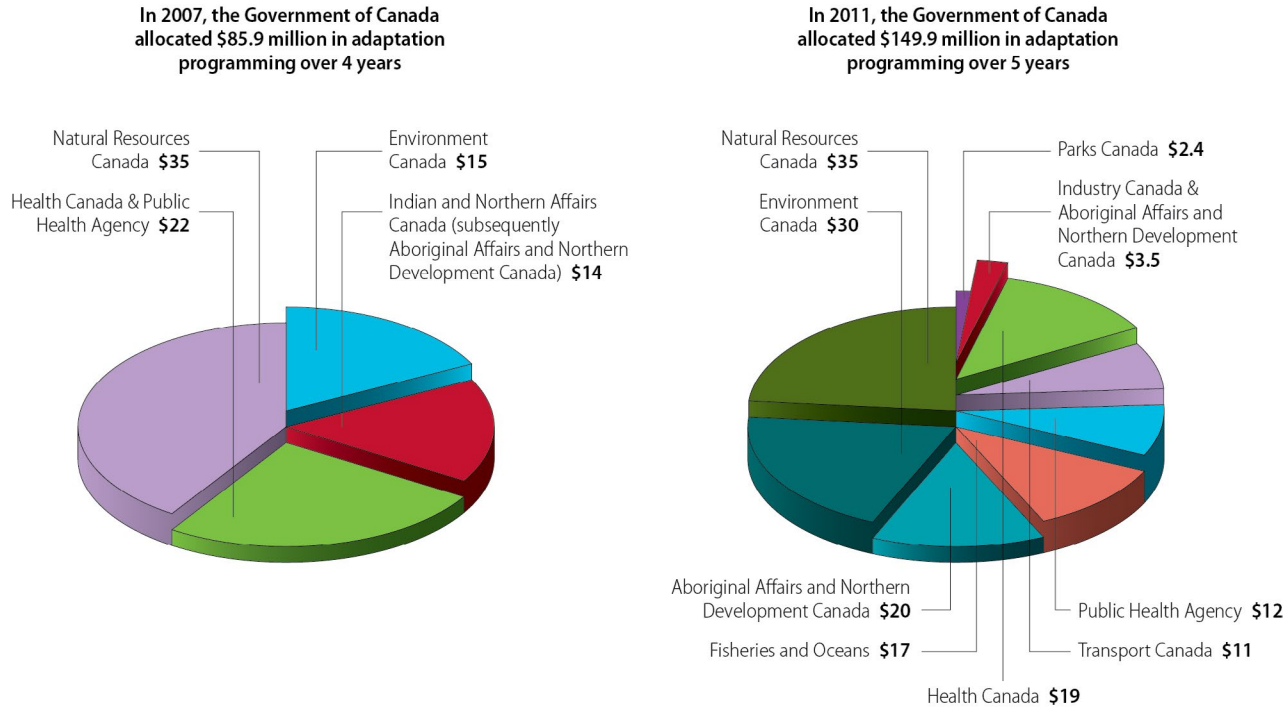

FIGURE 3: Evolution of federal spending on adaptation programs *(Data from: Environment Canada, 2013; CNW, 2007).*

Although criticized for the perceived lack of sustained leadership on adaptation and the absence of a national adaptation strategy (NRTEE, 2009; OAG, 2010; Dickinson and Burton, 2011; Hanna et al., 2013), federal efforts to build Canadians' capacity to adapt to climate change have deepened over the past five years. A rise in federal engagement on adaptation is evident: between 2007 and 2011 the number of departments and agencies delivering adaptation programs grew from five to nine (*see* Figure 3) while the Federal Adaptation Policy Framework was adopted in 2011 to guide future adaptation priorities (Government of Canada, 2011). Funding has supported, for example, development of climate change scenarios, community adaptation planning, provision of information and decision support tools targeting health and infrastructure adaptation (Environment Canada, 2010; 2013), and collaboration among different orders of government, industry and adaptation practitioners (*see* Case Study 1).

Available literature suggests several ways of enhancing federal action on adaptation, including: enhanced activity

CASE STUDY 1

COLLABORATION TO ENHANCE ADAPTATION DECISION MAKING

Recognizing that climate change impacts and adaptation decisions cross-cut jurisdictional and sectoral boundaries and involve a wide range of actors, Canada's federal, provincial and territorial governments have adopted collaboration as a key principle for advancing knowledge and action on adaptation. Although collaboration takes time and can present many challenges, it also offers significant benefits with respect to efficient use of resources, sharing of data, experience and expertise, inspiring action amongst peers, and helping to avoid divergent goals and conflicts (Spencer et al., 2012).

Building on foundational work on climate change impacts and adaptation (e.g. Smit, 1993), the Canadian Climate Impacts and Adaptation Research Network (C-CIARN) was developed to raise awareness and build relationships on the issue. Operating from 2001 to 2007, the network consisted of 14 sectoral and regional offices, with the primary goal of building linkages between the research and the decision-making communities, including federal, provincial and territorial government departments.

Based upon the results achieved and relationships built by C-CIARN, six Regional Adaptation Collaboratives (RACs) were established across Canada in 2008 (North, BC, Prairies, Ontario, Quebec and Atlantic), which focused on activities to facilitate practical adaptation. Each RAC focused on priorities defined on the basis of scientific understanding (e.g. Lemmen et al., 2008) and regional policy priorities. Common themes included water resource management, infrastructure and municipal planning (Natural Resources Canada, 2013a). Each RAC developed its own network of decision makers and practitioners, including governments, industry and non-government organizations, and also drew upon the researchcommunity. In total, more than 150 organizations have been involved in the RACs, producing more than 230 products – including guidelines, standards, tools, adaptation plans, case studies and technical reports (Natural Resources Canada, 2013b; Figure 4). Regional networking was complemented by collaborative activities with targeted practitioner organizations, such as professional engineers and planners.

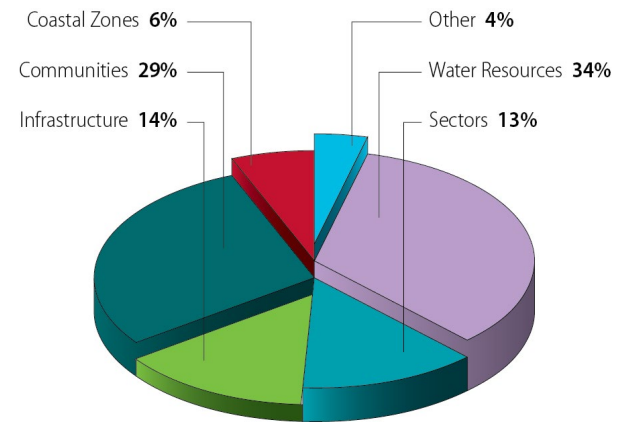

FIGURE 4: Thematic distribution of Regional Adaptation Collaborative products *(Source: Natural Resources Canada, 2013b).*

The most recent mechanism aimed at enhancing collaboration on adaptation across Canada is the Adaptation Platform, launched in 2012 (Natural Resources Canada, 2013a). The Adaptation Platform brings together many of the players previously engaged in collaborative activities (federal, provincial and territorial governments, and professional organizations) along with industry associations and financial sector representatives, to address shared adaptation priorities by pooling knowledge, capacity and financial resources to produce information and tools that regions and sectors need in order to understand and adapt to the effects of a changing climate.

The Platform provides a structure to initiate and undertake activities to advance shared regional and sectoral adaptation priorities in Canada. It consists of a plenary and a series of working groups. Plenary members are senior-level representatives who help define priority areas for working-group efforts, align interests and resources, and identify opportunities for adaptation. Working groups focus on key economic sectors (e.g. forestry, mining), common information needs (climate scenarios), and broader themes deemed important in continuing to advance adaptation (e.g. measuring progress, science assessment).

related to generating and disseminating information for adaptation; improving adaptation mainstreaming efforts in policy areas such as disaster risk reduction, major project approvals, infrastructure funding and fisheries management; and improved coordination to avoid duplication and adverse side-effects, and to ensure that lessons are transferred across sectors and geopolitical boundaries (Jessen and Patton, 2008; Dickinson and Burton, 2011; NRTEE, 2012b).

4.1.2 PROVINCIAL AND TERRITORIAL GOVERNMENTS

Adaptation has grown in importance among provincial and territorial governments (*see* Table 2). British Columbia, Ontario and Quebec have stand-alone adaptation strategies and action plans and have established scientific advisory bodies to guide adaptation efforts. The remaining provinces and territories have either integrated their adaptation efforts into broader climate change action plans, or are in the process of developing adaptation strategies or plans (e.g. Saskatchewan, New Brunswick, Prince Edward Island and Northwest Territories) (David Suzuki Foundation, 2012). In recent years, several governments have completed some form of risk or vulnerability assessment (e.g. BC Agriculture and Food Climate Action Initiative, 2012) and some provide for specific sectoral actions and commitments (e.g. measures to enhance the health of individuals and communities in a changing climate; Government of Quebec, 2012). Evaluations of jurisdictional efforts relative to adaptation needs do not yet exist; however, differences are apparent across the country in terms of capacity to assess vulnerability, and to plan and implement adaptation actions (*see* Chapter 7 – Human Health).

Province / Territory	Strategy, plan, framework	Examples of adaptation activities or resources
British Columbia	Preparing for Climate Change – British Columbia's Adaptation Strategy (2010)[2]	$94.5 million to establish the Pacific Institute for Climate Solutions (PICS) to assess, develop and promote viable emission reduction and adaptation options as inputs to policy[3] Forest policy guidance, decision support tools and knowledge to help BC forest managers adapt to climate change[4]
Alberta	Climate Change Strategy: Responsibility. Leadership. Action (2007) – includes adaptation efforts[5]	A Climate Change Adaptation Framework and accompanying manual to help organizations integrate climate change risk into existing Enterprise Risk Management systems and strategic planning approaches[6] Involvement in research on climate change and water supplies[7], including through the Prairie Adaptation Research Collaborative (PARC)
Saskatchewan		Launched in 2010, Saskadapt.ca is the province's climate change impacts and adaptation information portal to help residents and organizations adapt[8] The Management and Reduction of Greenhouse Gases and Adaptation to Climate Change Act, including provisions for coordination of adaptation planning[9]
Manitoba	Climate Change Action Plan "Beyond Kyoto" (2008) includes adaptation efforts[10]	Improvements in flood protection, including upgrading the Red River Floodway to withstand a 1-in-700- year spring flood from a previous 1-in-90-year spring flood[11] The new Provincial Planning regulation includes provisions for local planning to prepare for climate change impacts[12]
Ontario	Climate Ready: Ontario's Adaptation Strategy and Action Plan 2011-2014[13]	A guide to help integrate climate change projections into hydrologic modeling to inform water budgets required under the Clean Water Act A web-based adaptation toolbox to help plan for the impacts of climate change on ecosystems and natural resources[14]
Quebec	Quebec in Action: Greener by 2020 – 2013-2020 Government Strategy for Climate Change Adaptation[15]	$200 million has been allocated to implement adaptation actions in the province Adaptation has been mainstreamed into several laws and policies: the Water Act, the Dam Safety Act; and the Québec Strategy for Drinking Water Conservation
Yukon	Climate Change Action Plan (2009) – includes adaptation efforts[16]; Pan-Territorial Adaptation Strategy (2011)[17]	Sector-specific risk and vulnerability assessments (infrastructure, forest health, forest tree species, water resources)[18] An inventory of permafrost information[19]
Northwest Territories	Pan-Territorial Adaptation Strategy (2011)	An Adaptation Framework for the Northwest Territories is in development[20] Vulnerability assessment of highway corridor completed in 2011[21]

Table 2 continued on next page

Province / Territory	Strategy, plan, framework	Examples of adaptation activities or resources
Nunavut	Upagiaqtavut – Setting the Course: Climate Change Impacts and Adaptation in Nunavut – framework for adaptation activities (2011); Pan-Territorial Adaptation Strategy (2011)	The Atuliqtuq project aims to build community capacity to adapt through awareness-raising, research, tool development and planning A permafrost monitoring network that operates in cooperation with hamlets and the federal government[22]
New Brunswick	Climate Change Action Plan 2007-2012 includes adaptation efforts[23]; Climate Change Adaptation Strategy for Atlantic Canada[24]	Launch of a Climate Change Indicators website that uses local information to help the public understand how the climate is changing[25] Assessment, tool development and planning support to enhance climate resilience of infrastructure and communities[26]
Nova Scotia	Toward a Green Future: Nova Scotia's Climate Change Action Plan (2009) – includes adaptation efforts[27]	A Climate Change Action Fund launched in 2009 issues yearly calls for projects to support community efforts to understand impacts and actions to prepare for climate change[28] Requirement for municipalities to develop and submit climate change action plans (including emissions mitigation and adaptation) for receipt of federal gas tax revenue[29]
Prince Edward Island	Prince Edward Island and Climate Change: A Strategy for Reducing the Impacts of Global Warming (2008) – includes adaptation efforts[30]	Development of climate change scenarios for use by nine target communities[31] Assessment and tool development to increase understanding of communities' vulnerability to climate change[32]
Newfoundland and Labrador	Charting Our Course: Climate Change Action Plan (2011) – includes adaptation efforts[33]	Development of a 7-step guide to help the province's communities assess climate change vulnerabilities, complete with case studies and a resource guide[34] Development of a workbook to help municipal officials and staff manage the impacts of climate change on infrastructure[35]

TABLE 2: Examples of provincial and territorial adaptation activities.

Governments commonly frame adaptation by drawing attention to current vulnerabilities, local experiences and observations. Mountain pine beetle infestations in British Columbia, permafrost degradation and changing glacier cover in Yukon, and Nova Scotia's hurricane experiences are a few examples. Sectors receiving the most attention are those that factor heavily into the regional economy or make-up (e.g. forests in British Columbia, agriculture in Alberta and Saskatchewan, infrastructure and human health in Ontario, coastal areas in Atlantic regions). Territorial and many provincial documents highlight the cultural and heritage impacts of a changing climate on northern communities.

Building community and local government capacity to adapt is a priority shared across provinces and territories. Common lines of action include: funding climate change adaptation research; enhancing existing emergency preparedness initiatives; strengthening urban and rural land-use planning and infrastructure investment through adaptation mainstreaming; and providing guidance, coordination and sharing of data information and lessons learned. Provinces and territories have jurisdiction over a number of local matters germane to climate change adaptation, including land-use planning (Richardson and Otero, 2012), so attention on enabling local preparedness and action is expected.

4.1.3 COMMUNITIES AND LOCAL GOVERNMENTS

Adaptation planning is gaining momentum in many communities and local governments across Canada. Surveys of Canadian municipalities and case studies indicate an upward trend in adaptation activity (Robinson and Gore, 2011), a roughly equal distribution of activity between preparation, assessment, planning and implementation (Carmin et al., 2012), efforts to develop adaptation plans, policies or programs in consultation with internal and external stakeholders (Richardson and Lemmen, 2010), and some indications of staff time being allocated to adaptation planning (Merrill and Zwicker, 2010). Among global counterparts sampled by ICLEI–Local Governments for Sustainability, Canadian cities stand out for their concern about housing safety, health impacts of shifting disease vectors, degree of integration of adaptation within community planning, partnerships with other cities and

non-governmental organizations and creation of adaptation-focused commissions or task forces (Carmin et al., 2012). Support from local politicians and government agencies is variable, with some studies noting strong support (e.g. Carmin et al., 2012) and others highlighting lack of political will as a barrier to adaptation (e.g. Davidson and Bowron, 2012). Small communities are less likely to engage in adaptation than larger ones (Hanna et al., 2013).

Several factors incite communities and local governments to address adaptation (*see* Case Study 2). Adaptation planning and projects emerge in response to extreme climate and weather events (e.g. Wellstead, 2011; Rodgers and Behan, 2012) as well as to gradual changes such as sea level rise and permafrost thaw (Richardson and Lemmen, 2010). Other factors include learning from peers and coupling actions to adapt to climate change with immediate priorities, such as water conservation (Richardson and Lemmen, 2010; Picketts et al., 2013).

CASE STUDY 2

HOW DO COMMUNITIES ADAPT TO CLIMATE CHANGE? A COMPARATIVE CASE STUDY OF HALIFAX, NOVA SCOTIA AND BEAUBASSIN EAST, NEW BRUNSWICK

This case study compares the approach to adaptation taken by two Atlantic communities: Halifax Regional Municipality (HRM), Nova Scotia and Beaubassin East, New Brunswick. Although exposed to similar climate threats, the differences between the two communities in terms of size, location, culture and resources dictate different management responses (*see* Table 3). With a population of 390 000, Halifax is a major seaport with significant industrial, military and municipal infrastructure, whereas Beaubassin East is a coastal community of 6000 inhabitants.

Adaptation planning in Halifax

Halifax has experienced frequent extreme weather in recent years. Of particular note is Hurricane Juan, which flooded part of downtown in September 2003 and caused an estimated $200 million in damages to property and infrastructure. This event and others since have heightened public awareness of climate change threats and helped spur the community to take adaptive action (Richardson, 2010).

In August 2006, the HRM Council adopted a Regional Municipal Planning Strategy, which included policies to address climate change (Halifax Regional Municipality, 2006). The strategy recognized the need to gather scientific information on sea-level rise, storm surges and vulnerability, to inform the development of an area-specific land use plan for Halifax Harbour. In 2009, HRM planners collaborated with scientists from federal and provincial governments and universities to deliver the information needed (HRM et al., 2010). Three scenarios of future sea levels and extreme water levels in Halifax Harbour were developed: a minimum scenario based on continuation of the historic rate of sea level change; a medium scenario using the upper limit of projections for mean sea-level rise from the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (2007); and a higher projection based on more recent scientific literature (Forbes et al., 2009).

In early 2010, Halifax Council agreed to use the medium scenarios on an interim basis and as a baseline upon which a plan could be developed. Planners have been working on preparing an adaptation plan since 2010 (Richardson, 2010), with several interim adaptation measures being implemented in the meantime. For example, planners have created a risk assessment database containing information on the vulnerability of harbour-front properties and council passed an updated Municipal Planning Strategy and Land Use By-law for the downtown Halifax waterfront in 2010, prescribing a 2.5 m threshold above the ordinary high water mark for ground floor elevations of any new development downtown. More recently, the city used development agreements to establish a minimum ground floor elevation for new buildings in at-risk zones (Richardson and Otero, 2012). In one example, local officials and the developer agreed to establish minimum elevations for a new marina and other seaside structures in downtown Dartmouth that were several metres higher than prescribed in area plans.

Adaptation planning in Beaubassin East

Beaubassin East has been affected by various strong storm surges in the last 15 years. A storm in January 2000 was the most severe in the last hundred years, flooding parts of the community and damaging homes, cottages and quays (Doiron, 2012).

In 2007, a new planner for the Beaubassin East Planning Commission noticed that new buildings in the community were not constructed to withstand anticipated future changes in sea level. He undertook to modify local regulations to enhance resilience to rising sea level. The planner delivered a series of presentations to inform councillors about local climate change impacts and the need to develop adaptation measures to address them.

Case Study 2 continued on next page

Two steps enabled the development of a new zoning by-law. First, a literature review identified tools and practices that other communities had used to adapt, as well as best estimates of sea-level rise. Second, the Planning Commission obtained Lidar data and a grant to develop a high resolution digital map of the projected depth of a flooding event in 2100, using the January 2000 storm as a baseline. This map was an important tool to engage councillors and the public.

Council passed an updated zoning by-law in March 2011 to enhance protection of new construction in the coastal zone of Beaubassin East (Doiron, 2012). The by-law identifies a sea level rise "protection zone" in which the minimum ground floor elevation of any new building must be at least 1.43 m above the current 1-in-100-year flood mark. The regulation is an "overlay" zone – where all previous zoning conditions apply. Rather than prohibit development outright, the zoning by-law imposes stricter building requirements and includes a two-phase permitting system. The developer is first required to get a land surveyor to establish the minimum ground floor elevation for the proposed building. After construction, a surveyor must measure the ground floor elevation and certify compliance with the new standard.

The enactment and implementation of the by-law has provided opportunities for outreach to developers and the community on the impacts of climate change and sea level rise (Richardson and Otero, 2012). For example, a local planner has compiled a binder of information that includes reports and articles documenting adaptation measures and design techniques implemented in other jurisdictions that prospective developers can access. Since the by-law was passed, several new homes and cottages have been constructed to the new standards. The by-law has also subsequently been adopted by the Town of Shediac (population 6000), a nearby coastal community.

Summary Table		
	Halifax	**Beaubassin East**
Population	390 000	6000
Climate change issues	Sea level rise and storm surge flooding	Sea level rise and storm surge flooding
Land use planning tool	Development Agreements (i.e. minimum ground floor elevation established through negotiation)	An updated zoning by-law imposes a minimum ground-floor elevation in at-risk zones of the community
Adaptation plan	Halifax in process of developing an adaptation plan (since 2009)	No stand-alone plan. New "sea level rise protection zones" identified within the zoning by-law, which includes a preamble outlining the issue and approach

TABLE 3: Land-use planning tools and adaptation plans in the two communities.

Conclusions

Halifax and Beaubassin East are among the first coastal communities in Canada to take concrete action to build resilience to climate change. Although their approaches are distinct, certain enabling factors are present in both cases, including exposure to significant damage from recent storms, one or more champions advocating for action on adaptation, a solid scientific basis to determine the extent of the threat in the local area, public and councillor engagement to obtain buy-in, and the use of visualizations to engage the public, council and stakeholders. Beaubassin East's experience demonstrates that even a small community with limited resources can implement regulations to build resilience to climate change. Halifax is an example of the iterative nature of adaptation planning, where interim measures can be implemented in the lead up to a comprehensive plan.

The evolution of adaptation activities by communities and local governments varies, and largely depends on context. Some community adaptation initiatives have stemmed from internal planning processes (e.g. Toronto's Climate Change Action Plan [City of Toronto, 2007] and Halifax's Harbour Plan [City of Halifax, 2005]), while others received significant external support and prompting for their adaptation activities (e.g. District of Elkford, 2009). Collaboration is important in many cases (Carlson, 2012). An example of local authorities working with higher levels of government is the collaboration between Health Canada, the Manitoba government and the Winnipeg and Assiniboine local health authorities to develop and test the effectiveness of heat alert and response systems (Health Canada, 2012). In some cases, mainstreaming is a guiding principle. For example, Toronto's Climate Change Action Plan calls for consideration of climate change mitigation and adaptation across the city's policies, activities

and programs, and in their Heat Alert and Response System (City of Toronto and the Clean Air Partnership, 2008).

Berrang-Ford et al. (2011) found that most adaptation action in developed countries is occurring within municipalities. Although definitive evidence is not available to support this conclusion for Canada at present, relative to other levels of government, Canadian communities and local governments have been objects of much case-study research (e.g. Parkins and MacKendrick, 2007; Ford et al., 2008; Burch, 2010; Richardson and Lemmen, 2010; Boyle and Dowlatabadi, 2011; Richardson and Otero, 2012; Rodgers and Behan, 2012; Picketts et al., 2012; 2013). The relatively high level of community and local government activity could be a combination of the local nature of climate impacts (Richardson, 2010), the belief among community planners and infrastructure engineers that a changing climate affects their practice (Davidson and Bowron, 2012; CSA Group, 2012), and support from higher-level governments in the form of policies, decision support tools and other resources to inform adaptation planning (e.g. Hanna et al., 2013).

4.1.4 INDUSTRY

Canadian businesses and industry sectors are becoming aware of the risks and opportunities that a changing climate presents. Concerns about more frequent and severe weather events predominate; both negative and positive climate change impacts are recognized, with the balance between risk and opportunity differing by sector (NRTEE, 2012b). Of the industry sectors analyzed in NRTEE (2012a), companies in financial services and insurance sectors were the most likely to report opportunities from the impacts of climate change, such as the creation of new financial products. However, research on business opportunities in a changing climate is scant (Chapter 5 – Industry). Globally and within Canada, industry councils and associations are increasingly engaged in raising awareness of the business relevance of climate adaptation. For example, some have facilitated knowledge sharing (the Canadian Electricity Association), funded applied research and tool development to inform industry strategy (the Insurance Bureau of Canada), issued policy statements to guide industry practice (the International Federation of Consulting Engineers) and released adaptation frameworks of general applicability to members (NRTEE, 2012b; ICMM, 2013).

Although Canadian businesses are adjusting practices in response to individual weather and climate-related events, actions in anticipation of future climate change remain limited (Johnston et al., 2011; NRTEE, 2012b). Companies that are taking action to adapt are primarily focused on understanding the implications of climate change on their operations, developing frameworks to guide strategic and operational decisions and assessing the merits of alternative adaptation options (Chapter 3 – Natural Resources; Chapter 5 – Industry; Horton and Richardson, 2011; NRTEE, 2012a). Outside of proactive planning in some mining sites in Canada's North (Chapter 3 – Natural Resources), revisions to corporate design standards and codes of practice are among the most concrete documented examples of business adjustments in light of changing climate (Horton and Richardson, 2011; NRTEE, 2012a). The integration of climate adaptation into planning and management approaches already used by business is also taking place, but to unknown degrees and effect. These approaches include contingency and disaster planning as well as adaptive management.

This Assessment highlights forestry, hydroelectricity, insurance and tourism as sectors most engaged in adaptation. Other research also emphasizes the adaptation activity of sectors reliant on nature and natural resources, such as forestry, agriculture and tourism, and of those with major capital assets, such as utilities and transportation (Deloitte, 2011; Ford et al., 2011; Ceres and Climate Change Lawyers Network, 2012). Factors that can contribute to a difference between actual and reported levels of preparedness include a lack of common benchmarks and performance metrics for adaptation, along with confidentiality and reputational concerns (Agrawala et al., 2011; NRTEE, 2012b).

4.2 BARRIERS AND CHALLENGES

Understanding of the barriers and challenges to planned adaptation has grown since 2008 (e.g. Richardson, 2010; Johnston et al., 2011; NRTEE, 2012a; Picketts et al., 2012) and has given rise to new scholarship that explores factors that constrain the 'readiness' of organizations to adapt (Moser and Ekstrom, 2010; Clar et al., 2013; Ford et al., 2013) beyond those associated with adaptive capacity (Smit and Pilofosova, 2001; Yohe and Tol, 2002).

This section expands on barriers and challenges to adaptation identified in Chapters 3 to 8 of this Assessment. It considers the role of information and communications, resources, governance and norms, psychology and values, and leadership in hindering progress on adaptation by various stakeholder groups (*see* Table 4).

Type of barrier / challenge	Example	Chapter
Information and communications	Difficulties teasing out multiple influences on visitation choices (e.g. fuel price, transportation costs, border restrictions, reputation, demographic and market trends) from climate change impacts	5
	Mismatch between spatial and temporal resolution of climate projections and management needs. Difficulties obtaining reliable projections at scales relevant to management needs	3, 5, 6
	Availability of guidance to interpret climate scenarios and factor modeling outputs into infrastructure and mine closure design	3
	Lack of data and information on weather extremes (e.g. future patterns of rainfall extremes)	5, 8
	Limited data and information on past and future sector-specific climate change impacts (e.g. climate change impacts on forests, wind, solar and biomass energy production; water-related impacts of climate change and implications for oil sands development, shale gas and enhanced oil recovery; climate change impacts on water resource infrastructure; health impacts)	3, 7, 8
Resources (economic, skills, technology)	Few incentives for action beyond business as usual (e.g. incremental cost of applying existing engineering or technological solutions to adapt mine operations to climate change, or of preserving ecological goods and services on agricultural lands)	3, 5, 6
	Lack of expertise and understanding surrounding local impacts of climate change on business operations, and effective adaptation solutions	5
	Limited adaptation options for snowmobiling (e.g. widespread implementation of snowmaking is impractical)	5
	Lack of: financial resources for surveillance, prevention and control of vector-borne diseases; expertise and capacity to diagnose emerging vector-borne diseases; licensed and effective products for disease-vector control	7
Governance and norms	Complexities redefining sustainable forest management related to number of players and trade-offs involved	3
	Influence of non-climate stressors, such as region-wide demographic changes and rural outmigration	4
	Reliable access to non-commercial food supplies at risk if infrastructure integrity is vulnerable to climate change	4
	Designs based on future climate projections shift paradigm from building code and current design approaches	5
	Coastal adaptation plans typically led by government agencies outside of public health such that health impacts may not considered	7
Psychology and values	Perceived importance of climate change low relative to economic challenges, job losses and mill closures facing the sector	3
	Uncertainty in future climate change projections hinders investment decisions on adaptation	3
	Optimism about capacity to overcome climate change adaptation challenges	5
	Continued focus on replacement of aging infrastructure, on capacity upgrades to deal with increasing population and on changing regulatory requirements to address risks to water supply infrastructure – with the role of changing codes, standards and related instruments receiving less attention	8
Leadership	Proactive adaptation planning in mining is rare despite use of climate scenarios for impact assessment and identification of monitoring and adaptation strategies	3
	Taking a 'wait-and-see approach' due to difficulties finding the correct balance between waiting for more information to inform future action and taking action in the short term based on available information	3

TABLE 4: Barriers and challenges to adaptation highlighted in previous chapters.

Although discussed separately below, the different types of barriers and challenges to adaptation are often interrelated and can be mutually reinforcing (e.g. Burch, 2010). For example, the combined effects of high rates of household poverty and low levels of education, limited capacity of public health practitioners to monitor, diagnose and treat climate-sensitive diseases, inter-jurisdictional issues and unequal access to resources constrain adaptation of Aboriginal health systems (Chapter 7 – Human Health).

4.2.1 INFORMATION AND COMMUNICATIONS

Barriers and challenges related to information for adaptation continue to be widely-cited as factors constraining action in Canada. Previous chapters in this assessment highlight issues related to the availability and accessibility of data and information on both average and extreme climate conditions, climate projections and their interpretation, climate change impacts research, and methods and tools to help integrate climate change information into decision making.

A key concern raised in the literature on this subject is the mismatch between the climate data and information available and that which is perceived necessary for adaptation purposes. Calls for site-specific, detailed and short-term climate projections to inform provincial and territorial (ACC Community of Practice, 2011), industry (Kovacs, 2011) and community (McLeman et al., 2011) risk assessments and planning processes are documented, as are demands for local projections of climate variables other than temperature and precipitation averages. A related concern is the density and effectiveness of weather and climate monitoring networks (Steenhof and Sparling, 2011; Pennesi et al., 2012), which are the source of data for downscaling climate projections. Challenges in meeting such information demands are not unique to Canada. For example, Reisinger et al. (2011) identify gaps in baseline climate data and in the availability of probabilistic climate projections as impediments to adaptation of local governments in New Zealand.

Gaps in data and information to help characterize vulnerability to climate change also create challenges in assessing risks and planning for adaptation (NRTEE, 2009). Historical records of system responses to climate-related events can be used to inform estimates of potential climate change impacts. For example, reliable records of direct and indirect health impacts from extreme-weather events, climate-related damages to homes and tourist responses to environmental change would support trend analysis (Chapters 5 – Industry, and 7 – Human Health) useful for building a case for action. Targeted climate change risk assessments – of municipal infrastructure for example – also benefit from the documentation of climate-related damages to operations and assets (Peck et al., 2013).

However, not all decisions are equally subject to climate change risk, and initial discussions are underway on the resolution of climate change information needed to adapt. Factors such as the degree of sensitivity to climate and the types of management options being considered influence the detail and precision of climate change information needed to make good decisions (Willows and Connell, 2003). Information needs surrounding climate change impacts and adaptation – and the mechanisms and approaches to consolidate and integrate this information in decision making – will vary by sector, geographic location and by end-use. On a regional basis, climate service centres (e.g. Pacific Climate Impacts Consortium, Ouranos) are working with users to define what they require and what is feasible to supply (Murdock and Burger, 2010).

Despite advances in building the knowledge base to support climate change adaptation, challenges remain in conveying complex scientific and technical information to a range of groups (ACC Community of Practice, 2011). Factors limiting interest and understanding include: framing of climate change as an environmental issue, rather than as an economic and social issue; failing to relate climate change impacts to existing concerns and local action; difficulties communicating complex science and underlying uncertainties to non-specialist audiences; and science outreach activities that are limited to a one-way flow of information (Shaw et al., 2009; Sheppard et al., 2011; NRTEE, 2012b; Picketts et al., 2013). Researchers and adaptation practitioners are becoming aware of approaches to enhance the uptake of climate change information in local planning processes (e.g. Shaw et al., 2009; Sheppard et al., 2011) and deploying communications strategies tailored to public health officials and other professionals (Clarke and Berry, 2012).

4.2.2 RESOURCES

Limitations – whether real or perceived – with respect to economic resources, skills and expertise, and technologies for adaptation, are commonly identified as barriers to taking adaptation action.

ECONOMIC RESOURCES

Despite a noted lack of quantitative information on the costs of adaptation (e.g. NRTEE, 2010; Ochuodho et al., 2012), these costs stand out as a key perceived barrier for stakeholders in both private and public sectors. Survey research cited the costs of adaptation as "the most significant barrier to taking climate change into account in decision making" for over half of business, provincial and municipal government respondents (Environics Research Group, 2010). Although some adaptation actions – such as infrastructure upgrades – can be costly, the costs of not adapting are typically underemphasized (e.g. NRTEE, 2012a, b). Over the past 5 years there has been a significant rise in interest in examining the economic merits of implementing adaptive measures (Mills, 2008; Desjarlais and Larrivée, 2011; NRTEE, 2011; Olar and Lessard, 2013), although few Canadian guides and tools to appraise the costs and benefits of adaptation are currently available (e.g. Webster et al., 2008).

The ability to allocate scarce resources to adaptation is another concern raised by several groups. Within an organization, competing priorities (ACC Community of Practice, 2011), the lack of visibility of the unit championing adaptation and budgetary processes that consider capital and operational spending separately (Burch, 2010) can diminish the chances of securing funding for adaptation activities. In extreme situations, crisis management and urgent needs hinder consideration of investments in planned adaptation (e.g. Boyle and Dowlatabadi, 2011; Ford and Berrang-Ford, 2011; Pearce et al., 2011). Market signals can also discourage investment in adaptation actions. For example, companies currently have limited incentives to pay the added cost of

applying existing engineering or technological solutions to adapt operations to climate change (Chapter 3 – Natural Resources; NRTEE, 2012b). The size of a company also appears to play a role (Environics Research Group, 2010; NRTEE, 2012b), due in part to limited financial resources and dedicated staff, as well as short-term planning horizons (NRTEE, 2012b; C2ES, 2013).

Beyond funding, context and timing also influence vulnerability to climate change and options to adapt cost-effectively. For example, economic reliance on a single industry and the ability to adopt economic diversification strategies were key considerations in assessing adaptation options for communities affected by the mountain pine beetle outbreak in British Columbia (Parkins and MacKendrick, 2007). Other research emphasizes strategic consideration of replenishment and renewal cycles as windows of opportunity for adaptation (Williamson et al., 2012).

SKILLS AND EXPERTISE

There are limitations related to accessing the required knowledge, skills and dedicated staff to assess climate risks, devise adaptation strategies and integrate adaptation in routine planning and operations in the public sector. Provinces and territories identify a lack of dedicated staff and staff with the right skills as concerns for advancing adaptation (ACC Community of Practice, 2011). Survey analysis of public servants in British Columbia concludes that they would benefit from information on climate change impacts and current adaptation efforts specific to their mandate areas (BC Stats, 2012).

These limitations in human capacity have affected the rate at which adaptation is being addressed. For example, in Ontario, the first round of Source Water Protection plans do not include climate change modeling outputs in water budgets, because of the variable capacity of the province's 34 Conservation Authorities to manipulate climate change scenario outputs, apply downscaling methods and meet reporting requirements (de Loë et al., 2011). Climate data, and guidance on integrating climate model outputs into hydrological modelling and training were made available as a result (http://waterbudget.ca/climatechangetraining). In the public health sector, officials admit to lacking the necessary knowledge to inform adaptation decisions despite the availability of information resources such as weather warnings and air quality reports (Clarke and Berry, 2012). Low scientific capacity and understanding of climate change impacts and adaptation have also been found among forest managers working in companies and regulatory agencies (Johnston et al., 2011).

Capacity constraints related to human resources appear to be the most pronounced within small planning departments and agencies (OECD, 2012; Hanna et al., 2013). The capacity of municipalities in Canada's North to plan for emergencies is uneven, with particular challenges for small, remote communities (NRTEE, 2009). Hiring outside expertise to provide analysis and tailored information on climate change impacts and adaptation is an option for some organizations with low scientific and technical capacity (e.g. Johnston and Hesseln, 2012).

TECHNOLOGIES FOR ADAPTATION

Challenges related to technological options are sector-specific, but, in all cases, the right incentives need to be in place to develop and deploy novel technologies. Current technological options available to forest managers can address current climate risks. However, cost and public acceptability could limit the widespread deployment of novel technologies, such as high flotation tires on skidders that allow operations to proceed on unfrozen ground, or genetic modifications to tree species to thrive in future climate conditions (Johnston and Hesseln, 2012). Limits in technological options for sectors such as public health (Chapter 7 – Human Health), electricity (Chapter 3 – Natural Resources) and tourism (Chapter 5 – Industry) indicate potential opportunities for innovation.

4.2.3 GOVERNANCE AND NORMS

Research on the governance of adaptation has gained ground in the past few years (Adger et al., 2009; 2010), exploring issues such as how to promote coherent and collaborative action within and across public and private sectors. Policy development on adaptation is challenged by the need for integration across policy domains and levels of government, engagement of non-government organizations, and mobilization of scientific knowledge (Bauer et al., 2012). For complex policy domains such as fisheries and oceans management, climate change adds to governance uncertainty. Some large-scale changes such as ocean acidification are unprecedented, and effective management responses are unclear. Communications and negotiations with fisheries stakeholders now need to account for diverse understanding and perceptions of climate change (McIlgorn et al., 2010). This complexity can cause agencies to focus on short-term implications and their own policy silos (Lemieux et al., 2013). Moreover, coordination within and across levels of government, and any partnered work, takes time, resources (McLeman et al., 2011; ACC Community of Practice, 2011) and the deployment of specific skills (e.g. communication, negotiation, development of shared visions).

Networks, both formal and informal, can enhance capacity to adapt (*see* Case Study 1). However, opportunities to take

up climate change information and establish relationships across policy domains are not always seized. For example, analytical capacity in the Canadian financial sector is high, yet employees in this sector seem resistant to engage in climate change adaptation issues (Williams and McNutt, 2013). As adaptation grows in maturity as a policy issue, a transition from governance reliant on voluntary networks, to a mix of networks and hierarchical approaches is likely (Bauer et al., 2012).

As an approach to addressing adaptation, mainstreaming is both promising and challenging. Several studies conclude that creating new processes or frameworks to tackle adaptation are unnecessary. Reasons include the already-high workload of, for example, public health officials (Clarke and Berry, 2012) and a preference to work within existing rules and with familiar planning approaches (Jantarasami et al., 2010; Davidson and Bowron, 2012). Integrating adaptation considerations across existing policies and management approaches is not necessarily straightforward. Consistent and agreed-upon guidance on how to mainstream adaptation is a recognized gap in the areas of built infrastructure and codes, standards and related instruments (Steenhof and Sparling, 2011) and forest management planning (Johnston et al., 2011; Johnston and Hesseln, 2012). Adjusting existing processes and frameworks to account for changing climate can involve challenging core assumptions (Steenhof and Sparling, 2011).

Policies designed to address issues unrelated to climate change can also pose barriers to adaptation. For example, for natural resource and conservation managers, policies that target single species management (e.g. biodiversity, alien invasive species), as opposed to focusing on broader management goals, can become problematic with climate change-related shifts in ranges and abundances of species (Jantarasami et al., 2010; Johnston et al., 2011). By stipulating conditions, such as harvest levels and species to be replanted, aspects of provincial forest policies, such as tenure agreements, limit the potential to adopt innovative adaptation approaches by forest companies (Johnston et al., 2011; Johnston and Hesseln, 2012). Finally, outdated community development plans and provincial planning frameworks, as well as a lack of long-term sustainability plans, discourage municipal adaptation – as shown for three municipalities in the lower mainland of British Columbia (Burch, 2010).

4.2.4 PSYCHOLOGY AND VALUES

People and groups perceive, interpret and act on new situations differently and the implications of this for adaptation are increasingly being recognized. Psychology research has helped to understand why capacity to adapt does not necessarily translate into action. Understanding of the roles played by values, culture and social interactions in framing problems and in identifying acceptable solutions is growing (Burch and Robinson, 2007; Lynam, 2011). The interplay between individual and collective attitudes and behaviour has also been explored (Wellstead and Stedman, 2011; Cunsolo Willox et al., 2012; Wolfe et al., 2013).

Limitations in how we think, view the world and perceive risk figure prominently in the literature on psychological barriers to adaptation (Gifford, 2011). Short-term thinking, using uncertainty as a reason to postpone action, being selective about what is paid attention to and optimism bias are apparent in research into governments (ACC Community of Practice, 2011), business and industry (Johnston et al., 2011; Kovacs, 2011; Johnston and Hesseln, 2012; Linnenluecke et al., 2012; NRTEE, 2012 a, b), public health and emergency preparedness (Hutton, 2011; Clarke and Berry, 2012) and vulnerable populations (Berry, 2011; Wolfe, 2011). World views shape people's definition of acceptable adaptation options. For example, in one study, experts rejected novel approaches to biodiversity and conservation policy that considered species-for-species tradeoffs (Hagerman et al., 2010). In some cases, people perceive behavioural change as risky, either financially, socially, and functionally (Gifford, 2011). At present, financial risk appears to be the dominant source of risk that constrains adaptation (e.g. Johnston and Hesseln, 2012).

Values underlie beliefs, attitudes and behaviour, both by individuals and as groups. Until recently, the literature mainly addressed values by way of highlighting impacts on culturally-significant activities and places and the importance of indigenous knowledge and perspectives (Burch and Robinson, 2007; Pearce et al., 2011; Wolfe et al., 2013). Understanding the influence of values on responses to a changing climate is an emerging research topic (Hutton, 2011; Cunsolo Willox et al., 2012; Wolfe et al., 2013). Research has shown, for example, that residents in communities of comparable location and socio-economic characteristics can perceive climate-related events – and therefore the relevance of adaptation – differently. In Labrador, one community associated an unseasonably-warm winter with a sense of loss and isolation, whereas another rated the warm winter as neutral to positive (Wolfe et al., 2013). Other studies test the influence of individual attitudes and organizational culture on engagement in adaptation. For example, public servants in British Columbia are more likely to integrate adaptation thinking in their work if they work in natural resource ministries (BC Stats, 2012). Accounting for cultural differences among professions – municipal planners, engineers and employees in direct service delivery – is also important in adaptation planning (Burch, 2010).

4.2.5 LEADERSHIP

Leaders – whether individuals or organizations – who are willing to champion new ideas and create change can be influential drivers of adaptation (*see* Case Study 2). Conditions internal and external to the organization affect leadership abilities. Limited demand from citizens and other external stakeholders is considered to be a factor slowing government action on adaptation (ACC Community of Practice, 2011).

Internal organizational structures can also hinder action. Rigid hierarchies, the absence of clear mandates and delegation of responsibilities can deter managers from allocating resources and staff time to adaptation planning and resources (Jantarasami et al., 2010). Even individuals who are motivated to integrate climate change adaptation in their work and are knowledgeable about how to do so may fail to act because of competing priorities (Davidson and Bowron, 2012).

5. OVERCOMING BARRIERS AND FACILITATING ACTION

Research on overcoming barriers and challenges to adaptation tends to focus on enhancing awareness and building adaptive capacity; however, there is increasing recognition that for adaptation to be successfully implemented, the will or desire to adapt is also necessary. This requirement has received little attention so far in the literature on climate change and adaptation. This section discusses approaches and mechanisms being used to overcome existing barriers and facilitate sustained adaptation.

5.1 INCREASING AWARENESS

The first step towards adaptation implementation is awareness of climate change, potential impacts, and the need to adapt (*see* Box 2). Increased awareness of climate change can occur spontaneously (e.g. through the experience of extreme events) or through planned activities (e.g. workshops, awareness-raising campaigns, learning modules or publications).

Extreme events can act as a wake-up call, raising awareness of current vulnerabilities to weather, which can trigger adaptive responses (Berrang-Ford et al., 2011; Ford et al., 2011). Media coverage of extreme weather events often makes the association with climate change (e.g. CBC, 2013; Kolbert, 2012; Thompson, 2013), which can provide an opportunity for initiating discussions on adaptation. There are several examples throughout this report and elsewhere of adaptation actions being catalyzed by extreme events, such as floods, wildfire and windstorms (e.g. Lemmen et al., 2008; Richardson, 2010). For businesses, extreme weather events can also increase awareness of climate change (NRTEE 2012a; IEMA, 2013). Extreme weather and climate events can present a shock that stimulates organizations to rethink their operations and assumptions and adjust appropriately (Burch, 2010). However, others caution that adaptation in response to a crisis or disaster brings risks of redundancies if time is not taken to adequately incorporate and consider adaptation in the context of existing policies, procedures and practices (Plummer et al., 2010).

Several organizations in Canada have developed tools to raise awareness of adaptation among practitioner groups and decision makers. For example, the Canadian Institute of Planners (CIP) introduced a Climate Change Impacts and Adaptation Program that includes the development of Continuous Professional Learning (CPL) modules for its members (Canadian Institute of Planners, 2013). Similarly, the Federation of Canadian Municipalities (FCM) partnered with the Canadian Standards Association (CSA) to develop an e-learning course for municipalities, which is focused on adapting critical infrastructure to climate change and severe weather events (FCM, 2013). The National Round Table on the Environment and Economy (NRTEE) developed a 'dashboard for business success in a changing climate,' to raise awareness of adaptation within organizations, and help businesses assess and manage climate change risks and opportunities (NRTEE, 2012b). University-level courses are also an important mechanism for raising awareness of climate change adaptation through education. Targeted activities such as these take into account the culture and values of the groups they are seeking to influence, which is important for addressing psychological and communication barriers to adaptation (*see* Section 4.2).

Workshops are frequently used as a mechanism to raise awareness and stimulate local adaptation. These typically bring together people with expertise in climate change science and adaptation with community leaders, municipal staff and sometimes the general public. Although the explicit goals of these workshops vary, and may include, for example, identifying priorities (e.g. Picketts et al., 2012; Stocker et al., 2012), setting the stage for ongoing collaboration and dialogue (e.g. Stocker et al., 2012) and enhancing adaptive capacity (*see* Case Study 3), they all have the underlying benefit of increasing awareness of the value of adaptation

CASE STUDY 3

BUILDING ADAPTIVE CAPACITY IN THE COLUMBIA BASIN

The Columbia Basin in southeastern British Columbia covers 671 000 square kilometres and encompasses a variety of ecosystems including grassland, interior rainforest, wetlands and alpine (Figure 5). Hydroelectric power generation, forestry, mining, tourism and agriculture constitute major economic activities in the Basin, all reliant on natural resources. Adaptation to climate change is one initiative of the Columbia Basin Trust (CBT), which supports efforts to create and maintain social, economic and environmental well-being in the Canadian portion of the Columbia River Basin. Identified risks associated with a changing climate include changes in glacial runoff, water temperature, freeze/thaw cycles, diseases and pathogens, flooding, frequency of droughts, severity of wildfires, landslides, avalanche risk and biodiversity (Columbia Basin Trust, 2008).

Building on their past work, the CBT established a model for one-day workshops to help mainstream adaptation efforts throughout the basin using climate projections and guidance material (e.g. Columbia Basin Trust, 2012). An adaptation planning process that could take a year or more is condensed into a single day filled with local government dialogue that defines three priorities for the community in terms of climate change resilience. The condensed workshop models have been well received by communities and by practitioners, such as watershed and emergency managers. Collaborative follow-up work has included refinement of communications strategies and existing plans, such as flood hazard plans, to incorporate climate-related data.

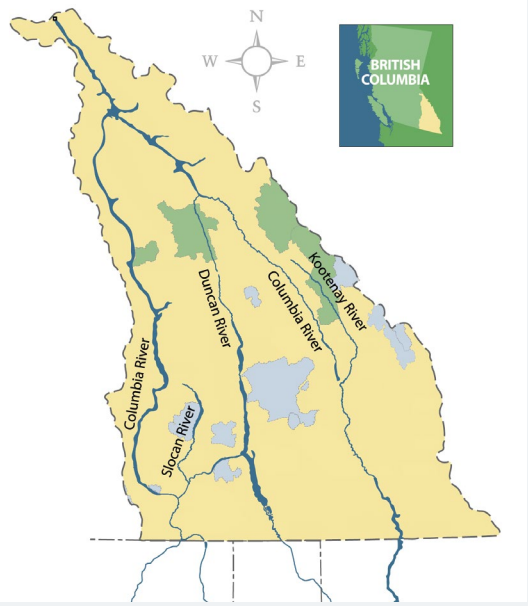

FIGURE 5: Map of the Columbia Basin Region *(Source: Columbia Basin Trust, 2008).*

among those who are positioned to implement and/or demand change.

Data visualization has emerged as an important tool to enhance communication at workshops, portraying scientific data on projected climate impacts in a way that is relevant to local users (e.g. Sheppard et al., 2011; Cohen et al., 2012; Colombo and Byer, 2012). Examples include illustrations of how flooding would increase in a specific region with projected sea level rise (Figure 6) or how mountain snow conditions would change in response to changing climate (Cohen et al., 2012). Variables can be adjusted to demonstrate the influence of adaptation measures, thereby increasing awareness and encouraging continued dialogue (Cohen et al., 2012). Other approaches to interactive visuals include the use of Google Earth in workshops, where researchers present a base map of the region, then overlay economic, social, ecological and cultural layers to allow participants to work together to identify 'sustainability hotspots' and to stimulate discussion on climate change adaptation (Stocker et al., 2012).

FIGURE 6: Example of a graphic output of data visualization – visualizing a dyke infrastructure scenario *(Source: www.fraserbasin.bc.ca/_Library/CCAQ_BCRAC/bcrac_delta_visioning-policy_4d.pdf).*

5.2 BUILDING CAPACITY

This section highlights ongoing efforts and evolving approaches to continue building capacity to adapt effectively to future climate change.

5.2.1 ADDRESSING INFORMATION NEEDS

One of the most commonly cited barriers to adaptation is deficiencies in information for decision making (*see* Section 4.2). Decision makers are looking for the right type of information, at an appropriate scale and level of detail that is accessible and understandable.

Over the past 5 years there has been an increase in the availability and quality of climate scenarios. Several groups in Canada have focused on providing scenario data, and making it publicly accessible (e.g. the Canadian Climate Change Scenarios Network, the Pacific Climate Impacts Consortium, and Ouranos). These groups assist decision makers in adapting to climate change by providing access to relevant and useable data, maps and graphs of future climate conditions.

In recognition of the need to package climate data in understandable and useable formats, many projects have focused on communicating and interpreting information relevant to decision makers through workshops, community meetings and other participatory initiatives (e.g. Ogden and Innes., 2009; Shaw et al., 2009; Hennessey, 2010; Picketts et al., 2012; Stocker et al., 2012). Engaging stakeholders in defining research questions and outputs is recommended as a way to make science more useable for decision makers (Halliday, 2008; Ford et al., 2013). Lessons learned from these projects can help to inform other communities, particularly with respect to methods and approaches, and there is an opportunity for jurisdictions that are more advanced on adaptation planning to share their knowledge with others. The National Climate Change Adaptation Community of Practice (CCACoP) is an example of a mechanism to transfer information, knowledge and understanding on adaptation (Case Study 4).

CASE STUDY 4

PROMOTING ADAPTATION BY SHARING INFORMATION AND KNOWLEDGE THROUGH A VIRTUAL COMMUNITY OF PRACTICE

The Climate Change Adaptation Community of Practice (CCACoP) supports the efforts of Canadian provinces and territories to incorporate climate change adaptation into planning and policies through the transfer of knowledge across jurisdictions. It is an interactive online portal that provides a space for researchers, experts, policymakers and practitioners from across Canada to come together to ask questions, generate ideas, share knowledge and communicate with others working on climate change adaptation. Launched in 2010, the CCACoP stemmed from an idea of the Council of the Federation, a provincial and territorial forum, which endorsed the creation of such a virtual community in 2008. It currently has more than 500 members.

The knowledge-exchange and communication that takes place during webinars and through the 'Call for Knowledge' forum helps to form new relationships and connect practitioners from across Canada. The growing and increasingly diverse membership (*see* Figure 7) and the intensifying site activity help to increase awareness and promote adaptation. The community has evolved to include issue-specific sub-communities such as the *Forestry Adaptation Community of Practice* (FACoP), established in 2012 on behalf of the Canadian Council of Forest Ministers. The main elements contributing to the success of the portal are (1) a stable web platform; (2) advisor input and member feedback; (3) a dedicated community facilitator; (4) cross-disciplinary membership; and (5) ongoing and consistent communication to members.

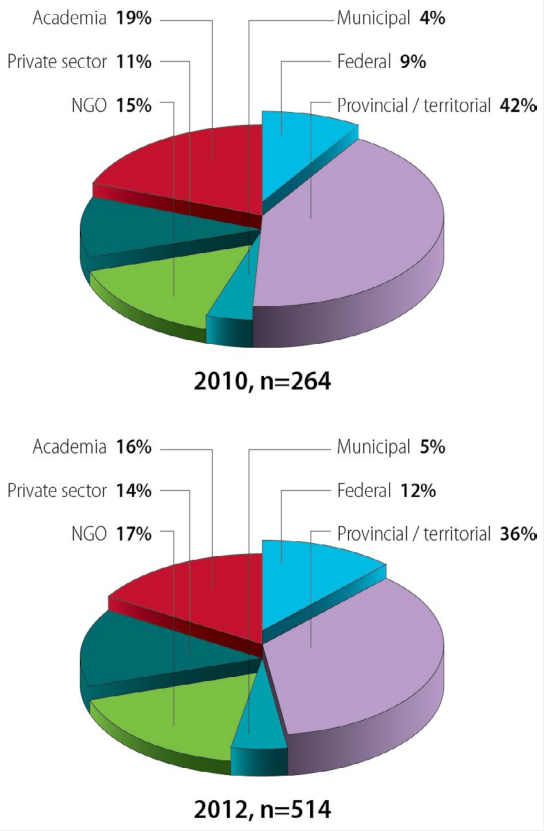

FIGURE 7: Membership of the national Climate Change Adaptation Community of Practice.

5.2.2 DEVELOPING AND DISSEMINATING ADAPTATION TOOLS

Over the past 5 years, there has been a substantial increase in the number of decision support tools available for municipalities. These include maps and visualizations, guidance for scenario interpretation and use, and adaptation guidebooks and toolkits (*see* Carlson, 2012; Richardson and Otero, 2012; Health Canada, 2013).

Professional organizations have also been developing tools to assist their members in adapting to a changing climate. For example, in 2008, the Canadian Institute of Planners developed a policy that required members to consider climate change in their actions and recommendations, developed a model standard of practice and assessed current planning tools for their use in adaptation. This work was supported by training modules for university planning courses and in-service training of planners (Canadian Institute of Planners, 2013).

Engineers Canada (along with partners) developed the PIEVC Protocol to assess the vulnerability of public infrastructure from an engineering perspective and consider adaptation options using a triple bottom line perspective. The tool has been applied in 26 case studies to both test the tool, and develop a reference library of case studies (PIEVC, 2012). The information in the case studies provided the basis for a review of codes, standards and related instruments in three categories of infrastructure (water resources, transportation and buildings; *see* Chapter 8 – Water and Transportation Infrastructure). Training workshops were held across the country to raise awareness of the need to adapt and to encourage awareness and use of the tool. Such follow up is important, as developing tools is only the first step – dissemination and facilitating uptake must follow, to ensure the tool is used effectively.

5.2.3 ADDRESSING ECONOMIC RESOURCE CONSTRAINTS

Approaches to addressing financial and economic constraints for adaptation will vary, depending on the actor and context. For industry and business, adaptation implementation will often depend on having a business model where the benefits of adapting are clearly laid out. This can involve cost-benefit analyses, but such analyses are relatively few (IEMA, 2013), perhaps because of the intrinsic difficulties in estimating potential future benefits. However, companies may be able to identify opportunities where acting today (in present value terms), would cost less than acting later (e.g. where it is more cost-efficient to incorporate adaptive measures into building design, rather than retrofitting later; Fankhauser and Soare, 2013).

Assessing costs of adaptation should give consideration to co-benefits (NRTEE, 2011; IEMA, 2013). Other ways to moderate the potential costs of adaptation include developing policies and strategies that can be reassessed and updated over time, which reduces the up-front costs and the risks associated with over-adapting (Colombo and Byer, 2012). A focus on win-win measures that would provide immediate benefits and increase longer-term resilience to climate change, is another recommended strategy. Examples include improving water efficiency, enhancing flood protection, implementing measures to deal with heat stress and improving environmental management to protect ecosystems (Fankhauser and Soare, 2013).

In many cases, issues of economic constraints in Canada are more about facilitating the use of existing resources, rather than creating more financial resources (Burch, 2010). In cases where large investments in infrastructure are required, the costs are sometimes shared by multiple levels of government (e.g. Andrachuk and Smit, 2012).

5.2.4 CREATING THE WILL TO ADAPT

Underlying attitudes also need to be considered to advance adaptation, especially within work environments, in both the public and private sector. For example, cultural norms within organizations that value maintaining the status quo can be challenging to address (Jantarasami et al., 2010). Suggested ways to foster an adaptation-supportive environment and empower employees to change their way of thinking about climate change adaptation include: i) developing dynamic and flexible management processes; ii) establishing clear mandates that prioritize adaptation; iii) providing education on the issue of climate change; iv) clearly designating responsibilities; and v) ensuring adequate funding (Jantarasami et al., 2010; Davidson and Bowron, 2012).

Although there are many commonalities between the public sector and the private sector with respect to the will to adapt, there are also key differences. Businesses may have more flexibility to respond in innovative ways, being less constrained by policies and procedures than in the public sector; but at the same time, they are driven by their bottom-line and, if publicly owned, are accountable to their shareholders. Businesses may also be less likely to share or report on their information on adaptation for proprietary reasons (*see* Chapter 5 – Industry). To increase the will to adapt within the business environment, highlighting adaptation initiatives that would increase comparative advantages over competitors (for example by building resilience to supply chain disruptions) is a motivating influence, as is demonstrating the potential for co-benefits (IEMA, 2013) and enhancing corporate reputation. Differences in the nature of the business are also important to consider, as

some industries place great value on innovation and leadership, while others tend towards a more conservative business culture. Approaches and attitudes will also differ between large, international conglomerates, and small and medium enterprises (NRTEE, 2012b).

Mechanisms that promote corporate social responsibility and environmental sustainability (e.g. forest certification schemes, environmental management systems) could increase awareness and interest in adaptation in the private sector (Johnston and Hesseln, 2012), as could growing demands for reporting on climate change and material risk (*see* Chapter 5 – Industry; NRTEE, 2012a, b). However, relying on market-based mechanisms to drive adaptation is likely insufficient. For example, research suggests only a minor role for insurance in inducing planned adaptation of built infrastructure to climate change (NRTEE, 2009; Cook and Dowlatabadi, 2011; OECD, 2012).

CASE STUDY 5

DEVELOPING ADAPTIVE MANAGEMENT PLANS: GREAT LAKES EXAMPLE

The International Upper Great Lakes Study (IUGLS) of water level changes in the Great Lakes basin concluded that costs and environmental and institutional constraints precluded investment in structural adaptation measures at this time. Adaptive management provided the best mechanism for addressing future uncertainties and the risks associated with extreme water levels due to natural variability and climate change (Leger and Read, 2012; *see also* Case Study 4 in Chapter 8).

The study used an adaptive management scoping process to explore a number of key questions (Figure 8). The process used "decision scaling" to link *bottom-up* stakeholder-defined water level thresholds with *top-down* development of climate change scenarios (Brown et al., 2011; 2012; Moody and Brown, 2012). The first step engaged stakeholders and resource experts using a range of methods (onsite surveys, interviews, data collection, analysis and modeling, expert judgment, and public information sessions) to assess system vulnerability and define coping zones for key issues.

Three coping zones were defined, with corresponding management alternatives. Zone A levels are acceptable (within the historical range, but not the extreme highs and lows) and within the tolerance and expectations of stakeholder groups. In Zone B, levels are outside the expectations of an interest but current management regimes can be used to cope with them. While there may be significant changes in activities, benefits, and costs in this zone, most interests do not face serious financial consequences or irreversible impacts. Zone C levels create persistent negative consequences. For example, hazard zone policies and major infrastructure would be compromised. In this state, interests are forced to make significant changes in activities, forego long-standing benefits, or experience significant permanent or long-lasting adverse impacts (Leger and Read, 2012). Then a range of methods – historical data, General Circulation Model (GCM) and Regional Climate Model (RCM) scenarios, stochastic and paleo-analysis – were employed to generate climate information on the range and frequency of water level conditions, including extremes (International Upper Great Lakes Study, 2012; *see also* Chapter 2). These were then used to develop risk matrices that examine the probability and consequence of specific events.

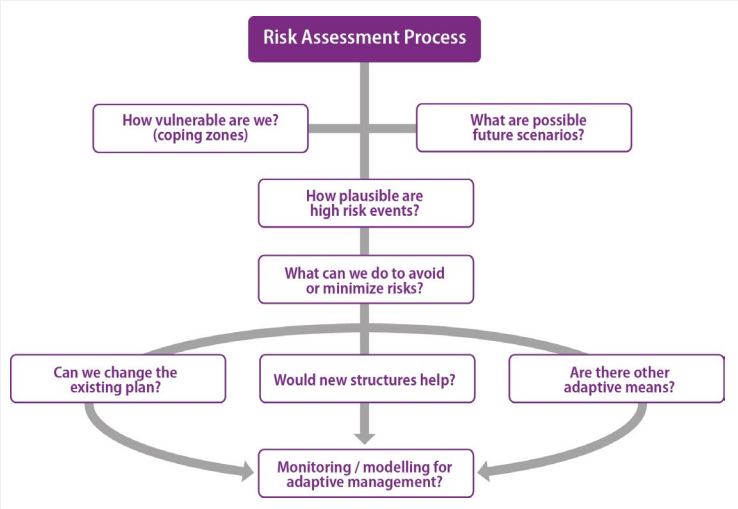

FIGURE 8: Adaptive management assessment process *(modified from Leger and Read, 2012, Figure 2-1, p. 8).*

Armed with this understanding of key risks and thresholds, long-term monitoring, system modeling and performance assessment inform the ongoing evaluation of management activities. Existing policies, practices and plans need to be reviewed, and where found wanting, be revised as new information emerges, knowledge evolves and/or the water level regime changes. To that end, according to Leger and Read (2012), "[…] the adaptive management strategy […] is focused on what is necessary […] in order to develop a greater understanding of appropriate adaptive actions, and of when and how they should be implemented or adjusted to minimize future risks." Adaptive Management Pilots addressing pressing regional or local water level issues have been proposed as a means of initiating the process and testing and refining methods of collaboration.

To date, adaptation in Canada has been primarily focused on no-regrets options, incremental changes to existing systems and flexible, adaptive approaches (*see* Case Study 5). These approaches tend to minimize the actual and perceived risks of adaptation, such as over-adapting, mal-adapting and wasting resources. Some researchers suggest, however, that these will not always be sufficient as climate continues to change and that larger, transformational changes will be needed (Kates et al., 2012; O'Brien, 2012; Rickards and Howden, 2012, *see* Box 3). In such cases, increasing the will to adapt and to embrace this type of change will likely be even more challenging than for incremental approaches.

5.2.5 CREATING AN ENABLING ENVIRONMENT

Creating an environment that is supportive of adaptation includes removing and reducing barriers (such as policies and regulations that constrain adaptation), enabling adaptation and empowering people to accept and embrace change.

Government policies and programs influence adaptive capacity (Ford and Pearce, 2012), with the role of government varying, depending on level (e.g. municipal, provincial/territories, federal) and respective mandates (*see* Section 4.1). Roles for all levels in creating an enabling environment include building strong communication channels, providing access to data and information (e.g. research, project results, tools and climate change information), increasing engagement of citizens and stakeholders, and implementing flexible and adaptive policies (Corkal et al., 2011). Adaptive policies are designed to respond in an ongoing manner to changing, uncertain and complex conditions (Swanson et al., 2010). Assisting vulnerable groups and addressing existing barriers are also seen as roles for governments (Fankhauser and Soare, 2013). Clearly articulating climate change adaptation as a priority and providing opportunities to integrate climate change throughout the organizational structure can also contribute to building an enabling environment (Burch, 2010; Lemieux et al., 2013). Providing opportunities for, and encouraging – enhanced and effective collaboration (between various levels of government, different departments and external stakeholders, including industry) is also an important role for government. Indeed, in the Canadian context, collaboration is seen as fundamental to advancing adaptation (Government of Canada, 2011; *see also* Case Study 1).

The importance of "champions" in driving adaptation within organizations – people who have the initiative, enthusiasm and authority to implement change – has also been noted in the literature (Tompkins et al., 2010; Richardson and Lemmen, 2010; *see also* Case Study 2). While the role of individuals can be important, Van Damme (2008) and Johnston and Hesseln (2012) emphasize the importance of embedding progressive attitudes and adaptation thinking in corporate culture, rather than relying on the presence of key individuals.

BOX 3

TRANSFORMATIONAL CHANGE

Transformational change as a response to climate change is an emerging field of research (O'Brien, 2012). As such, definitions and interpretations are still evolving (Rickards and Howden, 2012). Some see 'transformation' as a separate and distinct response to climate change (in addition to mitigation and adaptation; O'Brien, 2012). Others interpret transformation as a type of adaptation that encompasses larger scale, more extensive adaptations, and adaptations that are new to a region or resource system (Kates et al., 2012), differentiating instead between *incremental* and *transformational* adaptation (Park et al., 2012; Figure 9). Either way, transformational changes would result in significant and widespread shifts which, while bringing significant benefits, could also challenge environmental, social and economic norms, the status quo and/or current value systems.

Examples of transformational change include significant changes in land use (e.g. from agriculture to forestry), relocating entire communities to reduce risks from coastal erosion (Kates et al., 2012) and paradigm shifts in thinking (ACT, 2013). Compared to incremental approaches, transformational adaptation brings potential for greater gains, but with greater risks (Rickards and Howden, 2012). However, it is noted that while the changes would be fundamental, they are not necessarily irreversible (Park et al., 2012; Rickards and Howden, 2012). As applied to climate change, the concept of transformational change has primarily been discussed to date in the context of natural ecosystems and agriculture, and through a theoretical lens.

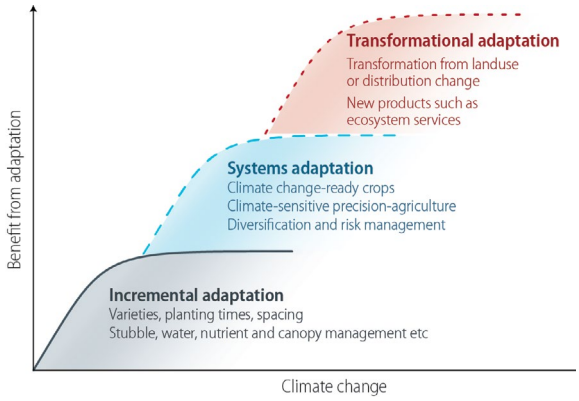

FIGURE 9: Differentiating levels of adaptation with examples from agriculture *(from Howden et al., 2010; Rickards and Howden, 2012)*.

6. SUMMARY

Trends in adaptation research and action in Canada over the past 5 to 10 years reflect a complex issue informed by diverse research, expanded levels of engagement, and increasing examples of implementation. Discussions have moved beyond justifying and clarifying the legitimacy of adaptation as a response to climate change, to understanding the process of adaptation – who is adapting, how and why they are adapting, and what is constraining or enabling the process.

In Canada, there are examples of adaptation occurring at all levels of government, by industry groups, non-governmental organizations and individual companies. Similar to the situation in 2008, activity at the municipal level still appears to dominate. Municipalities have been developing adaptation plans, participating in awareness-raising workshops, and some have made changes to their policies and procedures to take a changing climate into account. Higher levels of government have also developed adaptation strategies and policy frameworks, and have been facilitating climate change adaptation through the establishment of collaborative mechanisms to facilitate applied research, development of decision support tools and sharing of adaptation experiences. Industry has become more engaged in the issue, particularly within sectors with high sensitivity and exposure to climate and weather (e.g. forest, hydroelectricity and tourism) and adaptation activities have grown within public service sectors, with, for example, numerous examples of proactive adaptation planning within the health sector.

Overall, significant progress has been made on adaptation activities in Canada; over the past five years there has been an increase in adaptation engagement, research, awareness, planning (including strategies and policies) and collaboration. Progress is less evident in the implementation of measures to adapt to future climate conditions (i.e. specific changes made to structures or approaches to reduce vulnerability or take advantage of potential opportunities). Although some examples are available, such as the revised sea dyke guidelines in BC (*see* Chapter 8 – Water and Transportation Infrastructure) and the diversification of winter resorts to include warm-season activities (*see* Chapter 5 – Industry), the number does not appear proportionate to our high capacity to adapt and our ever-growing knowledge base. This is similar to the situation in other developed countries, where implementation is also still in its early stages (e.g. *see* Bierbaum et al., 2013; Bauer et al., 2012; Biesbroek et al., 2010).

At each step of the adaptation process (Figure 2), barriers and challenges can constrain or limit adaptation. Some of these – such as limited resources, information gaps, or lack of technology – are increasingly understood. Others, such as values and psychological biases, are less tangible, though likely just as important as they influence the will to adapt, a critical factor in ensuring that awareness and adaptive capacity actually translate to action. New understanding of barriers has emerged, both as a result of increased adaptation activities, and of increased integration of perspectives from other disciplines.

Moving forward will require further attention on overcoming barriers and facilitating adaptation. Learning from others and the practical application of research will help in this regard, as will continued contributions from organizations developing learning modules and guidance material on adaptation. As the public and private sectors continue to become more engaged on the issue, understanding the benefits and trade-offs of implementing adaptation measures will become more pressing. All levels of government have a continuing role in creating an enabling environment for adaptation.

In conclusion, our understanding of the adaptation process in Canada is continually improving, and examples of adaptation implementation have grown over the past 5 years. We have the awareness and the capacity needed to adapt in most cases. Continuing efforts on addressing barriers and enhancing our will to adapt (for all groups involved) will help ensure that adaptation continues to advance to the degree necessary for maintaining social, economic and environmental sustainability in the long term.

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