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Adapting to Climate Change
Is Canada Ready?

REGULATORY POLICY AND TAXATION

Adapting to Climate Change: Is Canada Ready?
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Preface

While large-scale climate change mitigation initiatives such as the Kyoto Protocol have attracted much attention, less attention has been paid to developing adaptation strategies to deal with the consequences of climate change in the near, medium-term and distant future.

As a part of its ongoing efforts to anticipate policy issues and to help develop effective adaptation strategies, The Conference Board of Canada, with the cooperation of Natural Resources Canada, investigated the country's preparedness to deal with the consequences of climate change. The result is this report, which provides an overview of adaptation strategies and highlights areas for future adaptation activity.

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At a Glance

- Adaptation and mitigation ought to be complementary parts of any climate change strategy.
- Climate change adaptation measures have localized impacts. However, successful implementation of any measure needs the cooperation of all levels of government.
- A long-term perspective that considers all costs and benefits to the economy is needed to assess adaptation strategies.
- There is both a need for further research into the impacts of climate change on Canada and a need to better utilize existing research.
- To develop effective policies, policy-makers need better estimates of climate change's financial impact on assets, as well as of the costs of implementing adaptation strategies.

Future climate change will have a major impact on Canada in general and a substantial impact on specific areas of the country. A critical question that has to be asked is, "To what extent are Canada and Canadians prepared for the climate-related challenges of the future?" Conference Board of Canada research indicates that there is much work to be done and that the sooner work begins, the better the chances of effectively dealing with the climate challenges ahead.

Responses to climate change tend to have two aspects. The first, mitigation, is directed at reducing atmospheric concentrations of greenhouse gases by reducing the amount society discharges. The second, adaptation, is directed at dealing with the geophysical impacts of climate change. While Canada ought to pursue both options, this report focuses on the latter.

Adaptation strategies have to reflect the fact that climate change will affect numerous parts of the country in different ways and with differing degrees of severity. Sea levels will rise while the Great Lakes and the Prairies will have to deal with lower water levels resulting from a warmer environment. Adaptation strategies are critical, especially to prepare for distant events. However, they need not be dramatic or disruptive. They can include relatively minor changes to established practices. Adaptation strategies have to relate to local impacts. In addition, all levels of government must cooperate and provide clear leadership on adaptation issues.

Effective adaptation strategies will take a holistic approach that includes all the costs and benefits of policy changes rather than focusing on narrowly defined

consequences. The “economic value at risk” concept is a useful means of assessing the broader implications of climate change on economic actors and supports.

More research investment is needed to better understand future climate change impacts and to provide the basic information needed to develop and implement effective adaptation strategies. Canadians and their governments ignore the future realities of climate change at their peril. The sooner adaptation strategies are developed and implemented, the more secure the future will become.

Adapting to Climate Change
Is Canada Ready?

INTRODUCTION

Climate change will have a major impact on Canada in general and a substantial impact in specific areas of the country in particular. To what extent are Canada and Canadians prepared for the climate-related challenges of the future? This report engages in the evolving discussions on that critical issue by examining the concept of adaptation and adaptation strategies.

Canada's approach to dealing with climate change should be two pronged: a program of mitigation to reduce the amount of greenhouse gases (GHGs) being emitted and a program of adaptation to ensure the Canadian economy is prepared to cope with the ramifications of climate change. Mitigation measures such as the Kyoto Protocol aim to reduce, over time, atmospheric GHG emissions. In contrast, adaptation involves collecting policies, actions and research to modify existing facilities and structures to minimize future disruptions caused by climatic changes.

To what extent are Canada and Canadians prepared for the climate-related challenges of the future? This report examines adaptation strategies.

Without diminishing the importance of effective mitigation strategies, this report's focus is on adaptation in Canada. The report provides an overview of adaptation issues and costs, informational needs and research imperatives. It illustrates some areas where changes may be necessary for Canada to deal effectively with climate issues emerging in the short and medium terms.

This emphasis on adaptation reflects an approach advocated by the British House of Lords in July 2005. Its Select Committee on Economic Affairs argued that adaptation considerations ought to be cornerstones of any policy decisions related to investments, especially investments in "infrastructure, housing, coastal development and international development assistance."[1]

Canadians deservedly expect their governments and research communities to help them prepare for climate changes that could have profound effects on some parts of the country. Therefore, as in the U.K., there is a pressing need to start defining approaches and establishing societal systems to anticipate and adapt to the negative impacts of climate change.

Earth's atmospheric GHGs play an essential life-sustaining role. However, over approximately 250 years, human industrial activity has increased the atmospheric concentration of a key GHG, carbon dioxide (CO_2), from 280 parts per million (ppm) in 1750 to 375 ppm in 2005.[2] Termed the "greenhouse effect," the continuing increases in CO_2 concentration in the air will likely affect climatic processes. (See box, "General Circulation Models [GCMs], Climate Change Predictions.")

If the models are correct, Canada could, within the next couple of decades,[3] have to deal with the inundation of low-lying lands on its seacoasts, a shrinking Arctic ice cap, reductions in Great Lakes water levels, permafrost thawing and reduced river flow on the Prairies.[4] Reduced river flows will mean there will be less water available for agriculture and power generation. To adequately appreciate the full impact of such a development, and

General Circulation Models (GCMs[1]), Climate Change Predictions

- A doubling of CO_2 or its equivalent would cause an average global temperature rise of 1.5ºC to 4.5ºC.
- Over the next century, the net average rate of global temperature rise will be 0.2ºC to 0.5ºC per decade.
- The greatest warming will occur in high northern latitudes in winter.
- Drier summer soil conditions will be found in interior continental regions of northern mid-latitudes.
- Over the next century, sea levels are expected to rise by 15 cm to 95 cm, and they will continue to rise for centuries after the global climate has stabilized.

1 Linda Mortsch, Henry Hengeveld, Murray Lister, Brent Lofgren, Frank H. Quinn, Michel Slivitzky and Lisa Wenger, "Climate Change Impacts on the Hydrology of the Great Lakes–St. Lawrence System," *Canadian Water Resources Journal* 25, 2 (Summer 2000), Table 2, p. 160.

to recommend effective adaptation measures, it is necessary to view the total economic value put at risk. Canada must urgently develop and implement competent strategies and policies, since adaptation measures will need time to prove their economic effectiveness.

Adaptation is a process by which individuals, communities and countries seek to cope with and reduce the risks and consequences of climate change.

In this report we review some of the impacts that Canada may experience as a result of climate change and we look at the need for measured responses. The direct costs of adaptation and the economic consequences are then considered in various areas of Canada to examine the societal costs of these changes and value of modifying behaviours and facilities to accommodate the changes. Finally, the need for additional information, research and policy actions to guide the adaptation measures is discussed.

RESPONDING TO CLIMATE CHANGE

The highest profile efforts to address climate change have focused on reducing GHG emissions. This mitigation effort is critically important but time is a major complicating factor. Time is needed before the impact of GHG reductions are felt in the atmosphere and today's emissions will linger and perpetuate climate change for years hence. However, since economies change slowly, they need adjustment time to undergo significant changes to systematically reduce GHG emissions. Economies also need considerable time to enact policies and permit the responses to gain momentum.

Mitigation of climate change has become the focus of considerable national and international research and policy activity. Most significantly, the Kyoto Protocol under the United Nations Climate Change Convention has resulted in industrialized nations taking on targets to reduce GHG emissions levels "by at least 5 per cent below 1990 levels in the commitment period 2008 to 2012."[5] Signatories need to implement significant internal programs to meet these targets.

While there is substantial international support for mitigation efforts, it has long been recognized by international groups ranging from the Arctic Council to the British House of Lords that climate change will have a major impact. While mitigation is necessary, these groups understand the need to develop effective adaptation strategies.[6]

Some climate change is inevitable, as previous emissions have increased atmospheric CO_2 concentrations. Of special relevance to Canada is the need to reduce the impact of these anticipated changes by using adaptation mechanisms. Adaptation is a process by which individuals, communities and countries seek to cope with and reduce the risks and consequences of climate change. It refers to activities that would minimize the negative impacts of climate change or that would enable us to take advantage of new opportunities that may arise in a new environment. Adaptation is not a special issue. It is part of a more general process that considers and implements responses to changes in environmental conditions.

Adaptation is not new; what is innovative is the idea of incorporating adaptation to future climate risk into policy-making.[7] Because adaptation efforts occur within a continuum, some issues will require immediate attention while others are far enough in the future to allow for more measured and ongoing policy responses in which gradual changes prepare us for future realities. Regardless, the length of time necessary to implement good policy changes necessitates an immediate, active adaptation focus. Adaptation, especially in preparation for distant events, need not be dramatic or disruptive but could also include relatively minor changes to established practices.

The concepts of risk and risk approach, introduced here and further discussed later in this paper, are key to understanding adaptation. "Risk" is a probabilistic term used to denote the possibility of negative consequences resulting from decisions or processes. "Risk approach" denotes the process of deciding on preparatory action associated with risk.[8] Based on the considered risks of various actions or non-actions, ameliorative decisions may be possible and can be taken in accordance with the risk approach. If it is not possible, then decisions can deal with the consequences.

Canada is a minor player in global climate change. Acting unilaterally and solely to eliminate GHG emissions, even with all the resources at the country's disposal, would have minimal impact in reducing global

atmospheric GHG concentrations.[9] Nevertheless, as an advanced industrial country, Canada has decided to take part in global mitigation efforts. Former environment minister David Anderson said that Canadians wanted the country to sign on to the Kyoto Protocol because it was "the right thing to do, they believe Canada should play a part in the international battle against climate change."[10] It is also in the country's self-interest to engage in adaptation, as it has numerous sensitive areas that are vulnerable to climate change.

The most effective and cost-efficient adaptation responses for policy-makers will generally be anticipatory and will involve collaborations.

Canada could experience a level of climate change in the decades ahead that could increase stress on the whole range of Canada's natural and physical capital assets. Thus, adaptation thinking will need to become an integral part of the decision-making process to ensure a sustainable future. The different types of capital may require different approaches to adaptation.

Natural capital includes water resources, fisheries, forests and agricultural lands that are routinely utilized by societies for survival and wealth creation. For example, it may be necessary to modify forest management practices to accommodate new climatic realities. Physical capital comprises human-made assets such as roads and utility networks, buildings, dams and reservoirs. An example of adaptation would be adapting road and rail networks in coastal areas to accommodate increases in sea levels.

Adaptation policy development is inherently multifaceted and complex. The consequences of climate change within geographic areas, such as the Arctic, are often fraught with conflicting opportunities and challenges. For example, climate change will likely lead to the opening of Canada's fabled Northwest Passage to year-round navigation as early as 2020. That change will bring with it vast economic opportunities in terms of resource exploration, international shipping and trade. However, it will also bring new challenges, such as increased requirements related to protecting the Canadian perimeter. For example, in August 1999 China sent a ship into the Canadian Arctic in previously unnavigable territory, without notifying Canadian officials beforehand.[11]

Arctic adaptation also raises many other policy issues that will need to be addressed.[12] Scientists consider the Arctic to be a bellwether of the impacts of climate change globally.[13] Policy-makers concerned with adaptation and sovereignty should view the Arctic in the same way.

ADAPTATION STRATEGIES

Adaptation strategies help soften the negative consequences of climate change. However, varying circumstances may demand different responses, and adaptation strategies must be tailored to the particular situation. There are a variety of approaches available to policy-makers working on adaptation issues. Decision-makers could adhere to an *active anticipatory* approach, where policy actions help reduce climate change damage before the effects are felt. Alternatively, a *reactive* approach would seek to reduce effects once they are clearly delineated and the costs of inaction well known. There is also the *passive* approach, in which policy developers refrain from implementing any policy measures and do not actively help society adapt to climate change, although this may be an unacceptable position for governments.

Determining the cost of climate change adaptation measures is fundamental to sound policy decisions.

The basic theoretical choice is between planned policy, which is the result of deliberate decisions, and inadvertent, ad hoc policy development, which occurs spontaneously and lacks direction. In terms of time, the most effective and cost-efficient adaptation responses for policy-makers will generally be anticipatory and will involve collaborations among individuals, organizations, industry and all levels of government.

ADAPTATION COST

Determining the cost of climate change damage and the cost of adaptation measures is fundamental to making sound policy decisions. Various researchers have addressed the effects of climate change, its cost and the cost of adaptation measures. As a rule, however, these studies do not explicitly report adaptation costs. Costs are instead measured as the difference between net social benefits (that is to say, social welfare) with and without climate change. This measurement is based on

the economic assumption of optimal adaptation to the existing climate (without climate change) and the altered climate (with climate change).

According to Dore and Burton,[14] modelled adaptation is effective in finding efficient or optimal solutions, but it is also misguided and subject to unrealistic assumptions. This usual approach treats the environmental damage as marginal to the economy and indicates that the optimal expenditure on remediation is reached when the marginal cost of remediation equals the marginal benefit of that remediation.

The level of adaptation is optimal when the last dollar spent on adaptation just equals the reduction in climate change damages achieved.

The modelled adaptation approach fails to recognize that the impacts of climate change are not marginal. Rather, they are global in two senses: first, they permeate every sector of the economy, and second, in a purely spatial sense, they extend over the entire biosphere. Thus, even if the impacts of climate change are spread over 50 to 200 years, as expected, the impacts cannot be treated as marginal. They are marginal only if a decision-maker adopts an excessively short-term horizon of three to four years. Such short-term horizons may be appropriate for small or even some medium-sized businesses, but policy-makers and larger enterprises need to cultivate a longer view.

Fankhauser's analytical model minimizes the sum of the two cost elements—adaptation cost and unmitigated damage cost—assuming the level of damage due to climate change and the level of global mitigation are fixed.[15] Both of these costs depend on the level of adaptation. However, adaptation costs increase as the level of adaptation increases, while the level of unmitigated damages decreases as adaptation increases. In this framework adaptation actions are justified as long as the additional costs of adaptation are lower than the additional benefits from reduced damage levels. The level of adaptation is optimal when the last dollar spent on adaptation just equals the reduction in climate change damages achieved by this expenditure. This is the marginal approach that Dore and Burton criticize as being inadequate to dealing with adaptation.

According to Fankhauser, there are five types of costs:

- *Adaptation costs* are the costs of the resources foregone by society to undertake adaptation measures.
- *Climate change damages* are the value of the extra damages that occur exclusively because of climate change.
- *Ordinary climate damages* include the adverse effects associated with current climate—that is, all climate-related costs that would also occur in the absence of climate change.
- *Other relevant costs* are the indirect costs that result from taking adaptation actions.
- *Imposed costs of climate change* are defined as the difference in overall costs (all above costs) between the climate change and the reference scenario.

In contrast to the marginal approach taken by Fankhauser, Dore and Burton take the portfolio approach to adaptation used in the preservation of capital portfolios. This approach involves taking options into account. Because some of these options may be lost forever due to irreversibility they have values, called "option values." According to Dore and Burton, the literature on option values acknowledges that we have a portfolio of natural assets, which yield perpetual dividends in the form of ecological services and other benefits to society. In the case of climate change, there will be a change in the distribution of some of these services (such as the hydrologic cycle and the carbon cycle), which will involve costly adaptation measures. If these adaptations are seen as portfolio management actions, designed to preserve natural capital assets and their perpetual dividends, then the key guiding principle should be the preservation of capital. For example, consider the law of trusteeship and the obligations that the law imposes on an executor of an estate. The moral and legal responsibility of an executor of an estate or a trustee is to preserve the capital that will be passed on to the beneficiaries of the estate.

In the environment, the preservation of capital requires adaptations that are not determined by the "Marginal Benefit = Marginal Cost" rule but by the need to restore the capacity and capability of the biosphere so that it can continue to deliver ecological services. This approach requires preserving ecosystem integrity as part of an adaptation strategy. Thus, part of an adaptation strategy would be to preserve *future options* by preserving the portfolio of natural assets, so that the same ecological dividends continue to flow.

That must be done under conditions of uncertainty, as the probabilities of events associated with climate change are not known. Capital preservation requires an approach that does not hinge on comparing the marginal costs and benefits of adaptation to climate change. In general, this portfolio approach to adaptation is more holistic.

CANADIAN EXAMPLES OF ADAPTATION

One reason for adaptation is to reduce the effect of severe weather events which are predicted to be more frequent in climate change scenarios.[16] In Canada, insured losses caused by severe weather-related events have grown substantially from losses in 1984 of about $39 million to $1.5 billion in 1998. Also, from 1993 to 1997, federal disaster payments averaged more than $500 million per year and reached $1.3 billion in 1998.[17] The Insurance Board of Canada data indicates that major multiple-payment occurrences for property damage due to extreme weather-related events totalled $860 million from January 1999 to July 2004.[18] The scale of these losses suggests that measures should be taken to avoid them, particularly if we anticipate more of them under most climate change circumstances scenarios.

The experience of the Winnipeg floodway exemplifies adaptation and protection. The floodway was built in 1968 at a cost of CDN$68 million to divert floodwaters around Winnipeg. Without it, 80 per cent of the city would have been left nearly underwater during the 1997 flood and 550,000 residents would have been forced to leave.[19]

Another example of this approach is the suite of policies and institutions established after Hurricane Hazel hit Ontario in 1954, causing widespread flooding and damage, as well as 81 fatalities in the Toronto area. New planning policies limited development in critical flood plains, and urban drainage designs minimized peak flows from storm events, thereby reducing floods. In combination these measures have left southern Ontario remarkably free of widespread damage over the past 50 years.

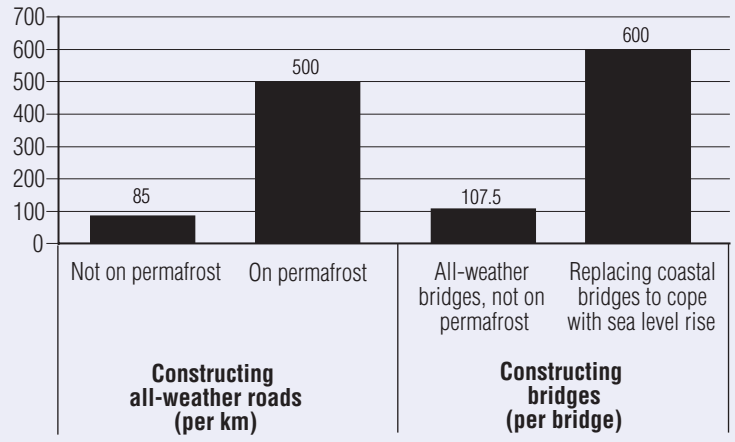
Dore and Burton generate scenarios over the next 100 years, based on General Circulation Models, that estimate that maximum precipitation in Toronto will increase from the baseline period (1961–90) to 2020 by a factor of four. Dore and Burton predict that the City of Toronto will face wastewater treatment adaptation costs of between CDN$633 million and CDN$9.4 billion, depending on the level of protection required.[20]

Canada faces significant adaptation costs related to constructing roads, bridges and water infrastructure. (See Chart 1.) For example, Halifax alone could spend, by some estimates, as much as CDN$6.5 billion to expand its waste treatment capacity, due to an increase in temperature and precipitation, and depending on the climate change scenario used. Estimating the total cost of adapting bridges and roads is harder because there are so many of them in Canada and because of particular local circumstances. However, a national program of local studies to delineate these risks and costs would help identify the exposure.

ECONOMIC VALUE AT RISK AND THE COST OF CLIMATE CHANGE IMPACTS

Canadian policy-makers have a difficult task in determining the effects of climate change on Canada and in deciding the most effective policy approaches to adaptation. Economic analysis can be useful in identifying the most efficient policy measures to deal with climate change's meteorological, biological and geographical effects. However, other factors must be taken into account as well—such as the cultural impact on Canada's Inuit population. The habitat effects of reduced

Chart 1
Estimated Costs for Adapting Infrastructure—to a 5 per cent increase in mean temperature and a 10 per cent increase in mean precipitation over the present century
(2001 $, 000s)



Source: Mohammed H.I. Dore and Ian Burton (2001).

sea ice cover and thawing permafrost will significantly change hunting and food-gathering possibilities. But even if political and equity concerns dominate policy interventions, economic analysis can illuminate policy options.

In this discussion, "economic value at risk" addresses the value of the economic activity supported by the infrastructure and other economic or social elements damaged by climate change. As an example, the cost of a railway bridge is a relatively straightforward engineering calculation. However, the value of the cargo hauled across the bridge, and hence its value to the enterprises that need this cargo, far outweighs the cost of the bridge. Further, if the goods transported across the bridge are critical items for some of the businesses, and if their loss would imperil the businesses' existence, the economic value of the bridge can be seen to include the contribution it makes to the businesses' integrity. This context again is an aspect of *asset preservation*: namely, preservation of the businesses.

Estimates are that sea levels will rise between 9 cm and 88 cm between 1990 and 2100, with an average estimate of 50 cm.

Economic value at risk and the cost of climate change are broadly synonymous concepts. The cost of climate change is whatever value a society loses to a changing climate. Economic value at risk is the estimated potential cost, with risk implying varying degrees of uncertainty in the estimates. Estimating the cost of replacing a bridge and the loss of cargo would be an example of "partial equilibrium" analysis. A "general equilibrium" analysis would trace the impacts of the lost bridge and cargo, the potential impact on capital assets (such as the businesses) and other cost impacts throughout the economy.

The cost of climate change, or value at risk, is different from the cost of adaptation. In the case above the direct value of the cargo and its value to enterprises that need the cargo would constitute the climate change cost. The adaptation cost would entail expenditures to replace the bridge with one suitable for the new conditions.

PHYSICAL AND DIRECT ECONOMIC EFFECTS OF CLIMATE CHANGE

Various studies have attempted to estimate the potential national costs of climate change in various economic sectors in both the United States and Canada. In the following sections we will review some of these costs. Caution is necessary when comparing these results, as each study employs its own methodology and assumptions.

SEA LEVELS ARE ON THE RISE

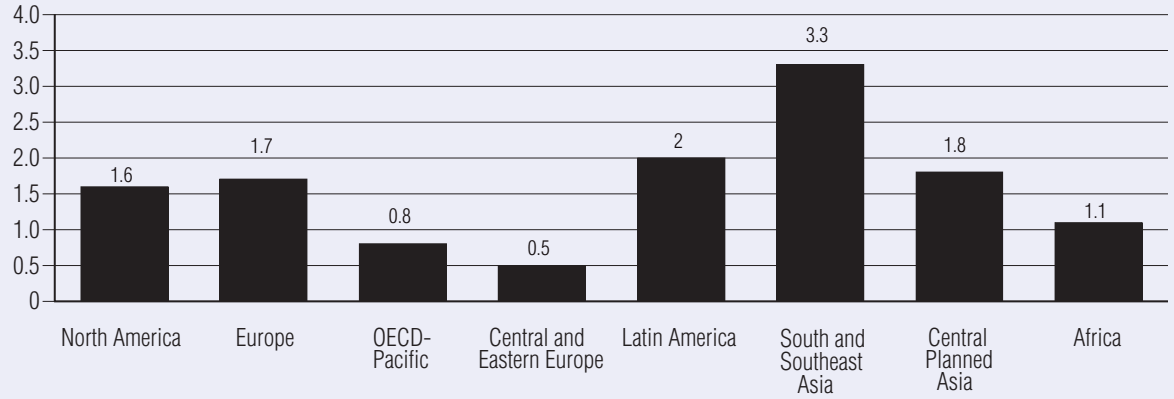
Sea level rise is among the most profound impacts of climate change. The thermal expansion of ocean waters, and the melting of land and sea ice due to higher ambient temperatures, are expected to raise the average sea level, affecting Canada's entire 240,000-km coastline. Estimates are that sea levels will rise between 9 cm and 88 cm between 1990 and 2100, with an average estimate of 50 cm.[21] The coastal zone is typically one of the most productive and diverse natural areas. Human activities cluster near low-lying coasts because of the fertility of land in deltas, the proximity of seafood and transport opportunities.

The costs of rising sea levels can be divided into three types: capital costs of protective construction (adaptation measures), the costs of foregone land services, and an ancillary cost associated with dry land loss when people are forced to leave flooded land.

While both the Atlantic and Arctic coasts will be affected, in this study British Columbia was chosen to illustrate some themes that will apply to Canadian coastal regions. A key area is the lower mainland of British Columbia, where the Fraser Delta could be affected by flooding, erosion and salt water intrusion. As this delta is a major agricultural and transportation area and home to hundreds of thousands of people, these are real risks.

The total cost of a 1-m sea level rise for all regions of the globe has been estimated. (See Chart 2.) Using this information and OECD data, the impact on Canada of a 1-m rise in sea level can be crudely estimated to be a total cost/loss of CDN$238 million per year. (The cost/loss estimate is based on the assumption

Chart 2
Impact of 1-m Sea Level Rise
($ billions; total costs*)



* Total costs include dryland loss, wetland loss, protection cost and migration.
Source: Chart by The Conference Board of Canada. Adapted from Tol, "Estimates of the Damage Costs of Climate Change" (2002), Table IV.

that Canadian gross domestic product (GDP) is 9.2 per cent of North American GDP, with an exchange rate of US$1 = CDN$1.25.[22]) This crude estimate illustrates the planners' dilemma. How robust is this loss estimate and what resources should be expended to reduce this loss? Such a decision must be based on careful estimates of actual costs and the risks of their occurrence. Indeed the magnitude of the potential loss will guide the effort to be expended in estimating the effects and ultimately the adaptation approach.

Sea levels are expected to rise up to 30 cm on the north coast of British Columbia and up to 50 cm on the north Yukon coast by 2050, mainly due to warmer ocean temperatures.[23] Parts of the Queen Charlotte Islands, the Fraser Delta, the sand cliffs at Vancouver and portions of Victoria are sensitive to the sea level rise, which could result in breaching of dykes, flooding, erosion and resultant changes to coastal ecosystems, infrastructure, and agricultural and archaeological sites.[24]

It is estimated that a 1-m sea level rise will threaten the natural ecosystem, affect the quality and quantity of groundwater supply, and inundate more than 4,600 ha of farmland and more than 15,000 ha of industrial and residential urban areas in British Columbia.[25] A detailed estimate of the cost of these effects will be necessary to identify the adaptation policies required.

Sea level rise could have a major impact on bridges in Atlantic Canada, where there are many coastal roads and bridges. The loss of navigational clearance probably means that Atlantic Canada will have to replace many of its bridges. In general it is cheaper to replace a bridge than to raise one. Since the average replacement cost of a coastal bridge is CDN$600,000 and there are about 3,000 coastal bridges in Canada, Dore and Burton estimate the costs of adaptation for all those coastal bridges to be about CDN$9 billion.[26]

GREAT LAKES

While sea levels are expected to rise, the great interior water systems of the continents are expected to suffer from diminished water levels. The Great Lakes shared by Canada and the United States are a vast water resource that covers a surface area of 246,000 km^2 and that contains almost 20 per cent of the world's fresh surface water. The five lakes and their connecting channels are bounded by 18,000 km of shoreline, much of it highly developed.[27] The Great Lakes perform ecosystem functions, such as providing fish and wildlife habitat. They also provide drinking water for millions of Canadians and Americans, and processing and cooling water for industries and thermal generating plants. They are used for commercial navigation and recreational boating and the connecting channel flows generate hydro power. Other significant uses include beach and wetland recreation, residential development, sport and

commercial fishing and waste assimilation. All of these resource uses depend on current levels and flows and will be affected by changes produced by atmospheric warming.

The impact of climate change could be significant. Depending on the scenario chosen, the mean temperature in the Great Lakes basin could increase by 1.5ºC to 2ºC in the autumn and 4.5ºC to 5ºC in the winter. Most areas of Canada will experience more precipitation, including the Great Lakes and the St. Lawrence Lowlands, but in these two areas, the increase will occur primarily as rain, with less snowfall. Combined with increases in evaporation and evapotranspiration, this change could reduce water levels by anywhere from 0.5 m to 1.6 m.[28]

Climate change could have a significant long-term impact on Great Lakes water levels . . . Many Great Lakes ports would have to be dredged . . . .

These hydrologic impacts will, in turn, affect a variety of water resource uses. Warmer climates will produce a lengthened, 11-month shipping season, but it is estimated that more frequent lower lake levels could increase Canadian commercial navigation costs by 35 per cent, or CDN$99 million.[29] Lower water levels would render some marinas temporarily or permanently inaccessible, and increased seasonal variability would make it more difficult to predict navigational hazards.

Commercial navigation contributes billions of dollars and thousands of jobs annually to the Canadian economy.[30] Lower water depths in connecting channels will cause ships to reduce their cargo weight to avoid grounding and, thus, unit shipping costs will increase. If more ships are required to carry the same volume of cargo, then increased delays may be experienced at locks. Some loading and unloading facilities and some smaller, regional ports may even become temporarily inaccessible during extreme low water periods.

In addition to these direct costs, shipping in the Great Lakes supports many industries, which in turn provide jobs and support communities. If the capability of the Great Lakes and the St. Lawrence Seaway to carry large vessels is compromised, these communities will be vulnerable to dislocations. To estimate the impact it is important to consider the types and volumes of commodities shipped through the seaway. A study of American ports, completed in 2001, suggests that the tonnage of commodities moving through these ports directly supported 37,000 jobs.[31] While similar data are not available for Canadian ports, the impacts would likely be proportional.

Climate change could have a significant long-term impact on Great Lakes water levels. Using the volumetric results derived from modelling and from arbitrary water level scenario analysis, a range of cost scenarios was generated for dredging the Goderich Harbour. It could cost as much as CDN$6.8 million to dredge the outer harbour and the harbour channel. Without the dredging, vessels would be required to reduce their total capacity, significantly affecting overall shipping costs.[32] Many Great Lakes ports would have to be dredged as part of the adaptation effort and likely re-dredged from time to time as water levels continued to change and flow regimes deposited silt in unexpected places.

These and other examples demonstrate the value and cost of adaptation measures. However, it is difficult to gain a useful, overall, high-level impression of these costs and benefits. Estimates vary and are fraught with methodological difficulties. However, an important barrier to improved estimates is the lack of reliable local bio-physical data on impacts. To estimate costs in the absence of impact data requires the use of many assumptions about these impacts. In addition, according to Burton et al., some of the principles of monetary estimation are not consistently followed.[33]

After the Yangtze River floods the Chinese government banned tree cutting . . . . Effective strategies for Canada may require similar broad thinking.

It may also be necessary to develop a more in-depth view of natural resource use in specific instances. For example, after the Yangtze River floods of 1998 caused over $30 billion in damages, the Chinese government banned all tree cutting in the river basin. Officials concluded that standing trees acted as a natural bulwark against future floods, and therefore “trees standing [were] worth three times as much as trees cut.”[34] Effective climate change adaptation strategies for Canada may also require similar broad thinking in terms of resource use.

CLIMATE CHANGE, WATER AND ELECTRICITY

The impact of climate change on water resources will also affect the generation of electricity. Beyond the direct use of falling water to generate hydroelectric power, water also plays a critical cooling role in the operation of electrical generation stations that run on fossil or nuclear fuels.[35]

In Canada, Quebec researchers examining the likely impact of climate change on hydroelectric production came to the tentative conclusion that impacts would vary. In northern Quebec trends indicated greater inflows into the river system. Water loss due to shorter freezing periods and due to increased evaporation and evapotranspiration would be more than compensated by precipitation increases of between 10 per cent and 25 per cent during winter months and between 5 per cent and 10 per cent during the summer.

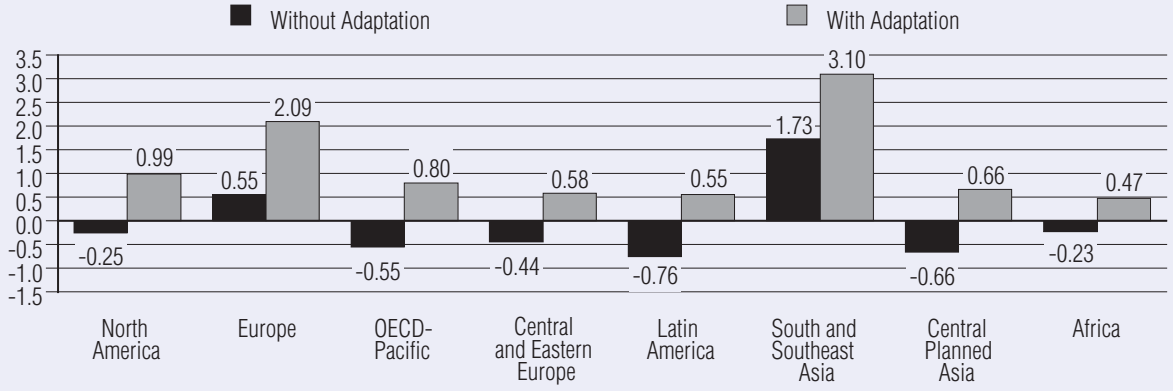
This is in contrast to southern Quebec, where hydro generation problems were predicted. Precipitation increases in the range of 10 per cent to 20 per cent during the winter and up to 5 per cent in the summer would not compensate for increased water losses due to runoff and evaporation. An Ouranos report corroborated arguments presented earlier by Mortsch concerning reduced water levels in the Great Lakes and St. Lawrence Lowlands. With less water available in the St. Lawrence River Basin, there would be less water to drive electricity turbines.[36]

It was stated above that climate change will probably alter the distribution of precipitation nationally, with some eastern parts becoming wetter. In the case of Halifax, projections by Dore and Burton show that projected mean annual precipitation could increase a dramatic 315 per cent by about 2020, compared to the 1961–1990 baseline period. Beyond 2020, the projections show that precipitation remains 149 per cent to 232 per cent higher. Increases of this magnitude may overwhelm recent wastewater treatment investments and necessitate additional expenditures within the climate change adaptation envelope. Without these additional expenditures, governments could conclude that developments in the Halifax basin should be limited, negatively affecting economic growth for the region.

AGRICULTURAL EFFECTS

Many studies describe the impact of climate change on agriculture. Results compiled by Tol[37] show that only two regions, Europe and parts of Asia, will see greater agricultural productivity, assuming climate warming of 2.5ºC. (See Chart 3.) However, all regions would benefit from adaptation measures. For Canada, it is estimated that crop production would fall by CDN$2.5 billion each year without adaptation. However, production could increase by CDN$10 billion if proper adaptation measures were applied. The increased production figures use Canadian crop production data and are based on the assumption that the effect of climate change on Canadian agriculture will be the same as the effect on all of North America.[38]

Chart 3
Impact of Climate Change on Agriculture as Percentage of Gross Agricultural Product
(per cent)



Source: Chart by The Conference Board of Canada. Adapted from Tol (2002), Table II.

Tol's calculation of CDN$2.5 billion in lost agricultural production does not include secondary and tertiary effects, such as lost employment in processing plants and transportation losses. Adaptation measures clearly improve farmers' prospects if they are implemented correctly, especially if they turn a projected loss of CDN$2.5 billion into a CDN$10-billion opportunity.

While changes in precipitation and temperature patterns may affect agriculture in many parts of the country, we will focus on the Prairies.

IRRIGATION IN SOUTHERN ALBERTA

Alberta is especially sensitive to climate change due to yearly and seasonal variability in stream flows.[39] Approximately 2.8 billion m^3 of Alberta's water is withdrawn every year, predominantly from rivers and streams. Roughly 82 per cent of that water is allocated to irrigation.[40]

Dry conditions can cause severe consequences . . . crop production on the Prairies could be reduced by up to CDN$1.5 billion per year.

Estimates of the impacts of climate change for the Oldman River basin in southern Alberta suggest that soil is likely to dry out and that there will be less runoff. Three general circulation models suggest that under a doubled CO_2 scenario, temperature is likely to increase by between 2.8ºC and 6.2ºC, while precipitation is likely to increase by between 2 per cent and 11 per cent. Predicted increases in precipitation will not compensate for increased evaporation and evapotranspiration. Thus, average decreases in stream flow under the three scenarios were estimated to be 31.8 per cent. Given that Alberta's agricultural sector is almost entirely dependent on stream flow such a change is likely to have severe impacts.

Dry conditions can cause severe consequences. For example, in 2001 a severe drought reduced wheat and canola production by 43 per cent and decreased grain production by CDN$5 billion. Previous years' figures showed that average potential crop yields could fall from 10 per cent to 30 per cent as climate change dries the soil and raises the temperature.[41] Therefore, we can estimate that crop production on the Prairies could be reduced by up to CDN$1.5 billion per year.[42]

All of the above tells us that significant areas of Canada will endure substantial bio-physical changes as a result of climate change and that these changes will have economic effects. Damage estimates will need to be developed in advance if adaptation policy interventions are to be properly designed.

FUTURE RESEARCH NEEDS

A broad long-term perspective is required to determine how much spending on adaptation strategies is justified. Much of the current literature focuses on the costs of infrastructure repair and protection. While this approach is useful, it is not sufficient and a full picture of the costs, including secondary and tertiary impacts, must be calculated.

As mentioned earlier, the Ouranos report showed that climate change would cut Quebec's hydroelectric generation capacities, depending on location.[43] The international literature on adaptation reflects the fact of substantial local variation in climate change impacts. While adaptation has to be local, mitigation by its very nature has to be global. A July 2005 report from the British House of Lords stated that a key difference between adaptation and mitigation was that the former tended to be based on local initiatives while the latter "required action on a global scale."[44] An analogous dichotomy is useful when discussing climate change and adaptation research.

Mitigation research, Kyoto-style inquiries, trading systems and treaties all require international and national action, while adaptation measures are inherently local. It is therefore important to establish national and provincial strategies and goals. However, a lot of implementation and impact will occur at the local level and will require financial support from the federal and provincial governments.

For example, sea levels are rising due to global warming and melting polar ice, which is an international concern. But the Confederation Bridge linking Prince Edward Island and New Brunswick accommodated sea level changes in its design as a local adaptation response.[45] Similarly, predictions of the likely impact of climatic warming on North American boreal forests indicate that central and eastern areas will have to contend with more frequent fires while the northeastern portion of North America will likely see fewer fires.[46]

Canada's federal government has a significant role to play in adaptation policy at the national and international levels, but it also needs to be aware of the local element in developing adaptation policies and strategies. The government can, and ought to, establish national guidelines, goals and initiatives, but implementation and administration should be decentralized. Localized research is well suited to provinces or other agencies, in partnership with federal government departments. A key research topic in all regions will be the development of holistic and effective costs-benefit analysis for proposed adaptation initiatives in response to predictions of climate change effects. Canadian policy-makers could follow the advice of the British House of Lords who urged "that explicit comparisons between the monetary cost of adaptation measures and their benefits" be carried out.[47]

Many meteorological and other modelling studies have broadly identified the kinds of climate change effects Canadians can expect to see. In addition, economic analyses of climate change effects have shown that the economic costs of these changes will be significant. Transition costs are often not addressed to everyone's satisfaction in these cost studies, but policy-makers should consider the loss of well-being associated with their results, as should anyone looking at long-term societal projects, be they public or private. Transition costs should be an important focus of economic research.

It is clear from these studies that climate change will impose substantial costs on the Canadian economy, particularly in the Lower Mainland of British Columbia, the Prairies and the Great Lakes. Adaptation measures can reduce the overall negative economic effects and allow opportunities to be realized in, for example, the agricultural and forestry communities.

Decision-makers will have to consider the effects of climate change over the full lifetime of their projects and accommodate these changes . . . .

However, adaptation measures are not without their own costs, and we do not know how much adaptation will be necessary. Doing detailed estimates of damages and adaptation costs will require formidable effort, and estimates done from the top down will be too imprecise to be anything other than simply indicative. Therefore, it is important to determine locally the appropriate adaptation expenditure to reduce negative climate change impacts.

Studies addressing the cost of adaptation tend to be large and based on economic modelling techniques. Specialists in many disciplines have a role to play in determining the ultimate effects and remedies, including climate scientists who identify the effect, economists who can identify the possible costs and benefits of measures and, ultimately, engineers who design and implement physical measures. All these areas need resources to ensure the appropriate measures are taken.

In some cases these studies would examine specific regions, such as the Great Lakes, the Prairies or the Lower Mainland. These studies could usefully be developed through cooperation agreements among government bodies. Also required is research into the effects on electricity generation of the decreased river flow in the Great Lakes basin and likely in other basins as well. This research will be much easier if private and public utilities work together.

Decision-makers will have to consider the effects of climate change over the full lifetime of their projects when they develop infrastructure, place major industrial facilities and new dams, and improve housing stock. They must then include features that will accommodate these changes into the design and operation of these facilities. The climate change measures incorporated into the Confederation Bridge are good examples of such accommodation.

The federal and provincial governments should work together on research so that they can establish the policy drivers for changes, perhaps through new or existing institutions and instruments. Doing so will ensure that this decision-making framework is established in Canada. Canada's regulatory bodies can play an integral role within that framework. Therefore, we could benefit by studying the country's environmental, energy, agricultural, forestry and other regulatory agencies, and their roles in effective adaptation strategies.

There are clear federal and provincial roles, but local authorities are closest to the places where adaptation is needed. It will be important for the three levels of government to work together and carry out research, with the federal and provincial levels ensuring that local decision-makers are considering adaptation.

The Ouranos Consortium in Quebec highlighted the clear need for increased attention to adaptation research. The consortium argued that to better understand the impacts of climate change, it was "vital to dedicate substantial efforts to developing tools and models that will yield a better understanding of . . . various phenomena and . . . a finer spatial resolution so as to better anticipate the climate of the upcoming decades for the different regions of Quebec."[48]

THREE IMPORTANT THRUSTS

In general we need more information before we can estimate the full costs of climate change and choose adaptation strategies. Three specific key thrusts are needed. First, more climate change scenario research is vital if we are to better understand and locate biophysical impacts. This data will help us enhance the economic cost-benefit analysis of adaptation options. Second, we need research into technology and design innovations for buildings and other long-term facilities. Third, we need a comprehensive assessment of current regulations to determine their suitability.

Many segments of society will be called on to respond to climate change, and governments will need to play a coordinating role.

In terms of the first thrust, climate change scenario research is necessary to identify biophysical impacts, flooding areas, salt water intrusion, soil stability issues and transportation infrastructure at risk in areas such as the Lower Mainland of British Columbia. This research is best suited to a multi-year coordinated effort engaging a wide variety of expertise. With the help of information on planning practices and development approaches, these outcomes could be fed into cost-benefit analysis of possible infrastructure improvements. Provincial and regional governments could then implement policy options. Other areas in Canada would warrant similar treatment and several of these large-scale research programs designed to feed into development and economic policy initiatives would be necessary.

A second thrust is more in the line of detailed information development and as such may be smaller in scope but more widespread. This type of effort would, for example, devise new measures for building code improvements in insulation, roof drainage or other areas that will benefit buildings by making them more energy efficient or better able to withstand extreme weather. This work could also include technological or planning innovations for improved urban design that would be better able to accommodate geophysical changes. A wide variety of these measures is necessary to address the many conditions that could prevail across the country but also to harness the creativity of societal forces needed to transfer our knowledge of potential impacts to adaptation responses.

A third thrust is to discover the most effective roles to be played by Canadian regulatory agencies in facilitating feasible and effective adaptation strategies. There is a need to find out if Canada's regulatory regimes are properly designed to effectively deal with these changes. There could be regulatory advantages such as examining physical and infrastructure initiatives within a broader social science framework. There are also inherent questions related to overlap and redundancies, while there may be areas where new forms of regulatory bodies will be required for effective adaptation.

While large and small measures could work in tandem to produce the most effective adaptation response, governments should develop a clear idea of the research capacity related to these topics and interest in them. Regulatory agencies could develop a clear direction for their involvement in developing adaptation strategies.

POLICY IMPLICATIONS FOR ADAPTATION

While it is instructive to consider the implications of climate change and the adaptation measures necessary, addressing the related risks is a huge task. Many segments of society will be called on to respond to climate change, and governments will need to play a coordinating role. To fulfill that role effectively, the federal government will need to establish organizing principles

to guide its actions and the desired outcomes. Several basic conclusions are worth stating:

- Climate change is real.
- Current mitigation measures will not stop changes for decades to come.
- Canada is at risk of damage from climate change.
- Adaptation measures can minimize damage or take advantage of opportunities.
- Government has a role to play in minimizing damage and capitalizing on opportunities.
- Adaptation requires local actions and initiatives, as well as large regional or national initiatives.

Funding direct physical and economic research into adaptation measures, both regionally and nationally, should be a goal of federal government policy.

To state a primary objective of the federal government is to provide a focus for adaptation activities and a clarifying principle for others working with the federal government. Accordingly, for the purpose of the discussion below, we envisage the role of the federal government as the task of inculcating adaptation thinking and supportive information gathering into the identification of and implementation of measures designed to address climate change risks.

Information and research, partnerships, regulatory structures and adaptation culture are four broad areas of policy intervention for the federal government to consider.

INFORMATION AND RESEARCH

Excellent information on impacts and possible responses is central to the development of good adaptation measures. In the area of natural capital, programs designed to measure the extent and quality of our natural capital should be reinstated or established. In the past decade, various programs were curtailed to reduce operating costs, to the detriment of basic data collection useful in determining the effects of climate change. These data would be useful in determining the magnitude and extent of local impacts and the infrastructure changes necessary. It is important to reinstate these programs and design new ones to take advantage of powerful new data collection technologies.

Funding direct physical and economic research into adaptation measures, both regionally and nationally, should be a goal of federal government policy. These large studies will contribute to national priorities and focus on areas of critical concern in specific regions, such as the Lower Mainland of British Columbia, the Prairies, the Great Lakes and the Arctic. These studies must focus on the impact climate change will have on the physical capital and economy of the region as a way of establishing appropriate adaptation actions.

PARTNERSHIPS WITH OTHER GOVERNMENTS

Preserving and enhancing social capital is a key goal of all governments and this principle is useful in giving meaning to the local nature of adaptation measures. The federal government should ensure that the science and funding available to its agencies is co-coordinated with the actions and project implementation skills that provinces and cities can bring to bear on local projects or programs. Once identified, specific effects, such as ocean and lake levels, would be addressed through these partnerships. Such partnerships could establish funding allocations, measurable outcomes and joint oversight to ensure success.

Policy improvements must be made with the goal of reducing climate change impacts, along with other reasonable goals, such as safety and security.

POLICY- AND REGULATION-MAKING CAPACITY

The demands of managing all the adaptation aspects of policy-making may place a strain on the capacity of existing regulatory structures and policy incentives. Policy improvements—such as updating building codes, land development standards or best practices—must be made with the goal of reducing climate change impacts in mind, along with other reasonable goals, such as safety and security. Governments should review their regulatory structures to ensure that policy-makers and regulation-makers pay attention to adaptation considerations. The federal and provincial levels of government should ensure that they are prepared for joint discussions to develop adaptation measures.

AN ADAPTATION IMPERATIVE

Optimum leveraging of human capital also plays a role in successful adaptation measures. Adaptation may be inherently a professional issue involving public trust, where the general public looks to governments and the professionals on whom they depend to ensure relatively predictable future problems are anticipated and measures are in place to deal with expected consequences. Hence, it is a public trust responsibility to ensure that public policy and infrastructure planning processes make adaptation a basic consideration. Under these conditions adaptation could become as germane to policy and development discussions as public safety and security are today.

Education policy-makers can play an important role by ensuring that professionals and managers are informed of the need to address adaptation in long-term decision making. Doing so will be critical to imbedding adaptation considerations into policy and infrastructure planning processes. We can achieve this goal by modifying engineering, science and management curricula in post-secondary educational institutions. Also, regular conferences and other initiatives can continuously dispense information on the latest adaptation measures and trends, thus maintaining awareness among those involved in designing and implementing long-term projects and programs.

All levels of government, as well as prudent businesses, ought to make long-term adaptation considerations the standard. Nothing less than an adaptation culture within the senior management cadre should be their goal.

Governments must set society on a course that can adapt to the changes climate change will bring.

However, establishing the societal systems and the physical and intellectual infrastructure for adapting to climate change effects will take time. Governments, under the leadership of the federal government, are now presented with an opportunity to start the process before large-scale impacts are observed. To be effective, governments have a short window for considering the main elements of the approach, but they must begin to set society on a course that can adapt to the inevitable changes climate change will bring.

1 House of Lords Select Committee on Economic Affairs, *2nd Report of Session 2005–06, The Economics of Climate Change*, Volume I: Report (London: House of Lords, 2005), p. 6 and p. 67.

2 International Panel on Climate Change (IPCC), *Climate Change 2001: The Scientific Basis: Summary for Policy Makers* (Geneva: IPCC Secretariat, 2001), p. 6 and pp. 10–12. T.J. Blasing and Sonja Jones, *Current Greenhouse Gas Concentrations* [online]. (Updated February 2005), [cited November 18, 2005]. cdiac.esd.ornl.gov/pns/current_ghg.html. Jim Motavalli, "Climate for Change," *E Magazine* (May/June 2005), p. 22.

3 David Noble, Jim Bruce and Mark Egener, *An Overview of the Risk Management Approach to Adaptation to Climate Change in Canada* (Ottawa: Global Change Strategies Institute Inc., March 2005). National Snow and Ice Data Center, *Sea Ice Decline Intensifies* [online]. (September 28, 2005), [cited January 31, 2006]. nsidc.org/news/press/20050928_trendscontinue.html.

4 Noble et al., *Overview.* National Snow and Ice Data Center, *Sea Ice Decline Intensifies.*

5 United Nations, *Kyoto Protocol: United Nations Framework Convention on Climate Change* [online]. (December 11, 1997), [cited October 14, 2005]. unfccc.int/resource/docs/convkp/kpeng.html, p. 1.

6 Arctic Council, *Arctic Climate Impact Assessment: Policy Document* [online]. (November 24, 2004), [cited February 24, 2006]. www.acia.uaf.edu/PDFs/ACIA_Policy_Document.pdf. House of Lords Select Committee on Economic Affairs, 2nd Report, p. i and p. 29.

7 Bo Lim and Erika Spanger-Siegfried, eds., *Adaptation Policy Frameworks for Climate Change: Developing Strategies, Policies and Measures* (Cambridge, U.K.: Cambridge University Press, 2005).

8 Kalle Lyytinen, Lars Mathiassen and Jane Ropponen, "Attention Shaping and Software Risk—A Categorical Analysis of Four Classical Risk Management Approaches," *Information Systems Research* 9, 3 (September 1998), p. 235. Beverly Rockhill, "The Privatization of Risk," *American Journal of Public Health* 91, 3 (March 2001), p. 365.

9 Gregg Easterbrook, "Hot and Not Bothered," *The New Republic* (May 4, 1998), p. 20. Tim Studt, "Change or Adapt," *RD Magazine* (October 2004), p. 7.

10 David Anderson, "Interview with Maclean's: 'A Free Shot on Goal,'" *Maclean's* (March 18, 2002), p. 39.

11 Joel Baglole, "Northern Thaw Raises Defense Concerns: A Canadian Waterway Free of Ice May Bring Commerce—and Foes," *The Wall Street Journal*, December 20, 2000, p. A4. "On Thin Ice: Global Warming Spells Big Trouble at the Top of the World," *Current Events* (December 17, 2004), p. 3.

12 Arctic Council, *Arctic Climate Impact Assessment: Policy Document*, p. 3. Arctic Council, *Arctic Climate Impact Assessment: The ACIA International Scientific Symposium on Climate Change in the Arctic* (Cambridge, U.K: Cambridge University Press, 2004). Baglole, "Northern Thaw."

13 "On Thin Ice," p. 2.

14 Mohammed H.I. Dore and Ian Burton, *A Review of the Literature on the Costs of Adaptation to Climate Change* [online]. (November 15, 2000), [cited 24 February 2006]. adaptation.rncan.gc.ca/app/filerepository/E74BFBF66A704A778C4D1AD4A8C4BFC2.pdf.

15 S. Fankhauser, *The Costs of Adapting to Climate Change,* Working Paper No. 13 (Washington, D.C.: Global Environment Facility, 1997). See also United Nations Environment Programme, *Mitigation and Adaptation Cost Assessment: Concepts, Methods and Appropriate Use* (Roskilde, Denmark: UNEP Collaborating Centre on Energy and Environment, 1998), chapter 5.

16 David Etkin, Emdad Haque, Lianne Bellisario and Ian Burton, *An Assessment of Natural Disasters in Canada: A Report for Decision-Makers and Practitioners* (Ottawa: The Canadian Natural Hazards Assessment Project, 2004), pp. i–ii and p. v. David Francis and Henry Hengeveld, *Extreme Weather and Climate Change* (Ottawa: Environment Canada, 1998), pp. 21–23 and pp. 25–28. Angus Ross, *Reflections on the Future: Climate Change and its Impacts on the Insurance Industry*, Institute for Catastrophic Loss Reduction Research Paper Series No. 8 (Toronto: Institute for Catastrophic Loss Reduction, 2000), pp. 1–13.

17 James Bruce, Ian Burton and I. Egener, *Disaster Mitigation and Preparedness in a Changing Climate* [online]. (1998), [cited February 24, 2006]. ww3.psepc-sppcc.gc.ca/research/resactivites/disMit/disMit/DisMit_e.pdf. (Ottawa: Global Change Strategies International Inc., 1999).

18 Insurance Board of Canada, *Natural disasters—major multiple-payment occurrences* [online]. (2004), [cited February 8, 2006]. www.ibc.ca/pdffiles/industry_issues/naturaldisasters-multiple-paymentoccurrences.pdf, p. 19.

19 Francis and Hengeveld, *Extreme Weather and Climate Change*.

20 Mohammed H.I. Dore and Ian Burton, *The Costs of Adaptation to Climate Change in Canada: A Stratified Estimate by Sectors and Regions* [online]. (April 17, 2001), [cited February 24, 2006]. www.adaptation.nrcan.gc.ca/app/filerepository/44AD1A1663F2424FB9C04DFA46E21D71.pdf. p. 17 and p. 54.

21 *Impacts of Sea Level Rise and Climate Change in the Coastal Zone of Southeastern New Brunswick* [slide show]. Presented by Réal Daigle at *Adapting to Climate Change in Canada 2005: Understanding Risks and Building Capacity.* Montréal: May 4, 2005. Noble et al. Overview. Government of Canada, *Sensitivities to Climate Change in Canada: Sea Level Rise* [online]. (May 12, 2003), [cited February 6, 2006]. adaptation.nrcan.gc.ca/home2_e.asp?CaID=17&PgID=64.

22 If we used the purchasing power parity rate, the GDP ratio would be higher. OECD, *Main Economic Indicators: Country Comparison Tables* [online]. (December 9, 2005), [cited February 24, 2006]. www.oecd.org/dataoecd/43/20/35827900.pdf. Richard S.J. Tol, "Estimates of the Damage Costs of Climate Change, Part 1: Benchmark Estimates," *Environmental and Resource Economics* 21, 1 (January 2002), pp. 47–73, Table IV.

23 Government of Canada, *Canada Country Study, Climate Change Action Fund* [online]. (June 2, 2004), [cited February 24, 2006]. www.climatechange.gc.ca/english/publications/ccs/#prairies.

24 Natural Resources Canada, *Climate Change Impacts and Adaptation: A Canadian Perspective* (Ottawa: Natural Resources Canada, Climate Change Impacts and Adaptation Directorate, 2004), pp. 121–22.

25 Natural Resources Canada, *Climate Change Impacts and Adaptation.*

26 Dore and Burton, *The Costs of Adaptation*.

27 Rob C. De Loë and Reid D. Kreutzwiser, "Climate Variability, Climate Change and Water Resource Management in the Great Lakes," *Climatic Change* 45, 1 (April 2000), pp. 163–179. Mortsch et al., Table 2, p. 160.

28 Mortsch et al., Table 2, p. 160. Ouranos, *Adapting to Climate Change* (Montreal: Ouranos, 2004), p. 26.

29 Frank Millerd, *The Economic Impact of Climate Change on Canadian Commercial Navigation on the Great Lakes*, draft (Waterloo, Ontario: Wilfrid Laurier University, Department of Economics, April 2005), Table 3.

30 Rob de Loë, Reid Kreutzwiser and Liana Moraru, "Adaptation Options for the Near Term: Climate Change and the Canadian Water Sector," *Global Environmental Change* 11, 3 (October 2001), pp. 231–245.

31 Martin Associates, *Economic Impact Study of the Great Lakes St. Lawrence Seaway System: Transportation Cost Savings* (Lancaster, Pennsylvania: Martin Associates, August 1, 2001).

32 Ryan C. Schwartz, Peter J. Deadman, Daniel J. Scott and Linda D. Mortsch, "Modeling the Impacts of Water Level Changes on a Great Lakes Community," *Journal of the American Water Resources Association* 40, 3 (June 2004).

33 Ian Burton, Peter Bein, Quentin Chiotti, David Demeritt, Mohammed Dore and Dale Rothman, *Costing Climate Change in Canada: Impacts and Adaptation* (Ottawa: Natural Resources Canada, Adaptation Liaison Office, 2000).

34 Lester R. Brown, "A Planet Under Stress: Rising to the Challenge," *The Futurist* (November 2003). Saskia Sassen, "The Ecology of Global Economic Power: Changing Investment Practices to Promote Environmental Sustainability," *Journal of International Affairs* 58, 2 (April 2005).

35 Center for Strategic and International Studies (CSIS), *Addressing Our Global Water Future* [online]. (September 30, 2005), [cited October 15, 2005]. www.csis.org/media/csis/pubs/050928_gwf.pdf, p. 29 and p. 95.

36 Ouranos, *Adapting*, pp. 25–26. Mortsch et al., "Climate Change," p. 160.

37 Tol, "Estimates of the Damage Costs of Climate Change."

38 Estimates convert percentages to reflect Canadian portions of North American percentages. Calculations based on Statistics Canada *Catalogue no. 21-010 to 018-X1E: Farm Business Cash Flows—Agriculture Economic Statistics*, (January 2006).

39 de Loë et al., "Adaptation Options," p. 236.

40 Government of Canada, *Canada Country Study*.

41 Government of Canada, *Canada Country Study*.

42 Estimates are based on Statistics Canada C*atalogue no. 21-010 to 018-X1E*.

43 Ouranos, *Adaptation*, pp. 25–28, p. 62.

44 House of Lords Select Committee on Economic Affairs, *2nd Report*, p. 30.

45 Kyle McKenzie and Kathryn Parlee, *The Road Ahead—Adapting to Climate Change in Atlantic Canada* (Ottawa: Canadian Climate Impacts and Adaptation Research Network, 2003), p. 6.

46 Christopher Carcaillet, Yves Bergeron, Pierre J.H. Richard, Bianca Frechette, Sylvie Gauthier and Yves T. Prairie, "Change of Fire Frequency in Eastern Canadian Boreal Forests During the Holocene: Does Vegetation Composition or Climate Trigger the Fire Regime?" *Journal of Ecology* 89, 6 (December 2001), pp. 930–946.

47 House of Lords Select Committee on Economic Affairs, *2nd Report*, p. 55.

48 Ouranos, *Adaptation*, p. 62.

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