Chapter 1: The Security of Canadian Ecosystems

Chapter Overview:

Agriculture, terrestrial, and costal ecosystems all contain natural resources that are vital to the Canadian economy. The Second IPCC Assessment on Climate Change identified three sectors in Canada that are particularly vulnerable to climate change: agriculture and aquaculture, forestry, and fresh water resources. Projected changes in climate are expected to bring a range of challenges and benefits to Canada as our economic and social well-being is greatly influenced by the health and sustainability of these resources.[1] In 2007, the agriculture, forestry, and fishing industries generated approximately 2% of Canada's Gross Domestic Product[2], and accounted for approximately 3% of total employment. However, these numbers may be slightly misleading, both because the resources supplied by these industries have a multiplied effect on productivity in Canada's manufacturing, heavy industries, and service industries, as well as the obviously vital importance of affordable food and clean drinking water for all Canadian citizens. Given this, this section considers the implications of climate change on a wide range of socio-economic variables across these sectors.

The **Canada Country Study**[3] concluded that the potential impacts[4] of climate change on our forests, fisheries, agriculture, and water could be both varied and extreme. These impacts include:

- longer growing seasons and extension of agriculture further north, but also risks to agriculture such as moisture deficits, pests, disease, and fires;
- impacts on fish populations, which could increase in some areas, mostly in the Arctic and on northern areas of the Pacific coast, and decrease in others, particularly the lakes and rivers of the Canadian Shield;
- risks to waterfowl populations due to lower water levels in lakes, rivers, and wetlands; and
- projected changes in the occurrence and severity of extreme events, which would have serious implications for the security and integrity of Canada's

[1] http://www.adaptation.nrcan.gc.ca/perspective/pdf/report_e.pdf (page viii)
[2] http://www43.statcan.ca/03/03b/03b_000_e.htm
[3] Adapted from Maxwell, B., Mayer, N. and Street, R. (1997): National summary for policy makers; *in* The Canada Country Study: Climate Impacts and Adaptation, Environment Canada, 24 p.
[4] A recurring issue in the field of climate change impacts and adaptation is uncertainty. There is uncertainty in climate change projections (degree and rate of change in temperature, precipitation and other climate factors), imperfect understanding of how systems would respond, uncertainty concerning how people would adapt, and difficulties involved in predicting future changes in supply and demand. Given the complexity of these systems, uncertainty is unavoidable, and is especially pronounced at the local and regional levels where many adaptation decisions tend to be made. Nonetheless, there are ways to deal with uncertainty in a risk management context, and most experts agree that present uncertainties do not preclude our ability to initiate adaptation.

natural resources, social systems, and infrastructure with subsequent implications for the insurance industry and supporting public sectors.

Climate Change Impacts on Agriculture

Although agriculture is a vital component of the Canadian economy, only a small percentage of the country is actually farmed due to, in large part, climate and soil limitations. With the length of frost-free growing seasons restricted to between 200 days in the extreme south and merely a matter of weeks in the far north, Canadian soils remain inactive for a major part of the year.[5]

Furthermore, severe winters can cause frost damage even to dormant vegetation, thus restricting the cultivation of over-wintering crops, such as winter wheat, on the Prairies and in other similarly affected areas. [6] When growing seasons do arrive, growth rates of plants in Canadian climates are further restricted by the amount of heat energy available to them during the season. [7] These factors impose major limitations on the types of crops that can be grown in Canada, as well as on the yields and the number of crops that can be harvested in one year.[8]

Agriculture is very sensitive to climate. Under conditions of climate change, climate variability in major producing countries can have significant effects on world food supplies and markets.

Figure 9 lists the projected climate changes in Canada and their impacts on the agriculture sector. Much of the research on the impact of climate change on Canadian agriculture has suggested positive gains in production. Across Canada, there would be considerable potential for cultivating higher yield crops requiring longer and warmer growing seasons, increased multi-cropping, and the expansion of agriculture northward.[9] Grain corn could become an important agricultural crop in areas such as Manitoba and northern Ontario, winter wheat could do well on the Prairies, and apples and grapes could become highly productive in Quebec. [10] The direct effects of higher carbon dioxide as a fertilizer for plants could further add to these benefits. [11]

Gains in productivity are expected due to:

1) increased production of wheat in the Prairies,
2) increased corn and soybean yields in Atlantic Canada, and
3) increased soybean, potato and winter wheat yields across the country

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[5] (page 37)
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[7] (page 37)
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[9] (page 37)
[10] (page 37)
[11] (page 37)

These gains are generally associated with higher temperatures and extended growing seasons. However, climate change is expected to bring both advantages and disadvantages for agricultural crops in Canada, which are summarized in figure 10. Table 3, summarizes the expected regional impacts of climate change on agriculture.

Table 3: Regional Impacts of Climate Change on Agriculture[12]

Region	***Provinces and Territories***	**Impacts**
West	British Colombia Yukon	Have not found Data
Artic	Northwest Territories Nunavut	Have not found Data
Prairies	Alberta Saskatchewan Manitoba	• Increase precipitation • Increased evapotranspiration in north • Reduction is crop diversity • Severe of droughts • Decreased production of wheat • Across the prairies, crops yields will vary. All crops in Manitoba may decrease by 1%, Alberta wheat, barley and canola may decrease by 7% and Saskatchewan wheat, barley and canola may increase by 2-8%. • The value of agricultural production in Alberta could fall by 5 percent. • Farm income in Saskatchewan could fall by $160-273 million, leading to declines of between $146 million and $248 million in provincial income. • Grain sales in Manitoba could either rise or fall by several millions of dollars. . If drought conditions similar to those in 1961 prevail, provincial agricultural output could decline by almost 20 percent, resulting in a loss of $400 million in revenue.
Ontario	Ontario	• Corn and soybean cultures will shift northward • Pressure for fresh water irrigation will affect the Great Lakes
Quebec	Quebec	• Lengthened growing season • Longer growing period for apple and grape production
Atlantic Canada	New Brunswick Nova Scotia Prince Edward Island Newfoundland and Labador	• Flooding in the St. John Valley may be more frequent

In other studies, negative impacts are projected to result from increased winter damage of forage crops, increased problems with insect pests, and water shortages.

[12] Adapted from pages 117-118) and http://www.iisd.org/pdf/agriculture_climate.pdf

Warmer winters would reduce cold stress, but would also increase the risk of damaging winter thaws and potentially reduce the amount of protective snow cover.

As well, many crops, are sensitive to heat stress, particularly during key stages of development, and may be adversely affected by the increased frequency and severity of summer heat waves. Impacts would vary regionally and with the type of crop being cultivated. Studies have suggested that yields of certain crops (e.g., grain corn in the Maritimes and canola in Alberta) may increase, while others (e.g., wheat and soybeans in Quebec) could decline.[13] Climate warming is expected to increase the frequency of extremely hot days, which have been shown to directly damage agricultural crops. As well, changes in the frequency and intensity of extreme events (e.g., droughts, floods and storms) have been identified as the greatest challenge that the agricultural industry would face as a result of climate change. [14] Extreme events are difficult to both predict and prepare for, they can devastate agricultural operations. Several times in the past extreme whether events affected farm operations across the country, causing significant reductions in crop yields and increased outbreaks of insects and disease. [15] Weather extremes are the major cause of crop disasters, and recent events in the Canadian Prairies, such as the sequence of drought years between 2000 and 2003, as well as the very wet year in many parts of that region in 2004, while not unprecedented in Canada's climate history, are in many respects useful examples of what may occur more frequently during the decades to come. [16] Climate models suggest that there will be changes in summer precipitation and the duration and severity of droughts may increase significantly. When rain does occur it is expected to be more intense, increase the likelihood of floods, and create excessive soil moisture. Figure 11 demonstrates the economic impacts of crop failures, but listing the annual crop insurance payouts for crop damage by province.

Climate change is also expected impact moisture availability, which is a key concern for agriculture in Canada. As the supply of water decreases during the growing season, while the demand for water increases due to greater crop production, the supply of water may not meet the demands of the sector in the future. Without limited adequate water available, the projected gains in productivity would not be realized. Water shortages are expected to be a problem in several regions of Canada (see Water Resources).

In addition to its impact on crops, climate change is also expected to affect livestock operations. It is projected that there will be both negative and positive impacts on livestock, with warmer weather decreasing feed requirements, increasing survival of young and reducing energy costs, while increased heat stress would adversely affect milk production, meat quality and dairy cow reproduction.

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[13] Page xii
[14] Page xii
[15] Page xii
[16] (page 38)

Under conditions of climate change there is also the risk of severe pest infestation as insects, pests, and plant diseases respond well and quickly to climate change. These factors could have devastating impacts on crop yields in the future.

Climate change is expected to change global production opportunities and the basic structure of international and interregional trade in agriculture and could have major implications for Canada's competitive position. Some estimates suggest, that world wheat crop production is expected to decline 10% every decade as the climate changes.[17] Canada will have the potential to fill some of this global shortage. Table 4 shows the expected increases and decreases in grain production as a result of climate change.[18]

Table 4: Expected Changes in World Grain Production under Climate Change[19]

Region	Wheat	Corn	Barely	Oats	Soyabeans	Rice
Canada	Increase	Increase	Decrease	Decrease	Decrease	n/a
Other North/Central America	Decrease	Decrease	n/a	n/a	Decrease	n/a
South America	Decrease	Decrease	n/a	n/a	Decrease	n/a
Europe	Decrease	Decrease	Decrease	Decrease	n/a	n/a
Africa	Decrease	n/a	n/a	n/a	n/a	n/a
Former Soviet Union	Increase	Increase	Decrease	Decrease	n/a	n/a
Asia	Decrease	n/a	n/a	n/a	n/a	Increase
Oceania	Decrease	n/a	n/a	n/a	n/a	n/a

Already, changes in demand and production yields of wheat are being experienced in Canada. Revenues have fluctuated between $3.8 to $5.95 billion over the last five years, the harvested area has increased from 24.7 million acres to 34.3 million acres and production has increased from 19.9 million tonnes to 31.2 million tonnes.[20] In Nova Scotia, data indicates that 12 of the past 15 growing seasons have exceeded the 50% probability level in terms of heat units, and 4 out of 5 have been exceedingly dry. There has been a northern migration of corn production in Nova Scotia and New Brunswick, and an increase in soybean production throughout the region, with an increased adoption of weather sensitive crops.[21]

[17] Myers 1996 in (pages 117-118)
[18] Page 117, note: does not include synergistic changes such as sea-level rise or crop damage from insects.
[19] Smit, 1989 in (pages 117-118)
[20] http://www.c-ciarn.uoguelph.ca/documents/2002_pdf_summary_fewgraphics.pdf page 9
[21] http://www.c-ciarn.uoguelph.ca/documents/2002_pdf_summary_fewgraphics.pdf Page 7

Adaptations to climate risks and opportunities could involve innovations in farm management practices, crop breeding, weather forecasting, farm financing, crop insurance, and government relief programs. These impacts and adaptation issues are NOT well addressed in current research programs and little information exists on their implications for the agri-food sector.[22] According to Herbert and Burton (1995), the cost of agriculture adaptation to current climate in Canada is over $1.3 billion, and the costs of adaptation (e.g. crop insurance, irrigation, research and development) are likely to increase under climate change (with the exception of a decrease in the cost of heating fuel).[23]

Climate Change Impacts on Fisheries

Most fish species have a distinct, although complex set of environmental and habitat conditions within which they thrive and beyond which they decline and possibly perish.[24] Air and water temperature, precipitation, and wind patterns all effect fish health, productivity, and distribution. The relationship between climate and fish resource is complex, involving both the direct effects on each species as well as the indirect effects through changes in abundance of food supply and predators. Under conditions of climate change, some species will become healthier and more abundant, and others might disappear completely. Shifting climatic conditions may also encourage the migration of new species into ecosystems resulting in invasion or changes in patterns of species domination. Evidence suggests that climate change is already an important factor in declining salmon stocks off the coast of British Columbia, while sockeye and pink salmon are being reported in Arctic regions well beyond their known range. [25] In the Atlantic Ocean, recent rises in water temperatures are believed to have contributed to a decline in flounder.[26]

Changes in ocean climate also affect the distribution and significance of certain marine diseases, such as the eastern oyster disease, and the risks of harmful toxic algae blooms. In the Arctic, more open water may increase the food supply and hence abundance of many fish species, but could threaten Arctic cod and alter traditional northern fishing practices because of changes in sea ice cover.[27]

In fresh water lakes and rivers, warmer temperatures would generally benefit warm water fish such as bass and sturgeon, but reduce the abundance of cold water species like trout and lake salmon. New species that thrive in warmer waters can be expected to migrate into these lakes, competing with existing species, some of which may disappear completely.[28] Lower water levels would threaten shoreline wetlands

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[22] http://www.c-ciarn.uoguelph.ca/documents/2001_Workshop_Report.pdf page 5
[23] http://www.iisd.org/pdf/agriculture_climate.pdf
[24] Page 39
[25] Page 39
[26] Page 39
[27] Page 40
[28] Page 40

that provide important fish habit and result in degraded water quality. However, shorter ice cover seasons would reduce over winter fish mortality.[29]

The relationship between ecological changes and the fishery sector is complex. Table 6 identifies the expected changes in climate and their subsequent effects on marine ecosystems and thereby the fishing industry.

Table 6: Changes in Climate: Fish Ecology and Consequences for Fisheries[30]

Impacts of Fish Ecology	Consequences for Fisheries
- Change in overall fish production in a particular aquatic ecosystem	- Change in sustainable harvests for all fish populations in the ecosystem
- Change in relative productivity of individual fish populations in a particular aquatic ecosystem	- Change in the relative levels of exploitation that can be sustainably directed against the fish populations of the ecosystem
- Large scale shifts in geographic distribution of species	- Change in the mixture of species that can be sustainably harvested within a specific geographic area - Change in location of profitable fishing grounds
- Small scale shifts in the spatial distribution of members of a specific population	- Change in sustainable harvest for the population - Change in efficiency of fishing gear, leading to change in sustainable levels of fishing effort

Table 7 identifies some expected regional impacts of climate change on Canadian fisheries.

Table 7: Regional Impacts of Climate Change on Fisheries [31]

Region	***Provinces and Territories***	**Impacts**
West	British Colombia Yukon	• 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. This could cause increased sedimentation, permanent inundation of some natural ecosystems, and place certain marine species at risk. • Increased winter precipitation, permafrost degradation, and glacier retreat due to warmer temperatures may lead to landslides in unstable mountainous regions, and put fish and wildlife habitat at risk. • Glacier reduction could affect the flow of rivers and streams that depend on glacier water, with potential negative impacts on fish habitat.

[29] Page 40
[30] http://www.ucsusa.org/greatlakes/pdf/fish_responses.pdf page 5
[31] Adapted from http://www.ec.gc.ca/climate/overview_canada-e.html; http://www-comm.pac.dfo-mpo.gc.ca/publications/speciesbook/introduction/climate.html; and page xvi; and http://www.ucowr.siu.edu/updates/pdf/V112_A3.pdf

		• Summer droughts along the south coast and southern interior will mean decreased stream flow in those areas, putting fish survival at risk. • Migrating salmon, are extremely sensitive to slight changes in the temperature of their environment. Studies of sockeye, steelhead and coho populations have already turned up evidence of the effects of declining ocean nutrient levels due to climate change and the mixing of fresh water and salt water. • Changes in ocean currents will lower temperatures will force species that require cooler waters to travel further north, increasing migration times and reducing the fish's ability to reach spawning grounds.
Artic	Northwest Territories Nunavut	• Fish shifting northward 150 km for each degree increase in air temperature. • A decrease in sea-ice cover would affect marine productivity, fish distribution and fishing practices (e.g., accessibility to sites, safety), as well as marine mammals. • Climate change has already begun to affect fisheries and marine mammals along the Arctic coast. • Currently, types of salmon outside of known species ranges may be early evidence that distributions are shifting. • The opening of the Northwest Passage to international shipping would also affect Arctic fisheries, through the increase in traffic, pollution and noise in the region. • Key climate change impacts for freshwater fisheries are expected to result from higher water temperatures, lower water levels, shifts in seasonal ice cover and the invasion of new and exotic species.
Prairies	Alberta Saskatchewan Manitoba	• Semi-permanent and seasonal wetlands could dry up, leading to reduced production of waterfowl and other wildlife species
Ontario	Ontario	• Warmer water temperatures are expected to change aquatic ecosystems and alter wetlands • Warmer water exotics will invade the Great Lakes. • Changes in winter survival, growth rates, and thermal habitat generally increase in deep-latitude lakes • In smaller mid-latitude lakes, particularly those that do not stratify or are more eutrophic, warming may reduce habitat for many of the cool-water and cold-water species because deep-water thermal refuges in summer are not present or become unavailable as a consequence of declines in dissolved oxygen concentrations • Climatic warming will produce a general shift in species distributions northward, with extinctions and extirpations of cold water species at lower latitudes and range expansion of warm-water and cool-water species into higher latitudes. • Expand the ranges of smallmouth bass and yellow perch northward across Canada by about 500 km
Quebec	Quebec	• Lower water levels in the St. Lawrence River will effect the marine environment of the river

Atlantic Canada	New Brunswick Nova Scotia Prince Edward Island Newfoundland and Labador	• Atlantic Canada is particularly vulnerable to rising sea levels, whose impacts could include greater risk of floods; coastal erosion; coastal sedimentation; and reductions in sea and river ice. • Potential impacts include the loss of fish habitat • Climate change has already influenced production with a shift from groundfish to shellfish • Future warming trends may impact the shellfish populations on which the region now relies. • Concerns over increasing frequency and intensity of toxic algal blooms which can cause shellfish poisoning, may increase. • Concerns over changes in spawning environment and migration of Atlantic Salmon

Climate change is expected to have significant impacts on fish populations and sustainable harvests. As conditions change in response to a changing climate, fish would be impacted both directly and indirectly. However, what role climate change will play in abundance levels of fish stocks is the subject of much debate.[32] Sorting out which changes in fish populations are the result of long-term climate change, regime shifts or shorter term weather patterns presents enormous challenges. Because fish stocks are influenced by so many factors, including over fishing, a relationship between climate change and marine species cannot be easily determined.[33] See table 8 for some possible changed to fish populations in Canada under conditions of climate change.

Table 8: Expected Changes to Fish Populations under Climate Change in Canada[34]

[32] http://www-comm.pac.dfo-mpo.gc.ca/publications/speciesbook/introduction/climate.html
[33] www.adaptation.nrcan.gc.ca/posters/ac/ac_10_e.php
[34] Adapted from and page xvi and http://doc.nprb.org/web/BSIERP/Drinkwater%20Cod%20and%20Climate%20Change%202005.pdf

Fish	**Impacts**
Salmon	• Temperature changes affect salmon reproduction directly • Temperature effects predator-prey dynamics and habitat • Changes in river flows and extreme climate events have also been shown to affect salmon survival and production • One possibility is that salmon will retreat northwards as the oceans warm. By the time the salmon complete what will be lengthier migrations to spawn, they will be weaker and fewer in number, however this may be offset by reduced mortality of juvenile salmon as they head out to see.
Shellfish	• Currently the most valuable catch. • Water temperature has been shown to have a strong influence on snow crab reproduction and distribution. • Concern that the frequency and intensity of toxic algal blooms, shellfish poisoning.
Trout	• Higher water temperatures have been shown to decrease the growth rate and survival of rainbow trout • Northward migration of fish species and local extinctions are expected, and would lead to changes in sustainable harvests • Higher temperatures and lower water levels would also exacerbate water quality problems, which would increase fish contamination and impair fish health.
Cod	• Cod will likely spread northwards along the coast of Labrador, occupy larger, may even extend onto some of the continental shelves of the Arctic Ocean. • Spawning sites will be established further north than currently. • It is likely that spring migrations will occur earlier, and fall returns will be later. There is the distinct possibility that, where seasonal sea ice disappears altogether, cod will cease their migration. • Individual growth rates for many of the cod stocks will increase, leading to an overall increase in the total production of Atlantic cod in the North Atlantic. • Responses of cod to future climate changes are highly uncertain, as they will also depend on the changes to climate and oceanographic variables besides temperature, such as plankton production, the prey and predator fields, and industrial fishing.

While it is impossible to say at this point whether the effects of climate change will increase or decrease Canada's commercial stock of fish, what is certain is that commercial fisheries will not be able to continue doing business as usual. Climate change effects will be responsible for changes in: traditional fishing patterns, species available for consumption, and location of the best fishing grounds.[35] For many Canadians, particularly in aboriginal and small coastal communities, fishing it is a way of life – and an inherent part of their culture. Hence the well-being of fish resources is economically and socially important. Changes in fish stock are expected to disrupt the international fish market, to which Canada is a large supplier. However, loss of volume does not necessarily mean loss of revenue for Canada's fisheries. For example, between 1990 and 1994, the volume of fish commercially available had fallen by 620 kilotonnes, but the revenue received for the year's

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harvest rose by $276 million. [36] In this industry, climate change may well result in an improvement in Canada's competitive position. If the rest of the fishing industry also suffers a drop in catch volume, the commercial price of fish may rise enough to offset the loss financially. [37]

Climate Change Impacts on Forestry

Forests are a carbon sink—they take in carbon dioxide and convert it to wood, leaves and roots.[38] They are also a carbon source—they release stored carbon into the atmosphere when they decompose or burn.[39] As such, forests play a major role in the global carbon cycle. As the climate changes, forest carbon storage will be affected. A warmer climate can speed up vegetation growth, which means more carbon storage[40] However, it can also accelerate decomposition, resulting in more carbon emissions, and boost the risk of drought, pest outbreaks and fire, all of which can significantly reduce carbon storage. [41] The extent of these effects will also be influenced by the amount and/or timing of precipitation changes.

Even small changes in temperature and precipitation can significantly affect the growth behaviour of trees. For example, a modest 1°C warming over the past century has already caused a significant increase in the length of the growing seasons and enhanced plant growth in mid to high latitudes of Canada.[42] Trembling aspens in central Alberta now bloom more than three weeks earlier than they did 100 years ago. [43]

Currently, the effects of climate change on Canadian forests are already being observed, these observations include: increased drought, more frequent and intense forest fires, insect and pest outbreaks, slower tree growth, and shifting wildlife habitats. Drought stress has already increased in parts of the Boreal Forest, particularly in western Canada—and tree growth and carbon sequestration have already begun to suffer as a result. As well, lack of water has already been linked to growth declines and reduced carbon absorption across the Boreal Forest.[44] Likewise, drought stress has been correlated with range limitations and reduced growth in white spruce, one of the most widespread and important trees in the Canadian Boreal. As temperatures continue to rise, lack of water availability is expected to play a continuing role in limiting the growth and survival of some

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[36] Page 98
[37] Page 98
[38] http://canadaforests.nrcan.gc.ca/rpt#focus
[39] http://canadaforests.nrcan.gc.ca/rpt#focus
[40] http://canadaforests.nrcan.gc.ca/rpt#focus
[41] http://canadaforests.nrcan.gc.ca/rpt#focus
[42] Page 35
[43] Page 35
[44] http://us.greenpeace.org/site/DocServer/turning-up-the-heat-global-w.pdf?docID=122 page 17

trees— especially in the drier parts in west-central Canada—compromising the health of the forest as well as its ability to sequester carbon. [45]

As temperatures rise forest fires are likely to become longer, more frequent and more intense destroying habitats, ecosystems, and adding ore carbon to the atmosphere. Currently, forest fire cycles are speeding up.[46] As much as 7,600,000 hectares (18,780,000 acres) of forest burn in Canada each year and boreal forest fires have doubled in frequency since 1970. [47] The intensity of fires are increasing as well, as drier condition provide better quality fuel for fires, increasing their intensity and severity. In 2002, for some 2.8 million ha of Canadian forests were swept by fire. Experts agree that, in most regions of Canada, these losses will likely increase as temperatures rise (see Map 8).

Insect and pest outbreaks are another projected impact of global warming on forestry resources. Historically, many insects die off during the winter months when temperatures reach lower levels. However, winter temperatures are not reaching their usual lows, and many insects are surviving throughout the winter.[48] The result is increased insect population growth, and severe damage to forests across Canada. The highest-profile example of these climate-induced insect outbreaks is the ongoing mountain pine beetle outbreak in the western provinces of British Columbia and Alberta. Where the mountain pine beetle's population and range have historically been limited by freezing winters, warmer temperatures have allowed it to survive over the winter months. [49] Already, in 2001 alone, some 18.6 million ha of these forests were affected by insect defoliation.[50] One possible future pest is the balsam woolly aphid, a sucking insect which attacks balsam fir and damages the wood quality by staining the cells and which may also cause tree mortality. The distribution of this insect pest is currently restricted by cold winter temperatures but the situation might change with global warming.[51] The current problems caused by insect infestations such as the mountain pine beetle, the budworm, and other insects are only expected to increase as climate warming continues.

There is also evidence that warming temperatures will reduce the growth and survival of some trees in Canada. Contrary to popular belief, it's not necessarily true that the warmer it gets in the bigger and faster trees will grow. Instead, it appears that trees have optimum temperatures above which growth starts to level out or decline.[52] For example, climate warming may increase Boreal Forest growth initially, warming beyond a certain threshold will actually result in growth

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[45] http://us.greenpeace.org/site/DocServer/turning-up-the-heat-global-w.pdf?docID=122 page 17
[46] http://us.greenpeace.org/site/DocServer/turning-up-the-heat-global-w.pdf?docID=122 page 17
[47] http://us.greenpeace.org/site/DocServer/turning-up-the-heat-global-w.pdf?docID=122 page 17
[48] http://us.greenpeace.org/site/DocServer/turning-up-the-heat-global-w.pdf?docID=122 page 17
[49] http://us.greenpeace.org/site/DocServer/turning-up-the-heat-global-w.pdf?docID=122 page 17
[50] Page 37
[51] http://dsp-psd.pwgsc.gc.ca/Collection-R/LoPBdP/BP/bp254-e.htm#IMPACTStxt
[52] http://us.greenpeace.org/site/DocServer/turning-up-the-heat-global-w.pdf?docID=122 page 17

reductions. Some studies suggest that this point has already been reached, and that the Boreal is no longer benefiting from warmer temperatures.[53] Warming temperatures can compromise tree survival as well. When temperatures fluctuate close to the freezing point, ice-crystal formation can give trees "frost burn" and other injuries. [54]

Wildlife habitats are expected to shift northward under conditions of global warming. Many animals will respond to increasing temperatures by shifting their ranges northward. As well, southerly temperate-zone species will li. [55] kely be moving north, a dynamic which may cause conflicts and disruptions to ecosystem balance. There are at least 25 species (e.g. arctic fox, moose, grey wolf, red fox, caribou, muskox, grizzly bear, polar bear, and lynx) that have ranges bound by the Arctic Ocean to the north and that are likely to face pressure from species migrating from the southThe migrations of different plant and wildlife species are unlikely to happen at the same rates. Mismatches between species and ecosystems could disrupt forest ecology. In Canada, such mismatches have already resulted in increased mortality for bird populations. [56]

With model projections of increases in temperatures of some 2 to 6°C and changes in precipitation patterns across much of Canada during the next 50 years, much larger impacts on its forests can be expected in the decades to come. The net impact on the biosphere and on Canadians will depend on a wide range of other biophysical and socio-economic factors, and hence will vary considerably from region to region. [57] The effects of climate change could be positive in one region and negative in another. Once forests have fully responded to these changes — a process that could take centuries — the distribution of ecozones across Canada will likely have been altered radically (See figure 15). [58] Table 11 offers a summary of regional impacts of climate change on Canada's forests. The largest changes would occur in areas now covered by boreal forests, which span across Canada. At the southern edges of these forests, the dominant black spruce would gradually yield to the encroachment of grasslands and the evergreens and hardwoods of the cool temperate forests. [59] Meanwhile, at the northern margins, some northward expansion of the boreal forests into tundra regions would occur, although greatly delayed by the comparatively slow decay of the underlying permafrost and the poor quality of the soils in many parts in the tundra landscape. [60]

According to Environment Canada the boreal forest, currently occupying a wide swath that sweeps across Canada from Newfoundland to the Rocky Mountains and Alaska,

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[53] http://us.greenpeace.org/site/DocServer/turning-up-the-heat-global-w.pdf?docID=122 page 17
[54] http://us.greenpeace.org/site/DocServer/turning-up-the-heat-global-w.pdf?docID=122 page 17
[55] http://us.greenpeace.org/site/DocServer/turning-up-the-heat-global-w.pdf?docID=122 page 17
[56] http://us.greenpeace.org/site/DocServer/turning-up-the-heat-global-w.pdf?docID=122 page 17
[57] Page 35
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making up some 82% of Canada's forested area, is projected to shrink by 14%. At the same time, the cool temperate and moderate temperate climatic zones, currently covering only small southern areas of Canada, will grow to 15% and 5% of Canadian territory, respectively. Similarly, the grassland zone is projected to expand to 12% of total area from its current 5%.[61]

Table 11: Regional Impacts of Climate Change on Forests [62]

Region	Provinces and Territories	Impacts
West	British Colombia Yukon	• Drought stress and forest decline. • Increased frequency, duration, and intensity of forest fires • Infestation of mountain pine beetle. • Infestation of eastern spruce budworm, an extremely serious insect pest which causes defoliation of a number of valuable conifer species, including balsam fir, white spruce, hemlock, and eastern larch. Extensive tree damage and mortality in evergreen forests east of the Rock Mountains. • White spruce trees respond positively to small increases in temperature but then declined when mean temperatures rise above a critical threshold. • Decreased re-growth due to lower water levels and higher temperatures. • Warmer climate may result in an increase in winter damage to some tree species. If a warmer climate produces a decrease in snowfall, the frost may penetrate deeper into the ground and damage tree roots. This type of damage has already been implicated in the decline and death of hardwood trees.
Arctic	Northwest Territories Nunavut	• Invasive alien species as wildlife migrates northward due to warmer conditions in the Arctic. • Migration of temperate forests northward into the Arctic.
Prairies	Alberta Saskatchewan Manitoba	• Stunted growth in aspen tress due to lack of water • High risk of intense and frequent forest fires, especially in Manitoba. • Grasslands expand northward and eastward • Land use conflicts between forestry and agriculture may arise as grasslands move northward
Ontario	Ontario	• Dieback of birch and maple due to climatic stress. • Increased frequency, duration, and intensity of forest fires • Decreased re-growth due to lower water levels and higher temperatures. • Encroachment of grasslands.
Quebec	Quebec	• Higher levels of carbon, warmer temperatures, and more humid conditions could increase forest growth by 50-100% by 2050. • Increased frequency, duration, and intensity of forest fires. • Encroachment of grasslands.

[61] http://dsp-psd.pwgsc.gc.ca/Collection-R/LoPBdP/BP/bp254-e.htm

[62] Adapted from http://us.greenpeace.org/site/DocServer/turning-up-the-heat-global-w.pdf?docID=122

		• A warmer climate may result in an increase in winter damage to some tree species. If a warmer climate produces a decrease in snowfall, the frost may penetrate deeper into the ground and damage tree roots. Decline of Eastern Sugar Maple.
Atlantic Canada	New Brunswick Nova Scotia Prince Edward Island Newfoundland and Labador	• Increased ultraviolet radiation, ground-level ozone pollution, and acid rain may affect soils and harm trees. • Increased frequency, duration, and intensity of forest fires. • Decreased re-growth due to lower water levels and higher temperatures. • Encroachment of grasslands. • a warmer climate may result in an increase in winter damage to some tree species. If a warmer climate produces a decrease in snowfall, the frost may penetrate deeper into the ground and damage tree roots. Decline of Eastern Sugar Maple.

A rapidly changing climate has important implications for the forest sector and the more than 300 communities whose livelihood is closely associated with forests. Some studies suggest that forest production may increase by as much as 20% under conditions of climate change but actual harvesting levels may increase only by 3%, due to a 50 year lag as young stands reach harvesting age.[63] However, unpredictable forest fires and water shortages caused by droughts could affect the ability of Canada to reach this potential growth in forestry productivity.

Economic studies of the forestry sector show that both domestic and foreign consumers of wood and wood products would benefit in the short term under conditions of climate change. Canada will certainly export more lumber to the United States if its own domestic production increases as predicted. In this industry, climate change would likely increase Canada's competitive position relative to that of its trading partners. [64]

Climate Change Impacts on Water Resources

The impact of climate change on water resources is high priority issue. A clean and reliable water supply is critical for domestic use, food and energy production, transportation, recreation and maintenance of natural ecosystems. Although Canada possesses a relative abundance of water on a per capita basis, the uneven distribution of water resources and year-to-year variability mean that most regions of the country have experienced water-related problems, such as droughts, floods and associated water quality issues, and such problems are expected to become more common under conditions of climate change.[65] In general, it is anticipated that climate change will lower water availability while introducing greater variability to levels and flows.

[63] Page 97-98
[64] Page 97-98
[65] Page ix

The hydrological cycle is greatly influenced by temperature and precipitation, and even small changes in these parameters can affect water supply through shifts in runoff, evaporation and water storage (e.g., in glaciers, lakes and soil) .[66] There are still uncertainties, regarding the magnitude and direction of water flows given the limitations of current climate models. However, it is clear that extreme events, reduced ice cover and shifts in flow regimes, are some water related concerns throughout Canada. Overall, the most vulnerable regions would be those already under water stress, such as parts of the Prairies and the Okanagan Valley, where demand is already approaching or exceeding supply.

Climate models project that, during the coming decades, water resources will become more abundant across much of northern Canada. Furthermore, its presence as snow and ice will decrease over time, being replaced by water in its liquid form. Consequently, winter stream flows are expected to increase across much of Canada, spring freshets will occur earlier, and peak melt water runoff will be lower in magnitude. However, slowly degrading permafrost will also change the ground water hydrology in the north, changing stream flows and breaking down natural barriers that currently control much of regional drainage patterns.[67]

In contrast, summer water abundance in southern Canada will likely decrease – and become more variable. In many regions, decreases in flow volumes and water levels are expected to create or increase water supply problems during the summer months. In the summer, it is expected that climate change will reduce water supply and flows in rivers, groundwater is expected to decrease, and lake levels are expected to lower. Various studies suggest that the combined effects of increased evaporation of surface water under warmer climates and altered precipitation patterns will likely cause summer meteorological droughts in the interior of southern Canada to become more frequent, more intense, and of longer duration. These will result in intervals of very low stream flows and lake levels and depleted ground water resources. For larger water reservoirs, this is expected to lead to persistent decreases in mean water levels. For example, some of the Great Lakes could experience a drop in water levels of a meter or more within the next 50 to 75 years. Such intense periods of water shortages will have major impacts on hydro electricity production, marine transportation, agricultural irrigation, water recreational activities, municipal water supply, and a range of other socio-economic uses. In western Canada, these shortages will be exacerbated by the gradual disappearance of alpine glaciers that currently provide much of the freshwater input in regional streams and rivers in summer.[68] As well, lower water levels and higher temperatures could increase levels of bacterial, nutrient and metal contamination, while an increase in flooding could increase the flushing of urban and agricultural waste into source water systems. This would cause taste and

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[66] Page ix
[67] Page 39
[68] Page 39

odour problems and increase the risk of water-borne health effects in communities across the country. [69]

Furthermore, severe droughts will cause increased degradation of water quality, greater risk of eutrophication and extensive harm to aquatic ecosystems. Ironically, while spring floods due to rapid snow melt may decrease in frequency, there may be an increase in the risk of drought.[70] In the winter, less ice cover, more rain, and more frequent thaws could increase the risk of flooding in some areas. Some regional water quality concerns include saltwater intrusion in coastal areas and the rupture of water infrastructure in the North as a result of permafrost degradation.

Competition for water use and political pressures for water transfers between hydrological basins will increase. As all sectors of the economy depend on water resources to some extent or another conflict over the resource is likely to occur between industrial uses, agriculture, residential uses, and industries that depend on aquatic ecosystems such as fisheries and recreation. Much of existing industry, built environments, and transportation/distribution systems are not particularly resilient to changes of the type and magnitude of changes in water, especially when destabilized by a greater number and severity of extreme events. Impacts are likely to affect aquatic ecosystems, wildlife, tourism, recreation, property values, transportation, power generation, fisheries, effluent and drinking water treatment, channel dredging, infilling of impoundments and the local availability of water for agriculture, industry and urban areas. Figure 18 offers an example of the reverberating affects a change in water level would have on the environment, economy and society.

As water supplies diminish, at least seasonally, and water quality problems increase, there would be less high-quality water available for human use. At the same time, agricultural, residential and industrial demands (e.g., irrigation, lawn watering and equipment cooling, respectively), would likely increase in parts of the country that become warmer and drier. As a result, supply-demand mismatches are expected to become more common, and technological, behavioural and management changes would be required to deal with potential conflicts. [71]

For a summary of the regional effects of climate change on water resources see table 13.

Table 13: Regional Impacts of Climate Change on Water[72]

Region	Provinces and Territories	Impacts
West	British Colombia	• Glacier cover is decreasing to its lowest levels in the past 10,000 years.

[69] (page x)
[70] Page 39
[71] (page x)
[72] Adapted from http://www.c-ciarn.ca/pdf/ciarn_cwra.pdf

	Yukon	• Downstream flows were also declining, • Basins are entering a long term continuous declining flow period. • Increased water shortages downstream on the eastern slopes of the Rocky Mountains, of which there is already evidence in Alberta and Saskatchewan. • Large changes have been recorded in the Fraser River, with average flows per decade falling to low levels in the 1940s, rising about 30% by the late 1960s and falling again through to the present day • Spring runoff in South-central British Columbia to occur 20 days earlier than usual; and late summer flows were already lower from 1985-94 than from 1975-84. • Changes in the flow regimes and increase water temperature, may affect the current distribution of salmon in the Fraser River.
Artic	Northwest Territories Nunavut	• Climate models project that, during the coming decades, water resources will become more abundant across much of northern Canada. • Presence of snow and ice will decrease over time, being replaced by water in its liquid form • In communities across the Arctic inhabitants are noting widespread changes in snow cover, ice cover duration, and permafrost stability. • Melting permafrost, increased landslides and landslips • Permafrost close to the surface plays a major role in supplying freshwater systems since it often maintains lakes and wetlands above an impermeable frozen water table. Decrease in permafrost will impact fresh water supplies.
Prairies	Alberta Saskatchewan Manitoba	• Summer river flows are expected to decrease due to reduced water supply from snowmelt and glacier runoff. • Data indicate that a long-term trend of declining flows has already begun. • Decreases in shallow groundwater resources could further compound water shortages. • Flooding risk increase • Aquatic ecosystem habitats will be reduced in volume and area. • Prairie Pothole wetlands are highly susceptible to a lack of moisture occurring through the effects of decreased snowpack and associated spring recharge, droughts and increased climatic variability- this area is one of the most important wetland regions in the world • Trends in duck abundance already reflect the interactions between changing wetness regimes and landscape alterations • Since 1999 prevailing drought conditions in the Prairie Provinces have been of concern. • Farmers are already adapting by planting more drought-resistant crops, such as wheat, sunflower and lentils. • Warmer, but more arid conditions over much of the present Prairie agricultural area, since increased evapotranspiration will not be offset by the predicted increase in precipitation. This will require a shift in current cropping practices, particularly for spring seeded grains and oilseeds.

		• A drier climate will result in greater demand for deeper groundwater sources and increased withdrawal. • Poor water quality conditions in a river and consequent negative implications for aquatic life. • Many of the surface water bodies (wetlands, closed-basin saline lakes and water-supply reservoirs) in the Prairies are already shallow, saline and eutrophic due to increases in evaporation and higher water temperatures. • Lower stream flows reduce the capacity of streams to handle and transport pollutant loadings. • Warmer air temperatures lead to an increase in water temperature, a reduction in the frequency of water column turnover, a reduction in dissolved oxygen, and changes in nutrient cycling. Fish and other aquatic organisms will be affected by these changes.
Ontario	Ontario	• Water supply issues to become a greater concern in the Great Lakes basin. A range of sectors would be affected by declining water levels. • Water level changes and variation can be expected to threaten valued littoral and wetland habitat and impact both recreational and commercial fisheries as well as wildlife habitat. • Shoreline properties, infrastructure (docks, wharves, pipe locations, breakwaters, etc.) and shipping channels will be affected. • Temperature changes would alter lake structure and increase the probability of hypolimnetic anoxia. • Valued cold-water species would encounter restricted habitat and food sources. • Established bio-geochemical cycles, predator-prey relations and food-webs will be destabilized. • Changed flow and runoff patterns will result in altered concentrations of major ions, nutrients, contaminants, suspended solids and dissolved organic carbon. • Significant changes in the ice season on the Great Lakes over the past 35 years. • The ice season is occurring increasingly earlier at a number of locations. • T-Algal blooms and the growth and survival of certain opportunistic micro-organisms become more frequent in warmer water temperatures, leading to taste, odour and health problems in municipal water supply.
Quebec	Quebec	• The St. Lawrence River is by far the most significant component of Quebec's water resources. • Exposed to the longer-terms effects of climate change that occur within the Great Lakes region • Lower river flows will severely affect port and shipping transportation facilities. • Commercial navigation, recreation boating and marinas, municipal water supply, hydroelectric generation, shoreline infrastructure, and aquatic habitat and ecosystem protection are sensitive to water level and flow changes in the St' Lawrence River. • The ice season in 2001-2002 on the St-Lawrence was the

		shortest one experienced since record keeping begun in 1960 • The open water contributed to lower lake and flow levels due to the higher than usual amounts of evaporation; consequently, water levels are lower then average.
Atlantic Canada	New Brunswick Nova Scotia Prince Edward Island Newfoundland and Labador	• Sea level rise • Saltwater intrusion into rivers and coastal aquifers • Salt water intrusion could contaminate groundwater aquifers, which are the main source of regional water supplies. • Disturbance to sensitive estuary ecosystems, and displace freshwater fish populations. • Low-lying coastal lands are vulnerable to inundation under high tides and storm surges. The frequency of such flooding and the landward limits of flooding will increase with a rise in mean relative sea level. Related effects may therefore include groundwater intrusion, backwater flooding in coastal streams, and changes in saltmarsh zonation. • Substantive reduction in freshwater flowing from the St. Lawrence River and a rising mean sea level may allow further upstream penetration of salt water from the Gulf of St. • Increased flooding, intensity, and duration.

Chapter 2: The Security of Canadian Energy Resources

Chapter Overview

Access to energy is essential for modern lifestyles and modern economies. Over the past decade, increasing energy costs, together with rising demand and tight production, has resulted in a new type of security, commonly referred to as “energy security.”[73] The World Bank defines energy security as those activities which allow countries to produce and use energy sustainably at reasonable cost in order to facilitate economic growth and improve the lives of people.[74] Energy security depends on the type and availability of indigenous energy supplies, the regional distribution of those energy supplies, and the energy efficiency rates of a country. To ensure energy security it is important that energy supplies are continuous, diversified, that infrastructure reduces the dependence on imported supplies. A

[73] http://www.policyalternatives.ca/documents/Nova_Scotia_Pubs/2007/ccpa_ns_energy_security.pdf
Summary
[74] Need source

region is considered energy secure when local infrastructure allows energy supplies to be distributed so that the demand of all energy services is met.[75]

Canada has been called an 'energy superpower', implying that energy security is not an issue in Canada. Although this might seem to be a reasonable interpretation, based on the seeming abundance of natural resources found in Canada, such as coal, oil, natural gas, uranium, and hydroelectricity,[76] energy security is an issue in Canada mainly due to resource decline, uneven distribution of energy, and uneven infrastructure distribution.

In order to understand the state of energy security in Canada this section will address concerns regarding energy demand and supplies, availability of reserves at the domestic and international levels, distribution of reserves, energy efficiency, and threats to energy security. For a snapshot of energy in Canada see Figure 19.

Impacts of Climate Change on Energy Security

As the climate of Canada warms, the consumption of energy in climate-sensitive sectors is likely to change. Possible effects include (1) decreases in the amount of energy consumed in residential, commercial, and industrial buildings for space heating and increases for space cooling; (2) decreases in energy used directly in certain processes such as residential, commercial, and industrial water heating, and increases in energy used for residential and commercial refrigeration and industrial process cooling (e.g., in thermal power plants or steel mills); (3) increases in energy used to supply other resources for climate-sensitive processes, such as pumping water for irrigated agriculture and municipal uses; (4) changes in the balance of energy use among delivery forms and fuel types, as between electricity used for air conditioning and natural gas used for heating; and (5) changes in energy consumption in key climate-sensitive sectors of the economy, such as transportation, construction, and agriculture.[77]

Current knowledge about possible effects of climate change on energy production and use is not extensive. There has been a tendency to focus on the energy sector as a driving force of climate change, rather then analyzing the impacts of climate change on the energy sector. However, the energy sector – on both the energy use and energy supply sides – is vulnerable to stresses from climate change.[78]

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http://www.policyalternatives.ca/documents/Nova_Scotia_Pubs/2007/ccpa_ns_energy_security.pdf Summary (Costantini 2005; IEA 2001a).

76 http://www.policyalternatives.ca/documents/Nova_Scotia_Pubs/2007/ccpa_ns_energy_security.pdf Summary

77 From http://www.climatescience.gov/Library/sap/sap4-5/final-report/sap4-5-final-all.pdf page 23

78 Adapted from: http://www.climatescience.gov/Library/sap/sap4-5/final-report/sap4-5-final-all.pdf

Some of the expected effects of climate change have clear implications for energy production and use. Climate change could affect energy production and supply (a) if extreme weather events become more intense, (b) where regions dependent on water supplies for hydropower and/or thermal power plant cooling face reductions in water supplies, (c) where temperature increases decrease overall thermoelectric power generation efficiencies, and (d) where changed conditions affect facility siting decisions. Most effects are likely to be modest except for possible regional effects of extreme weather events and water shortages. Changes in precipitation could affect prospects for hydropower, positively or negatively. Increases in storm intensity could threaten further disruptions to oil supplies from the US Gulf Coast, of the sorts experienced in 2005 with Hurricane Katrina. As well, increased storm surges and more frequent storms in the Atlantic region could impact oil rigs adversely. [79]

Warm climates would also generally improve the efficiency of surface and marine transportation of oil and gas. However, climate change may also have significant effects on the production and transportation of energy. For instance, in southern Canada, an expected decrease in mean lake levels and river flows and increased frequency of severe droughts will likely decrease the potential for hydroelectricity generation. The reverse is likely in northern Canada, where water abundance is likely to increase. Such changes in energy distribution would require changes in infrastructure and energy transfer. There is also a risk that more intense winter storms could increase damage and disruption of electricity transmission grids. Milder winters would also benefit this sector through shorter ice seasons but also challenge it with the risk of more frequent mid-winter river ice jams. In northern and coastal regions, fossil fuel energy production and transportation activities will also need to deal with the effects of decaying permafrost on pipelines and roads, and of increased iceberg hazards along Canada's east coast.[80]

Climate change is likely to affect risk management in the investment behavior of some energy institutions, and it is very likely to have some effects on energy technology R&D investments and energy resource and technology choices. Concerns about climate change impacts could change perceptions and valuations of energy technology alternatives. As climate change affects other countries from which Canada imports energy, that in turn will affect Canadian energy conditions through their participation in global and hemispheric energy markets.[81]

As far as energy production is concerned, the most dramatic impacts of climate change are likely to be on hydroelectric production in the Great-Lakes basin due to decreasing water levels – there is a lack on consensus about other watersheds - and on offshore fossil fuels production. The loss of hydro potential in Ontario will require building more thermal stations. Water for cooling nuclear stations may be

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[79] Adapted from: http://www.climatescience.gov/Library/sap/sap4-5/final-report/sap4-5-final-all.pdf
[80] Adapted from page 42
[81] Adapted from: http://www.climatescience.gov/Library/sap/sap4-5/final-report/sap4-5-final-all.pdf

lacking. On the other hand, the hydro-generation potential will increase in the James Bay region.[82] In the lower reaches of the St. John River in New-Brunswick, generating facilities may have to be moved because of the risk of flooding.

Any decrease in hydroelectric capacity will result in a decrease in Canada's ability to meet its export commitments. Under the terms of NAFTA, member states must honor export contracts on the same footing as domestic contracts. For example, should Hydro Quebec contract to sell 15% of its production to Niagara-Mohawk in New York, it must maintain that percentage regardless of its total volume of output. Even if overall domestic production falls, Hydro Quebec cannot reallocate its production to meet domestic demand at the expense of its export contracts. Thus, climate change-induced shortages or overages in hydro production would affect exports as well as domestic consumption. Modeling these changes, however, is nearly impossible.[83]

Offshore fossil fuels production may benefit from the elimination of sea ice and icebergs (iceberg calfing notwithstanding); resulting increased height of waves may increase shore erosion and, thereby, affect long-lived coastal and offshore structures. Thawing permafrost may affect pipelines in the North. [84]

The production of oil from oil sands in western Canada involves the extraction of bitumen which requires a significant volume of water. Research has suggested that the climate is changing towards drier, warmer conditions, which could further limit the freshwater supply from the Athabasca River for use by oil sands.[85] As such, the availability of water resources for the extraction of oil may decrease, increasing the costs of production.

Natural gas availability is expected to change under conditions of climate change indirectly as consumer preferences change towards lower carbon emitting energy sources. The Kyoto Protocol along with fact that natural gas prices are set in an increasingly integrated North American market entail that Canadian producers will have to bear any costs they incur in order to comply emission constraints. In the continental marketplace, Canada's natural gas basins such as the Western Sedimentary Basin in Alberta and the Scotian Shelf in the Maritimes compete directly with natural gas sources in the U.S., and may eventually compete with those in Mexico.[86] Similarly, the market for coal is being affected by growing concerns over greenhouse gas emissions.

Climate warming will mean reductions in total Canadian heating requirements and increases in total cooling requirements for buildings. These changes in consumption

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[82] Page 116
[83] Page 116
[84] Page 116
[85] http://ess.nrcan.gc.ca/ercc-rrcc/theme1/t7_e.php
[86] http://www.heartlandgas.ca/position_climatechange_march2002.pdf

will vary by region and by season, but they will affect household and business energy costs and their demands on energy supply institutions. For example, energy consumption for space heating and cooling in our homes, offices and factories changes with outside temperatures. Within the next 50 years or so, the projected warming of Canada's climate could reduce winter heating costs in Canada by some 20-30%. These savings will be partially offset by increased summer cooling costs in southern Canada.[87] Electricity demand for heating will be reduced considerably in Ontario and Quebec while demand for cooling may increase slightly during the summer. [88] It is expected that in Alberta, electricity production and consumption will not be affected by climate. Natural gas demand for heating in Alberta will be reduced and the peak demand would be flattened. As well, if settlements patterns change considerably by shifting northward - an unlikely event, energy consumption patterns may change considerably as well. [89]

On the other hand, increased demand for water for irrigation will result in increased electricity consumption for pumping. In the Praries where conditions of drought are expected, energy demand for irrigation could increase the costs of agriculture production. [90]

It is expected that as heating demands lower in Canada, more energy resources will be available for export. Since Canada's biggest export market for energy is the United States, depending on the state of their domestic supply, this could represent an opportunity for increased revenue, although it is impossible to identify exactly how much.[91]

For a summary of the regional effects of climate change on energy see table 15.

Table 15: Regional Impacts of Climate Change on Energy[92]

Region	Provinces and Territories	Impacts
West[93]	British Colombia Yukon	• Glacier reduction and disappearance could adversely affect hydroelectric generation. • Drier summers and falls may reduce hydroelectric generation in southeast B.C.
Artic [94]	Northwest Territories Nunavut	• Melting of the ice caps could open opportunities for seabed oil exploration in the North. • Permafrost degradation could negatively impact overland

[87] (page 42)
[88] Page 116
[89] Page 116
[90] Page 116
[91] Page 99
[92] Adapted from http://www.c-ciarn.ca/pdf/ciarn_cwra.pdf
[93] Source: http://www.acee-ceaa.gc.ca/015/001/004/appendixA_e.htm#Anchor-26786
[94] Source: http://www.acee-ceaa.gc.ca/015/001/004/appendixA_e.htm#Anchor-26786

		pipelines.
Prairies[95]	Alberta Saskatchewan Manitoba	• Electricity has the potential to be severely impacted by climate change. Thermal power stations become less efficient as reservoir water temperatures increase. • Hydroelectric production will have to compete with a number of other uses, primarily agricultural, for the diminishing water supply. • Increased demand for water pumping and summer cooling, and a decreased winter demand could push electrical utilities into a summer peak load position. • Possible reduced hydropower production caused by decreasing water flow could result in increasing thermal power production with an increase in fossil fuel consumption and greenhouse gas emissions. • Competing uses of water due to drought could impact oil sand productivity.
Ontario[96]	Ontario	• Daily and year-to-year fluctuations in energy demand are driven largely by temperature. • Heat stress in summer could lead to increased demand for energy for the purposes of air conditioning • Warmer winters in the south would reduce the demands for heating. • Variability in temperature and precipitation causes variations in lake levels and river flows, which affect hydroelectric power generation. • Thunderstorms, freezing rain, high winds, freeze-thaw cycles and frozen ground affect the infrastructure of the energy distribution system. Wind patterns and cloud cover play a significant role in determining the feasibility of wind and solar energy.
Quebec	Quebec	• Changes in the hydrologic cycle may result in more variability in water supply for hydroelectric power production. • Energy demand is expected to increase in the summer and decrease in the winter.
Atlantic Canada[97]	New Brunswick Nova Scotia Prince Edward Island Newfoundland and Labador	• Changes in the number of ice free days would affect marine transportation and the offshore oil and gas industry. • Changes in precipitation and run-off affect generation of hydroelectric power temperature changes alter energy demand.

Chapter 3: Security of Canadian Arctic Sovereignty and Resources

[95] Source: http://www.acee-ceaa.gc.ca/015/001/004/appendixA_e.htm#Anchor-26786
[96] http://www.on.ec.gc.ca/canada-country-study/intro.html
[97] Source: http://www.acee-ceaa.gc.ca/015/001/004/appendixA_e.htm#Anchor-26786

Chapter Overview

-in progress w/ policy reviews

Impacts of Climate Change on Canada's Arctic

The high natural climate variability of the Arctic, together with the relatively sparse observational data sets, make it difficult to distinguish with confidence a climate change signal in the trends observed in the instrumental period of record (McBean et al., 2005). During more recent periods, all regions show warming. Trends were strongest in winter and spring. Annual and winter temperature anomalies and annual precipitation departures over four northern regions from 1948 to 2005 how greatest warming in the Yukon and Mackenzie District (2.2°C and 2.0°C, respectively). Annual precipitation totals (1948–2005) increased throughout all of northern Canada, with the largest increases over the more northerly Arctic Tundra (+25%) and Arctic Mountain (+16%) regions.[98]

The climate of the North during the last 10 000 years has been characterized by relative warmth and remarkable stability. In the last 2000 years, climate has been characterized by multi-centennial oscillations ranging from mild conditions (similar to the modern era) to widespread persistence of relatively cool conditions. Climate of the last 400 years has been characterized by warming and related changes over most of the Arctic, including retreat of glaciers, reduction in sea-ice extent, permafrost melting, and alteration of terrestrial and aquatic ecosystems. During the past approximately 150 years, however, it is evident that the rate and nature of change are unprecedented since the abrupt warming at the onset of the current interglacial period more than 10 000 years ago. This rapid acceleration in temperature increase over the Arctic is projected to continue throughout the twenty-first century.[99]

For the 2020s, both western and eastern regions exhibit mean annual temperature changes concentrated near +2.0 °C and precipitation increases ranging from 5 to 8%. Intermodel variability is greatest during the 2080s: median temperature changes for the western region are near +6.0 °C but range from +3.5°C (NCAR-PCM B2 scenario) to +12.5°C (CCSRNIES A1FI scenario); most scenarios project a 15 to 30% increase in annual precipitation. [100] The greatest temperature changes are projected to occur during winter.[101]

Spatial characteristics of annual and seasonal projected temperature changes over northern Canada indicate that the greatest temperature changes will occur at higher latitudes, particularly in the extreme northwest. Seasonally, the greatest

[98] http://www.adaptation.nrcan.gc.ca/assess/2007/ch3/2_e.php
[99] http://www.adaptation.nrcan.gc.ca/assess/2007/ch3/2_e.php
[100] http://www.adaptation.nrcan.gc.ca/assess/2007/ch3/2_e.php
[101] http://www.adaptation.nrcan.gc.ca/assess/2007/ch3/2_e.php

temperature changes over the entire region are projected to occur during winter and fall. Annual and seasonal precipitation changes show considerable spatial variability in the Canadian Arctic, with the greatest annual percentage increases projected over more northerly regions.[102]

Many components of the Arctic environment are sensitive to changes in climate including, sea ice, seasonal snow cover, glaciers and ice caps, permafrost, and river and lake ice. Terrestrial, freshwater and marine ecosystems will be impacted by changes in the cryosphere.[103]

The annual averaged area of sea ice in the Northern Hemisphere has decreased by 7.4% (3% per decade) between 1978 and 2003 (Johannessen et al., 2004). The annual maximum ice area has shrunk less rapidly, at about 2% per decade, whereas the annual minimum has declined more rapidly, at about 5.6% per decade. In the 21st century, there are projections for decreases in sea-ice extent during the twenty-first century. Projections from the CGCM2 model indicate an ice-free Arctic during September by the mid –twenty-first century, whereas other models project ice-free summers in the Arctic by 2100.[104]

In the Arctic regions, snow can account for up to 80% of annual precipitation. Snow insulates the ground, affecting the ground thermal regime and permafrost distribution (Marsh, 1990). Snow also influences surface radiation balances and water budgets (Gray and Prowse, 1993), and affects the habitat of terrestrial and aquatic biota (e.g. Adams, 1981). From 1972 to 2003, average annual snow-cover extent in the Northern Hemisphere decreased by about 10%. The largest decreases occurred during spring and summer, which correlated with a large spring warming over northern land areas (Brown, 2000; Walsh et al., 2005). Projected increases in temperature will decrease the length of time available for accumulation of a winter snowpack, thereby affecting the magnitude of the spring snowmelt, the major hydrological event of the year in most northern systems (Marsh, 1990).[105]

Canada has major glaciers and ice caps in the high Arctic and Yukon. In general, glaciers and ice caps across the Arctic show a retreat in glacier fronts and volume decreases since about 1920. Over the long term, the Greenland Ice Sheet is projected to make the largest contribution to future sea-level changes, but meltwater from glaciers in Alaska-Yukon are also projected to make a significant addition (Arendt et al., 2002; Meier and Dyurgerov, 2002).[106]

Active layer and permafrost thermal-monitoring activities during the last two to three decades indicate that recent warming of permafrost has occurred in many

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[102] http://www.adaptation.nrcan.gc.ca/assess/2007/ch3/2_e.php
[103] http://www.adaptation.nrcan.gc.ca/assess/2007/ch3/2_e.php
[104] http://www.adaptation.nrcan.gc.ca/assess/2007/ch3/2_e.php
[105] http://www.adaptation.nrcan.gc.ca/assess/2007/ch3/2_e.php
[106] http://www.adaptation.nrcan.gc.ca/assess/2007/ch3/2_e.php

regions of the Canadian permafrost zone and that summer thaw penetration has increased in the 1990s

Degradation of continuous permafrost to discontinuous permafrost, and disappearance of discontinuous permafrost, is projected to occur at the southern boundaries of these permafrost zones. Thawing of permafrost has the potential to release large pools of carbon, which can act as feedback to the climate system. Thaw sensitivity and settlement of permafrost have important implications for landscape stability and the performance of any overlying infrastructure. Frozen ground plays an important role in northern hydrology through its influence on infiltration, runoff and groundwater storage and flow. The implications of climate-induced changes in permafrost for northern hydrology are increased infiltration, greater groundwater storage, lower spring runoff, increase in base flow, changes in water quality, changes in drainage and the distribution of surface water. Thawing of ice-rich permafrost may also lead to loss of fish and wildlife habitat.[107]

From 1846 to 1995, freeze-up and break-up trends for lakes and rivers in the Northern Hemisphere, including a long-term site on the Mackenzie River, show an average delay of 5.8 days per century in freeze-up dates and an average advance of 6.3 days per century in break-up dates (Magnuson et al., 2000). Although changes are difficult to predict (Bonsal and Prowse, 2003), future warming will likely lead to a shortened ice season and thinner lake- and river-ice covers, and cover composition.[108]

Parts of the Arctic, may be subject to rapid increases in the sea level. Sea-level rise increases the risk of flooding and erosion on Arctic coasts and may exacerbate other coastal hazards, such as ice ride-up and pile-up. In the western Arctic, sea-level rise and coastal erosion threaten cultural heritage sites (e.g. former habitations and burial sites) on the Yukon coast (e.g. Herschel Island), seasonal settlements (e.g. Shingle Point, YT) and coastal communities (e.g. Tuktoyaktuk, NT; e.g. Colette, 2007). Coastal erosion is a concern at other communities in the western Arctic, including Sachs Harbour and, to a lesser extent, Ulukhaktok, NT (Manson et al., 2005), while high water levels have been noted as an issue in Cambridge Bay, NU (Shirley, 2006). In the eastern Arctic, high-water and erosion concerns have been noted at Hall Beach, Iqaluit, Pond Inlet and Arctic Bay, NU, prompting discussions about adaptation options (Shirley, 2006; Ford et al., 2006a; Bhabesh Roy, Regional Engineer, Government of Nunavut, pers. comm., March 14, 2007). The most severe flooding risks in low-lying communities, such as Tuktoyaktuk, are associated with large storm surges, which may reach more than 2 m above MSL (Manson et al., 2005).[109]

[107] http://www.adaptation.nrcan.gc.ca/assess/2007/ch3/2_e.php
[108] http://www.adaptation.nrcan.gc.ca/assess/2007/ch3/2_e.php
[109] http://www.adaptation.nrcan.gc.ca/assess/2007/ch3/2_e.php

The extreme temperature gradients of the Arctic mean that plant communities will likely show a quick and strong response to temperature change. Vegetation-model projections for the present century indicate that, depending on location, the boreal forest will displace between 11 and 50% of all Arctic tundra (Harding et al., 2002; Skre et al., 2002). However, recent observations of the latitudinal treeline show a southward displacement, suggesting that a northward displacement, projected on the basis of changing climatic conditions alone, is unlikely (Callaghan et al., 2005). Increased disturbances, such as pest outbreaks and fire, will locally affect the direction of treeline response. [110]

Climate change will affect the structure and function of Arctic freshwater ecosystems. Community and ecosystem attributes, including species richness, biodiversity, range and distribution, will be affected and will consequently affect food-web structures and production levels. Although large uncertainties remain in projecting species- and system-specific responses, it is likely that locally adapted Arctic species will disappear from certain areas when environmental conditions begin to exceed their physiological tolerances and/or ecological optima.[111]

Changing climate will affect the capacity and operations of current and future hydroelectric developments, as well as affecting the demand for electricity. Projected increases in winter runoff from rainfall and enhanced winter snowmelt will lead to a decline in winter snow storage. Reservoir capacities on current and future developments may need to be expanded to offset this loss in natural storage.[112]

Exploration activities of oil and gas are likely to be affected by climate change in the Arctic. In 2006, there were active and potential exploration activities in the Eagle Plains area of the Yukon and in the Cameron Hills, Fort Liard and Mackenzie Delta areas of the Northwest Territories. Some of the largest future potential reserves exist within the Canadian Arctic Archipelago and projected decreases in sea-ice cover may result in this area becoming a focus of additional exploration activity. [113]

Thawing of permafrost and changes in snow cover will necessitate an increased focus on low-impact vehicles and/or changes in seasonal scheduling of exploration activities. The unpredictability of the winter season and the winter ice-road system will necessitate greater flexibility in scheduling of exploration and extraction activities. The greatest impact of changing climate on exploration, however, may relate to the use of in-ground sumps for drilling wastes. Disposal in sumps relies on the presence of permafrost to prevent subsurface movement of drilling wastes into the surrounding environment (French, 1980; Dyke, 2001). Increased ground

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[110] http://www.adaptation.nrcan.gc.ca/assess/2007/ch3/2_e.php
[111] http://www.adaptation.nrcan.gc.ca/assess/2007/ch3/2_e.php
[112] http://www.adaptation.nrcan.gc.ca/assess/2007/ch3/2_e.php
[113] http://www.adaptation.nrcan.gc.ca/assess/2007/ch3/2_e.php

temperatures resulting from increases in air temperature and/or snow depth (Jenkins et al., 2005) will increase the likelihood of contaminant transport. [114]

Offshore exploration drilling, such as that recently conducted by Devon Canada Corporation in the Beaufort Sea, will be affected by decreasing sea-ice cover. Future development may require design changes to drilling platforms to counter the effects of increased wave action and storm surges. One possible adaptation would be to increase the use of exploration drill ships (Croasdale, 1993). [115]

Oil and gas are delivered to markets through pipelines that are designed according to environmental conditions, many of which are influenced by climate. A number of geotechnical –climate change issues need to be addressed when constructing pipelines in permafrost zones, such as changes in the ground thermal regime, drainage and terrain stability, all of which may result from a warming climate over the lifetime of such a project.[116]

There are currently three major mines operating in the northern territories: two diamond mines in the Northwest Territories and one diamond mine in Nunavut. Declines in sea-ice cover, due to climate change, is likely to stimulate further mine exploration and development. The principal mineral deposits include diamonds, gold, tungsten, silver, lead, iron, copper, zinc, nickel, coal, tantalum, niobium, lithium, cobalt, bismuth, uranium, beryllium and barium. Resupply of existing mines is generally limited to winter periods and the availability of ice roads, whereas exploration activities are usually restricted to short summer periods. Of particular concern for mine access is the expected reduction in the availability of ice roads, which may necessitate development of all-season roads and/or water-based transportation systems.[117]

The most obvious impact of changing climate on Arctic marine transportation will be an increase in the length of the summer shipping season, with sea-ice duration expected to be 10 days shorter by 2020 and 20 –30 days shorter by 2080 (Loeng et al., 2005), although there is no expectation of an ice-free Arctic in winter. Even though a longer shipping season appears beneficial, ice conditions in all areas of the Canadian Arctic are highly variable from year to year and will likely remain that way. Hence, there will continue to be summers with ice conditions either more benign or far worse in the future. [118] Hudson Bay and the Beaufort Sea, are both likely to see increased numbers of transits by large ships. A longer summer shipping season will likely encourage shipping through the port of Churchill on Hudson Bay; in the Beaufort Sea, it will increase the appeal of offshore hydrocarbon development and of shipping oil and gas in large ships westward and through Bering Strait.

[114] http://www.adaptation.nrcan.gc.ca/assess/2007/ch3/2_e.php
[115] http://www.adaptation.nrcan.gc.ca/assess/2007/ch3/2_e.php
[116] http://www.adaptation.nrcan.gc.ca/assess/2007/ch3/2_e.php
[117] http://www.adaptation.nrcan.gc.ca/assess/2007/ch3/2_e.php
[118] http://www.adaptation.nrcan.gc.ca/assess/2007/ch3/2_e.php

Increased wind fetch will increase risks from waves and surges to barge traffic, coastal infrastructure and small-boat use by northern residents.

Climate change is also expected to change the nature of the risks to shipping traffic in many areas of the Arctic. Rather than being confronted with extensive ice pack that necessitates icebreaker escort, ships in the future will see easier navigating conditions in general, punctuated by frequent occurrences of ice pressure in congested straits, multi-year ice in low concentrations that is difficult to detect, and extreme variability of conditions from one year to the next. As such, there will be a need for continued, if not increased, icebreaking support for increased and more broadly dispersed shipping activities. [119]

Significant areas of the Yukon (22.79 million ha) and the Northwest Territories (33.35 million ha) are covered by boreal forest, together constituting about 13% of Canada's total forest cover. The cultural, spiritual, social and economic well-being of many First Nations is dependent on a healthy forest ecosystem. Gathering of food and the exercise of cultural practices are important uses of forest land in the Yukon and Northwest Territories. Less than 30% of the Yukon forest cover is of a species or size that might support timber-harvesting activities (Government of Yukon, 2006), with the majority of merchantable forests located south of latitude 61 °N. Farther north, Yukon forests are more affected by cold soils, poor drainage and aggressive fire regimes.[120]

The mounting evidence of local ecological responses to recent climate change demonstrates the sensitivity of northern forested ecosystems to climate change. Many of the projected impacts of changing climate on the northern forest sector are already visible. Increased forest disturbances due to insect outbreaks are almost certain to result from continued climate warming (Juday et al., 2005). The spruce bark beetle infestation of southwestern Yukon, which has led to widespread mortality of white spruce, is the largest and most intense outbreak to affect Canadian trees and is a notable example of ecosystem response to recent warming. Climate change is also projected to increase the frequency, extent and severity of forest fires, thereby reducing mean fire return intervals, shifting age class distributions toward younger forests, triggering more frequent shifts from conifer- to deciduous-dominated successional trajectories, and decreasing the amount of terrestrial carbon stored in the boreal forest. [121] See table 16 for the effects of climate change on Canada's Northern Forest sector. [122]

TABLE 16: Examples of the impacts of climate change on the northern forest sector (modified from Lemmen and Warren, 2004).

[119] http://www.adaptation.nrcan.gc.ca/assess/2007/ch3/2_e.php
[120] http://www.adaptation.nrcan.gc.ca/assess/2007/ch3/2_e.php
[121] http://www.adaptation.nrcan.gc.ca/assess/2007/ch3/2_e.php
[122] http://www.adaptation.nrcan.gc.ca/assess/2007/ch3/2_e.php

Biophysical impact	Socioeconomic impacts
Changes in forest productivity	Changes in timber supply and rent value
Increased atmospheric greenhouse gases	Introduction of carbon credit-permit mitigation policies that create a carbon sequestration market
Increased disturbances	Loss of forest stock and non-market goods
Northward shift of ecozones	Change in land values and land-use options
Change in climate and ecosystems	Economic restructuring leading to social and individual stresses
Ecosystem and specialist species changes	Changes in non-market values
Ecosystem changes	Dislocation of parks and natural areas, increased land-use conflicts

The northern fish fauna of Canada consist of an estimated 240 species. The number of species present in the region is likely to rise as climate changes, especially along the southern margin of the North. Several southern species are known to occur as vagrants in the North, including three species of Pacific salmon in the western Arctic and Atlantic salmon in the east. Colonization could result in new opportunities for fisheries, but could also add to existing stressors as ecosystems restructure, new predators appear, competition ensues and/or parasites are introduced by the colonizing species (Reist et al., 2006b, c; Wrona et al., 2006a). Experience with the vagrants in local fisheries enhances interest in future potential for fisheries based upon those species. [123]

Arctic species will likely experience declining productivity, local extirpation along the southern margin of their distribution and overall range contraction as local conditions exceed thresholds and southern species colonize and compete with or prey upon them. Both northern cold-water and southern cool-water species will likely increase in abundance and local productivity, and perhaps also extend their geographic range farther northward as conditions allow.[124]

Inshore coastal marine and lake-based commercial fisheries and aquaculture operations are likely to face significant adaptation challenges as a result of changing climate. In addition to fairly intensive capitalization of the fishing fleet, these fisheries are supported by harbour facilities and onshore fish-processing facilities that require significant capital expenditures and regular inspection and maintenance to maintain standards for processing commercial fish products. In the North, long-term, relatively stable production is required to recoup initial investments. Current views of such activities in the North being a major contributor to economic development in the future (e.g. Government of Nunavut and

[123] http://www.adaptation.nrcan.gc.ca/assess/2007/ch3/2_e.php
[124] http://www.adaptation.nrcan.gc.ca/assess/2007/ch3/2_e.php

Nunavut Tuungavik Incorporated, 2005) may have to be adjusted in view of the consequences of changing climate.[125]

[125] http://www.adaptation.nrcan.gc.ca/assess/2007/ch3/2_e.php