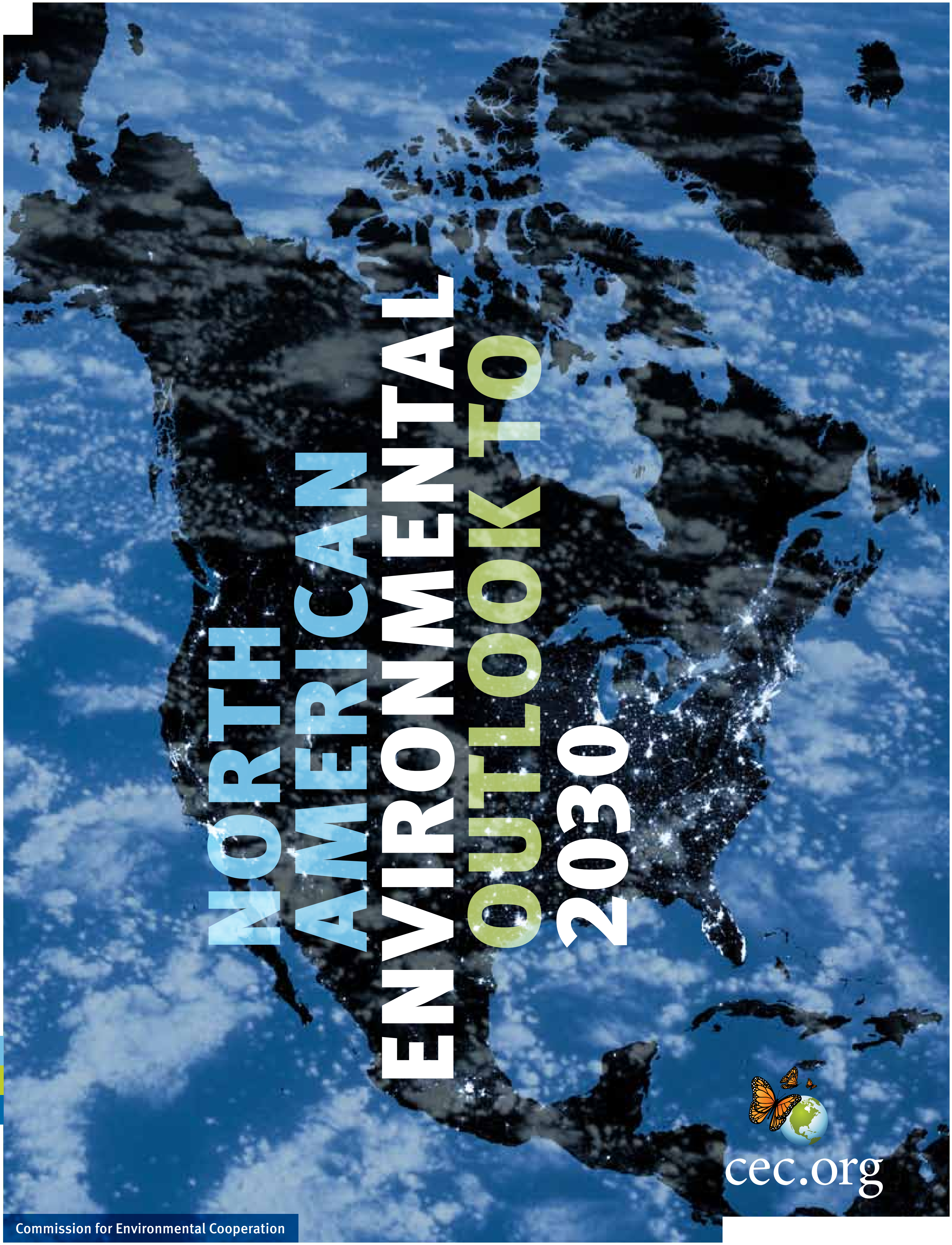
NORTH AMERICAN ENVIRONMENTAL OUTLOOK TO 2030



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Cover: Satellite image showing the nighttime lights of North America, from the *North American Environmental Atlas*, a striking indicator of the presence and impact of humans upon the land.

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Commission for Environmental Cooperation
Comisión para la Cooperación Ambiental
Commission de coopération environnementale

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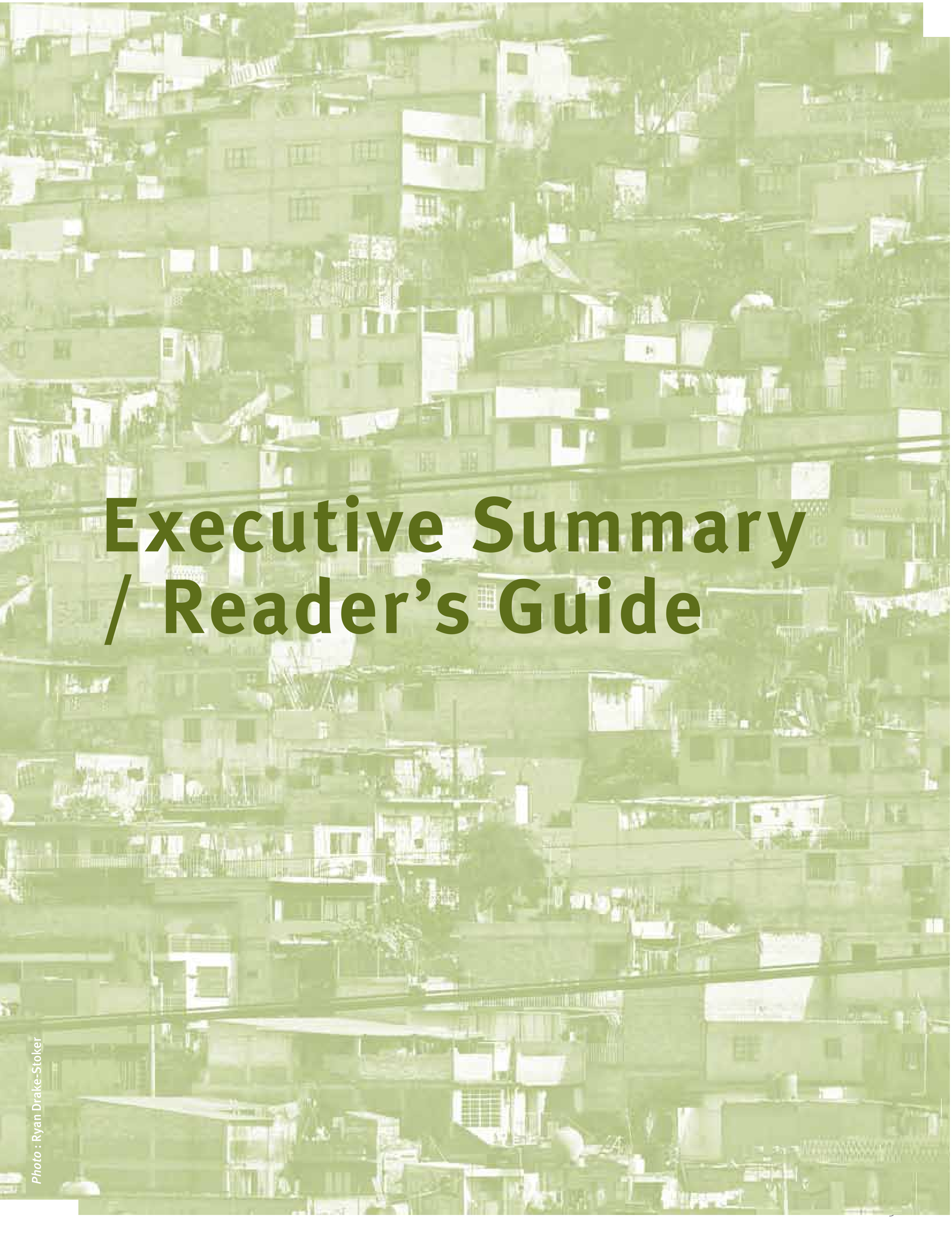
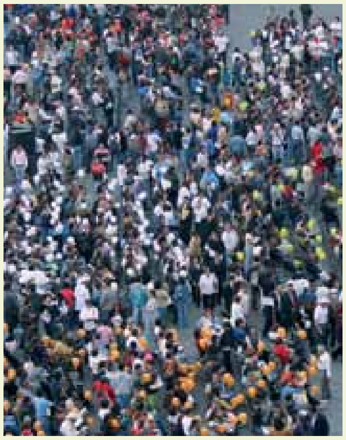
Acronyms and Abbreviations

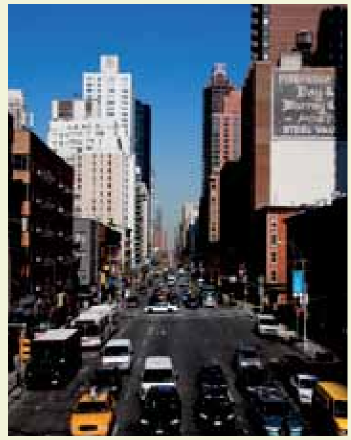
BRIC	Brazil, Russia, India and China
CEC	Commission for Environmental Cooperation
CO_2	carbon dioxide
CO_2eq	CO2-equivalents
DALYs	Disability Adjusted Life Years (the sum of years of potential life lost due to premature mortality and the years of productive life lost to disability)
DPSIR model	Driver-Pressure-State-Impact-Response model
EIA	Energy Information Administration (information agency concerned with energy, part of the US Department of Energy)
FAO	United Nations Food and Agriculture Organization
FTA	Free Trade Agreement
GDP	gross domestic product (either as measured overall or per capita)
GEO4	*Fourth Global Environment Outlook* report, produced by the United Nations Environment Programme GEO4 MF — GEO4 Markets First scenario GEO4 PF — GEO4 Policy First scenario GEO4 SeF — GEO4 Security First scenario GEO4 SuF — GEO4 Sustainability First scenario
GHG	greenhouse gas
IEA	International Energy Agency
IEO	reference scenario in *International Energy Outlook 2008* (EIA)
IMAGE	Integrated Model for the Assessment of the Greenhouse Effect
IPCC	Intergovernmental Panel on Climate Change
JPAC	Joint Public Advisory Committee (CEC)
MSE	Mean Species Abundance
NAAEC	North American Agreement on Environmental Cooperation
NAALC	North American Agreement on Labor Cooperation
NAFTA	North American Free Trade Agreement
NO_x	nitrogen oxides
OECD	Organisation for Economic Cooperation and Development OECD ppGlobal — scenario featuring comprehensive global policy package OECD 450ppm — scenario with atmospheric GHGs stabilized at 450 ppm CO2eq
POPs	persistent organic pollutants
ppm	parts per million
SO_x	sulfur oxides
UNEP	United Nations Environment Programme
UNPD	United Nations Population Division
WEO	reference scenario in *World Energy Outlook 2008* (OECD/IEA)



Executive Summary / Reader's Guide

Photo : Ryan Drake-Stoker






This report summarizes recent research concerning the major forces and underlying trends that are likely to shape the environment of North America in 2030. The intention of this report is not to present a prediction of the future. Rather, it is to consider the possibilities that the future might hold in light of the environmental and social stresses facing North America and the world at this time.

The report has been produced in response to a request by the Council of the Commission for Environmental Cooperation (CEC). It complements the CEC's 2008 report, *The North American Mosaic* (CEC 2008), which focused on recent environmental trends and divided issues by subject or medium—air and atmosphere, biodiversity and ecosystems, pollutants, and water. This allows for the telling of a coherent story for each issue, but can hide the interconnections among issues. This report takes a more systems approach, following a Driver-Pressure-State-Impact-Response model. Thus, it follows more directly from the discussion paper prepared for the June 2008 conference, North America 2030: An Environmental Outlook, hosted by the CEC's Joint Public Advisory Committee (Stratos Inc. and IISD 2008), upon which it expands. Together, these and other initiatives are intended to assist the CEC in the consideration and development of its work program by highlighting possible areas for cooperative action to support environmental mitigation, adaptation and innovation strategies across all three countries.

Several factors restrict the scope of this report. First, as a review, it is necessarily limited to available work to-date. Second, because it takes a North American perspective, the choice was to focus primarily, although not exclusively, on cases where consistent and comparable information is available for Canada, Mexico, and the United States. This precluded using some country-specific data, which provide greater within-country detail and may differ from similar data presented in international data sets. Third, there are numerous aspects of the environment for which historic data are available, but for which there has been no effort to make forward-looking projections. Fourth, each of these restrictions is exacerbated by the desire to include quantitative information as much as possible. Finally, most studies, including those explored here, have tended not to consider in detail the possibility of dramatic, albeit imaginable, surprises that would alter their projections significantly.[1]

The review draws heavily on two recent global studies—the United Nations Environment Programme's *Global Environmental Outlook 4* and the Organization for Economic Cooperation and Development's *OECD Environmental Outlook to 2030*, which provide projections for a range of environmental issues. These are complemented by more issue-specific studies at the global level—e.g., the *Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, the *Millennium Ecosystem Assessment*, the United Nations Population Division's *World Population Prospects* and the International Energy Agency's *World Energy Outlook 2008*—as well as select national studies and other available literature. The key messages that come out of the review can be grouped into three categories:

[1] Examples would be a sustained oil price shock or the interruption of international oil supplies, an "albedo flip" accelerating the melting of arctic ice, a disease pandemic, or technological breakthroughs.




1 There is a range of variation in the projections for many environmental issues and their drivers.

The studies reviewed here, and the various scenarios within these studies, differ in terms of their assumptions about the choices we make, either as individuals or as society. A wider range of variation in both the assumptions and the outcomes points to aspects where our actions can make a more significant impact to the year 2030. Those issues with the greatest variation in projections across the scenarios include:

- **Energy use and associated emissions**
- **Water use and treatment of wastewater**

2 Significant changes, stemming from major challenges, can be expected in a number of environmental issues and their drivers.

Significance here refers not only to the magnitude of a change, but also to its direction and persistence, the extent to which it approaches or exceeds critical thresholds, and the impacts it has upon society. The most important challenges are likely to include:

- **Continued and accelerated warming, particularly in the Arctic**
- **Continued loss of terrestrial biodiversity**
- **Persistence of elevated levels of ground-level ozone in urban areas**

3 There exist important gaps in the current knowledge base concerning environmental futures.

Recognizing that attempting to predict the future is a fool's errand, there is still much to be learned from considering the possibilities. To the extent that important issues have not received attention, they are less likely to receive consideration in the actions we take, including the policies we develop. Among those issues that deserve greater attention are:

- **The growth in urban and built-up land area**
- **Freshwater quality and groundwater availability and quality**
- **The specific economic and health effects of environmental change**
- **The impact of consumption in North America on the environment in other regions, and vice versa**

These point to an interlinked set of actions for consideration—addressing those changes that are amenable to policy action in the near term, preparing for those changes that are almost inevitable over the short term but are amenable to policy action in the longer term, and strengthening our knowledge concerning those changes about which we know the least.

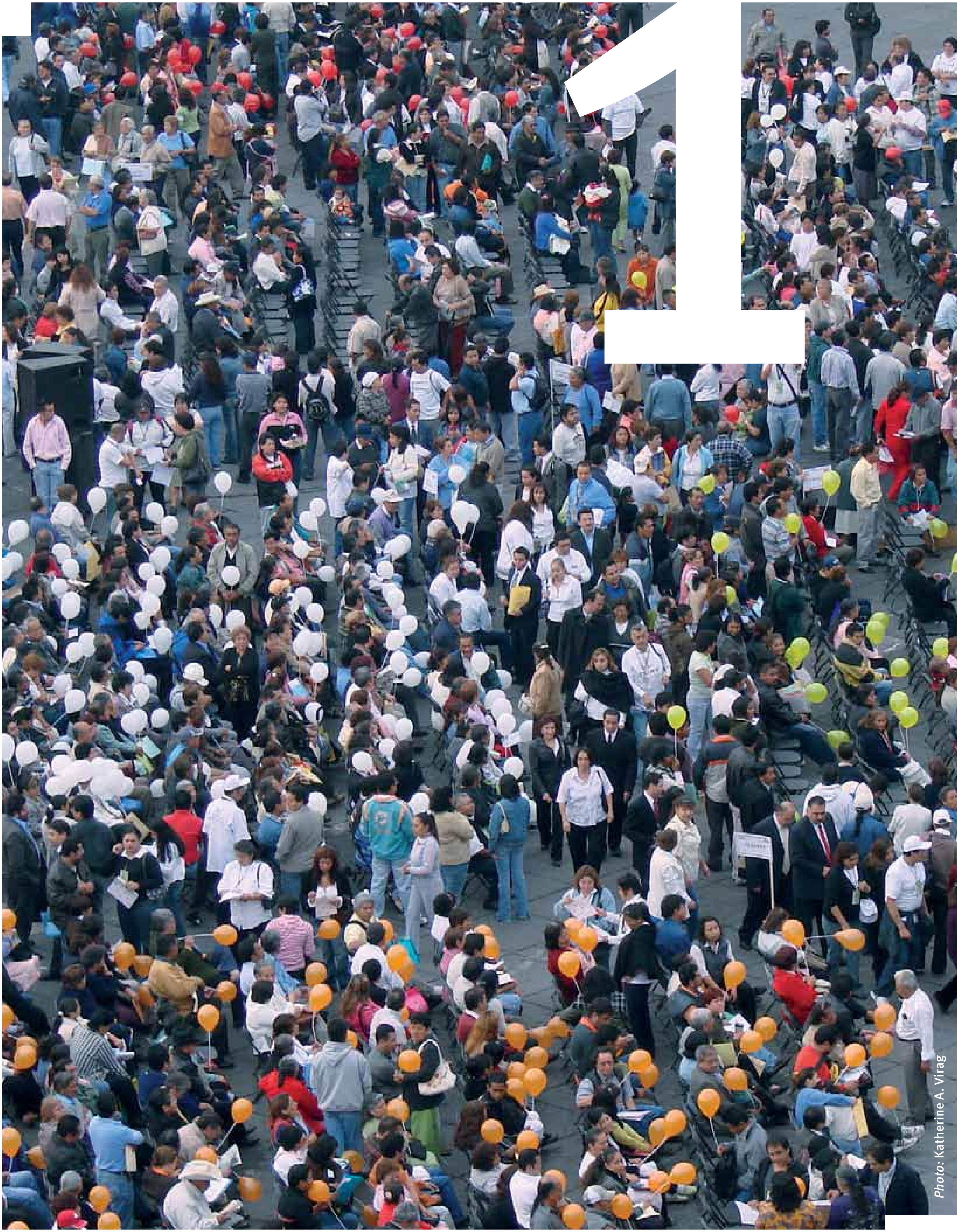


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Photo: Katherine A. Virag

CHAPTER 1
Introduction

North America's environmental future is not pre-ordained. A range of possible scenarios have been posited for the continent's environment in 2030. A recent study by the Center for Strategic and International Studies, in collaboration with the *Centro de Investigacíon y Docencia Económicas* and the Conference Board of Canada, states that the continuation of current trends, absent changes in policy and behavior:

> will result in a substantially degraded North American environment in 2025… The expense of protecting coastal areas against saltwater intrusion could become prohibitive, forcing abandonment of some of North America's most valuable real estate. Large parts of the western United States and northern Mexico could become uninhabitable as surface and groundwater disappears and the land dries out. Water scarcity and migration pressures could lead to conflict within and between North American countries. Extraction of oil and other resources in response to growing North American and foreign demand could irreparably damage some of North America's most beautiful ecosystems. Habitat degradation and loss of native species could leave our grandchildren with a much-diminished natural inheritance. (Vadgama, Nitze et al. 2008, p. 37)

The same study notes, however, that (p. 38) "this dire forecast does not necessarily have to come to pass.

This report reviews and summarizes recent research concerning the major forces and underlying trends related to the environment in North America. It presents current expert opinion on these matters as reflected in such global studies as the United Nations Environment Programme's *Fourth Global Environmental Outlook* (UNEP 2007), the Organization for Economic Cooperation and Development's *OECD Environmental Outlook to 2030* (OECD 2008), the *Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (IPCC 2007), and the *Millennium Ecosystem Assessment* (MA 2005), as well as regional and national studies. The focus is on the future—to where these forces and trends might take us in the coming years, acknowledging the uncertainties in making projections. Thus, it is meant to complement more formal state and trends reports, such as the recently released *North American Mosaic* (CEC 2008). It has a time horizon of 2030, recognizing that our actions, both historically and in these next two decades, will influence the environment into the further future.

The present report aims to be holistic, if not comprehensive. The most significant changes expected to occur over this period are highlighted. At the same time, the existence of a range of possibilities for the future, reflecting the inherent difficulties in projecting the future and varying assumptions made in developing these projections, receive specific attention. Finally, consideration is given to those areas where there is a lack of consistent and comparable information, but which warrant more attention.

The remainder of the report is organized as follows:

- Chapter 2 summarizes the approach that has been adopted for this report, considering the choice of the key studies reviewed, as well as the choice of how to present the results.
- Chapter 3 reviews meta-forces in the form of socio-political developments and global environmental changes.
- Chapter 4 provides an overview of the *drivers* influencing the outlook for the environment in North America.
- Chapter 5 describes the resulting *pressures* on the North American environment, in terms of what we take from the environment and what we return to it.
- Chapter 6 then sets out the anticipated changes in the *state* of the environment in North America.
- Chapter 7 presents the main anticipated socio-economic *impacts* of environmental change.
- Chapter 8 presents the report's conclusions.
- Annex 1 provides additional background on the key studies included in this review.
- Annex 2 presents tables with the detailed data underlying the figures and text presented in the body of the report.

The focus is on the future—to where these forces and trends might take us in the coming years, acknowledging the uncertainties in making projections.

2

Photo: Iain Sarjeant

CHAPTER 2
Approach

The intention of this report is not to present a prediction of the future. Rather it is to consider the possibilities that the future might hold, in a quantitative fashion where possible, in light of the social and environmental stresses facing North America and the world at this time. Homer-Dixon (2008) emphasizes three aspects of these stresses—convergence, synergy, and complexity. We are facing a convergence of multiple stresses; the effects of these stresses are a result, not of any one of these, but rather the synergy among them; and because of the complexity of the systems involved, the resulting changes are often unpredictable.

This places an obvious burden on those who would wish to anticipate environmental change, particularly if their efforts include quantitative estimates. Any projection, particularly one reaching several decades into the future, is subject to considerable uncertainty. In some areas there remain data gaps and disagreements over the historical record and the current state and trends of key variables.[2] Looking to the future, our understanding of social, economic and environmental systems remains incomplete. Finally, much of what the future will look like is dependent upon the choices we make, both as individuals and as society. These factors, along with the dubious record of past efforts, has led Smil (2008), among others, to question the value of most such quantitative projections.

Given the above, it is not surprising that there have been limited attempts to paint detailed, quantitative pictures of the future of the environment. Still, these efforts continue, even as the researchers involved profess greater humility, increasingly emphasizing the value they provide for decision-making today rather than their ability to predict specifically what the future will hold. It is fair to say that most experts would agree with Smil (2008, p. viii) when he states:

> Better understanding and heightened awareness should help us lessen the impact of unpredictable events, even prevent some whose timing might have been anticipated… They should also improve our efforts at moderating or reversing deleterious trends at a stage when changes are tolerable and sacrifices reasonable.

This report does not make any new projections, but rather brings together the results of recent studies. In choosing which studies to emphasize, a number of factors have been considered. First, studies differ with respect to their standing in the scientific and political communities. Second, many studies examine only a single issue or small number of them. This makes it more difficult to recognize key interrelationships, which can point to synergies and tradeoffs in addressing environmental issues. Third, studies differ in terms of their analytical approaches, geographic extent and resolution, time horizons and indicators—all which can make comparisons across studies difficult. Finally, comprehensive sets of the data required to make comparisons across countries, such as those desired for this report, were not always available.

Based upon these criteria, the quantitative results presented are drawn primarily from two recent studies: the Organization for Economic Cooperation and Development's *Environmental Outlook to 2030* (OECD 2008) and the United Nations Environment Program's *Fourth Global Environmental Outlook, GEO4*, (Rothman, Agard et al. 2007; UNEP 2007). The reasons for doing so include:

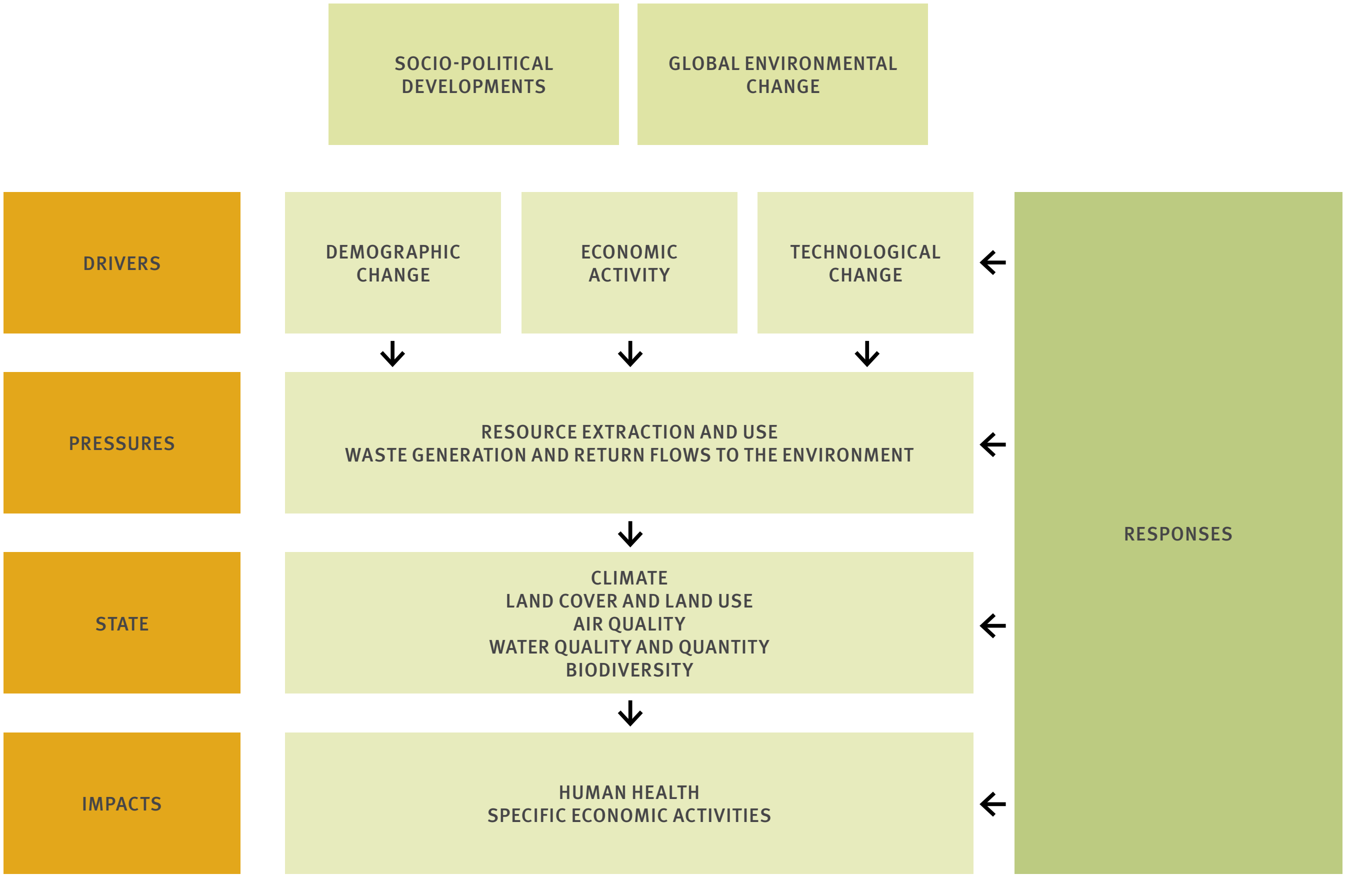
- Both studies benefit from the engagement and contribution of the governments of Canada, Mexico, and the United States.
- Both studies address a range of environmental issues and do so in an integrated fashion.
- Both studies use a similar suite of models to make their projections and present a similar set of indicators.
- Detailed results for Canada, Mexico, and the United States as individual entities have been made available for both studies.

It should also be noted that the two studies complement each other in that the *OECD Environmental Outlook* (OECD) developed a baseline scenario with a number of policy variants, while UNEP's *Global Environmental Outlook 4* (GEO4) explored four plausible futures, none of which was to be seen as a reference case. Box 1 summarizes the main scenarios from these studies and further details on the studies themselves can be found in Annex 1.

These are complemented by more issue specific studies at the global level—e.g., the *Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (IPCC 2007), the *Millennium Ecosystem Assessment* (MA 2005), the United Nations Population Division's *World Population Prospects* (United Nations 2007) and *World Urbanization Prospects* (United Nations 2008), and the International Energy Agency's *World Energy Outlook 2008* (OECD/IEA 2008). In addition, select national studies and other available literature has been reviewed. Annex 1 contains more detailed information on these studies, including key assumptions.

[2] *The North American Mosaic* (CEC 2008, p. 5) notes that "many measurements are not available at the national level, let alone in comparable forms across North America." Vadgama, Nitze et al. (2008, pp. 58-59), in particular, bemoan "the paucity of baseline data on North American biodiversity and ecosystem dynamics in particular."

FIGURE 1 :THE DPSIR FRAMEWORK



It is recognized that these choices precluded using a number of country-specific data sets. These could provide greater within country detail and, at times, present data that differ from those presented in international data sets. Given the scope of the present study, however, it was felt that inter-country comparability was necessary. This does point to the potential value of greater consistency and integration of environmental monitoring and foresight across Canada, Mexico, and the United States.

In addition to the selection of studies, we had to make a further choice related to the presentation of the information gathered for this report. Many studies, for example the *North American Mosaic* (CEC 2008), present information on a case-by-case basis for a set of environmental issues. This allows for the telling of a coherent story for each issue, but can hide the interconnections among issues. Furthermore, in most cases, a common set of key drivers underlies the trends for these issues.

Thus, for this report, a Driver-Pressure-State-Impact-Response model was determined to be more appropriate (Figure 1). A variation of the original DPSIR model (Smeets and Wetering 1999) is most explicitly reflected in the conceptual frameworks used in UNEP's GEO4 (UNEP 2007, p. xxii), but is also apparent in the structure of the *OECD Environmental Outlook* and in the conceptual framework of the *Millennium Ecosystem Assessment* (MA 2005, p. vii).

Any projection, particularly one reaching several decades into the future, is subject to considerable uncertainty...much of what the future will look like is dependent upon the choices we make, both as individuals and as society.

The basic logic of the DPSIR framework is that Drivers lead to Pressures being exerted on the environment. These cause changes in the State of the environment and result in Impacts for both natural and social systems. Societal Responses feed back to the Drivers, Pressures, State, or Impacts directly. In this report, Responses are addressed only to the extent that they are reflected in some of the policy and behavioural assumptions underlying the different scenarios. We have introduced a slight variation to reflect the importance of key socio-political developments and global environmental changes, which do not fit easily into the traditional DPSIR framework, but are expected to influence the future environment of North America. These are the subject of the next section of this report.

BOX: SCENARIOS IN THE OECD ENVIRONMENTAL OUTLOOK AND UNEP'S GEO4

The *OECD Environmental Outlook is* built around a baseline scenario, referred to here as the **OECD Baseline**. Bakkes, Bosch et al. (2008, p. 18) describe this as "a stylised picture of the environmental developments in the next decades. Its hypothesis is no new policies in response to environmental pressures—as well as no new policies on subsidies in agricultural production and on tariffs in agricultural trade (Bakkes and Bosch 2008, p. 18)." Various policy 'variants' are explored related to, for example, local and regional air pollution, greenhouse gas emissions, and agricultural support. These include comprehensive policy packages and separate climate change options. In this report we focus on the more stringent variants—the global comprehensive policy package, referred to here as **OECD ppGlobal**, and the climate change option reflecting policies needed to stabilize atmospheric concentrations of greenhouse gases at 450 parts per million by volume of carbon dioxide equivalents, referred to here as **OECD 450ppm**, as these provide the largest contrast with the baseline scenario.

The four scenarios in UNEP's GEO4 have fundamentally different assumptions about changes in individual behaviour and public policies. Briefly, in:

- Markets First (**GEO4 MF**) – reliance on market forces to bring about improvements for the environment and human well-being; this emphasizes technological solutions to environmental problems. Lip service is paid to sustainable development policies.

- Policy First (**GEO4 PF**) – strong policies to improve human and environmental well-being are implemented, primarily in a top-down fashion. Social and economic considerations prevail over environmental considerations.

- Security First (**GEO4 SeF**) – or 'Me First'; the focus is on power and wealth generation for the rich.

- Sustainability First (**GEO4 SuF**) – there is a persistent push for the implementation of sustainable development policies from all sectors of society. There is a strong emphasis on equity; and equal weight given to environmental and socio-economic policies.

3

Photo: Tarina Peterson

CHAPTER 3
Meta-Forces

The countries of North America and the region as a whole do not exist in isolation. The future of North America will both influence and be influenced by developments on the international stage. In this section, we review a number of these under the general categories of socio-political developments and global environmental changes.

3.1 SOCIO-POLITICAL DEVELOPMENTS

KEY POINTS:

- NAFTA has deepened and is expected to continue to deepen North America's economic integration.
- North American integration is occurring against a background of increasing globalisation of trade, finance, technology and culture.

Within North America, the signing of the Free Trade Agreement between Canada and the United States (FTA) in 1988, followed by the North American Free Trade Agreement (NAFTA) in 1993 with Mexico, along with its supplements—the North American Agreement on Environmental Cooperation (NAAEC) and the North American Agreement on Labor Cooperation (NAALC)—have heralded a period of increasing interdependence between Canada, the USA, and Mexico. Trade among the three countries has tripled in the 15 years since NAFTA was signed to nearly $1 trillion in 2008, integrating the North American economy to a greater extent than ever before. In 2005, the NAFTA partners launched the Security and Prosperity Partnership to strengthen their collaboration in a number of areas, including energy, emergency management, the compatibility of their regulations, food safety, environmental protection, and border security.

This pattern of growing interdependence has also been seen at the global scale. The growth in international trade over the last 15 years has brought greater integration in the world's capital and product markets, the rapid rise of multinational companies based in emerging economies and greater prosperity for hundreds of millions of people. Most notable has been the emergence of new actors on the world stage, often characterized as the BRICs—Brazil, Russia, India, and China, or more recently the BRIICS, with the addition of Indonesia and South Africa. Over the next 25 years, the BRICs, which already account for 14 percent of global GDP at purchasing-power parity (PPP), are likely to become a much larger force in the world economy because of their high economic growth rates and large populations. Some experts predict that in the next forty years China and India could become, respectively, the dominant global suppliers of manufactured goods and services while Brazil and Russia would become similarly dominant as suppliers of raw materials (Wilson and Purushothaman 2003).

> The countries of North America and the region as a whole do not exist in isolation.

This economic globalization has been accompanied by technological advances in communications, increases in travel and an unprecedented sharing of cultures. There have also been significant developments in international governance. In the environmental arena, this is best evidenced by the number of agreements covering such topics as climate change, biodiversity, and the transboundary movement of hazardous waste. Overall, though, it is fair to say that the international institutions, laws and financing mechanisms created to protect the global environment remain less well-developed and have had less of an impact than their economic counterparts, such as the WTO, even given the difficulties with the current round of negotiations.

There is currently significant uncertainty about the nature of these and other socio-economic developments over the next few decades. Different assumptions about how these will play out are in fact one of the fundamental elements of the frameworks used to define the sets of scenarios developed for UNEP's GEO4, as well as the IPCC's Special Report on Emissions Scenarios (IPCC 2000) and the Millennium Ecosystem Assessment (MA 2005). As the information summarized in this report will illustrate, these assumptions strongly influence the future of the global and North American environments.

3.2 GLOBAL ENVIRONMENTAL CHANGES

KEY POINTS:

- North America is a major contributor to global environmental change but will also be impacted by this change.
- The adverse environmental and socio-economic effects of climate change are expected to intensify over the next 25 years, primarily through changes in the availability of water in many regions and the rising incidence of extreme weather events.
- Biodiversity losses are increasing, with adverse consequences on the capacity of ecosystems to provide services.
- Invasive species are expected to continue spreading, with significant adverse environmental and economic consequences.
- The stratospheric ozone layer should recover fully but not until the second half of the century.
- Transboundary air and water pollution will remain problematic and may be exacerbated by climate change in spite of declines in emissions in some regions.
- Most marine fisheries are overexploited and many have already started to decline, but debate remains about their future.
- Land degradation remains a global problem; although it is less pronounced in North America, it may have indirect effects on the region.

North America's continued development will increasingly take place against a backdrop of global environmental change. By global environmental change, we are specifically referring to changes that are global in scope and drive environmental and socio-economic trends on the continent. In an increasingly interdependent world, North America cannot insulate itself from such changes. Even where they do not affect the North American environment directly, they may do so indirectly by increasing resource competition, exacerbating regional political and economic tensions and creating new patterns of migration. Furthermore, through its own activities, e.g., the release of transboundary pollutants and the importation of a wide range of products and resources whose environmental costs are concentrated at the point of production, North America is a significant contributor to these changes.

Among the most notable of the global environmental changes are climate change, biodiversity loss, the spread of invasive species and infectious diseases, the depletion of stratospheric ozone, the appearance of transboundary pollutants (including persistent organic pollutants), the decline of marine fisheries, and increasing desertification and land degradation.These changes are manifestations of how a growing human population is using the Earth's resources more intensively. Here we briefly review some of these changes. Their specific implications for North America are dealt with in more detail in later sections.

Climate Change

Numerous studies have explored the potential implications of a changing climate. These most recently culminated in the release of the *Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (IPCC 2007). More recently, the governments of Canada and the United States have also recently released studies, which are heavily based on the IPCC reports (Committee on Environment and Natural Resources National Science and Technology Council 2008; Lemmen, Warren et al. 2008).

These studies indicate that the clearest manifestation of climate change will be an accelerating rise in the Earth's mean temperatures, reaching around 0.3˚C per decade by 2030. This average hides important regional differences, with some parts of North America, particularly the Arctic, exceeding the global mean warming by a significant amount (IPCC 2007). This rate is one to which the world is essentially already committed as a result of greenhouse gases already emitted to the atmosphere since the start of the Industrial Revolution. As such, there is little difference across scenarios in this regard over the period to 2030. This includes the scenarios presented in this report from the *OECD Environmental Outlook* and UNEP GEO4.[3] At the same time, the amount of emissions emitted between now and 2030 will have an impact on the climate well beyond that date.

The effects of climate change will be complex and pervasive, and are already becoming evident. Based upon its review of recent evidence, the IPCC (2007, pp. 31-33) states that:

- there is high confidence that natural systems related to snow, ice and frozen ground (including permafrost) are affected;
- there is high confidence that a number of effects on hydrological systems are occurring, including: increased runoff and earlier spring peak discharge in many glacier- and snowfed rivers, and warming of lakes and rivers in many regions, with effects on thermal structure and water quality;
- there is very high confidence that recent warming is strongly affecting terrestrial biological systems, including such changes as earlier timing of spring events, such as leaf-unfolding, bird migration and egg-laying; and poleward and upward shifts in ranges in plant and animal species;
- there is high confidence that there has been a trend in many regions towards earlier 'greening' of vegetation in the spring linked to longer thermal growing seasons due to recent warming;
- there is high confidence that observed changes in marine and freshwater biological systems are associated with rising water temperatures, as well as related changes in ice cover, salinity, oxygen levels and circulation; and
- other effects of regional climate changes on natural and human environments are emerging, although many are difficult to discern due to adaptation and non-climatic drivers.

[3] If anything, these scenarios likely underestimate the increases in global mean temperature. This is because both relied on the same model, IMAGE, which used a median estimate for climate sensitivity from the IPCC's *Third Assessment Report*, 2.5˚C for a double of atmospheric GHG concentration over pre-industrial levels; this estimate was raised to 3.0˚C in the IPCC's *Fourth Assessment Report*.

Looking to the future, Figure 2, reproduced from the Synthesis report of the IPCC's *Fourth Assessment Report*, provides illustrative examples of impacts associated with varying degrees of global average temperature change. These are mostly adverse and are expected to continue to intensify as the temperature rises. Lesser developed and developing countries are expected to be among the most adversely impacted.

Climate change, for example, is expected to exacerbate the current stresses on water resources in large parts of the globe, including North America, arising from population growth, urbanization and economic and land-use change. Widespread losses of glaciers and reductions in snow cover over recent decades are projected to accelerate throughout the 21st century, reducing water availability, hydropower potential, and changing the seasonality of flows in regions supplied by meltwater from major mountain ranges. This trend will have profound adverse effects where irrigated agriculture depends on consistent and adequate replenishment of the aquifers and waterways with consequent implications on food production.

Beyond 2050 and into the next century, scientists have expressed concerns over sea-level rise as a result of the accelerated melting of land-based glaciers and the thermal expansion of the oceans. While the rate at which seas may rise remains the subject of debate, experts do agree that its consequences for coastal populations would be far-reaching and require the relocation of millions of people.

Many of the most severe and costly impacts of climate change will be associated with extreme climatic events and associated natural disasters. Weather-related events, such as floods, droughts and storms, already account for 75 percent of natural disasters. Climate scientists expect to see an increase in weather-related disasters over the coming decades (McBean 2008).

The above reflects the consensus expressed in the IPCC's *Fourth Assessment Report*. Since its release, however, there has been a debate among climate scientists as to whether it understates the rate at which the climate may change in the future. The recent reinterpretation of paleo-climatic data and the unprecedented melt of the Arctic Ocean icepack in 2007 and 2008, for example, have led some (e.g., Hansen 2008) to warn that the Earth may already be reaching tipping points where positive feedbacks amplify initial changes.

Biodiversity Loss

Ongoing global biodiversity loss has decreased the capacity of many ecosystems to provide services. Current documented rates of extinction are estimated to be roughly 100 times greater than typical rates in the fossil record. Of the major vertebrate groups that have been comprehensively assessed, over 30 per cent of amphibians, 23 per cent of mammals and 12 per cent of birds are threatened worldwide (Ash and Fazel 2007).

Global biodiversity loss is likely to continue to 2030, with the largest losses expected in sub-Saharan African, parts of South America, and some areas in Asia and the Pacific (Ash and Fazel 2007). Future global biodiversity loss is likely to mainly come from pressures from agriculture and infrastructure. Forestry, biofuels production, and climate change impacts will also have significant impacts through to 2030 (OECD 2008).

Invasive Species and Infectious Diseases

Invasive species are a major contributor to the loss of biodiversity. This worldwide issue has a significant impact on the global economy. Invasive species contribute to the loss of traditionally available resources, losses in food production, disruption of water transport, and increased costs for agriculture, forestry, fisheries, water management and human health (OECD 2008). The impacts associated with invasive species are very likely to continue, due in large part to the expected growth in global trade and travel.

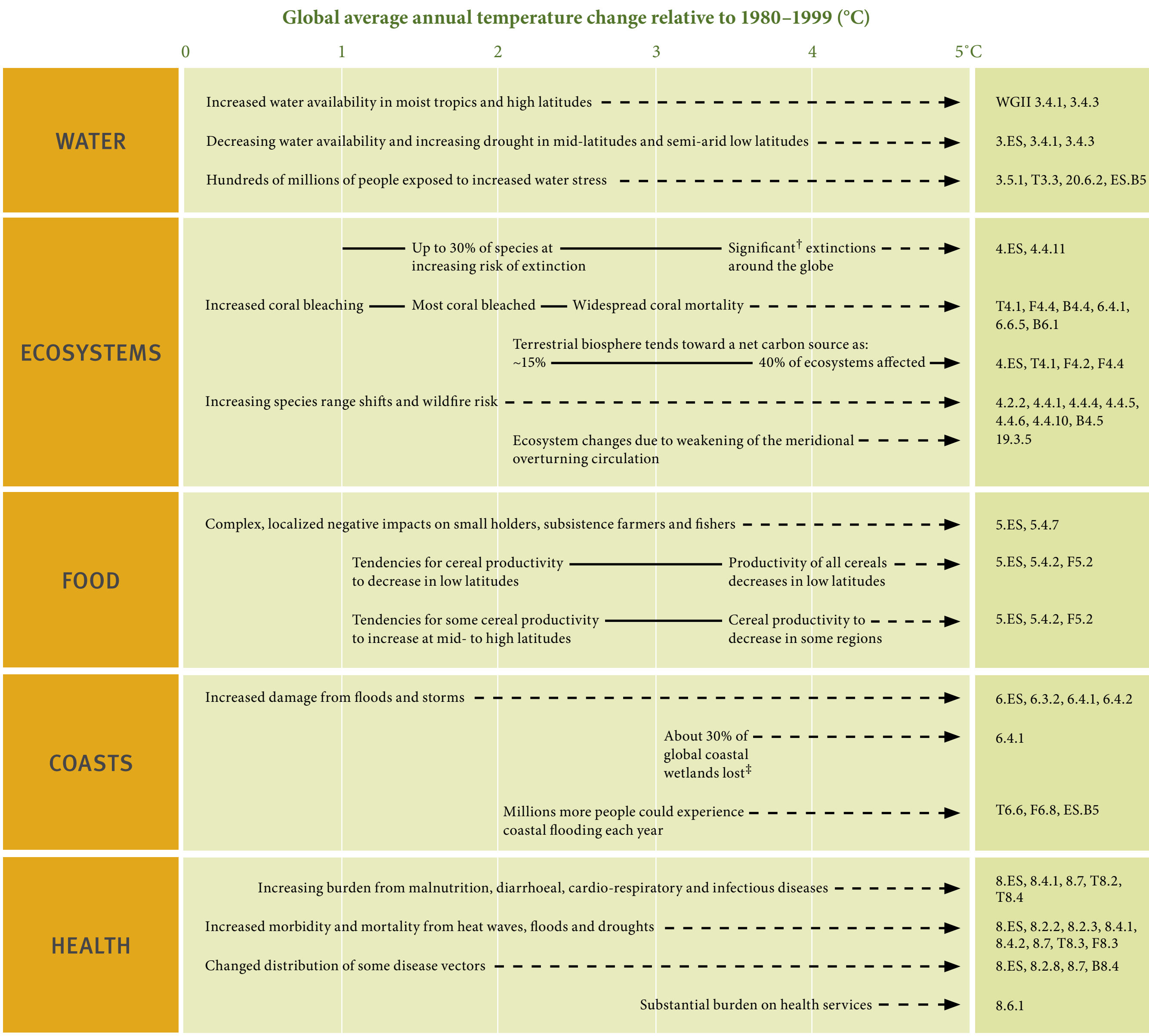
North America's continued development will increasingly take place against a backdrop of global environmental change.

Stratospheric Ozone

Although emissions of ozone-depleting substances have decreased over the last 20 years, the largest recorded 'hole' in the stratospheric ozone layer occurred in 2006 over the Antarctic. It is estimated that the ozone layer over the Antarctic will recover, but not until some time between 2060 and 2075 (Kuylenstierna and Panwar 2007). This timing will depend, in part, on the extent and effect of the current exemptions provided for some ozone-depleting substance.

Stratospheric ozone depletion has implications for human health and the environment. UV-B radiation affects many physiological and biochemical processes involved with growth, pigmentation and photosynthesis. Increasing UV-B radiation affects skin cancer rates, eyes and immune systems. Arctic ecosystems are particularly at risk to UV-B radiation because of the extensive wetlands and many shallow ponds and lakes, not to mention the extended periods of daylight in the Arctic summer (Kuylenstierna and Panwar 2007).

FIGURE 2: EXAMPLES OF IMPACTS ASSOCIATED WITH GLOBAL AVERAGE TEMPERATURE CHANGE



†Significant is defined here as more than 40%.

‡Based on average rate of sea level rise of 4.2 mm/year from 2000 to 2080.

(Source: Figure 3.6 from IPCC, 2007, p. 51)

Explanation: Illustrative examples of global impacts projected for climate changes (and sea level and atmospheric CO_2 where relevant) associated with different amounts of increase in global average surface temperature in the 21st century. The black lines link impacts; broken-line arrows indicate impacts continuing with increasing temperature. Entries are placed so that the left-hand side of text indicates the approximate level of warming that is associated with the onset of a given impact. Quantitative entries for water scarcity and flooding represent the additional impacts of climate change relative to the conditions projected across the range of SRES scenarios A1FI, A2, B1 and B2. Adaptation to climate change is not included in these estimations. Confidence levels for all statements are high. The right panel gives the WG II references for the statements made in the left panel, where ES = Executive Summary, T = Table, B = Box and F = Figure. Thus B4.5 indicates Box 4.5 in Chapter 4 and 3.5.1 indicates Section 3.5.1 in Chapter 3.

Transboundary Pollutants

Already, Arctic residents and wildlife are subject to exposure from persistent organic pollutants (POPs) and heavy metals originating outside North America (Kuylenstierna and Panwar 2007). The increases in mean temperatures due to climate change in the Arctic have been implicated as a significant contributor to increasing levels of POPs and other toxics as the volatile toxics are liberated from the warming soils, waters and fens of the Arctic (INAC 2003). At the same time, air pollution from Asia (including toxic substances such as mercury) is now being detected on the West Coast of the continent (Wilkening, Barrie et al. 2000; Akimoto 2003).

While transboundary waterborne contamination is less well understood, there may be implications for North America if trans-oceanic water currents deliver higher concentrations of toxicants from overseas sources. Similarly, with the melting of the polar icecap, previously unanticipated Arctic water currents may deliver or contribute overseas contaminants to receptors in Alaska and the Canadian northern territories.

Marine Fisheries

There is general agreement that marine fisheries have been subject to increased exploitation in recent decades, the total catch from marine fisheries has stabilized or declined slightly since the late 1980s, and that there has been a trend of 'fishing down marine food webs', i.e., an increasing share of the catch being species from lower trophic levels (Pauly, Watson et al. 2005; FAO 2007). There remains some debate, however, concerning the overall level of exploitation of marine fisheries and their future, particularly as trends vary by region. In its most recent *State of the World's Fisheries*, the FAO notes some stabilization of the share of overexploited, depleted, and fully exploited stocks in the first part of this decade after significant increases since the mid-1970s, even as the share of underexploited and moderately exploited stocks continues to fall (FAO 2007). Recent evidence has also pointed to a significant decline in the level of discards in the past decade (Kelleher 2005). Meanwhile, Worm, et al. (2006, p. 790), based upon a consideration of both the level of exploitation and species diversity, argued that a continuation of current trends would imply a "global collapse of all taxa currently fished by the mid–21st century." This conclusion has, not surprisingly, engendered a certain amount of debate (Murawski, Methot et al. 2007; Worm, Barbier et al. 2007).

Land Degradation and Desertification

Driven by increasing human population and economic development, the most dramatic land use changes over the last 20 years have been in forest cover and composition, expansion and intensification of cropland, and the growth of urban areas. Land degradation and desertification are changes that have had, and will continue to have, profound implications for human health, theenvironment and the global economy (Dent 2007). Although these trends are less of a concern in North America, particularly in Canada and the United States, they can still have an indirect effect on the region.

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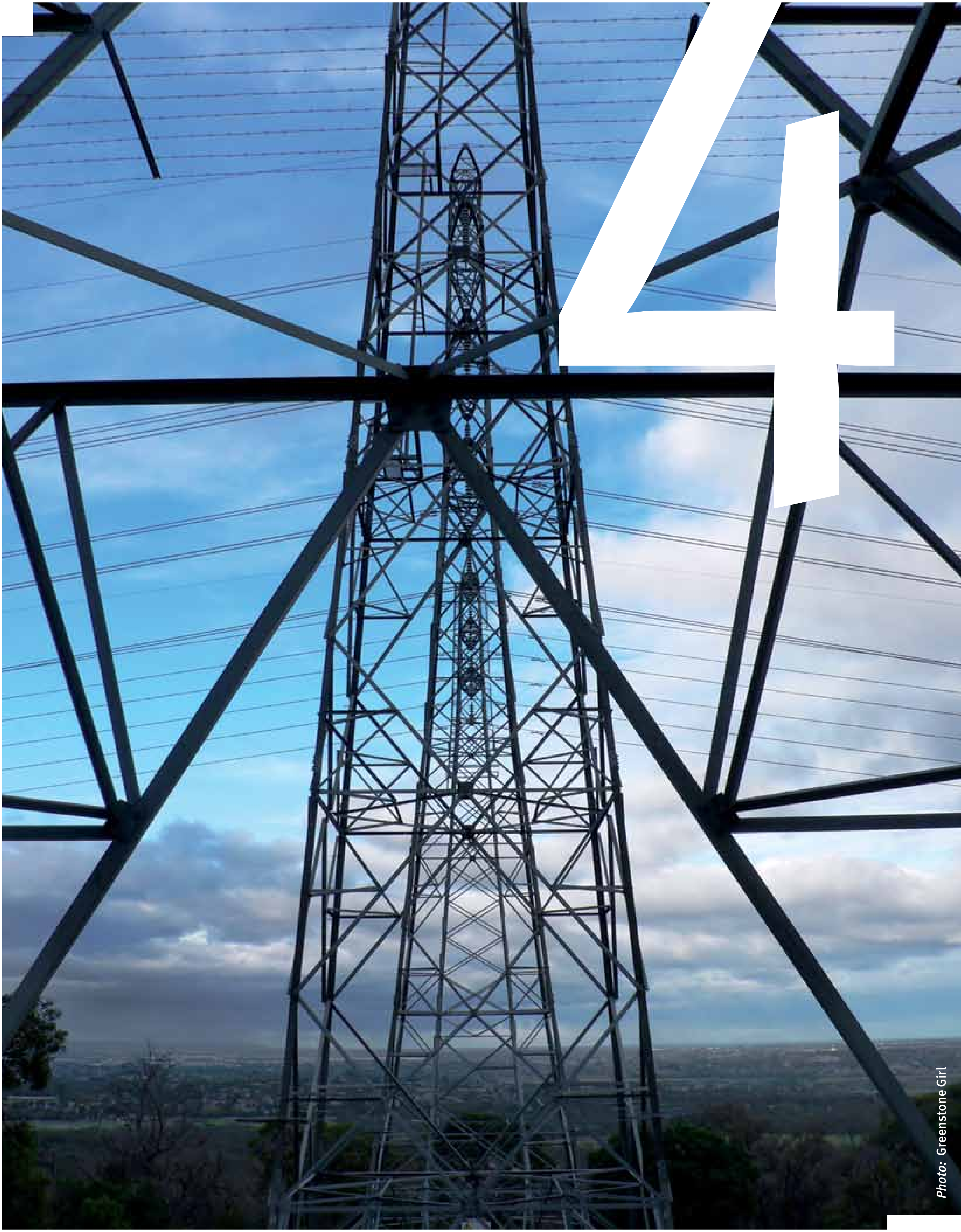


Photo: Greenstone Girl

CHAPTER 4
Drivers

In the context of the studies reviewed here, drivers, alternatively referred to as driving forces or indirect drivers, represent those forces that lead to activities that directly affect the environment. The most commonly cited drivers reflect the traditional IPAT formulation—Impact = Population * Affluence * Technology (Chertow 2001). These are often complemented by other socio-political and cultural factors. In this section, we summarize recent projections related to demographic patterns, economic activity, and technology.

4.1 DEMOGRAPHIC PATTERNS

KEY POINTS:

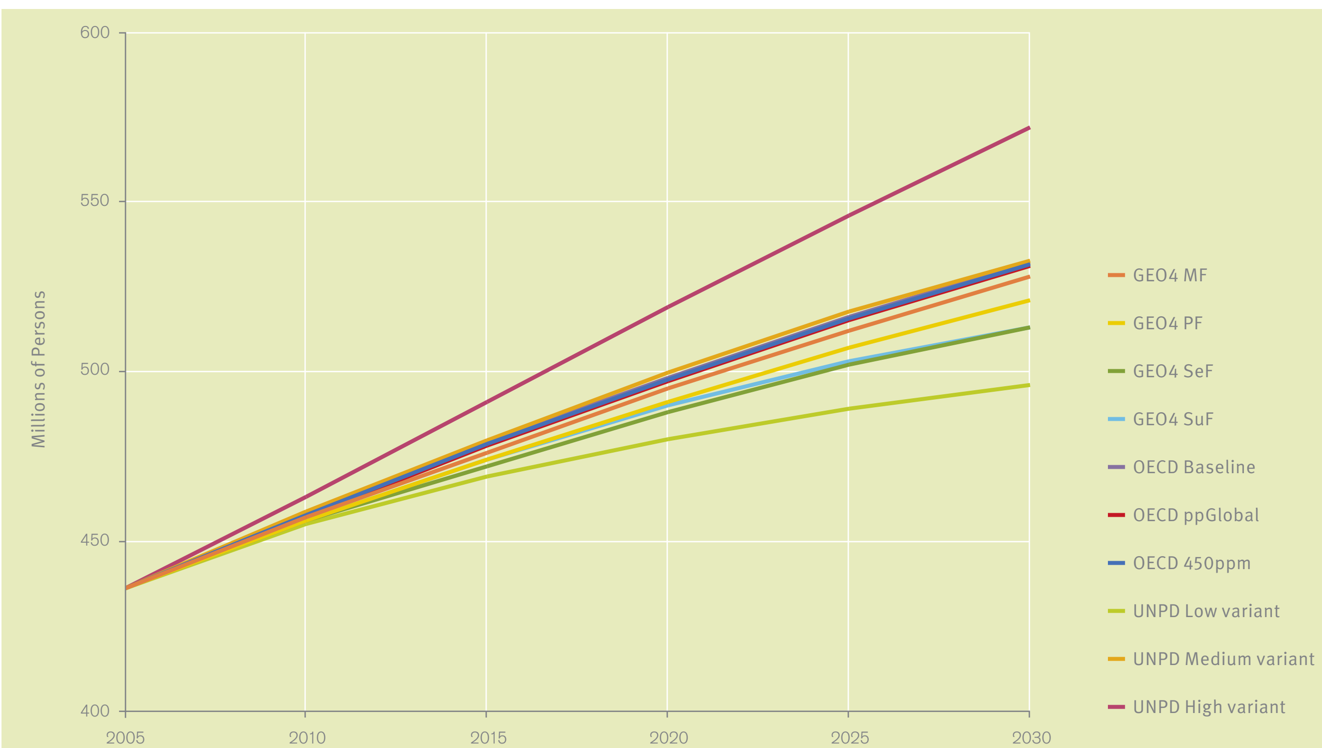
- North America's population is projected to increase by 60–135 million people between 2005 and 2030 or by 14–31 percent.
- North America's population is projected to become increasingly urban.
- The population distribution between countries is expected to remain roughly constant and North America's percentage of world's population will fall slightly from around 6.7 to 6.4 percent.

Everything else being equal, a larger population will put greater pressure on the environment. At the same time, other demographic factors can play a role. Thus, it is important to go beyond the size of the population to also consider issues such as migration, urbanization, and the age structure of the population.

Total Population[4]

The population of North America was just over 435 million in 2005: 32 million (7.4 percent) in Canada, 300 million (68.7 percent) in the United States, and 104 million (23.9 percent) in Mexio—repesenting 6.7 percent of the global population (United Nations 2007). The GEO4 and OECD scenarios project the population of North America to increase by approximately 18–21 percent between 2005 and 2030, resulting in a total of 515–530 million persons in 2030 (see Figure 3 and Table A2.1). The OECD scenarios all indicate the same rates of population growth, whereas there is some variation across the GEO4 scenarios. This reflects the fact that population growth was an exogenous assumption in the former and was calculated endogenously in the latter. These projections are in line with the most recent

FIGURE 3: TOTAL POPULATION, NORTH AMERICA



[4] Note that after the release of the initial draft of this report, the UNPD released updated population projections in the spring of 2009. These are not reflected in this report.
[5] Further details on the work of the UNPD are provided in Annex 1.

medium projection of the UN Population Division (UNPD).[5] The low and high projections of the UNPD define a wider range, an increase of 14–31 percent over this period, implying the addition of 60 to 135 million people in North America by 2030.

This rate of growth is a bit less than that projected for the rest of the world; still North America's share of the total global population is expected to decline only marginally over this period. Within the continent, the population growth rate in Mexico is slightly higher than Canada or the USA at present. By 2030, however, the studies project all three countries to have similar growth rates, with some scenarios even indicating lower growth rates in Mexico. The net effect is that the share by country of the total North American population is not expected to change significantly.

Migration

International migration is notoriously difficult to project, but several studies do include basic assumptions about their future patterns. Mexico is one of the countries with the highest levels of net emigration at the present time, particularly to the United States, and this is expected to continue. The UNPD estimates that an average of 360,000 Mexicans will emigrate each year between 2005 and 2010, many of these going to the USA.[6] Canada and the United States experience significant levels of net immigration; the UN estimates these as approximately 200,000 and 1,200,000 persons per year, respectively. In its projections, the UN assumes that these levels will remain fairly constant until 2030. The GEO4 PF and GEO4 SuF scenarios provide similar results. In GEO4 MF, which assumes significantly more open borders, the levels of emigration from Mexico and immigration to Canada and the USA are projected to be more than 30 percent higher. Alternatively, in the GEO4 SeF scenario, which assumes 'thicker' borders, these are projected to be approximately 25 percent lower.

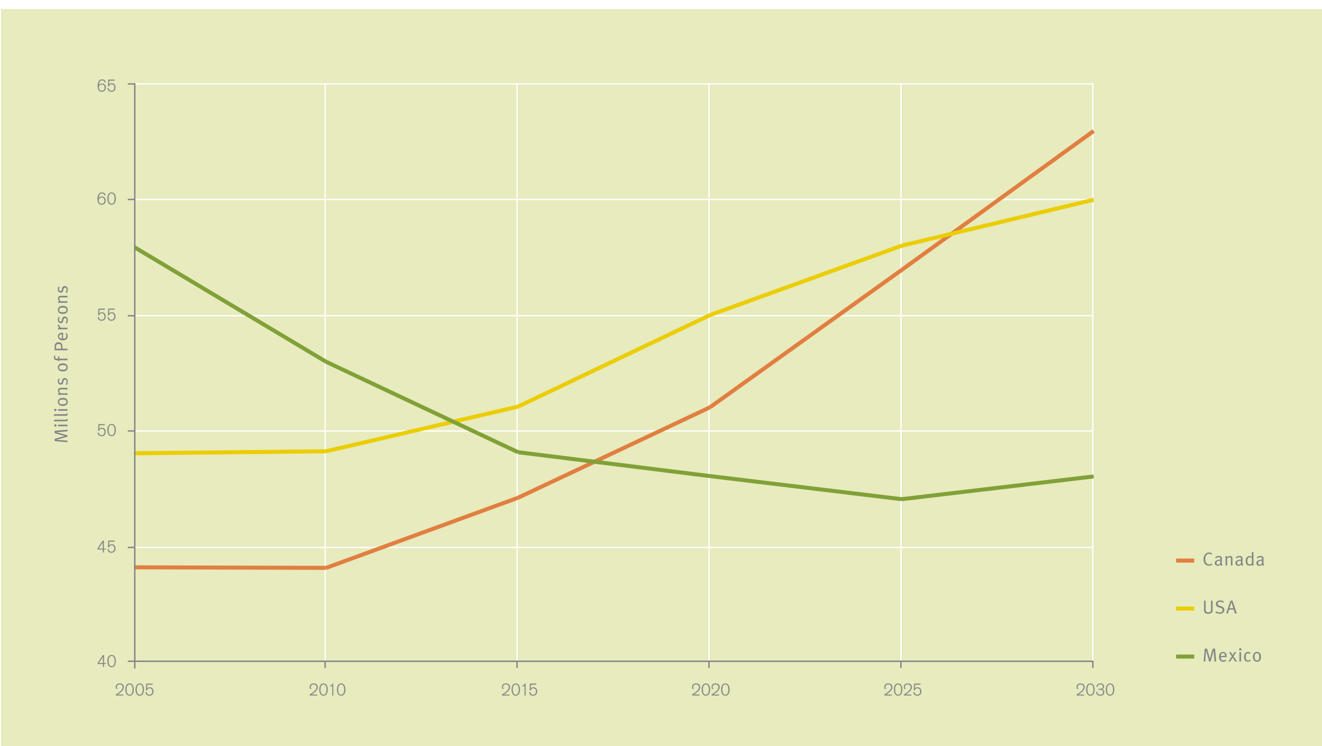
Urbanization

In 2005, the majority (just under 80 percent) of the North American population lived in urban centers—80, 81 and 76 percent in Canada, Mexico, and the United States, respectively. In its Medium Variant,[7] the UNPD projects this to increase in all three countries, such that nearly 86 percent of North Americas will live in urban areas in 2030. Significantly, this implies an absolute decrease in the rural populations in all three countries, by 5 percent in Canada, 17 percent in the USA, and 12 percent in Mexico. The GEO4 scenarios show the same pattern at the North American level in Canada and the United States. In Mexico, however, because of slightly higher projections of population growth and slower rates of urbanization, rural populations are expected to increase by 14 to 17 percent even as their share of the total population declines.

Age Distribution

A significant ageing of the population is expected throughout the region. In 2005, persons 65 years or older represented 13.1, 12.3 and 5.8 percent of the population on in Canada, the USA and Mexico, respectively. By 2030, these figures are expected to increase to 23.2, 19.4, and 12.3 percent. Meanwhile, the percent of the population under 15 is expected to decline, most rapidly in Mexico.[8] These changes are reflected in the shifts in the dependency ratios, the ratio of persons under 15 and over 64 to the number of people between ages 15 and 64, who traditionally make up the majority of the work force.

FIGURE 4: DEPENDENCY RATIOS, BY COUNTRY



[6] The same figures are provided for all of the UNPD variants. The *OECD Environmental Outlook* does not provide any information on migration.
[7] This is the only UNPD variant for which data are available. The *OECD Environmental Outlook* does not provide any information on urbanization.
[8] In the UNPD High variant, which includes higher fertility rates, these values increase very slightly in Canada and the USA.

This rises in Canada and the US; in Mexico it continues to fall for part of the period before leveling off and beginning to rise after 2025 (see Figure 4).

4.2 ECONOMIC ACTIVITY

KEY POINTS:

- North America's economic growth is expected to remain robust to 2030.
- North America will continue to be a major player in the world economy.
- Average per capita incomes is projected to rise in all three countries, but Mexico's will continue to lag behind the US and Canada.

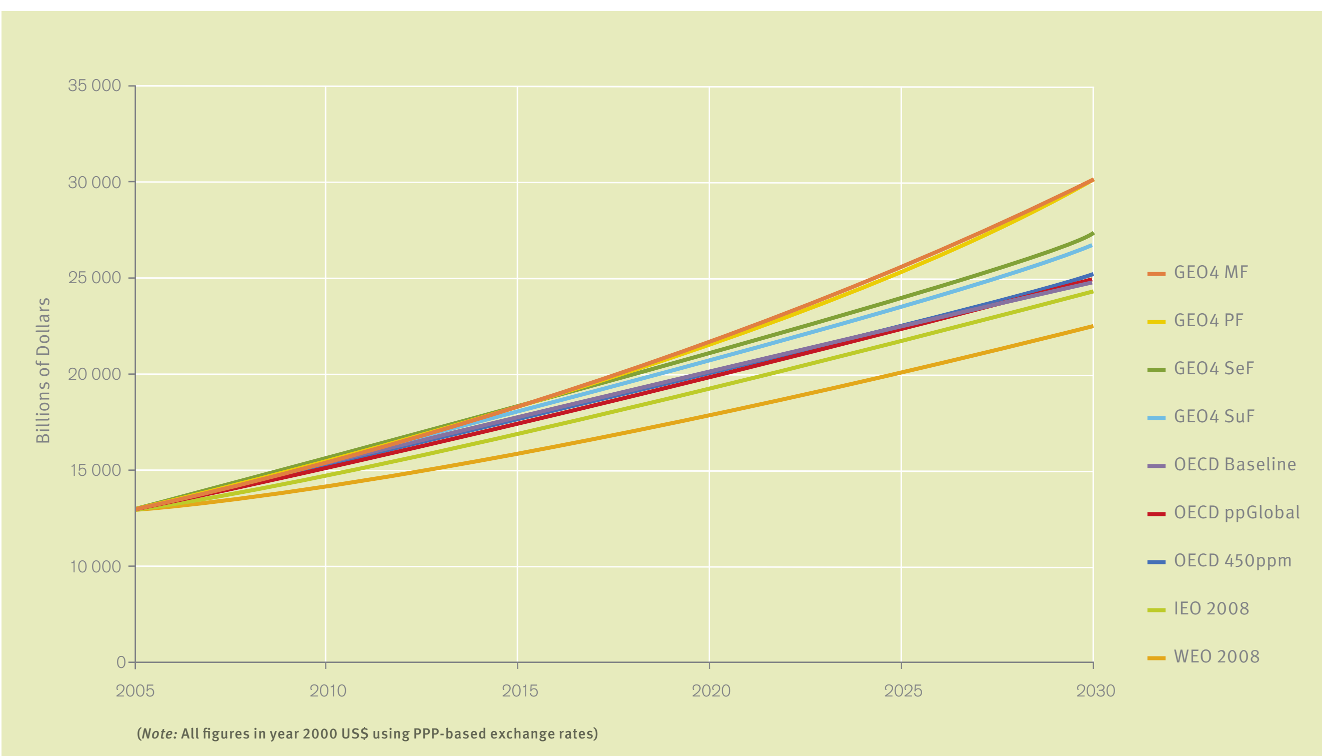
As with population, everything else being equal, a larger economy puts more pressure on the environment through greater demand for material inputs from the environment and larger amounts of by-products discharged to it. There is also a strong correlation between income per capita and individual consumption. Finally, the make-up of the economy is significant, as different sectors can have different levels of impact per unit of activity.

Total Economic Activity

Figure 5 and Table A2.2 present projections of total Gross Domestic Product from the GEO4 and OECD scenarios, as well as the reference scenarios in the International Energy Agency's *World Energy Outlook 2008* (OECD/IEA 2008) and the US Energy Information Administration's *International Energy Outlook 2008* (US EIA 2008).[9] The North American economy is projected to see a 70 to 130 percent increase between 2005 and 2030, reflecting average annual growth rates of between 2.2 and 3.4 percent. The OECD, WEO 2008, and IEO 2008 scenarios show the lowest rates of growth. This reflects, in part, the assumption of no policy changes, even those that might stimulate growth, in these scenarios. In the most recently published WEO 2008 scenario, it also reflects lowered expectations for growth given the financial upheavals and increases in energy prices in recent years. Note that the policy actions assumed in the OECD ppGlobal and OECD 450ppm scenarios have only a minimal effect on projected GDP. More significant differences are seen across the GEO4 scenarios, with the GEO4 MF and GEO4 PF scenarios projecting the highest rates of growth of all the scenarios presented. While these scenarios represent the mainstream consensus, it is important to note that some experts, e.g., Homer-Dixon (2008), do not believe that the implied doubling in energy and material throughput required can be achieved.

North America is projected to remain a major player in the world economy. Its share of total world GDP in 2005 was just under 24 percent. This is expected to remain above 20 percent in 2030 in the GEO4and OECD scenarios; in the IEO 2008 and WEO 2008 scenarios, which assumes relatively faster growth in the developing world, the share falls to 16–18 percent. Within the region, the United States will continue to be the dominant player, with little change from its current 85 percent share of the North American market in all projections. The studies do differ in one aspect, though; the GEO4 scenarios are relatively less optimistic about growth in Mexico and more optimistic about growth in Canada and the United States than the other studies.

FIGURE 5: TOTAL GDP, NORTH AMERICA



[9] Further details on these studies are provided in Annex 1.

GDP per Capita

Gross Domestic Product per capita (GDP/cap) is projected to increase considerably between 2005 and 2030 in all three countries of North America (see Figure 6 and Table A2.3). The range of growth projected does vary significantly by country and scenario, however, from a 40 percent increase for Canada and the United States in the WEO 2008 scenario to a doubling for Mexico in the OECD and IEO 2008 scenarios. In general, the OECD and IEO 2008 scenarios are more optimistic concerning growth in Mexico and less optimistic about growth in Canada and the United States. Only in these scenarios is any real convergence seen in GDP per capita. Still, even in the most optimistic case, Mexican GDP per capita is projected to be only slightly more than 35 percent of that in the United States, compared to 27 percent in 2005.

Sectoral Makeup of Economic Activity

Figure 7 and Table A2.4 present information on the sectoral breakdown of economic activity as measured by share of total GDP. The values shown in Figure 7 represent an average across the four GEO4 scenarios. The differences across the scenarios were minimal; also, this study provided a more disaggregated view of the economy than the *OECD Environmental Outlook* or other studies.

The results show that dramatic shifts in the sectoral makeup of economic activity within each country are not expected to occur between now and 2030. Services currently dominate in each country and continue to increase their share, particularly in the United States, where they approach 70 percent of the economy. The share of economic output produced in the next largest sector, Manufactures, remains fairly constant. The ICT (Information and Communications Technology) and Materials sectors are projected to see an increase in their shares in all countries, but these start from a small base. Somewhat steep declines are foreseen for the shares of Agriculture and Energy. Given the overall growth of the economies, however, even these declines in share do not necessarily translate into absolute declines in the size of these sectors.

4.3 TECHNOLOGY

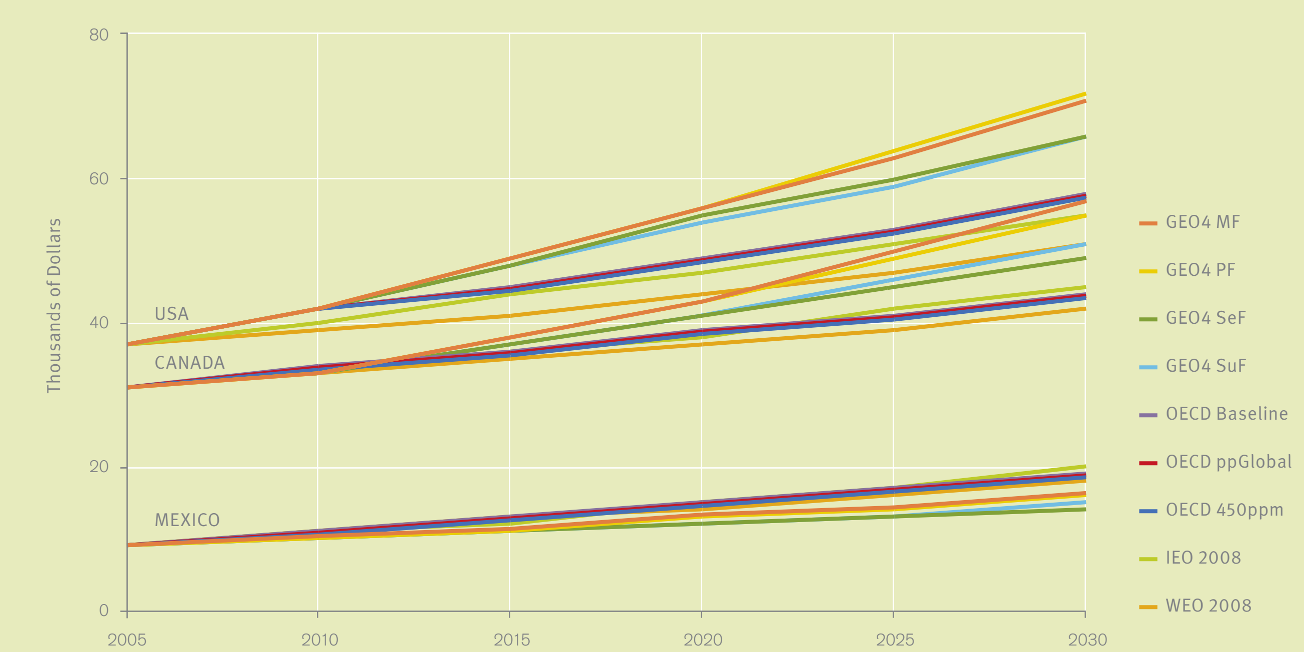
KEY POINTS:

- New technologies are expected to transform societies over the coming decades at least as much as they have over the past decades.
- The net effect of technological change on the environment is unclear and will vary by issue.

Technology is a fundamental determinant of humanity's impact on the environment. If demographic and economic factors largely determine the magnitude of our desires, then it is technology that determines how we meet them.

Technological change can reduce environmental pressures through greater efficiency, allowing for reductions in the use of resources and the production of wastes to meet the same level of demand. At the same time, these decreases in pressure per unit of demand can lead to increases in overall pressures if they result in

FIGURE 6: GDP PER CAPITA, BY COUNTRY



(*Note:* All figures in year 2000 US$ using PPP-based exchange rates) increased demand; this is commonly referred to as the "rebound effect." An example at the individual level would be an increase in the amount of driving after the purchase of a more fuel-efficient car that costs less to run. At asocietal level, technological progress has been key to the growth of both the size of the population and the size of the economy. Technological change can also lead to increased pressures when it creates new products and demands (e.g., electronic equipment and associated "e-waste"). Finally, it can have positive effects on one aspect of the environment, but negative effects on another. For example, the use of biofuels can reduce the emissions of greenhouse gases, but they can place increased pressure on land resources, often at the direct expense of biodiversity. In many cases, therefore, the aggregate effects of technological change are ambiguous or uncertain.

In most projections of environmental change, assumptions about technological change are imposed exogenously. In general, the OECD Baseline assumes that:

- New technologies will transform societies over the coming decades at least as much as that they have over the past decades, even if the specific areas of technological development change.
- Technological change is environmentally neutral. That is, technology does not, by itself, reduce environmental impacts.

Its policy variants, e.g., OECD ppGlobal and OECD 450ppm, however, do include the possibilities of accelerated technological changes as consequences of policy actions.

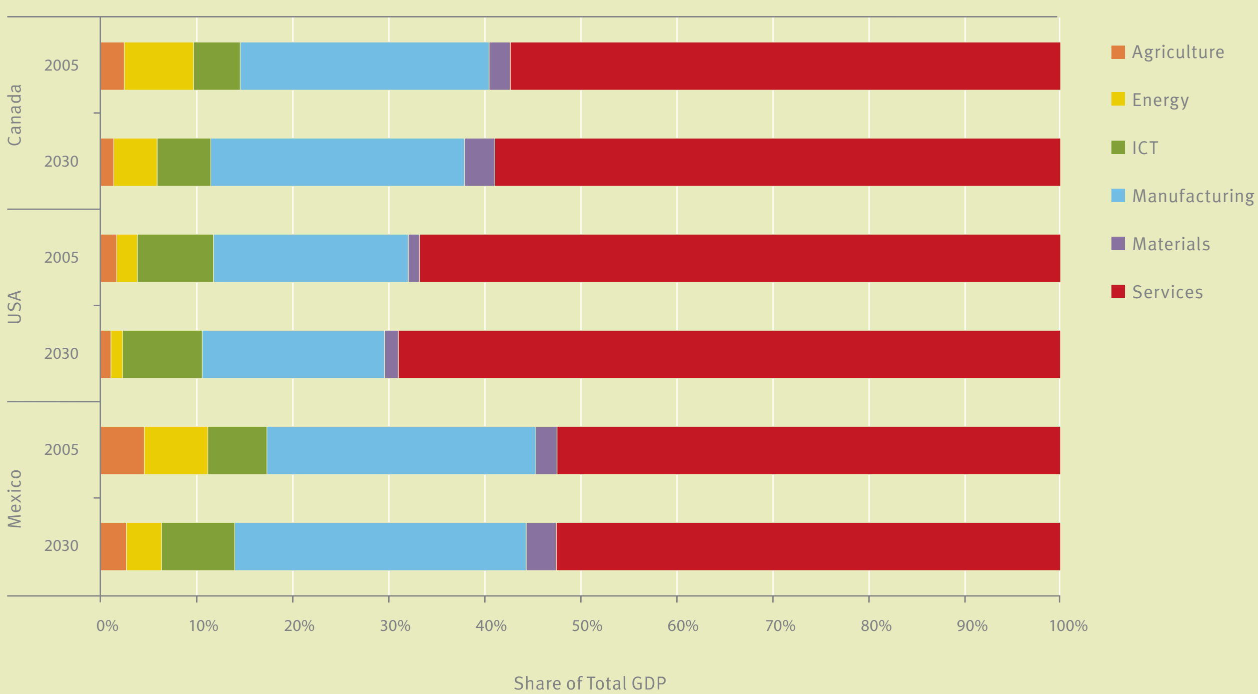
The GEO4 scenarios are somewhat more explicit in identifying different developments with respect to the levels of investment in technological change, the emphasis of these investments, and the access and availability of new technologies. Briefly:

- In GEO4 MF, there are high levels of investment, dominated by the private sector. The emphasis is on economic efficiency and profit. Access depends on the ability to pay.
- In GEO4 PF, there are high levels of investment, with governments playing a larger role. A balance is struck between economic efficiency and environmental improvements. Technology transfer and diffusion are actively promoted.
- In GEO4 SeF, investments are lower. There is more focus on the military and on security. Access to key technologies is closely guarded.
- In GEO4 SuF, there are high levels of investment from a range of sources. The emphasis is toward environmentally benign technologies. Technology transfer and diffusion are actively promoted, including the encouragement of more open-source activities.

Neither study assumes the appearance of any truly revolutionary technological breakthroughs between now and 2030.

Of course, when it comes to quantitative modeling, these general assumptions must take the form of changes in such specific factors as energy and water use efficiency, pollutant emission coefficients, agricultural yields, and the costs of certain resources and their availability. These can also include assumptions about the rates of change in overall economic productivity. The details of these a ssumptions are not provided here, but are reflected in the results presented elsewhere in this report.

FIGURE 7: SECTORAL BREAKDOWN OF TOTAL GDP, BY COUNTRY



(*Note:* All figures in year 2000 US$ using PPP-based exchange rates)

5

Photo: Eric Yip

CHAPTER 5
Pressures

5.1 INTRODUCTION

Humanity is perpetually interacting with and transforming the natural environment. Our existence depends on the exploitation of natural resources. Eventually, these resources are returned to the environment, often in the form of what are termed "pollutants" because of their negative impacts.

These flows to and from the environment are the pressures that lead to changes in the state of the environment. Their magnitude and nature are largely determined by the drivers discussed in the previous section, that is the size and composition of the population, the level and character of economic activity, and the available technology. Thus, the differences seen in the projections of those drivers will be reflected in the range of projections of the pressures presented in this section. Existing and assumed environmental regulations related to, for example, emissions of greenhouse gases and criteria air contaminants also influence the future evolution of these pressures.

This section reviews what the studies say about how a number of these flows may change in North America over the next few decades. In terms of resource extraction, production and use, we focus on energy resources, water, agricultural products, forest products, marine biota and other resources, notably minerals. With respect to the generation of wastes and return flows, we include greenhouse gas emissions, criteria air contaminants, and water (amount and pollutants). Ideally, international trade would be considered in each case, as it allows for the geographic separation of the extraction, production, use and disposal of many resources. This was only possible for a few issues, however, notably energy and food, even as it is recognized that North America is a significant net importer of many products, e.g., from marine fisheries (FAO 2007).

Finally, note that there do exist a number of aggregate indicators of environmental pressure. These include the ecological footprint (Ewing, Goldfinger et al. 2008), the human influence and human footprint indices (Sanderson, Jaiteh et al. 2002),[10] and a measure of the human impact on marine ecosystems (Halpern, Walbridge et al. 2008). While these provide interesting insights, to date there have not been systematic attempts to project these into the future at a regional or national level. Thus, these are not considered in this report.

Humanity is perpetually interacting with and transforming the natural environment. Our existence depends on the exploitation of natural resources.

[10] See also http://sedac.ciesin.columbia.edu/wildareas/.
[11] Further details on these studies are provided in Annex 1.

5.2 RESOURCE EXTRACTION, PRODUCTION AND USE

KEY POINTS:

Energy
- Forecasts of future energy use and production range widely, depending on the policy assumptions made.
- Driven by US demand projections, the region will remain a net energy importer. Canada and Mexico will continue to be net energy exporters.
- Although demand for alternative energy sources, such as biofuels and wind, will increase over the time period, fossil fuels will continue to dominate primary energy use.
- Energy intensity, i.e., energy use per unit of economic activity, is projected to decline with improved efficiencies, structural changes in the economy, and technological advancements.

Other resources
- Most scenarios posit a continued high use of water in the future.
- North America will remain a large net exporter of agricultural products.
- The production of wood products is expected to increase by 65 to 85 percent by 2030.
- Landings from marine fisheries bordering North America are expected to increase except in the Northwest Atlantic.

5.2.1 ENERGY RESOURCES

Energy Production
All three countries in North America are significant primary energy producers, although the models examined for this study reflect considerable differences in primary energy production scenarios at the national level. At the most general level, it appears that oil and natural gas production will fall within the United States, natural gas and nuclear production will increase in Mexico, hydro production will increase in Canada, and the production of other renewables will increase across all three countries. More specifically, Canadian energy production is expected to continue to grow through to 2030, with total oil production projected to increase as a direct result of growing oil sands production (NEB 2007). Overall US energy production is also expected to increase through to 2030 (EIA 2007). Coal production is projected to outpace all other fuels, reflecting both very large domestic supplies and an increase in demand.

Energy Use
There have been numerous projections of energy use for North America, both at the national and international level. In addition to the results presented in from the GEO4 and OECD scenarios, this section also considers those provided in the reference scenarios of the International Energy Agency's *World Energy Outlook 2008* (OECD/IEA 2008) and the US Energy Information Administration's *International Energy Outlook 2008* (US EIA 2008), as these provide comparable data for all three countries of North America.[11]

The studies depict a wide range of possibilities for energy use in North America to 2030. Figure 8 and Table A2.5 show that total energy use is projected to rise until 2015 in all scenarios, but afterwards these begin to differ significantly. In the GEO4 SuF and the OECD 450ppm scenarios, total energy use declines back to levels close to these seen in 2005. Alternatively, the GEO4 MF and GEO4 SeF scenarios project increases of over 40 percent between 2005 and 2030.

In each scenario, the projected increases in total energy use are largest in Mexico, which sees more than a doubling in GEO4 MF and a 50 percent increase even in GEO4 SuF. Even so, the United States is projected to continue to dominate the continent, maintaining a greater than 80 percent share of total energy use in North America all scenarios.

Comparisons of data show that North America, as a whole, will continue to be a net importer of energy resources. This is primarily a function of energy consumption projections for the United States. Canada and Mexico will continue to be net energy exporters.

The scenarios also show a wide variation in the evolution of per capita energy use (Figure 9 and Table A2.6), Per capita energy use is currently five times higher in the United States and Canada than in Mexico. This difference is projected to fall as all scenarios indicate increases in per capita energy use in Mexico, but either lower increases or decreases in the United States and Canada, depending on the scenario. Still, even in the scenario with the greatest convergence, the OECD ppGlobal scenario, per capita energy use in Mexico is still just over one-third of that in the USA in 2030.

Energy intensity, i.e., energy use per unit of GDP, is projected to decline in all three countries in all scenarios, but does so more rapidly in the United States and Canada than in Mexico (Figure 10 and Table A2.7). The most significant decreases are seen in the GEO4 SuF and OECD 450ppm scenarios in Canada and the United States. These are on the order of 50 percent. A final result of note is that in all of the GEO4 scenarios, the energy intensity of the US economy is lower than that of Mexico's in 2030. Canada is projected to continue to have the highest energy intensity in all scenarios. These results need to be understood in context, however: a significant amount of the energy use in Canada and Mexico is related to energy production for export.

Table A2.5 presents data on energy use by fuel from the various studies. Figure 11 shows these as percentages for North America as a whole. Fossil fuels—coal, oil and natural gas—are expected to continue to dominate the North American energy mix in 2030. They currently make up 85 percent of primary energy use. In the GEO4 SuF, OECD ppGlobal, and WEO scenarios, this falls slightly and it does even more significantly in the OECD 450ppm scenario. This primarily reflects differences projected in the shares represented by coal vis-à-vis modern biofuels and solar and wind. In all other scenarios their share increases beyond the 2005 level. Even the most optimistic scenarios (OECD ppGlobal and 450ppm) project the contributions of renewable sources of energy at less than 25 percent. As with the shares of the economy represented by different sectors, given the overall increases in energy use projected, declines in shares do not necessarily imply absolute decreases in energy use for a particular fuel.

FIGURE 8: TOTAL PRIMARY ENERGY USE, NORTH AMERICA

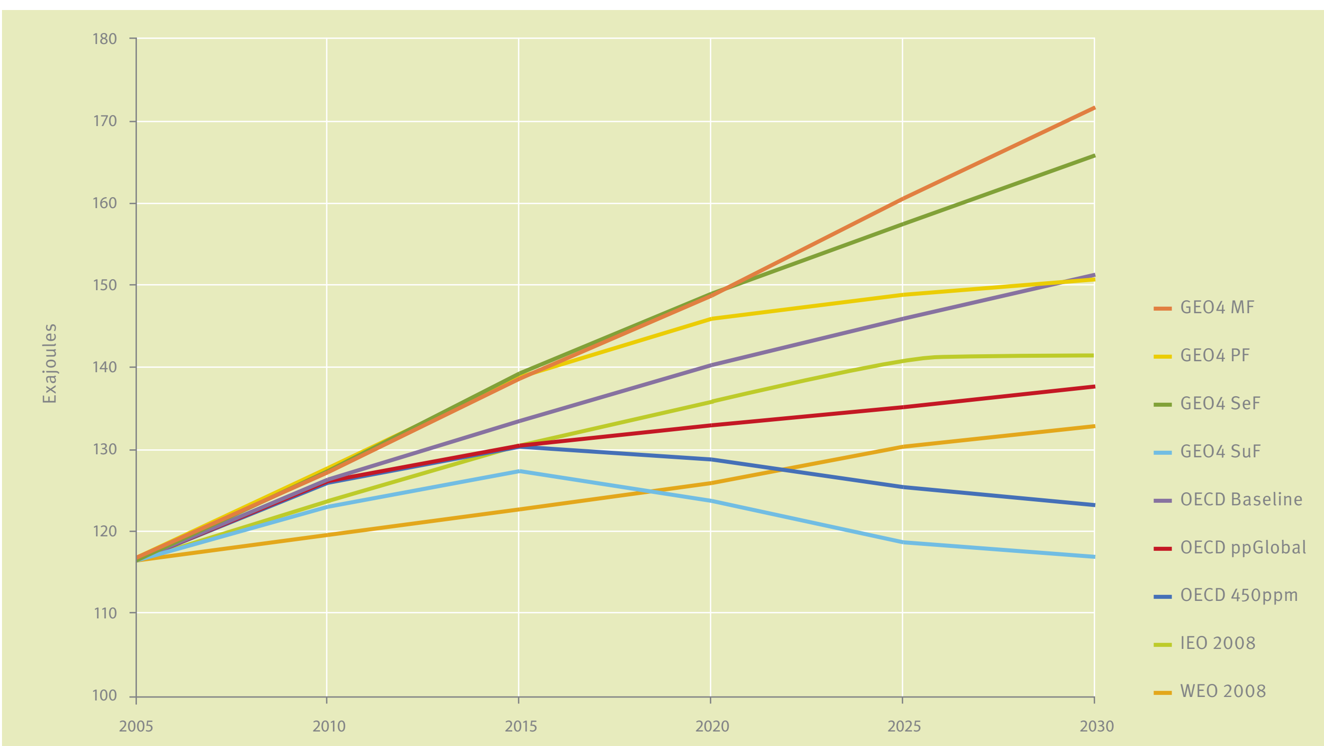


FIGURE 9: PER CAPITA PRIMARY ENERGY USE, BY COUNTRY

FIGURE 10: PRIMARY ENERGY USE PER UNIT GDP, BY COUNTRY

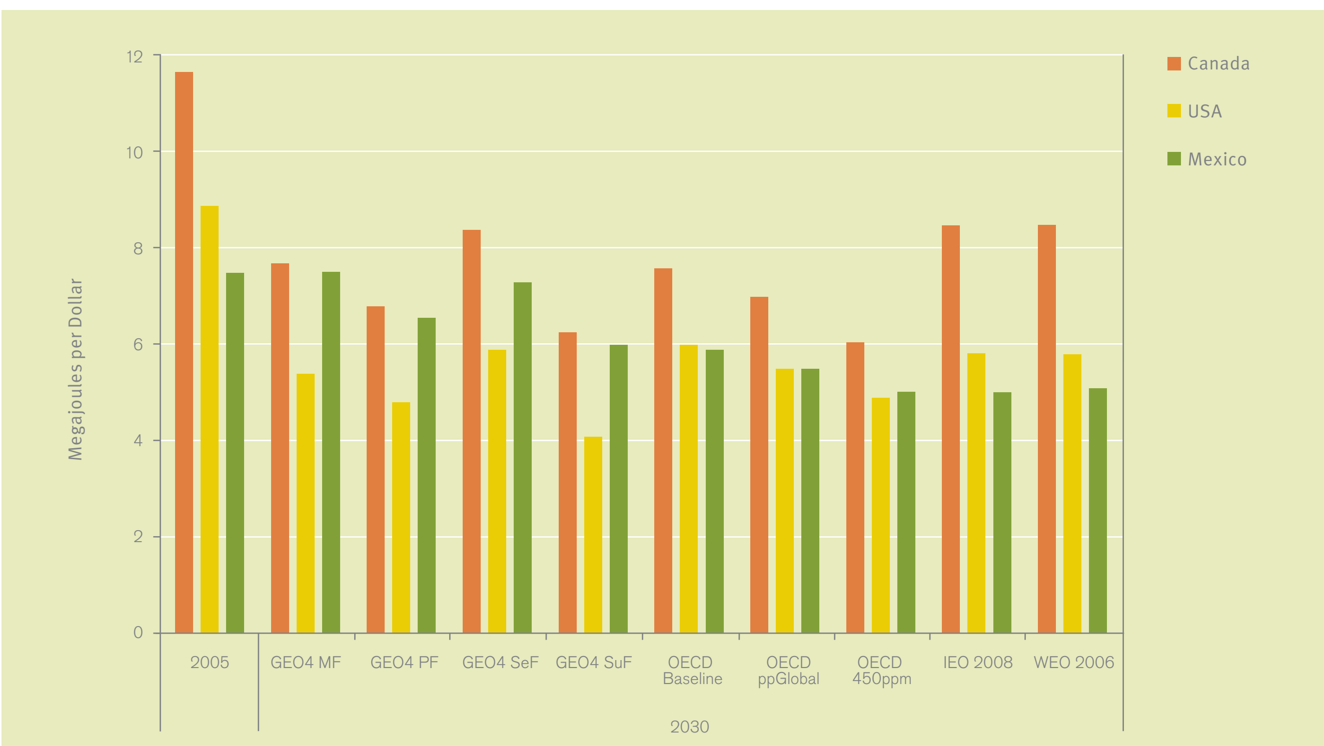
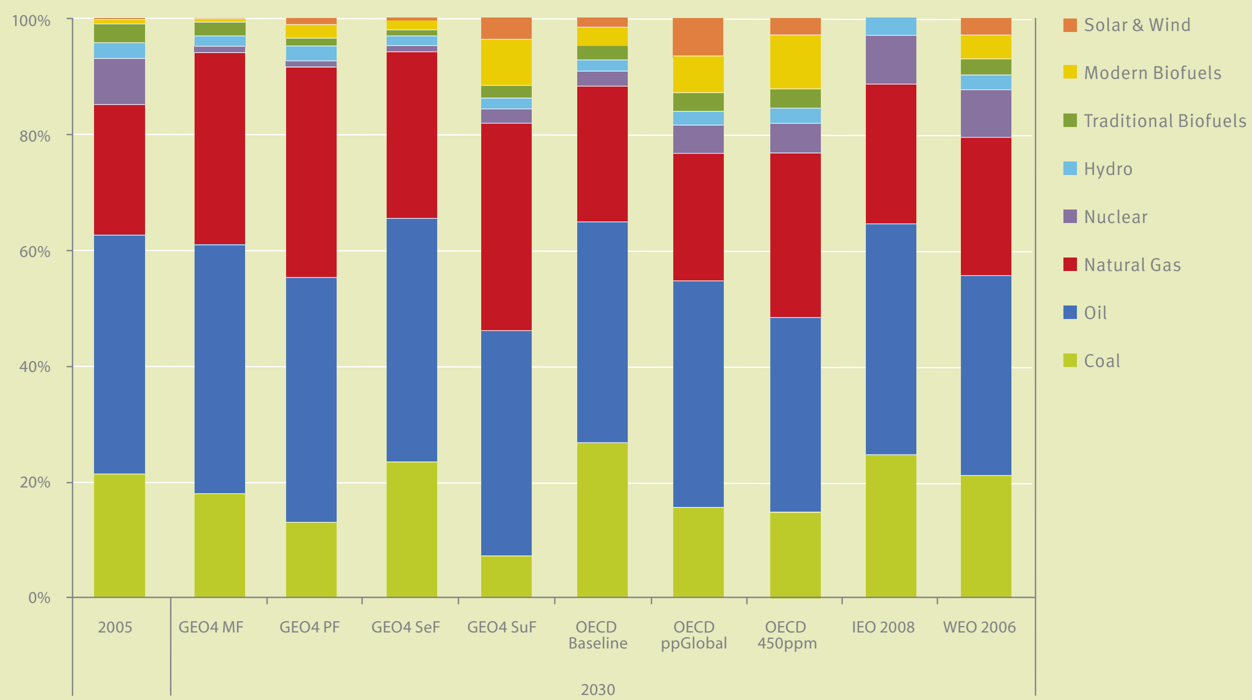
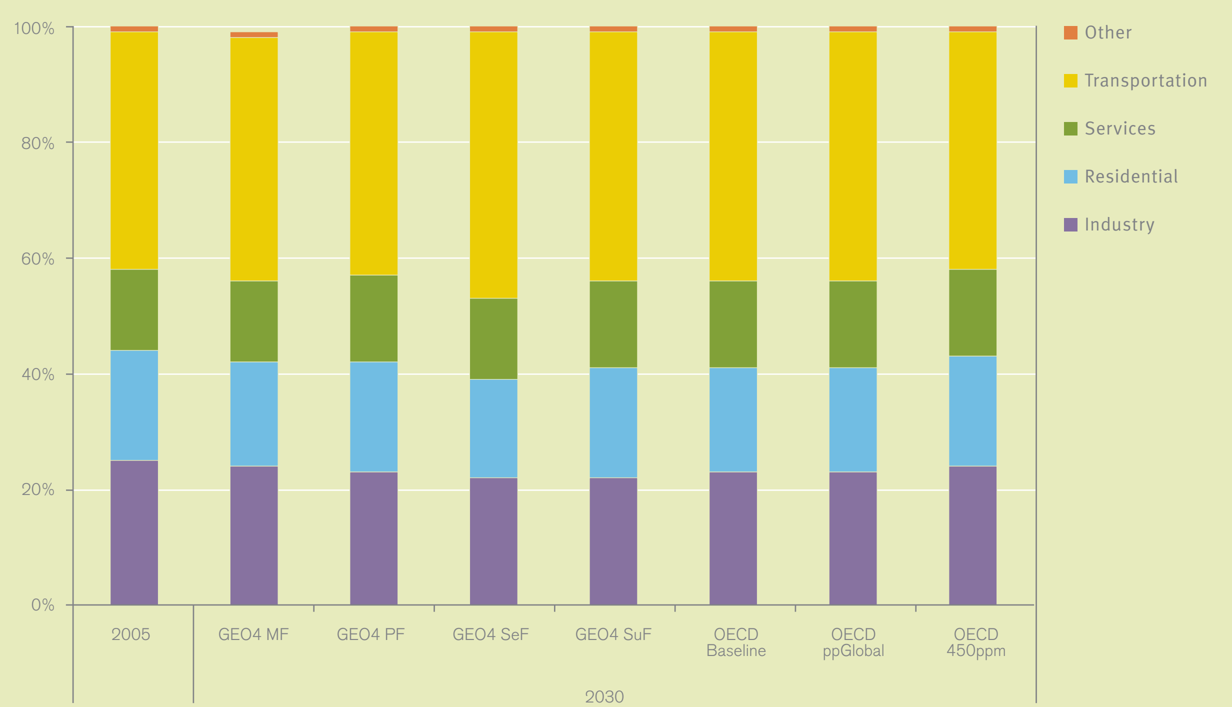


FIGURE 11: SHARE OF PRIMARY ENERGY USE BY FUEL, NORTH AMERICA



(*Note:* IEO 2008 data for Hydro includes all renewables)

FIGURE 12: SHARE OF FINAL ENERGY USE BY SECTOR, NORTH AMERICA



These patterns of change are reflected in the projections for the individual countries, but there are some differences worth noting. For example, Canada is expected to see a larger contribution from hydro than the United States or Mexico, but the latter are projected to see greater increases in solar and wind.

Figure 12 and Table A2.8 provide information on the projections for total final energy use by sector from the OECD and GEO4 scenarios.[12] Transportation currently has the largest share in all countries, reflecting its importance in energy demand; this share is expected to increase slightly by 2030. Services are also projected to represent an increasing share of final energy use. These trends are more pronounced in Mexico and Canada, with the compensating decreases in shares primarily being seen in the industrial sector in Canada and the residential sector in Mexico. Once again, it is important to remember that with increasing overall energy use, a decline in the share for a particular sector can still represent an absolute increase in energy use.

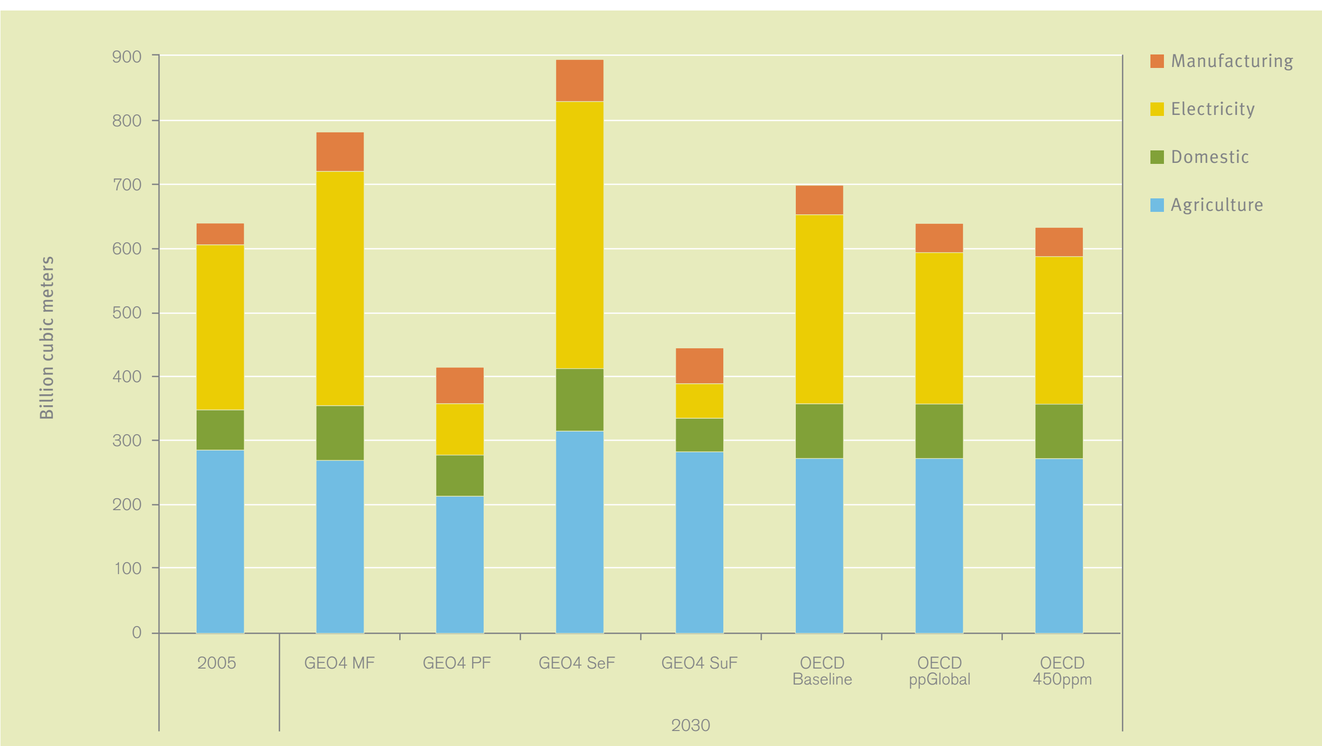
5.2.2 WATER

Freshwater withdrawals[13] in North America currently exceed 600 billion cubic meters per year (see Figures 13 and 14 and Table A2.9). On a per capita basis, Canada (1439 cubic meters per person in 2005) and the United States (1833 cubic meters per person) extract significantly more water than does Mexico (548 cubic meters per person). For North America as a whole, extractions are dominated by agriculture (approximately 45 percent) and electricity production (around 40 percent). Canada withdraws significantly more water for electricity than agriculture; this is the reverse in Mexico, with the United States somewhere in between.

The OCED and GEO4 scenarios suggest the possibility of a wide range for futures with respect to water withdrawals. The OECD Baseline scenario projects an increase of approximately 10 percent in total water withdrawals in North America, with the fastest growth occurring in the domestic and manufacturing sectors; agriculture is actually expected to see an absolute decline in water use. In the OCED ppGlobal and OECD 450ppm scenarios, there is no overall increase, almost entirely due to lower demands from the electricity sector. The GEO4 scenarios present a much larger range, from a decrease of more than 30 percent to an increase of almost 40 percent. The largest absolute differences between the scenarios also appearing in the electricity sector. In both the OECD and GEO4 scenarios, this is primarily a reflection of the differences in energy use between the scenarios, but also of improvements in the efficiency of water use, driven in part by assumptions of more consistent and comprehensive pricing of water, including the reduction of water use subsidies. The differences in population growth and overall economic activity also play a role.

The OECD scenarios shows decreases in per capita water withdrawals in Canada and the United States, and very slight increases in Mexico, with some overall convergence by 2030. These trends differ across the GEO4 scenarios, with significant convergence suggested in the GEO4 PF and GEO4 SuF scenarios.

FIGURE 13: WATER WITHDRAWALS BY SECTOR, NORTH AMERICA



[12] Similar data are available from the IEO2008 and WEO2008 studies, but the use of different categorizations of fuels and sectors would confuse the comparisons. It is not expected that including these would change the basic messages.
[13] Note that water withdrawal is the total amount of water that is taken from the terrestrial part of the water cycle. Consumption is understood as the part of the withdrawal that does not return to the terrestrial water cycle. The ratio of consumption to withdrawal can differ by sector, so these results must be used carefully in comparisons with other data that use water consumption as the key measure of water use.

5.2.3 AGRICULTURAL PRODUCTS

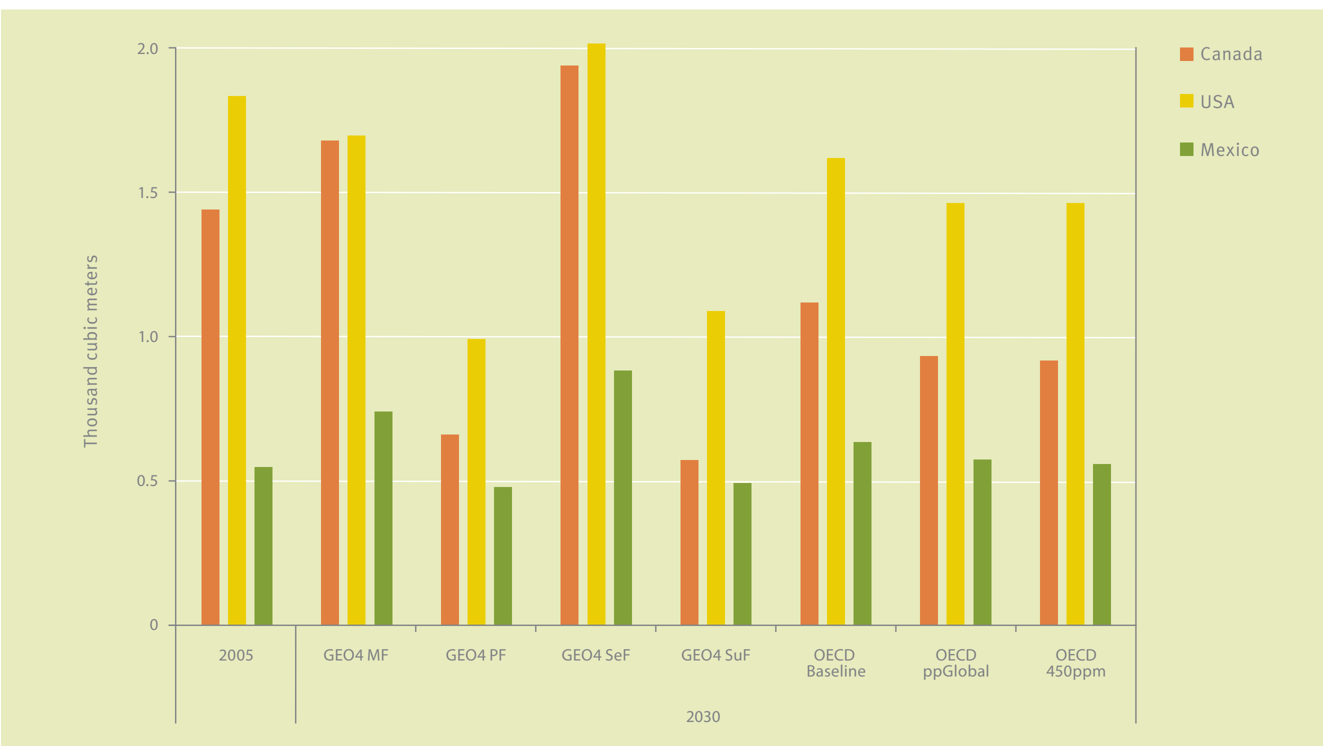
The previous section noted the significant role that the agricultural sector plays in water demand. The sector is also a dominant user of land, a topic to which we will return in a later section, as well as other resources such as fertilizers. In this section, we focus on the size of this sector in terms of the demand for, and production of, agricultural products.

Figures 15 and 16 and Tables A2.11–A2.13 provide results from the GEO4 scenarios for agricultural production and demand.[14] Total production in North America already exceeds a billion metric tons. Approximately 90 percent is in the form of non-animal products, slightly less in Canada and the United States and slightly more in Mexico. A similar distribution is shown in the demand for agricultural products. Note, however, that a portion of the demand for, and therefore production of non-animal products, is for their use in the production of animal products. In 2005, the shares of total agricultural demand represented by demand for feed were 41, 30 and 21 percent for Canada, the United States and Mexico, respectively. These country differences also help to explain why in Figure 16 the differences across countries in per capita food availability, a reasonable proxy for food consumption, are smaller than the differences in per capita demand for agricultural products. This reflects the fact that animal products, which require a substantial amount of non-animal products for their production, make up a larger share of food consumption in Canada and the United States compared to Mexico.

Production is also seen to exceed total demand. This reflects the fact that the continent is a net exporter of agricultural products. This pattern holds at the national level, with the only exception being that the demand for animal products slightly exceeds their production in Mexico. This is the case even though the per capita demand for animal products, as well as non-animal products, is lower in Mexico compared to Canada and the United States. According the GEO4 scenarios, total agricultural production is projected to increase by anywhere from 60–75 percent, with the largest percentage increases occurring in Mexico where there is more than a doubling of production. Meanwhile, total demand is also projected to increase, but only by 45–55 percent. Again, the greatest increases are expected in Mexico. This difference in the growth of production compared to demand implies an increase in net exports from the continent.

Looking across the scenarios, GEO SeF indicates slower growth in both production and demand. This is also reflected in the per capita food availability that increases by less than 10 percent in this scenario, versus 15–20 percent in the other scenarios, with the most striking differences being seen in Mexico. The GEO4 SeF scenario actually projects a further divergence in per capita food availability between Mexico and Canada and the United States. It should be noted, though, that the convergence is only minimal in the other scenarios.

FIGURE 14: PER CAPITA WATER WITHDRAWALS, BY COUNTRY



[14] The OECD scenarios do provide some results on agricultural production, but are only a subset of those presented in GEO4. Also, the OECD scenarios do not provide data on demand for agricultural products. Some indication of the shifts in agricultural production in the OECD scenarios can be seen in Section 6.3 of this report, which looks at land cover.

FIGURE 15: TOTAL AGRICULTURAL PRODUCTION AND DEMAND, NORTH AMERICA

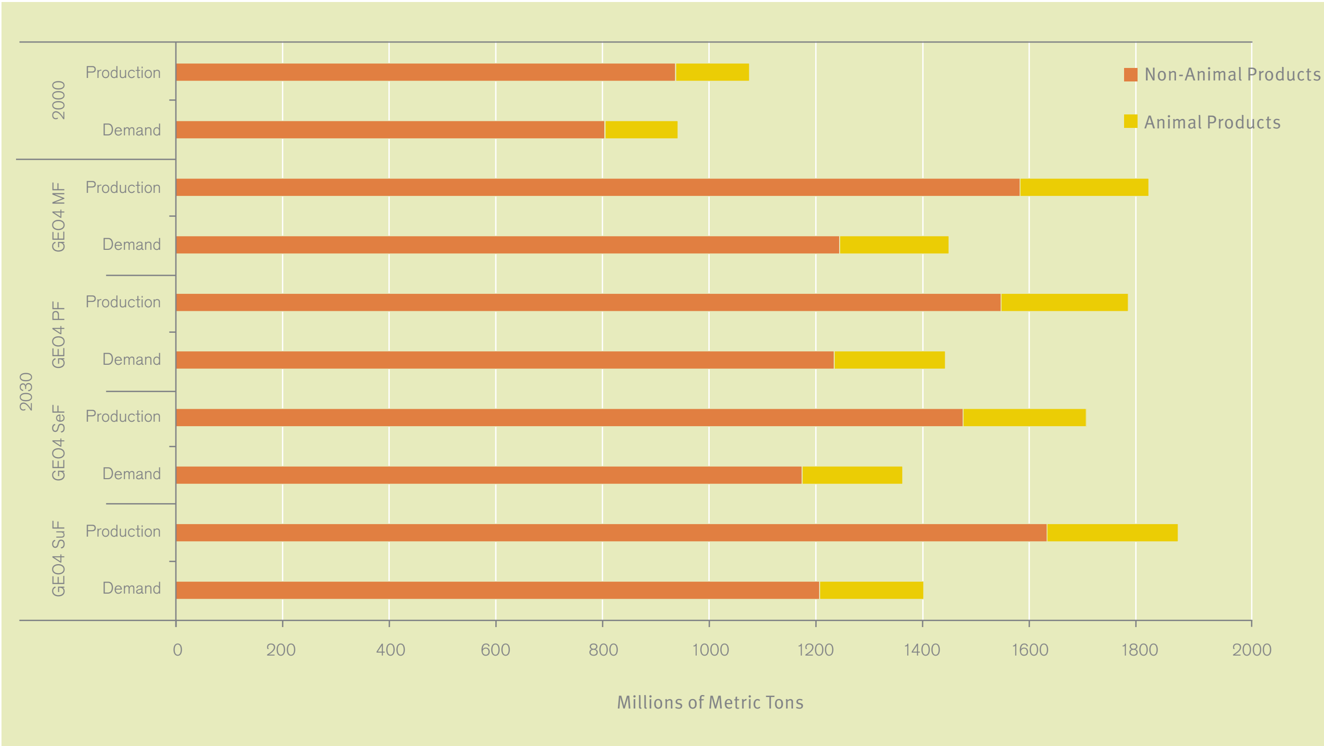
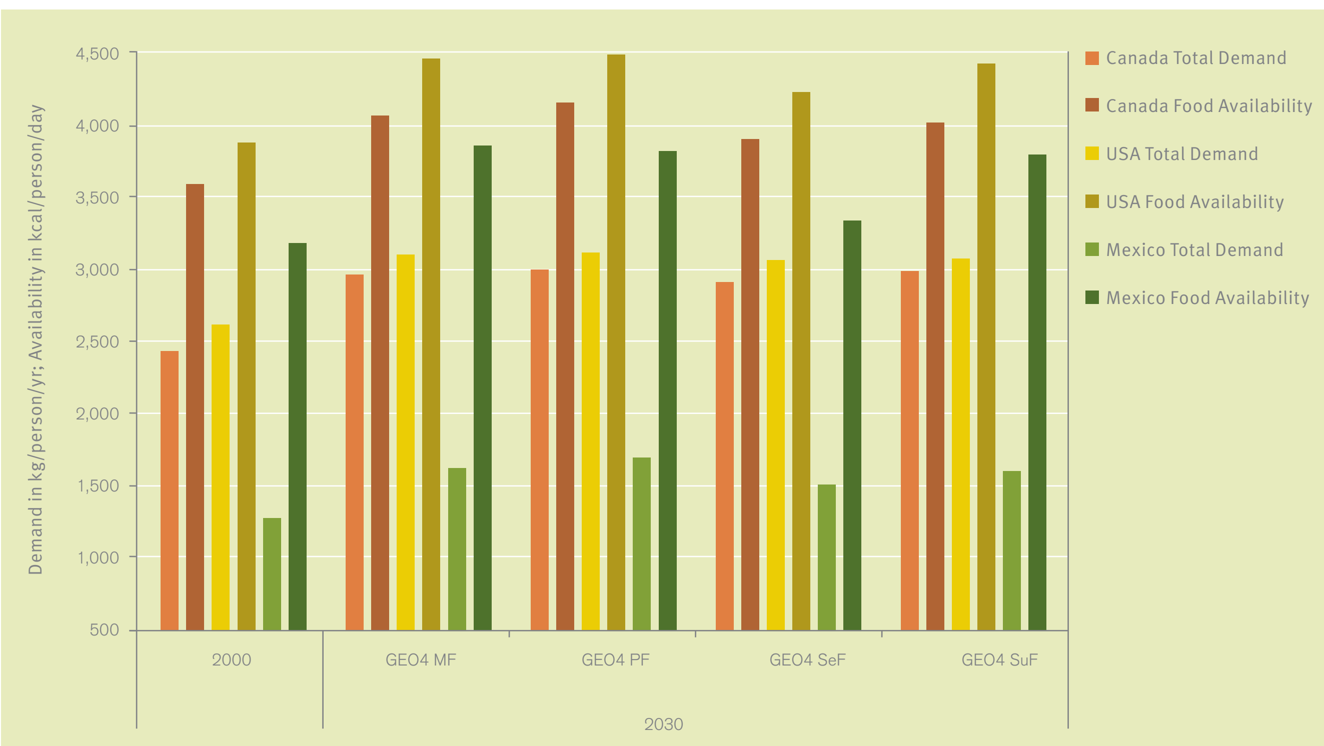


FIGURE 16: TOTAL PER CAPITA AGRICULTURAL DEMAND AND FOOD AVAILABILITY, BY COUNTRY



5.2.4 FOREST PRODUCTS

As with agriculture, this section will focus on the demand for, and production of forest products. The implications in terms of land cover by forest are addressed later in this report.

Compared to agriculture, there is less information available about forest products in the studies reviewed. GEO4 does, however, provide projections for the production of selected wood products.[15] These data are shown in Figure 17 and Table A2.13. For North America as a whole, production is projected to grow significantly, by approximately 65–85 percent between 2000 and 2030, depending upon the scenario. The highest growth rates, in all but the GEO4 SeF scenario, are seen in Canada, where they are similar to those in the United States. Mexico, on the other hand, is projected to see a 5–10 percent decline across the scenarios, reflecting a greater emphasis on agricultural production.

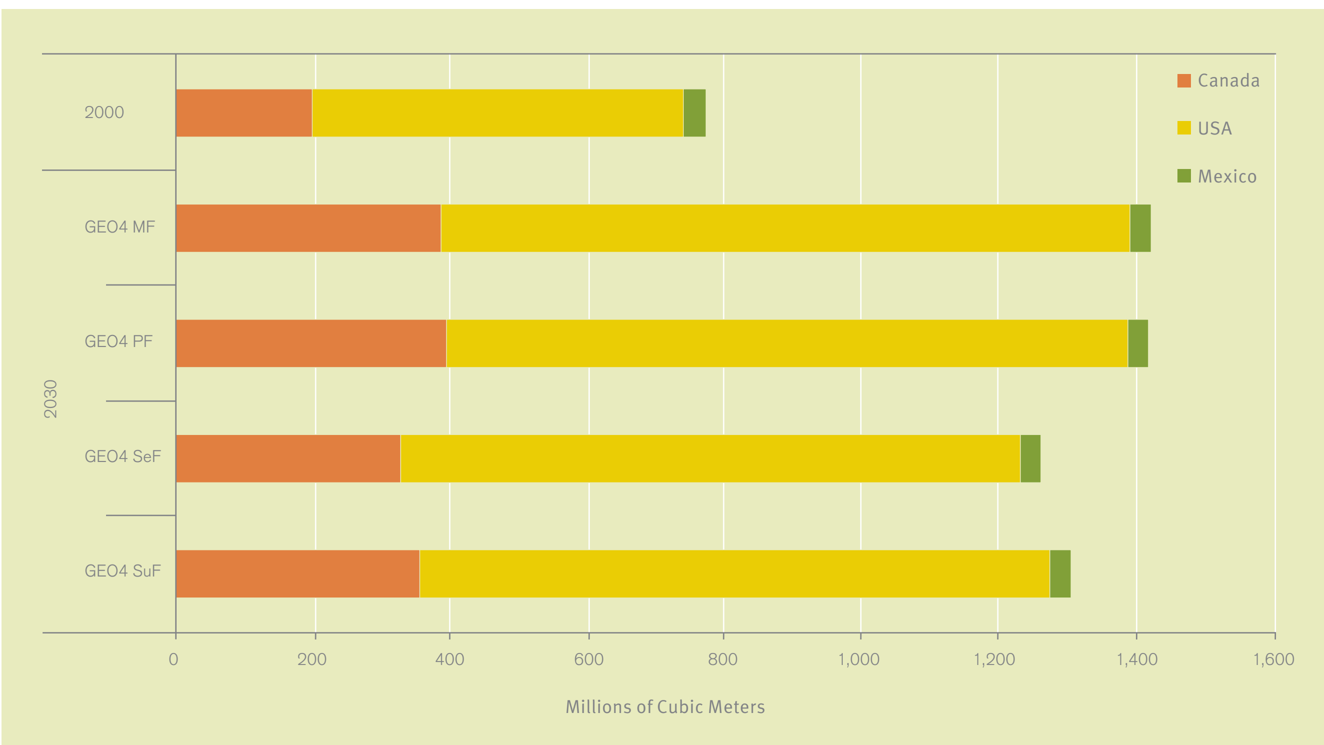
One issue that is of particular concern in Mexico is illegal logging. The International Tropical Timber Organization cites estimates of 5–7 million cubic meters of illegally harvested roundwood, compared to total roundwood production of 45.5 million cubic meters in 2003 (ITTO 2006, p. 256). GEO4 does not indicate to what extent illegal logging has been considered in its projections.

5.2.5 MARINE FISHERY PRODUCTS

Increased consumption is also reflected in the demand for products from marine fisheries. A map of the marine FAO regions is shown in Figure 18. Five of these—FAO 18 - Arctic Sea, FAO 21 - Northwest Atlantic, FAO 31 - West Central Atlantic, FAO 67 - Northeast Pacific, and FAO 77 - East Central Pacific—border on North America.

Figure 19 and Table A2.14 present projections of the total landings[16] for each of these FAO regions, except the Arctic Sea.[17] Across the four FAO regions, an increase of 15–20 percent is expected over the period 2000–2030 for each of the scenarios other than GEO4 SuF (see Table A2.14). In this case, the total landings remain almost unchanged. This reflects lower population growth as well as strong efforts to restore marine ecosystems in this scenario. These trends differ significantly by region, however. The most dramatic increase is projected for the Northeast Pacific. Meanwhile, the Northwest Atlantic is projected to see a decline in landings by as much as 55 percent. This represents a continuation of the declines seen in this region in recent years.

FIGURE 17: PRODUCTION OF SELECTED WOOD PRODUCTS



[15] The specific products are given as fuelwood, charcoal, pulpwood, particles, sawlogs, veneer, and other. Regional projections were not made of demand for forest products in GEO4; no projections of production or demand for forest products were made for the *OECD Environmental Outlook*.
[16] This includes the harvest of all marine organisms, not just fish. See Alder et al. (2007) for further details.
[17] Due to lack of data, it is not possible at this time to confidently model fishing activity and depletion in the Arctic (personal communication, Jackie Alder).

FIGURE 18: WORLD MAP WITH MARINE FAO REGIONS DELINEATED

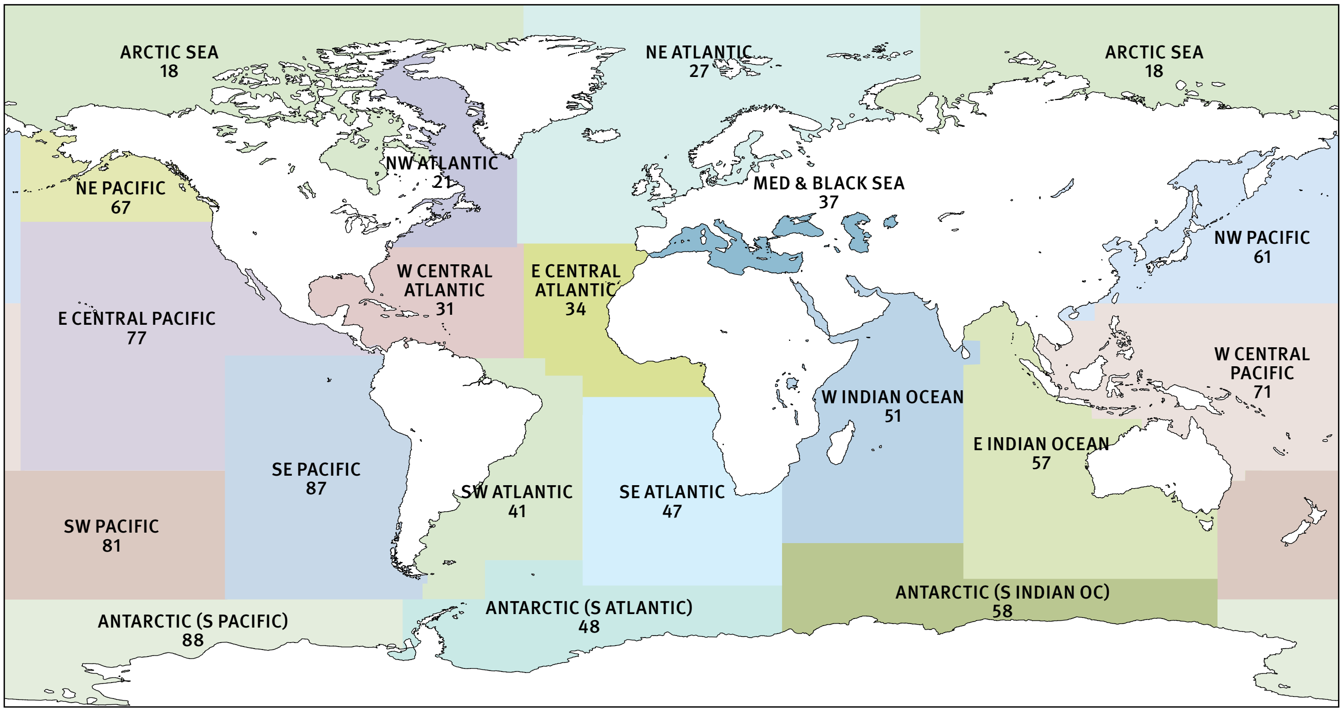
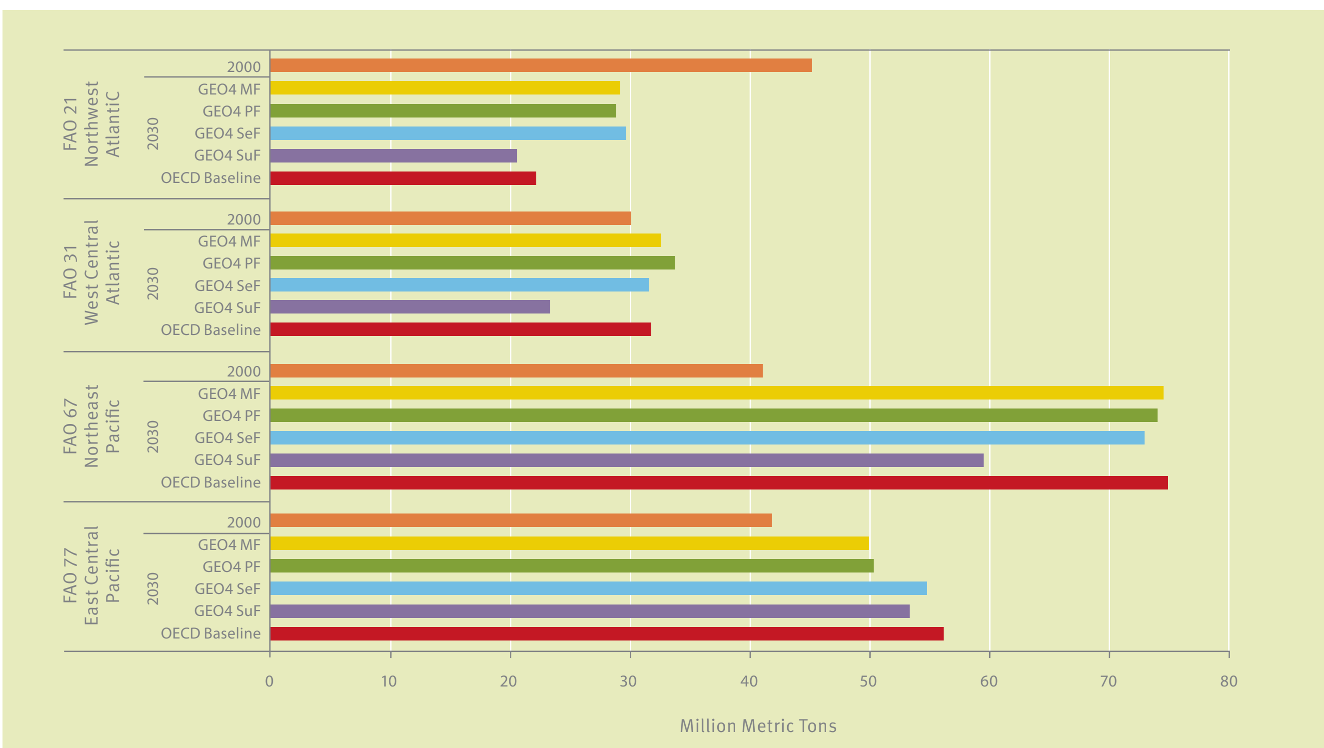


FIGURE 19: LANDINGS FROM MARINE FISHERIES



5.3 WASTE GENERATION AND RETURN FLOWS TO THE ENVIRONMENT

KEY POINTS:

- Projections of future greenhouse gas emissions vary greatly depending on the policy assumptions made. Scenarios range from a 40 percent increase to a 25 percent decline.
- Emissions of key air pollutants are expected to decline but these projections are also highly sensitive to policy assumptions.
- The absolute amounts of untreated water discharges are expected to increase.
- Nitrogen fluxes, a major source of water pollution, are expected to increase in Canada, decline in the United States and remain constant in Mexico.

5.3.1 GREENHOUSE GAS (GHG) EMISSIONS

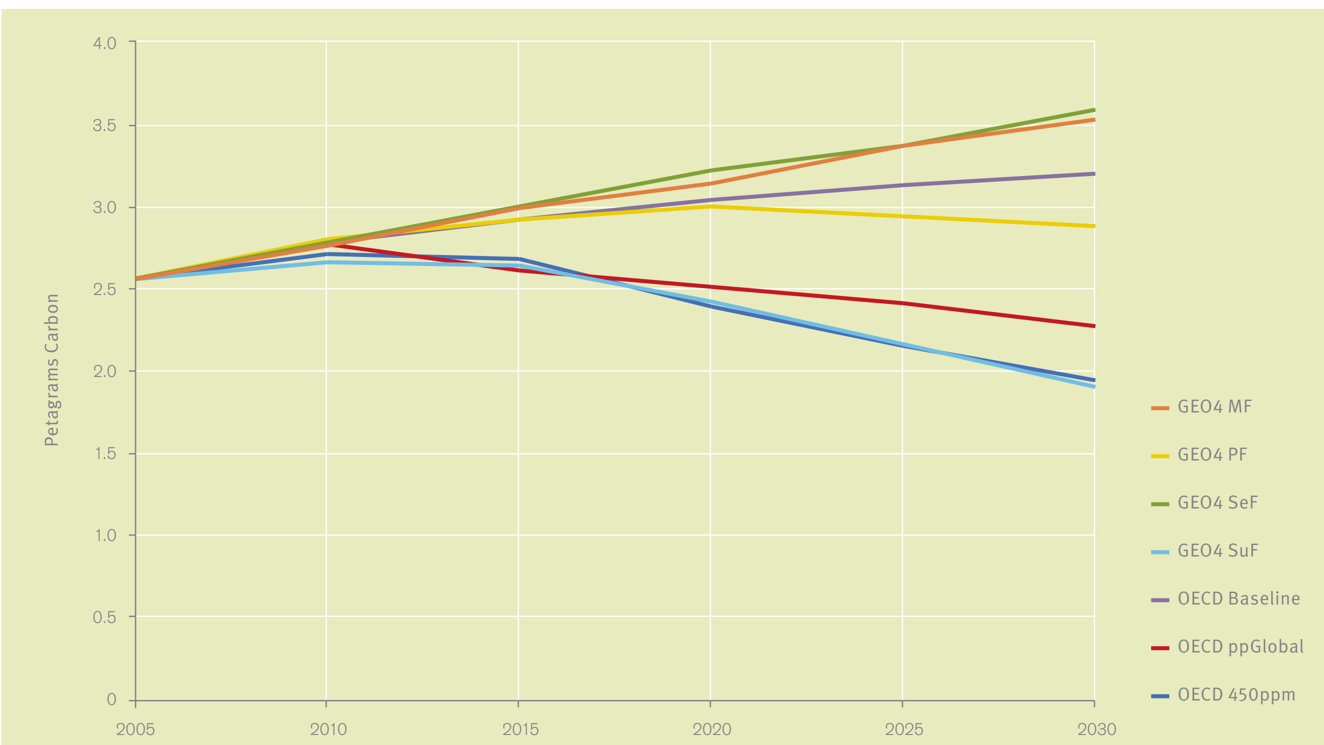
Figures 20 and 21 and Table A2.15 summarize the projections of greenhouse gas (GHG) emissions in the GEO4 and OECD scenarios. These include all of the gases considered under the Kyoto Protocol. Per capita emissions in Canada and the United States are currently among the highest in the world. North America as a whole contributed approximately 20 percent of total global emissions in 2005. Energy use was the dominant source in all three countries, although in Mexico land use[18] was responsible for nearly 40 percent of that country's emissions.

Future levels of GHG emissions will be driven by a number of factors, perhaps most importantly energy use. Thus, it is not surprising that the scenarios show a wide range of possibilities, reflecting what was seen with energy use. Depending upon the scenario, GHG emissions in North America are projected to rise from 2005–2030 by as much as 40 percent in the GEO4 MF and SeF scenarios or decline by as much as 25 percent in the GEO4 SuF and OECD 450ppm scenarios. These declines in the latter scenarios may seem dramatic, but they are in line with or even not as steep as what is already being discussed at the political level in the United States and Canada.

On a per capita basis, the United States and Canada will continue to far exceed Mexico's GHG emissions. The levels of per capita emissions are projected to increase in all three countries in the largely unregulated GEO4 MF, GEO4 SeF, and OECD Baseline scenarios, but also in the GEO4 PF scenario. None of these scenarios indicate any real convergence between per capita emissions in Canada and the United States vis-à-vis Mexico. Somewhat more convergence is projected in the other scenarios as the levels fall much further in Canada and the United States than in Mexico.

Energy use is projected to continue to be the dominant source of GHG emissions, with a significantly increasing share in Mexico in most of the scenarios. This is matched by a reduced share from land use, although not necessarily an absolute decline in emission. In Canada, the opposite is expected to occur, with some significant increases in the share of emissions attributable to land use.

FIGURE 20: TOTAL GREENHOUSE GAS EMISSIONS, NORTH AMERICA



[18] This primarily reflects land-use conversions and non–energy-related emissions from agriculture.

FIGURE 21: PER CAPITA GREENHOUSE GAS EMISSIONS, BY COUNTRY

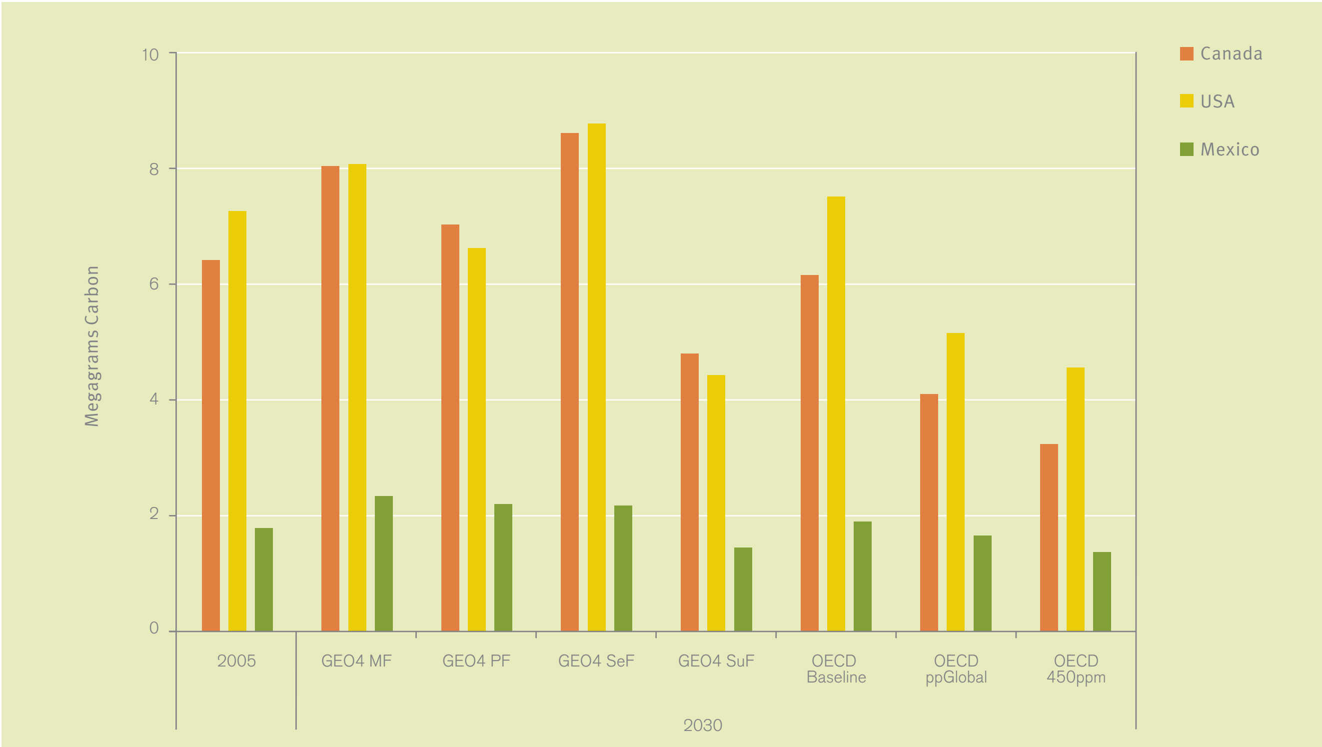
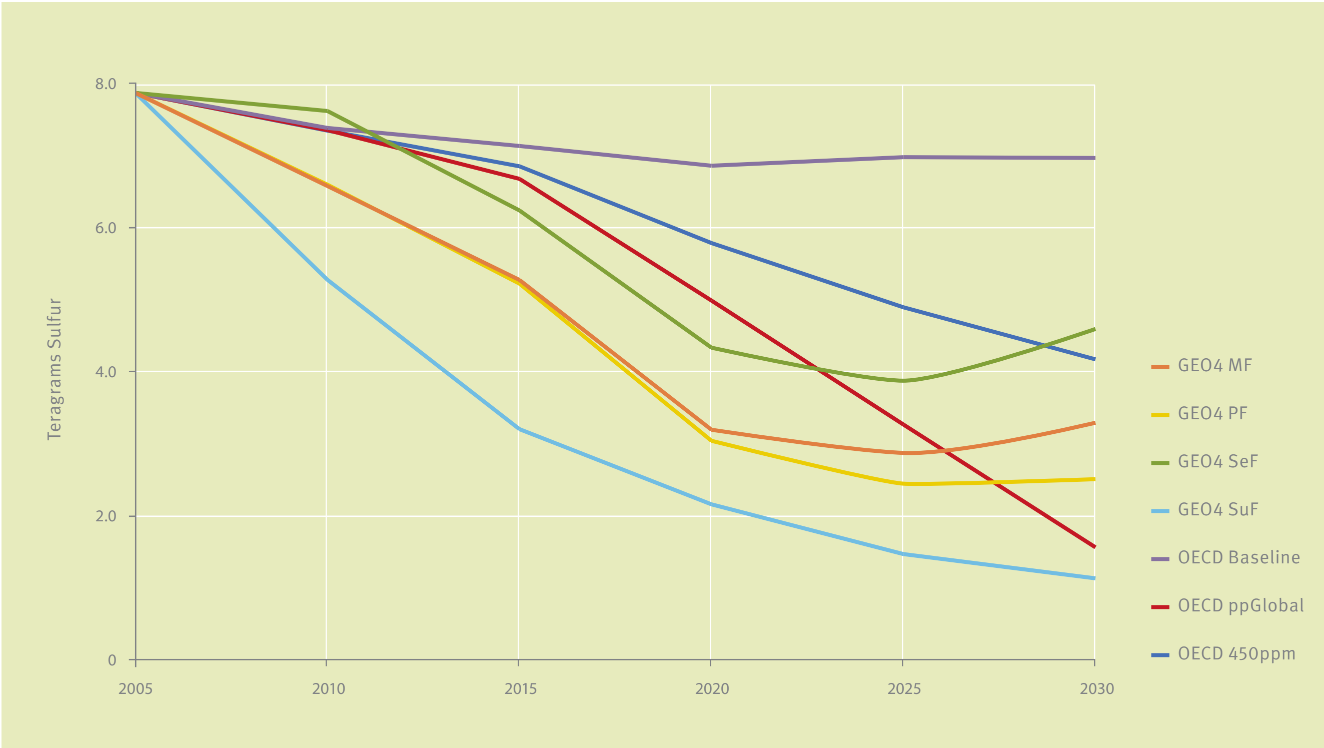


FIGURE 22: NO_x EMISSIONS FROM ENERGY USE AND INDUSTRIAL PROCESSES, NORTH AMERICA

FIGURE 23: SO_x EMISSIONS FROM ENERGY USE AND INDUSTRIAL PROCESSES, NORTH AMERICA



5.3.2 CRITERIA AIR CONTAMINANTS[19]

A number of air pollutants are of particular concern to human health and the environment. These include nitrogen oxides (NO_x), sulfur oxides (SO_x) and small particulate matter (PM). Figures 22 and 23 and Tables A2.16 and A2.17 present projections for emissions of the first two of these from energy use and industrial processes. As with GHG emissions, there are striking differences across the scenarios, reflecting the sensitivity of emissions to policy choices. Experts expect decreases in SO_x emissions for North America as a whole, but this may be as little as 12 percent or as much as 85 percent for the period 2005–2030. NO_x emissions are expected to fall in most scenarios by as much as 75 percent over the same period. In the GEO4 SeF scenario, however, they are projected to rise by 16 percent.

Canada and the United States have significantly higher per capita emissions than does Mexico at the present time. Aside from the GEO4 SeF scenario, a large degree of convergence is expected for NO_x emissions as these fall in Canada and the United States in all the other scenarios, while they increase or fall less dramatically in Mexico. This is even more dramatic for SO_x emissions, where the GEO4 scenarios actually project per capita emissions in Mexico to exceed those in Canada and the United States by 2030.

5.3.3 RETURN FLOWS AND WATER POLLUTION

To date, there has been little or no work to develop future projections related to water pollution. Data are provided in GEO4 on projections for total return flows of water, both treated and untreated. The *OECD Environmental Outlook*, meanwhile includes estimates of river nitrogen flux—nitrogen exported to coastal waters from sewage and non-point sources, primarily agriculture.

Figure 24 and Table A2.18 present the projections from GEO4 for return flows of treated and untreated water from the domestic and manufacturing sectors. As of 2000, most return flows from the domestic sector were treated in Canada and the United States, but less than 30 percent were in Mexico. The United States also treated more than 70 percent of the return flows from the manufacturing sector; in Canada and Mexico, these figures were much lower, approximately 40 percent and 15 percent, respectively. Looking out to 2030, the shares of the return flows that are treated are projected to remain around the same or increase in each sector, depending on the scenario. Since the total return flows increase in line with the total extractions, though, the total amount of untreated flows are projected to increase by 25–60 percent, 11–65 percent, and 31–168 percent in Canada, the United States, and Mexico, respectively. These large ranges point to the potential for policy to have a significant impact.

The data on river nitrogen fluxes, as projected in the OECD Baseline and OECD ppGlobal scenarios are shown in Figure 25 and Table A2.19. No estimates were made for the OECD 450 ppm scenario. In 2000, these fluxes totalled over 2500 thousand kilograms, with agriculture being the dominant source in Canada and the United States; in Mexico, the fluxes from agriculture and sewage were of the same magnitude. Looking out to 2030 for North America as a whole, they fluxes are expected to increase only slightly in the OECD Baseline scenario and fall by over 20 percent in the OECD ppGlobal scenario. This is primarily due to changes in the United States. In Canada, nitrogen fluxes are actually expected to increase by 70 and 30 percent in the OECD Baseline and OECD ppGlobal scenarios, respectively, almost entirely due to increases from agriculture. In Mexico, decreases in the agricultural sector are approximately balanced by increases from sewage.

[19] As discussed in more general terms previously, there are differences between data provided by the IMAGE model and those that may be extracted from national data sets.

FIGURE 24: RETURN FLOWS OF TREATED AND UNTREATED WATER

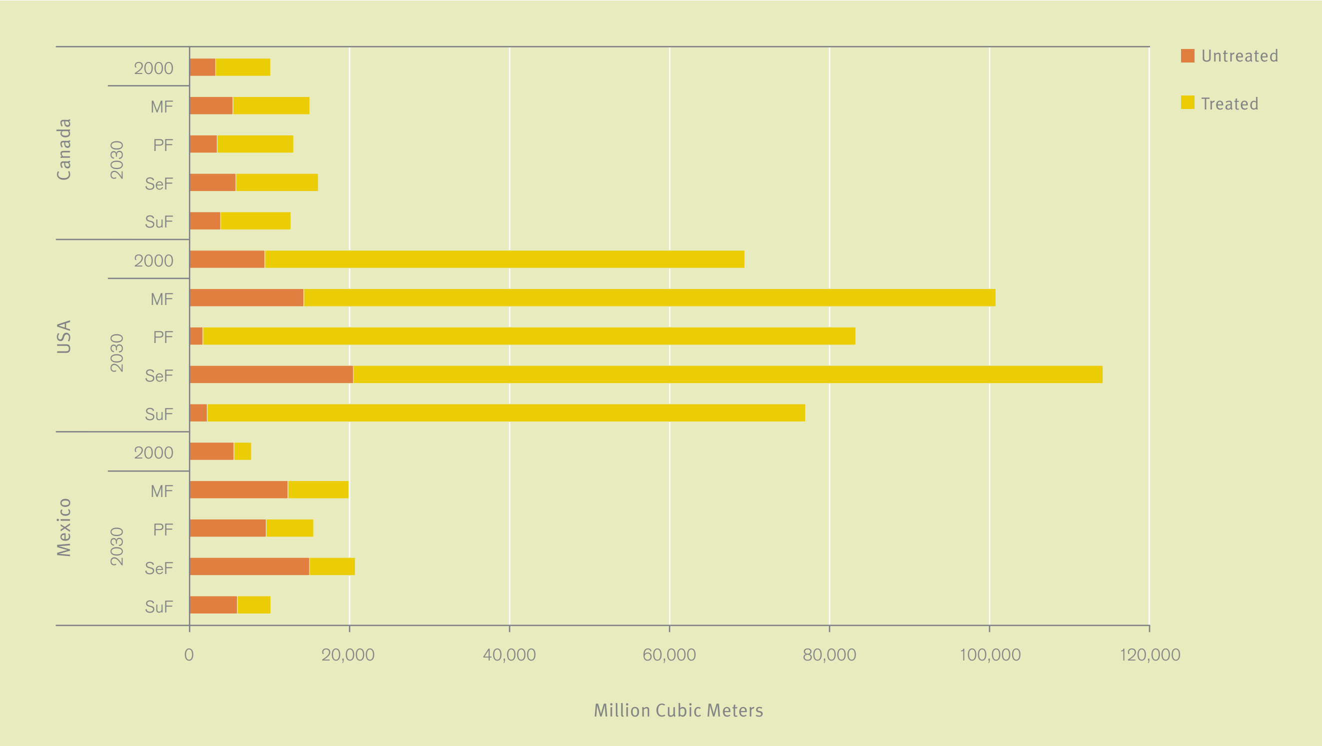
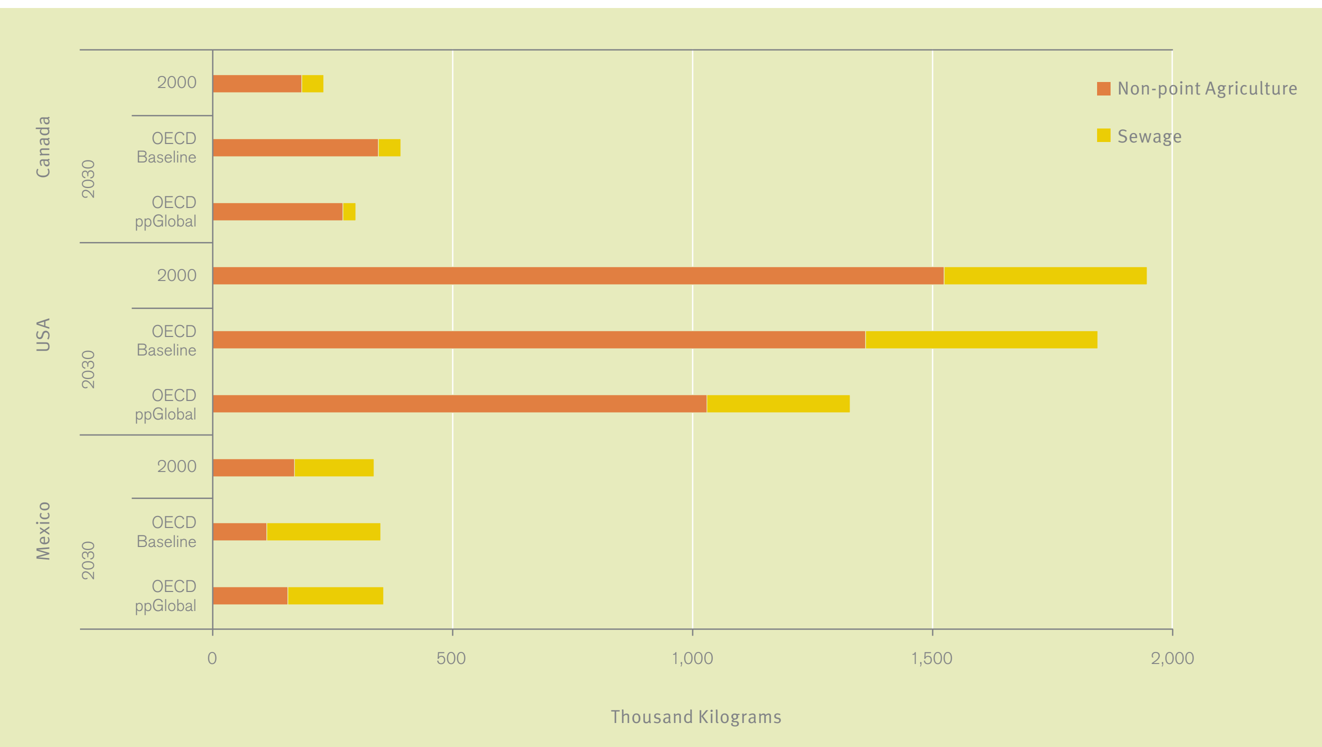
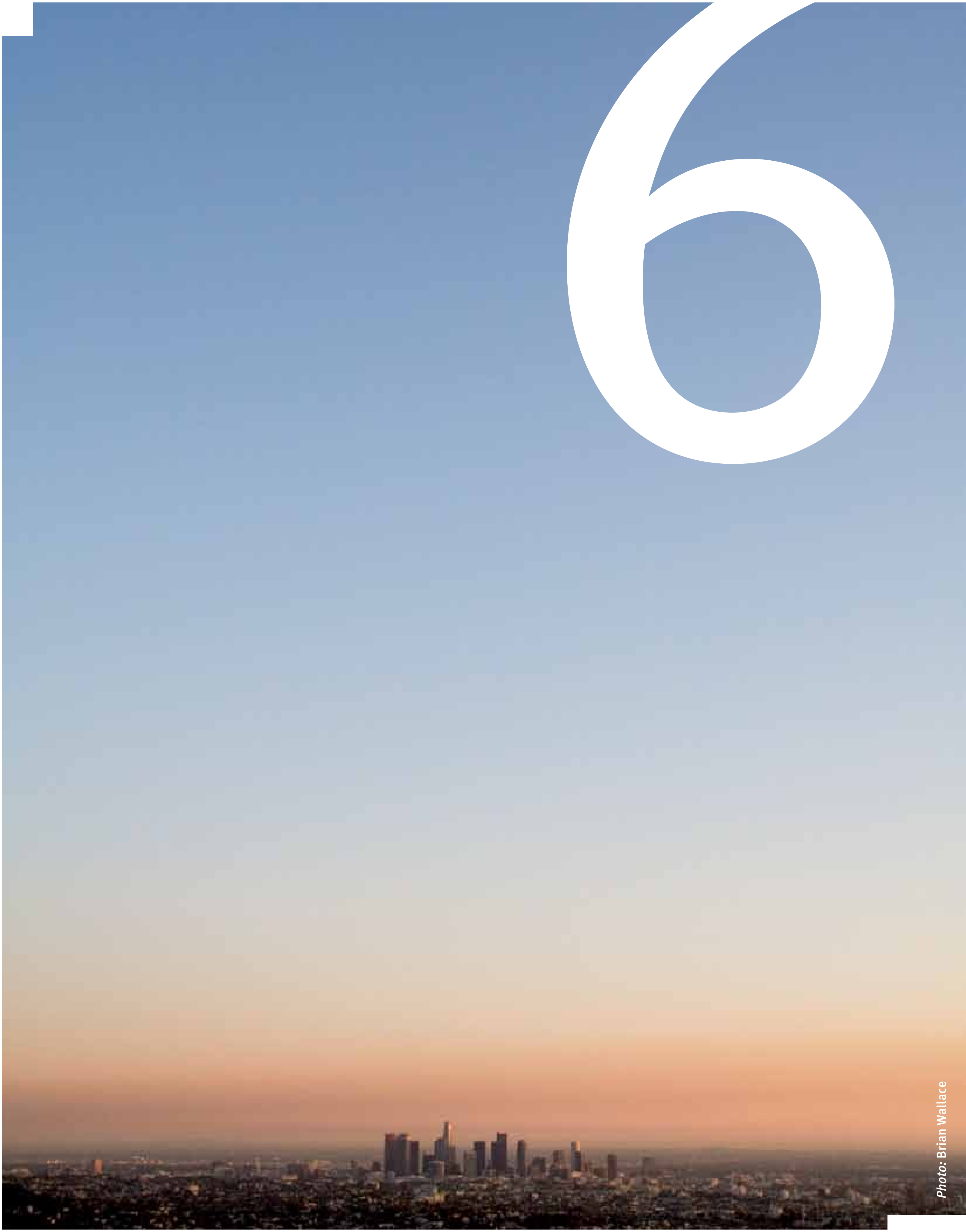


FIGURE 25: RIVER NITROGEN FLUXES





6

Photo: Brian Wallace

CHAPTER 6
State: Changes in Environmental Conditions

6.1 INTRODUCTION

In 1990, Turner et al. (1990) produced a book entitled *The Earth as Transformed by Human Action*, with the subtitle *Global and Regional Changes in the Biosphere over the Past 300 Years*. Our goal in this section is somewhat more limited in scope—how might we expect the meta-forces, drivers, and pressures described in the previous sections, as well as those that have come before, to transform the environment of North America over the next few decades. This section reviews what the *OECD Environmental Outlook,* GEO4 and other recent studies conclude on this topic. Given its importance to other aspects of changes in the environment and the extent of recent scientific attention it received, we begin with climate. We then consider projections related to land cover, air quality, water quality and quantity, and biodiversity.

Please note that the uncertainties discussed in the previous sections related to the size of the meta-forces, drivers and pressures are further compounded here by uncertainties in our understanding of the workings of the natural system. In addition, due to lags in the response of natural systems, a number of the changes in state are driven by previous changes in the size of the meta-forces, drivers and pressures, and the full effect of changes in these over the period to 2030 will become apparent only after that time.

6.2 CLIMATE

KEY POINTS:

- Average temperatures are projected to increase across North America, with the highest increases occurring at high latitudes and in winter.
- Precipitation patterns are expected to change but considerable uncertainty remains over the scope of these changes. The same is true for extreme weather events.
- Glaciers and sea ice are losing mass more quickly than anticipated, making an ice free summer in the Arctic more likely before mid-century.
- Climate change is expected to exacerbate other environmental changes (e.g., air quality, forest cover, biodiversity, water availability).

Section 3.2 discussed climate change as a key aspect of global environmental change. Here we focus on the North American context, emphasizing changes in temperature, precipitation, extreme events, and the implications for snow and ice cover. Even so, this overview will hide important differences within the region. The specific implications of these changes on other aspects of the environment (for example, biodiversity) and socio-economic systems, like human health, will be addressed in their respective sections.

Temperature

The IPCC projects that the United States and Canada, with the possible exception of the Atlantic offshore area, will see warming over the next few decades. The amount of warming is expected to be 1 to 3˚C over the norm for the period 1980–1999 (Field, Mortsch et al. 2007). Studies in Canada indicated that the temperature increases will be greatest in the high Arctic, and greater in the centre of the country than along the east and west coasts. Warming is expected to be greatest during the winter months. The frequency of extreme warm summer temperatures (exceeding 30˚C) is expected to increase, while extreme cold days are projected to decline significantly (Karl, Meehl et al. 2008; Lemmen, Warren et al. 2008).

While climate models imply that temperature changes will be less pronounced in lower latitudes than in higher latitudes, the changes expected in Mexico are still projected to be noticeable. The IPCC estimates for Central America and Mexico are for increases of 0.4–1.1˚C in the dry season and 0.5–1.1˚C in the wet season by 2020 compared to the period 1980–1999 (Magrin, Gay García et al. 2007).

Precipitation

In the 21st century, precipitation over North America is projected to be less frequent but more intense. This increase in storminess is projected to be accompanied by greater extreme wave heights along the coasts (CENR 2008).

Annual total precipitation is projected to increase across Canada during the current century. Due to enhanced evapotranspiration driven by higher temperatures, many regions will experience a moisture deficit despite greater amounts of precipitation. Seasonal changes in precipitation will generally have greater regional-scale impacts than the annual totals. Precipitation is expected to decline in the summer in south-central Prairies and southwestern BC. This means less available precipitation during the growing season in important agricultural regions (Lemmen, Warren et al. 2008).

Most climate models project an increase in winter precipitation in the northern tier of the United States and a decrease in portions of the Southwest during the 21st century. Summer precipitation is projected to decrease in the Northwest of the contiguous United States and increase in Alaska; it is uncertain whether summer precipitation will increase or decrease over large portions of the interior United States (CENR 2008).

...the full effect of changes in [meta-forces, drivers and pressures] over the period to 2030 will become apparent only after that time.

The uncertainty of projections of precipitation remains high for Mexico. The projected time-averaged precipitation decrease is accompanied by more frequent dry extremes in all seasons. The projections for the dry season looking out to 2020 range from decreases of seven percent to increases of seven percent; the range for the wet season is from a decrease of ten percent to an increase of four percent (Magrin, Gay García et al. 2007).

Extreme Events

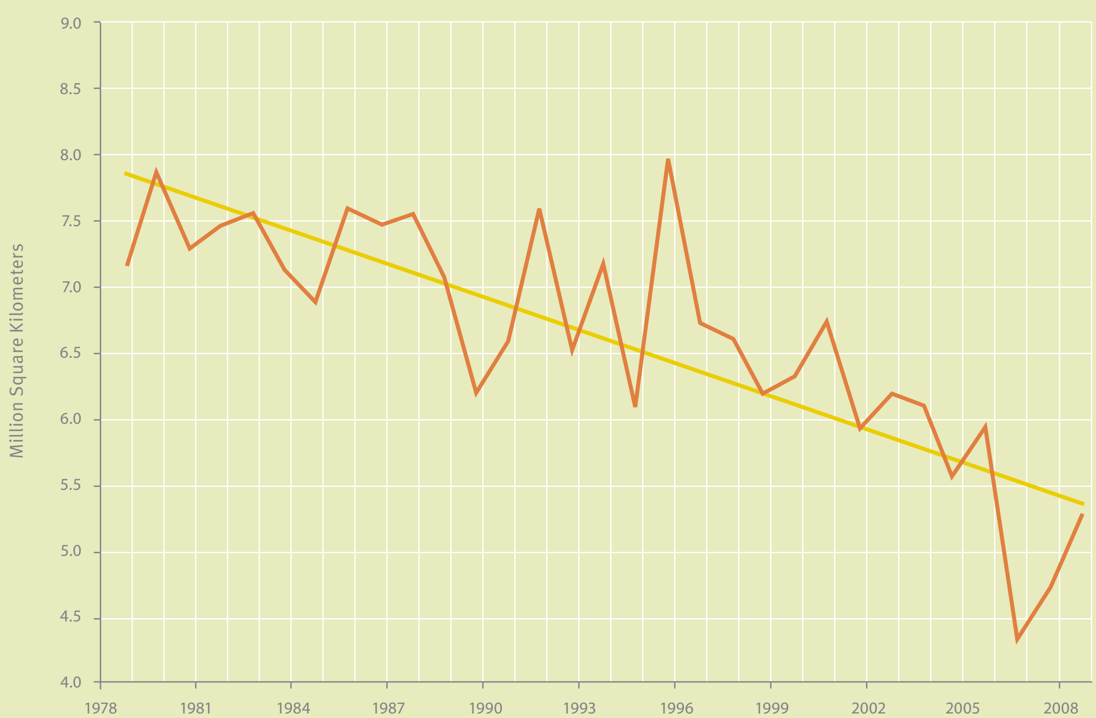
Future trends in extreme events remain very uncertain. Hurricane rainfall and wind speeds are projected to increase in response to human-caused warming, although there is less confidence in the projected changes in the number of tropical cyclones. The apparent increase in the proportion of very intense storms since 1970 in some regions is much larger than simulated by current models for that period, highlighting the uncertainty associated with this issue. Trends in other extreme weather events that occur at small spatial scales—such as tornadoes, hail, lightning, and dust storms—cannot be determined at the present time due to insufficient evidence (Karl, Meehl et al. 2008).

Snow and Ice

The speed at which climate change will reduce snow and ice cover is a key uncertainty that has been a major focus of the commentary since the release of the fourth IPCC Assessment. Several scientists have argued that the IPCC projections were unduly conservative and that the west Antarctic and Greenland ice sheets were vulnerable to even small additional warming, which could lead to a much faster sea-level rise (Hansen 2008). As the climate warms, snow cover is projected to continue to decrease. Glaciers and terrestrial ice sheets are projected to continue to lose mass as increases in summertime melting outweigh increases in wintertime precipitation. This will contribute to sea level rise. Widespread increases in thaw depth are projected over most permafrost regions, with costly implications for existing and new infrastructure (CENR 2008).

According to the IPCC, results from multiple model simulations indicate that an Arctic Ocean free of summer ice is likely by the end of the century, with some models suggesting that this could occur as soon as 2040. As Figure 26 shows, there has been a persistent downward trend in the minimum sea ice extent (as registered annually in September) in the past few decades, with the past five years having the least amount of ice cover since satellite monitoring began in 1978.

FIGURE 26: EXTENT OF ARCTIC SEA ICE IN SEPTEMBER



(*Source:* National Snow and Ice Data Center (http://nsidc.org/arcticseaicenews/ - accessed 31 October 2008)

6.3 LAND COVER AND LAND USE

KEY POINTS:

- North America may see a small net decline in total forest area although scenarios vary. This decline will be most pronounced in Mexico.
- Scenarios concerning changes in agricultural land use vary substantially and are sensitive to assumptions made about government policy.
- Urban land is likely to increase in all three countries, but there has been little specific work on this at the continental scale.

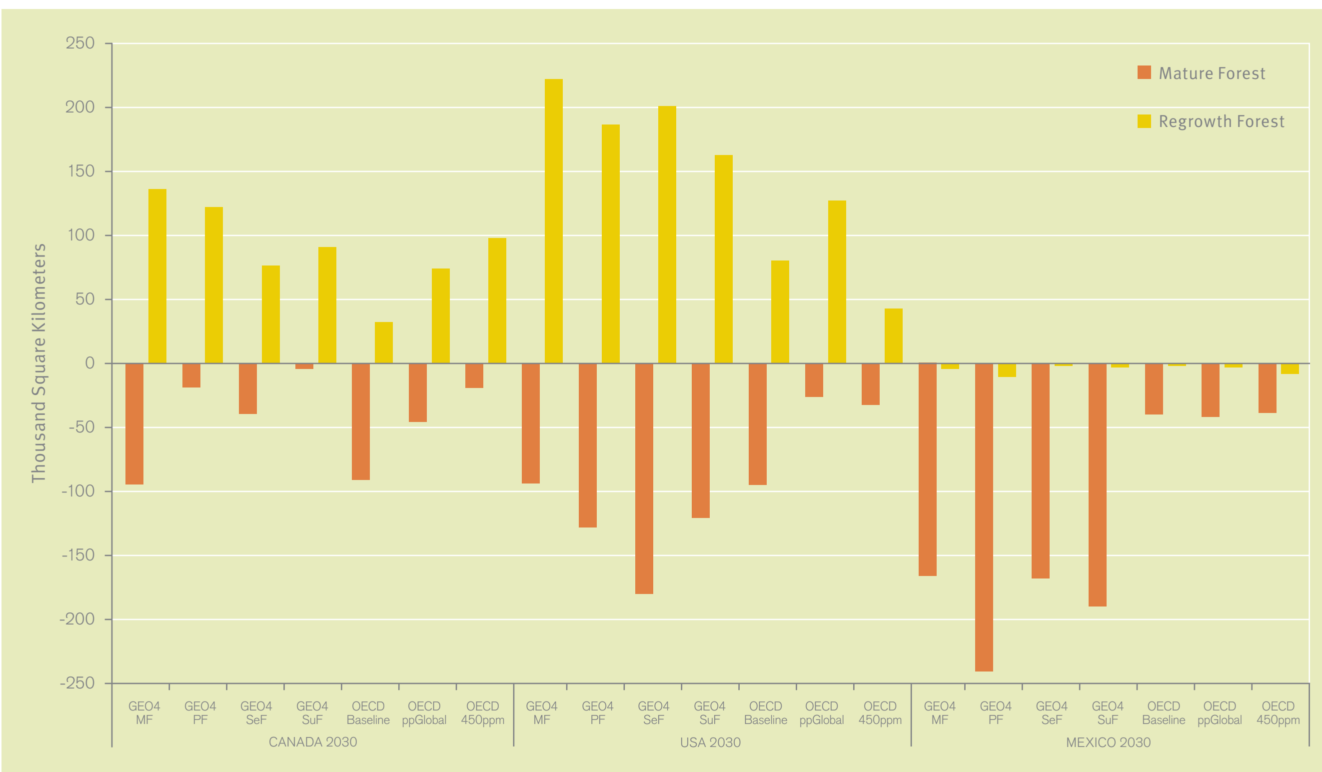
Changes in land cover and land use will be driven by a number of factors. As population grows and urbanization proceeds more land will be converted to built-up areas. Shifts in the demand for and production of agricultural and forest products will lead to changes in the extent of crop and managed forest land. Policies to protect biodiversity may result in more land being set aside for nature. Policies related to carbon sequestration and bioenergy production will affect both forest and agricultural land. On top of this, the changing climate itself will have impacts irrespective of our policy choices as biogeoclimatic zones shift and yields change. In this section we examine what recent studies have had to say about the extent of forests, agricultural land and urban and built-up areas.

Forests

Forests currently cover 45 percent of the land area in North America —62, 32, and 23 percent in Canada, the United States, and Mexico, respectively. Figure 27 and Table A2.20 show projections for changes in forest area between 2000[20] and 2030 projected by the GEO4 and OECD scenarios. In the GEO4 PF, GEO4 SeF, GEO4 SuF, and OECD baseline scenarios, the continent as a whole is projected to experience a small net decline (up to 1.25 percent) in total forest area as the loss of mature forests exceeds the gain from the regrowth on abandoned land or timber plantations. The OECD Baseline scenario projects relatively less loss of mature forest as well as less regrowth, but the net effect is similar. The other scenarios, GEO4 MF, OECD ppGlobal and OECD 450ppm, present a significantly different picture. Here, the balance between regrowth and loss of mature forests is such that there is a small net gain (0.5–1.0 percent) of total forests. One expected effect of climate change is that the northern tree line will move northward and to higher elevations (CENR 2008).

The most significant changes are expected in Mexico, where anywhere from just under 10 percent to nearly 60 percent of mature forests are projected to be lost, depending upon the scenario. Furthermore, it is the only one of the three countries that is projected to see a net decline in regrowth forests in most scenarios. Magrin, Gay García et al. (2007) argue that this loss in forest cover will be accelerated by climate change, with most of the semi-arid vegetation in central and northern Mexico being replaced by the vegetation of arid regions.

FIGURE 27: CHANGES IN FOREST AREA 2000–2030



[20] Land cover data and categories will differ between information provided by IMAGE model and national data. For example, the IMAGE forest area for Canada indicates, for 2000, an area 165 million ha larger than the estimated forest and other wooded land (402 million ha), as reflected in Canadian national data sets.

Meanwhile, in Canada and the United States, there is a fairly striking difference between the OECD Baseline scenario and the other scenarios. It is only in the former that a net loss is projected in both countries. The projection of a net loss in the United States is in line with estimates from the US Department of Agriculture, which notes that for the first time in a century, the United States is starting to see a reduction of its forested land base due to private landowners selling their land to developers. They go further to project that more than 50 million acres of non-federal forests will be converted to urban and development use in the next 50 years, with a net loss of 20 million acres after conversion of pastureland to forest is considered (Alig et al. 2003).

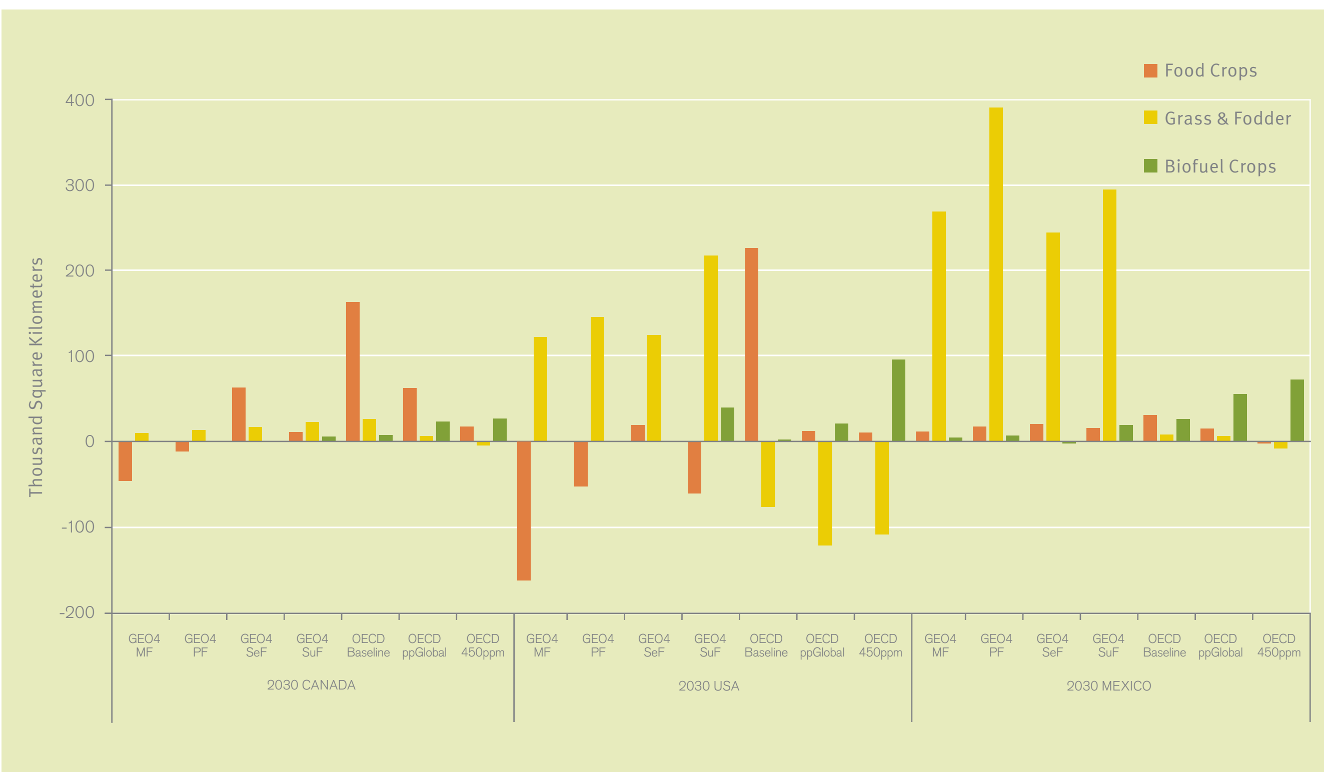
Agricultural Land

Figure 28 and Table A2.21 provide information on the extent of agricultural lands. In 2000, these accounted for 7, 45, and 55 percent of the land in Canada, Mexico, and the United States, respectively. The division between food crops and grass and fodder differ significantly across the three countries, with significantly more land devoted to grass and fodder in Mexico and the United States than in Canada. Also, only Mexico was assumed to have had significant areas devoted to biofuel crops in that year.

The divergent projections to 2030 from the GEO4 and OECD scenarios project important differences between the countries. The GEO4 and OECD Baseline scenarios project an overall expansion of land devoted to agriculture, by as much as 9 percent. In the GEO4 scenarios, this is due to increased areas for grass and fodder; in the OECD Baseline scenario, expansion of areas devoted to food crops are the main driver. The OECD ppGlobal and OECD 450ppm scenarios expect a small net loss of agricultural land (less than 2 percent), even as more land is devoted to biofuel crops.

In Mexico, slight increases are projected in cropland, but very large increases in land devoted to grass and fodder in the GEO4 scenarios, much of this at the expense of forests. The change in grass and fodder is much smaller in the OECD scenarios. Significant increases in grass and fodder and a contraction in cropland are expected in the GEO4 scenarios other than GEO4 SeF, particularly in GEO4 MF, which assumes a significant decline in many agricultural subsidies. This, in conjunction with the increased levels of agricultural production discussed earlier, implies an increase in the intensification of agriculture. The OECD scenarios paint a different picture, however, indicating expansion of cropland and decreases in land devoted to grass and fodder. The projections for Canada also vary across the scenarios, although except for the GEO4 MF and GEO4 PF scenarios, there is general pattern of more area devoted to both food crops and also grass and fodder. In all three countries, the greatest expansion of biofuels is projected in the more sustainability-oriented scenarios, i.e., GEO4 SuF, OECD ppGlobal, and OECD 450ppm.

FIGURE 28: CHANGES IN AGRICULTURAL AREA 2000–2030



In addition to the extent of agricultural land, it is also important to consider the quality of the land, recognizing the impact this can have on yields. One measure of this is the risk of erosion from water. Figure 29 and Table A2.22 provide an indication of how this risk might change. The United States presently has the most agricultural land at risk of erosion, reflecting its larger extent of agricultural land in general. The OECD Baseline scenarios project fairly significant increases in all three countries by 2030, with smaller increases in its policy scenarios. In the GEO4 scenarios, Canada and the United States are expected to experience increases only in SeF, reflecting, in part, the expansion of agricultural land in these scenarios. Mexico, however, which is projected to see an expansion of agricultural land in all scenarios, also sees this accompanied by significant increases in soil erosion risk. In addition, Magrin, Gay García et al. (2007) point to the potential of climate change to exacerbate problems such as salinization and desertification of agricultural lands.

Urban and Built-up Land

Neither GEO4 or the *OECD Environmental Outlook* provide explicit estimates of the change in urban and built-up land, although these can be expected to grow along with the overall population. One estimate is that urban land will increase from 3.1 percent of the conterminous United States to 8.1 percent in 2050 (Nowak and Walton 2005). This implies a rate of expansion that exceeds the growth of the urban population itself, indicating a further reduction in urban density and an increase in the opportunities and problems associated with the growth of metropolitan areas.

6.4 AIR QUALITY

KEY POINTS:

- A decline is expected in particulate matter but a slight increase in ground-level ozone in urban areas.

Air pollution in urban areas has been a key concern in the past, as well as a target of significant regulation. The OECD scenarios present a mixed picture for future urban air pollution in North America.[21] With respect to particulate matter[22] throughout North America they project a continued improvement. In the OECD Baseline scenario, average concentrations are projected to fall by nearly one-quarter in the United States between 2000 and 2030, and close to one-half in Canada and Mexico, although the absolute levels remain higher in Mexico than Canada or the United States (see Figure 30 and Table A2.23). In the OECD ppGlobal scenario the decreases are even larger. These translate into lower exposure of the urban population to high levels of particulate matter (see Figure 31 and Table A2.24). This is primarily related to a reduction in key emissions, e.g. sulfur oxides, driven largely by stronger regulatory policies targeting urban air pollution.[23] There is some concern, though, that air quality will be negatively impacted by an increase in wildfire frequency due to climate change. For example, boreal forest fires in Alaska and Canada are expected have consequences for air quality in the central and eastern United States (Ryan et al. 2008).

The outlook is somewhat less sanguine for ground-level ozone, however. The OECD Baseline scenario projects a slight increase in average concentrations in urban areas in Canada and the United States, and almost no change in Mexico (see Figure 30 and Table A2.23).[24] The net result is a slight increase in the share of the urban population being exposed to higher levels of ozone concentrations (see Figure 31 and Table A2.24). A warmer climate is expected to contribute to increased ozone levels (Field, Mortsch et al. 2007), but was not included in these estimates, implying these are likely conservative estimates.

[21] GEO4 did not include projections for air quality.
[22] Measured as micrograms per cubic meter of PM_{10}, i.e., particulate matter smaller than 10 microns in diameter.
[23] The *OECD Environmental Outlook to 2030* describes different scenarios for assessing the emissions outlook for each country. The baseline, or reference scenario, accords with OECD knowledge of enacted legislation as of 2008, and assumes the difference in regulation between countries is maintained over the period of the scenario. As OECD countries, Canada, Mexico, and the United States are treated similarly in the policy scenarios. In the policy scenarios, regulatory differences are generally eliminated by the year 2030. See chapter 8 (pp. 177–195), for discussion of air pollution and policy scenarios. On p. 189, they indicate that "The policy simulations model development towards—but not quite reaching—maximum feasible reduction of air pollutants (as defined by the International Institute for Applied Systems Analysis). To keep the policies realistic, albeit ambitious, the model assumes that eventual emission levels for each country remain 3 to 14 percent above what could be achieved with Maximum Feasible Reduction (MFR)." On p. 190, they note that: "The speed of implementation of emission control options is assumed to range between 15 and 30 years. The implementation is assumed to take at least 15 years; large point sources and transport will see enhanced emission controls introduced first, with other, diffuse sources being addressed typically a decade later."
[24] No results are provided for ozone levels in the OECD policy scenarios.

FIGURE 29: AGRICULTURAL AREA WITH HIGH RISK OF SOIL EROSION RISK FROM WATER

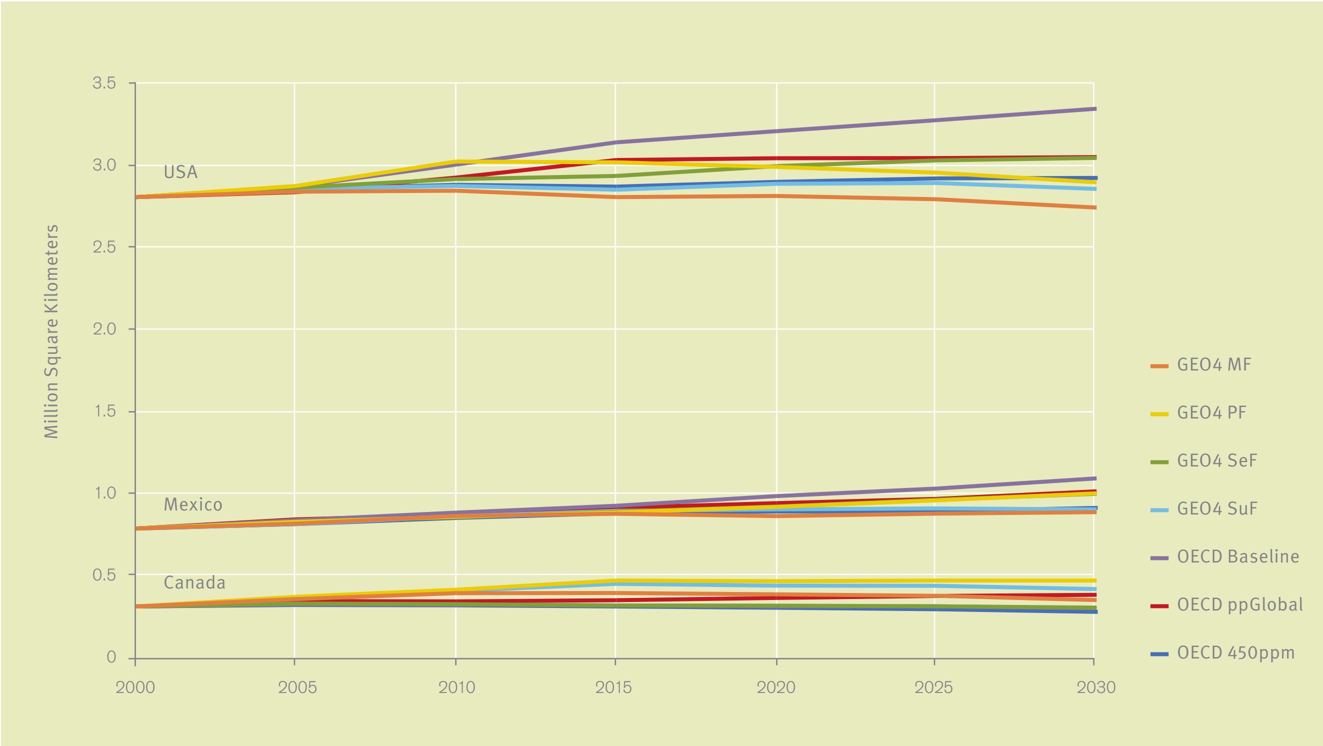
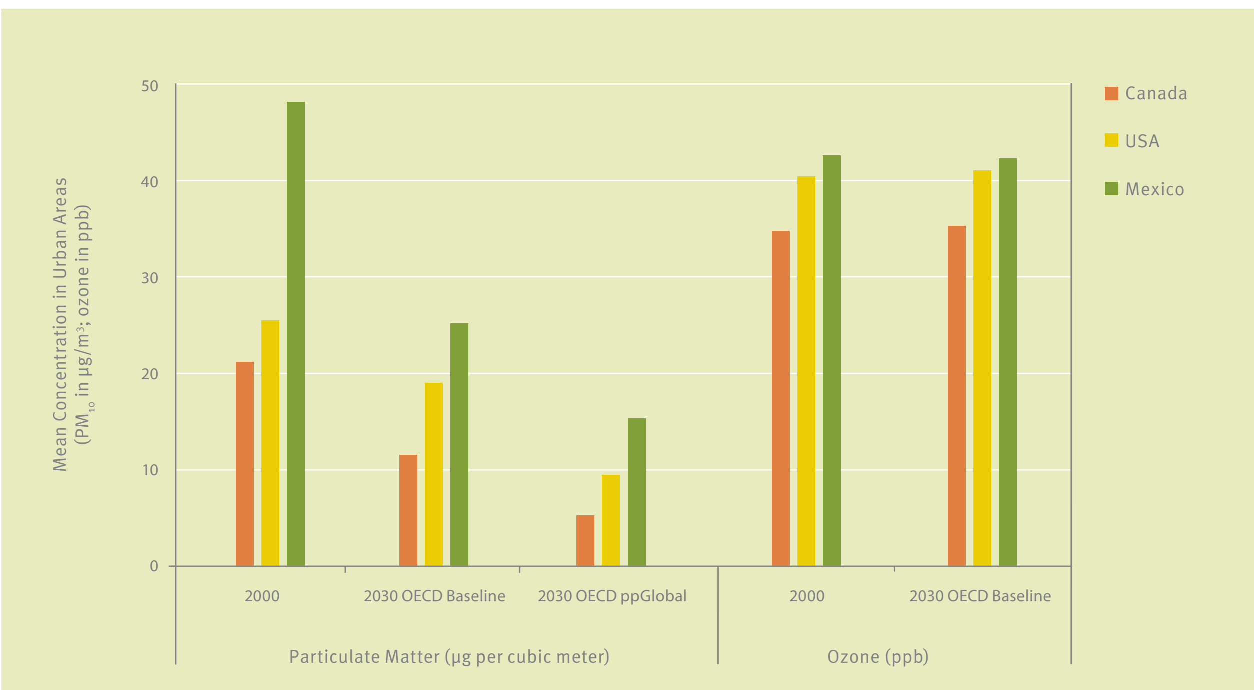


FIGURE 30: ANNUAL MEAN CONCENTRATIONS OF PARTICULATE MATTER AND TROPOSPHERIC OZONE IN URBAN AREAS, BY COUNTRY



6.5 WATER QUALITY AND QUANTITY

KEY POINTS:

- Increased water stress is expected across several parts of North America.
- Water quality may also be adversely affected by climate change.

No studies were found that took a detailed quantitative look at future water quality in the region. Still, a number of studies did consider the potential impact of various factors. The International Joint Commission (IJC 2006) noted that if shoreline development and urban sprawl go unabated around the Great Lakes, there will be a further degradation of water quality through increased runoff, air pollution, groundwater contamination, and reduced fish and wildlife habitat and wetlands. Various studies indicate that as a result of climate change, water shortages are projected to become more frequent in many parts of North America (e.g., southern Ontario, many regions of British Columbia, and the southwestern United States) (CENR 2008; Lemmen, Warren et al. 2008). It is also considered very likely that the trend toward reduced mountain snowpack and earlier spring snowmelt runoff peaks will continue across much of the western US (Lettenmaier, Major et al. 2008) and western Canada (Lemmen, Warren et al. 2008). This trend can be expected to lower water flows during the summer, with potentially adverse effects on agriculture. Increased water temperatures can be expected to have a negative impact on aquatic ecosystems and water quality across the continental United States. Water quality is also sensitive to changes in precipitation patterns. Expected increases in intense rain events will tend to result in the introduction of more sediment, nutrients, pathogens, and toxics into water bodies. However, most water quality changes are likely attributable to causes other than climate changes, such as pollutant loadings (Lettenmaier, Major et al. 2008).

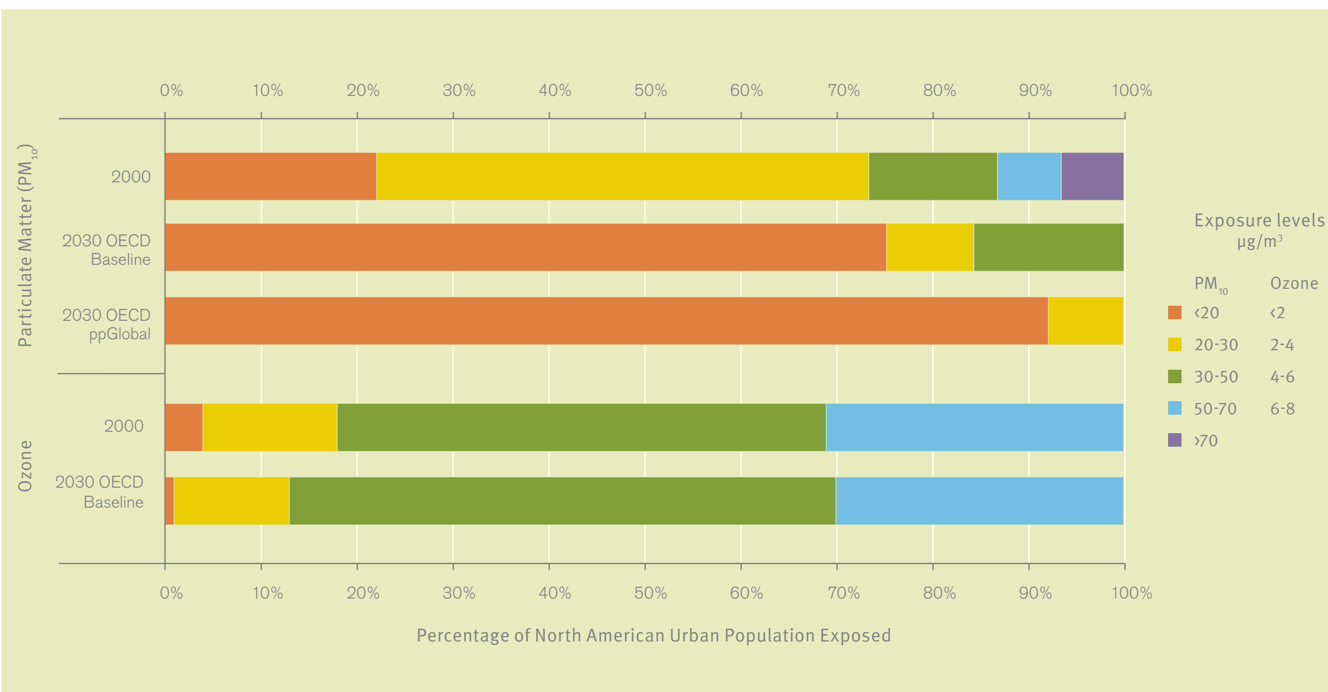
6.6 BIODIVERSITY

KEY POINTS:

- North America may see a further loss of 3 to 6 percent in mean terrestrial species abundance by 2030.
- Marine species in regions adjoining North America's coasts are expected to decline by slightly larger amounts.
- No projections were found related to freshwater biodiversity.

Changes in biodiversity are driven by a host of factors. Thus, in many ways, change in biodiversity acts as an integrated indicator of environmental impact. Furthermore, given its importance in the provision of ecological goods and services, it can also be seen as an indicator of the potential impacts of environmental degradation on human society. Vadgama, Nitze et al. note, however, that "given the paucity of baseline data on North American biodiversity and ecosystem dynamics, in particular, caution is required when projecting both the degree of change attributed to specific drivers and the resultant future condition. Nonetheless, it is possible to identify driver trajectories that point to likely biodiversity scenarios

FIGURE 31: NORTH AMERICAN URBAN POPULATION EXPOSED TO VARIOUS LEVELS OF PARTICULATE MATTER AND OZONE



at the ecosystem level" (2008, p. 58-59). In this section, we present results from recent studies that have attempted to do so for terrestrial and marine biodiversity. No projects were found related to freshwater biodiversity.

Terrestrial Biodiversity

Vadgama, Nitze et al. (2008) identify land use changes and the fragmentation of habitats, climate changes, the introduction of invasive species, and nitrogen deposition, which in turn are driven by underlying drivers related to population growth and economic activity, as key factors in driving changes in terrestrial biodiversity. With respect to climate change, warming will continue to result in shifts of species' ranges to the north and to higher altitudes, a particular problem for species that require higher-elevation habitat and that may have no options for migration (CENR 2008). Species' shifts will alter the structure, function and services of ecosystems. Ecosystem alternation will be enhanced where highly disturbed regions are colonized by invasive vegetation (CEC 2008). Vadgama, Nitze et al. (2008, p. 69) go on to note that, in general:

> Some species—those that are habitat or dietary specialists or have small range sizes—will have the least ability to adapt to the changing conditions…. Conversely, other groups of organisms such as microbes, insects, and invasive plants that reproduce rapidly and in large numbers are likely to be able to capitalize on the changes and become serious threats to native biodiversity, agricultural systems, and even human health.

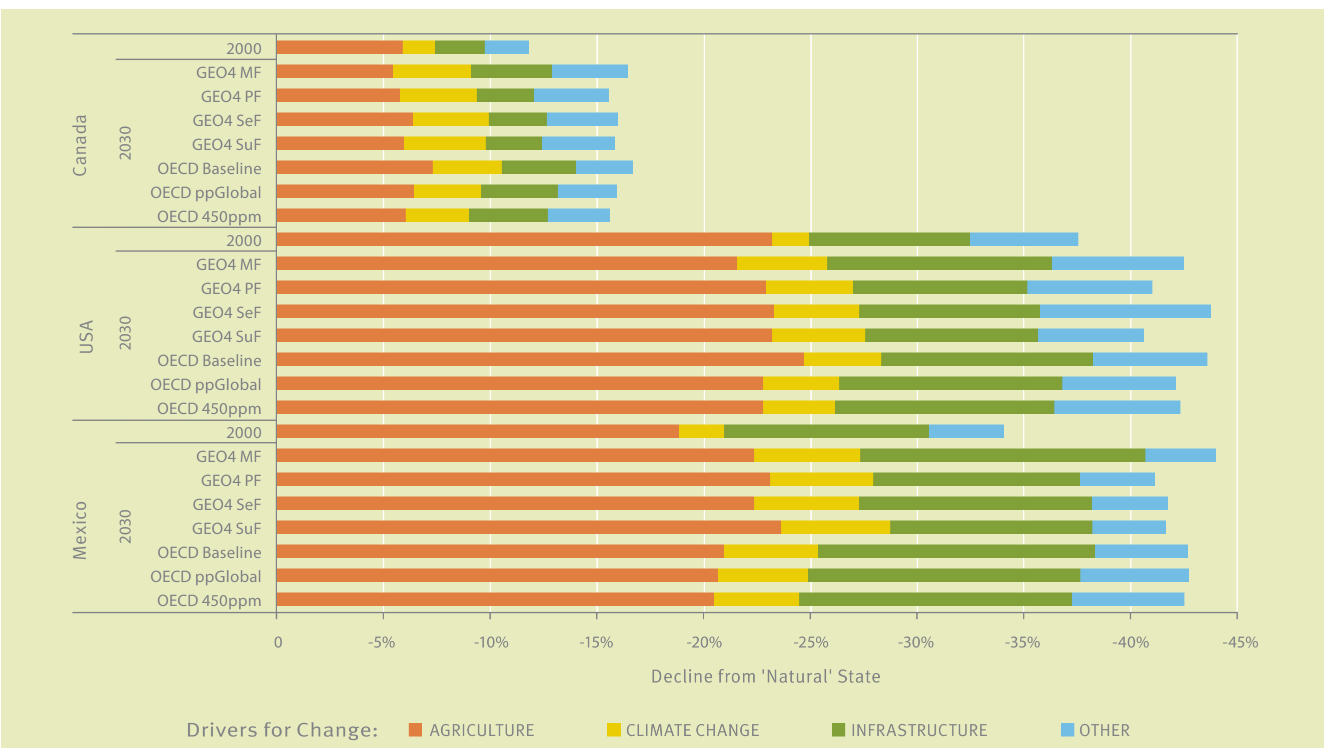
The same study goes ahead (p. 84) to predict that, "in 2025, North American ecosystems will be a composite of stalwart natives and eager transplants."

One of first efforts to make systemic projections of changes in terrestrial biodiversity was by Sala et al. (2000). More recently, a consortium of research institutes have developed the notion of mean species abundance (MSA), which attempts to capture the degree to which biodiversity, at a macro-biotic scale, remains unchanged. If the indicator is 100 percent, the biodiversity is similar to the natural or largely unaffected state. The MSA is calculated on the basis of estimated impacts of various human activities on biomes. A reduction in MSA, therefore, is less an exact count of species lost than an indicator that pressures have increased (OECD 2008).

The North American continent has already seen a significant decrease in terrestrial biodiversity estimated at around 25 percent in the year 2000, using mean species abundance as the measure (see Figure 32 and Table A2.25). The conversion of natural land for agricultural purposes has been the primary cause, but the expansion of human infrastructure, e.g. roads, has also played a significant role. Canada has experienced less decline, reflecting its large landmass and relatively small population.

A further loss of another 4–6 percent is expected in North America by 2030, with more significant losses, particularly in Mexico—one of the most biologically diverse countries on Earth. The major contributing factors to this further decline are climate change and expanding infrastructure—urbanization, transportation networks,

FIGURE 32: DECLINES IN MEAN TERRESTRIAL SPECIES' ABUNDANCE, BY COUNTRY



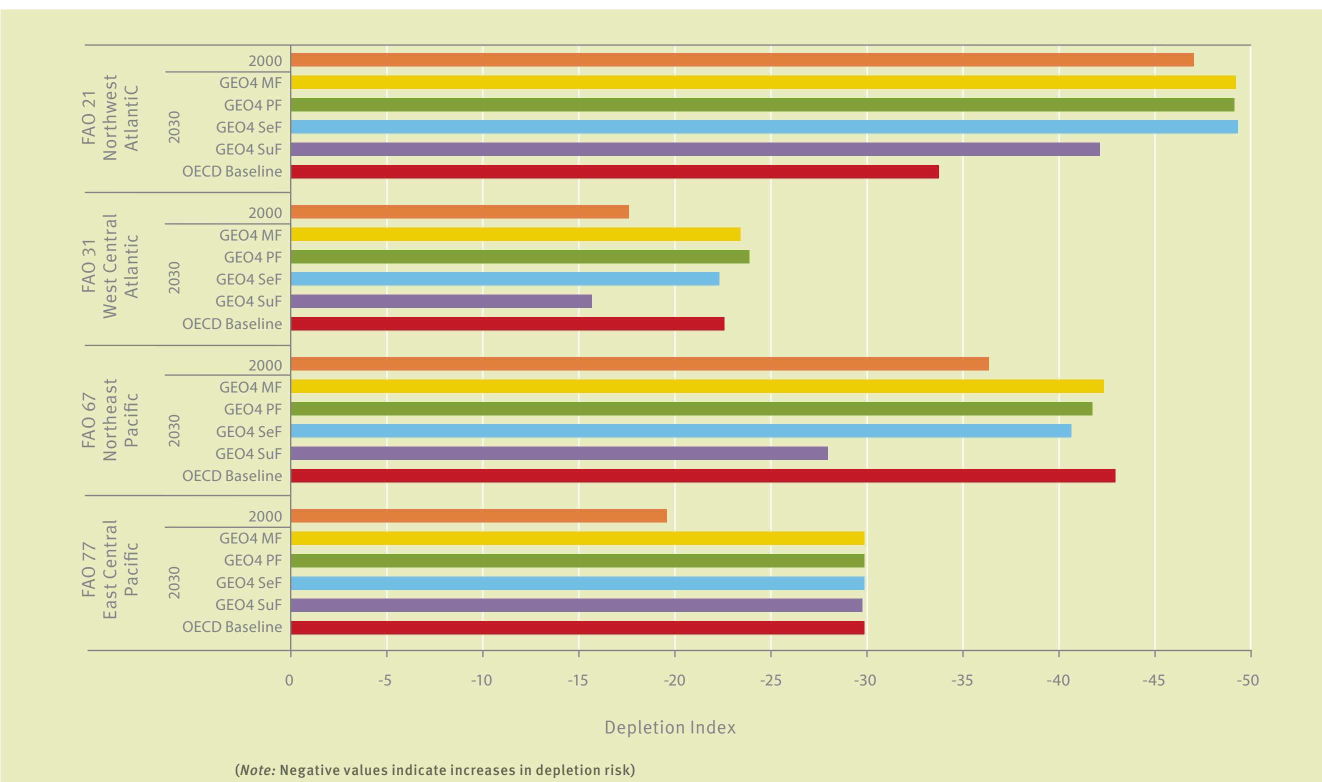
construction related to resource exploitation and other elements of human settlement. There is some further decrease due to the expansion of agriculture, but this occurs almost exclusively in Mexico. Looking closely at the results, it can be seen that the direct impact of climate change on biodiversity will be hard to address in the short term. Policies related to the development of infrastructure, however, can have a significant effect over this period. A key policy issue underlying the results presented here is that of protected areas, not only their extent, but also the actual degree of protection offered.

Marine

The increases in fishing pressure and nitrogen loadings, along with other environmental pressures will have a major negative impact on marine biodiversity. Vadgama, Nitze et al. (2008, p. 55) note that by 2025, three-quarters of the US population will live in coastal areas. The warming of the oceans with climate change will cause some species to shift their locations; those that cannot move within the time frame in which these changes are occurring, e.g., coastal reefs and associated species, will be adversely affected. A more recent concern is the extent to which marine ecosystems will be affected by ocean acidification resulting from the increasing levels of carbon dioxide being absorbed by ocean waters (CENR 2008).

The Fisheries Centre at the University of British Columbia has developed a marine equivalent to the MSA, the depletion index (DI) (Alder, Guénette et al. 2007). This indicator takes into account both the actual declines in biomass and the capacity of different species to respond to fishing pressure. Figure 33 and Table A2.26 present estimates of the changes in DI for four of the FAO marine areas bordering North America for the GEO4 and OECD baseline scenarios.[25] These show an already substantial level of depletion, particularly in the Northwest Atlantic. While most scenarios show further depletion in all regions, the GEO4 Sustainability First scenario indicates some recovery in all but the East Central Pacific. This reflects, among other things, the lower levels of exploitation in this scenario. As for the Northwest Atlantic Region, relatively small increases in depletion risk are projected in three of the GEO4 scenarios, with improvements projected not only in GEO4 SuF but also in the OECD Baseline scenarios.

FIGURE 33: CHANGES IN THE CALCULATED MARINE SPECIES DEPLETION INDEX FROM HISTORIC LEVELS



[25] See footnote 14.

7

Photo: Harry Mills

CHAPTER 7
Impacts: How Environmental Change Affects Socio-economic Conditions

7.1 INTRODUCTION

The environmental changes described above can be expected to have significant impacts on socio-economic conditions in North America and elsewhere. Given the complexity of the relationships between human and natural systems, though, there have been only limited attempts to make quantitative estimates of the socio-economic impacts of environmental change. In part, this is because these impacts will be mediated by many other factors, not the least by the meta-forces and societal changes noted earlier, along with the human capacity for adaptation. It should also be noted that no studies have truly 'closed the loop' by factoring the feedback from environmental change into the socio-economic changes that themselves drive environmental change.

Still, there have been increasing efforts in this realm. Here we review recent estimates related to water stress and the health effects of urban air pollution. We complement this with a presentation of potential impacts related to climate change.

7.2 POPULATION LIVING IN AREAS FACING SEVERE WATER STRESS

KEY POINTS:
- All scenarios project an increase in the number of persons living in areas facing water stress in North America even as the absolute percentage falls. The range is from an additional 3 to 70 million persons.
- Mexico will see the most consistent increase, ranging from 12 to 17 million persons.

As with any resource, an increase in the demand for freshwater without a concomitant increase in supply will result in increased competition. This is explored in GEO4 and the *OECD Environmental Outlook to 2030* using the concept of water stress, which considers the relationship between annual withdrawals and renewable supplies. Estimates for 2005 indicate that approximately 40 percent of North Americans, or 170 million people, live in river basins facing severe water stress.[26] This includes more than 50 percent of the Mexican population and much of the southwestern United States. The values are much lower in Canada.

FIGURE 34: WATER STRESS, BY COUNTRY

[26]Severe water stress is defined as a situation where withdrawals exceed 40 percent of renewable resources. It is assumed that the higher the levels of water stress the more likely that chronic or acute water shortages will occur.

In the OECD Baseline and ppGlobal scenarios, the percentage is projected to stay roughly the same from the present to 2030, but this still implies an additional 20 to 30 million people facing severe water stress by that date (see Figure 34 and Table A2.27). The reduced demands, even when combined with the slower population growth projected by the GEO4 PF and GEO4 SuF scenarios, are not able to fully counteract the expected negative impacts of climate change.[27] An additional 3 to 8 million persons will face severe water stress by 2030 according to these scenarios, even as the percentage falls. The faster population growth and increased demands considered in GEO4 SeF lead to projections of closer to 50 percent of the population of North America—more than 240 million persons, or 70 million more than at present—living in river basins that face severe water stress.

7.3 HEALTH EFFECTS OF URBAN AIR POLLUTION

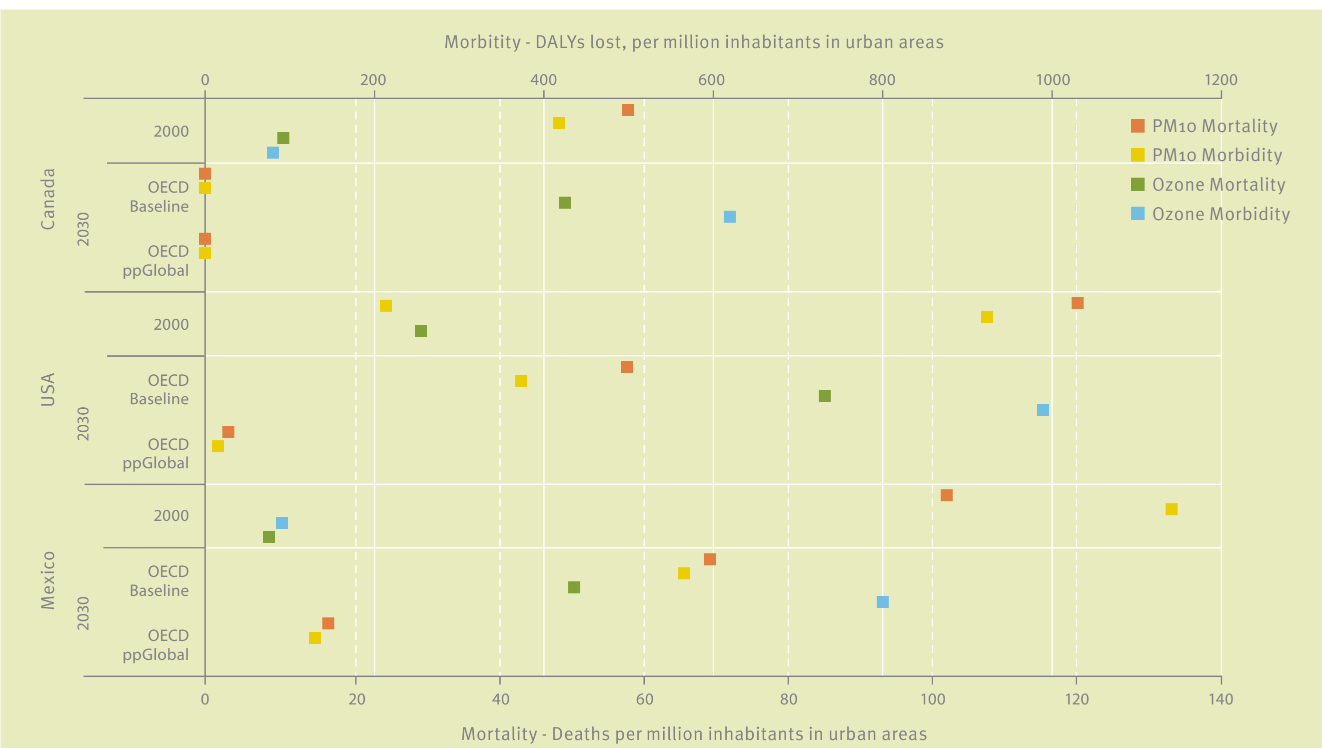
KEY POINTS:

- Significant reductions are expected in morbidity and mortality related to particulate matter.
- Significant increases are expected in morbidity and mortality related to ground-level ozone. This is primarily due to a lack of improvement in ozone levels and the growth in urban populations and increases in the number of elderly.

The changes in exposure to particulate matter and ground-level ozone discussed earlier can be expected to lead to shifts in mortality and morbidity associated with these pollutants. Figure 35 and Table A2.28 present estimates of the magnitude of these changes from the OECD Baseline and ppGlobal scenarios. Significant decreases are expected in mortality and morbidity from causes related to particulate matter from 2000 to 2030. The OECD Baseline scenario projects a reduction around 50 percent in North America and the projection of the OECD ppGlobal scenario approaches 95 percent. These reductions are seen in all three countries.

With respect to ground-level ozone, however, the lack of improvement in exposure levels, combined with the increase in total urban populations and the rising average age of the population, are expected to lead to increasing rates of mortality and morbidity. In the OECD Baseline scenario, the only one for which estimates are provided, North America is projected to experience a 3- to 4-fold increase in mortality rates and 5- to 6-fold increase in morbidity rates. All three countries are similarly affected.

FIGURE 35: HEALTH EFFECTS FROM URBAN AIR POLLUTION



[27] As we saw in Section 3.2, the scenarios differ little in their projection of actual changes in climate and, therefore, in total water availability, over the period to 2030. Thus, the differences in water stress primarily reflect differences in withdrawals.

7.4 CLIMATE CHANGE IMPACTS

KEY POINTS:

- Climate change is expected to have potentially significant impacts on human health as well as on society and the economy.

Figure 2 presented general examples of impacts associated with increasing temperatures related to climate change. As noted, though, the effects of climate change will be manifested in more ways than just temperature changes. Furthermore, the magnitude of these effects will differ by region, as will the vulnerability of different regions and sectors of society. A number of studies have considered the potential socio-economic implications of climate change in North America. While the severity of these impacts, and therefore their socio-economic costs, may be difficult to estimate in many cases, the nature of the impacts is easier to identify. Here, we summarize some of the key conclusions from these studies.

On balance, the socio-economic impacts of environmental change are expected to be negative, but this will differ significantly across sectors and regions (Ruth, Coelho et al. 2007). These are separated into impacts on human health and other socio-economic impacts, reflecting the categories used in many of the studies considered.

The negative impact of strained water resources on agricultural production throughout North America is expected to be in the billions of dollars.

Impacts on Human Health

- More intense and prolonged heat waves are likely (UNEP 2007). There is likely to be a substantial increase in health risks from heat waves in the Midwestern states because of demographic shifts yielding more vulnerable populations and an infrastructure no longer adequate to withstand severe heat (Ebi and Meehl 2007).
- Increased smog episodes can be expected in some locations (UNEP 2007). In the eastern United States, ozone-related deaths from climate change could increase by approximately 4.5 percent from the 1990s to the 2050s (Field, Mortsch et al. 2007). Health problems would be exacerbated in cities subject to atmospheric inversions, such as Mexico City (Magrin, Gay García et al. 2007).
- An increase in water- and food-borne contamination, and diseases transmitted by insects (such as Lyme disease, West Nile virus and hantavirus pulmonary syndrome) may occur in some locations (UNEP 2007). This would include an increase in the population at risk from malaria and dengue fever in Mexico (Magrin, Gay García et al. 2007).
- Many cities of Latin America, which are already vulnerable to landslides and mudflows, are very likely to suffer the exacerbation of extreme events, with increasing risks/hazards for local populations (Magrin, Gay García et al. 2007).

Other Socio-economic Impacts

- In northern Canada and Alaska, climate-induced changes in permafrost, sea ice, lake ice and snow cover have large and costly implications for infrastructure maintenance and design (Lemmen, Warren et al. 2008).
- Climate change will continue to exacerbate existing stresses on the forest industry (Lemmen, Warren et al. 2008). Climate change is expected to extend the forest fire season (Field, Mortsch et al. 2007), while warmer temperatures overall will facilitate the spread of forest pests, such as the pine beetle.
- There is expected to be a mixed impact on fisheries, with cold-water fisheries likely to be negatively affected, showing gains in the north and losses in the southern portions of ranges, while warm-water fisheries may gain (Field, Mortsch et al. 2007).
- Impacts on agriculture will likely be mixed across North America. Drought is projected to occur more frequently in the Canadian Prairies, the West Coast, and the southwestern United States (Lemmen, Warren et al. 2008). The negative impact of strained water resources on agricultural production throughout North America is expected to be in the billions of dollars (Ruth, Coelho et al. 2007). At the same time, initial, moderate climate change is projected to increase yields from rain-fed agriculture, specifically in parts of the United States and Canada (Field, Mortsch et al. 2007).
- Transportation along the Gulf of Mexico and Atlantic coasts will be impacted by increased damages from coastal storm events, aggravated by slowly-rising sea levels. A drop in water levels in the Great Lakes and the St. Lawrence will impact shipping lanes and hydroelectric production (Field, Mortsch et al. 2007).
- Increasing windstorms and projected sea-level rise, will affect coastal tourism revenues (Magrin, Gay García et al. 2007).
- Declines or shifts in species' populations and distributions, and other changes, will present unique challenges for many Arctic Aboriginal communities in maintaining and protecting their traditional and subsistence ways of life (Lemmen, Warren et al. 2008).

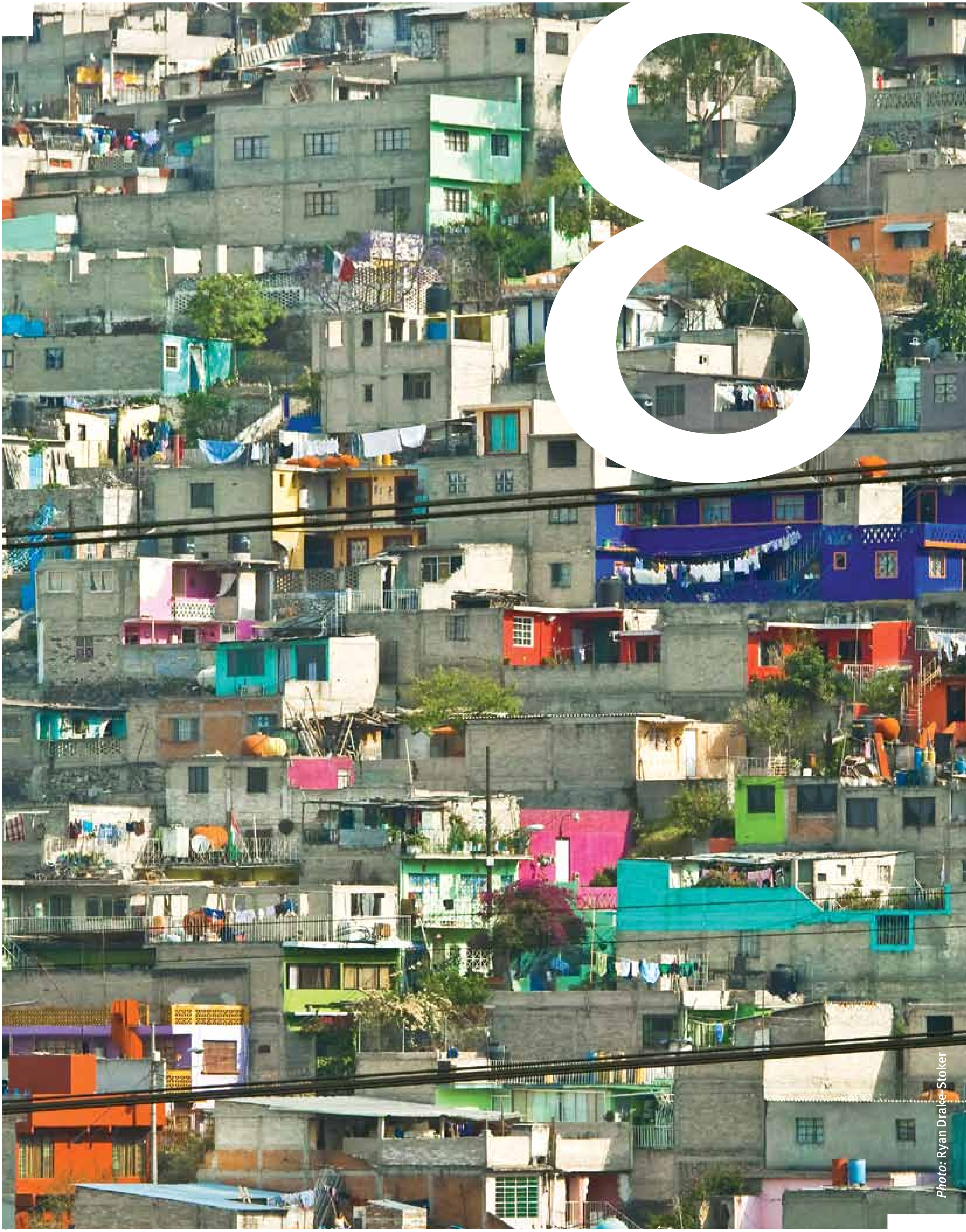


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Photo: Ryan Drake-Stoker

CHAPTER 8
Conclusions

The future is, and always will be, the realm of the unknown. Still, there is much to be gained from trying to understand the range of possibilities, not only to prepare for what may be ahead but, just as importantly, to take action to chart a course toward more desirable futures. In this report, we have reviewed what recent studies have had to say about the future of the North American environment projected to the year 2030. Although two decades hence, the year 2030 is well within the planning and policy horizons of many segments of society. The decisions we make today, and those we have made in recent years, will go a long way toward determining the kind of environment and the related social, economic and environmental challenges that will exist at that time.

Trying to see into the future is fraught with uncertainties. These include not only uncertainties about the workings of natural and social systems, but also about the choices that will be made by individuals and society as a whole. Thus, it is not surprising that there are only a limited number of studies that have made the attempt to examine the future of the environment in a structured fashion. Those that we have reviewed address the issue of uncertainty, in part, by positing plausible scenarios of the future. These are not predictions, but instead represent conditional projections based upon current knowledge and sets of assumptions about a range of developments, most importantly, societal choices.

Recognizing the limited set of available studies and the limitations in projecting the future in general, some key messages can still be drawn from this review. These can be grouped into three categories:

There is a range of variation in the projections for many environmental issues and their drivers.

The studies reviewed here, and the various scenarios they present, differ in terms of their assumptions about the choices we make, both as individuals and society. A wider range of variation, in both the assumptions and the outcomes, points to aspects where our actions can make a more significant impact out to the year 2030. Those issues with the greatest variation in projections across the scenarios include:
- Energy use and associated emissions
- Water use and treatment of wastewater

Significant changes, representing significant challenges, can be expected in a number of environmental issues and their drivers

Significance here refers not only to the magnitude of a change, but also to its direction and persistence, the extent to which it approaches or exceeds critical thresholds, and the impacts it has upon society. The most important challenges are likely to include:
- Continued and accelerated warming, particularly in the Arctic
- Continued loss of terrestrial biodiversity
- Persistence of elevated levels of ground-level ozone in urban areas

There exist important gaps in the existing knowledge base concerning environmental futures

Recognizing that attempting to predict the future is a fool's errand, there is still much to be learned from considering the possibilities. To the extent that important issues have not received attention, they are less likely to receive consideration in the actions we take, including the policies we develop. Among those issues that deserve greater attention are:
- The growth in urban and built-up land area
- Freshwater quality and groundwater availability and quality
- The specific economic and health effects of environmental change
- The impact of consumption in North America on the environment in other regions and vice versa

These point to an interlinked set of actions for consideration—addressing those changes that are amenable to policy action in the near-term, preparing for those changes that are almost inevitable over the short-term but are amenable to policy action in the longer-term, and strengthening our knowledge concerning those changes about which we know the least.

REFERENCES

Akimoto, H. 2003. Global Air Quality and Pollution. *Science* **302**(5651): 1716–19.

Alder, J., S. Guénette, et al. 2007. Ecosystem-based Global Fishing Policy Scenarios. **15**: 91. Vancouver, Canada: University of British Columbia, The Fisheries Centre.

Alig, R., S. Plantinga, and J. Kline. 2003. Land use changes involving forestry for the United States: 1952 to 1997, with projections to 2050, general technical report 587. Portland, OR: US Department of Agriculture, Forest Service Pacific Northwest Research Station.

Ash, N. and A. Fazel. 2007. Biodiversity. *Global Environment Outlook 4: Environment for Development.* Nairobi: United Nations Environment Programme, pp. 157–92.

Bakkes, J. A. and P. R. Bosch, et al. 2008. *Background Report to the OECD Environmental Outlook to 2030: Overviews, Details, and Methodology of Model-Based Analysis.* Bilthoven, The Netherlands: Netherlands Environmental Assessment Agency.

CEC. 2000. Background Note #4 Booming Economies, Silencing Environments and the Paths to Our Future. Montreal: Commission for Environmental Cooperation, p. 48.

____. 2008. *The North American Mosaic: An Overview of Key Environmental Issues.* Montreal: Commission for Environmental Cooperation, p. 62.

CENR. 2008. *Scientific Assessment of the Effects of Global Change on the United States.* Washington, DC: National Science and Technology Council, Committee on Environment and Natural Resources, US Climate Change Science Program.

Chertow, M.R. 2001. The IPAT Equation and Its Variants. *Journal of Industrial Ecology* **4**(4): 13–29.

Dent, D. 2007. Land. *Global Environment Outlook 4: Environment for Development.* Nairobi: United Nations Environment Programme, pp. 81–114.

Ewing, B., S. Goldfinger, et al. 2008. *The Ecological Footprint Atlas 2008*. Oakland: Global Footprint Network, p. 81.

FAO. 2007. *The State of World Fisheries and Aquaculture 2006*. Rome: United Nations Food and Agricultural Organization, p. 162.

Field, C. B., Mortsch, L.D., et al. 2007. North America. *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.* M. L. Parry, O. F. Canziani, J. P. Palutikof, P. J. van der Linden and C. E. Hanson. Cambridge, Cambridge University Press, pp. 617–52.

Halpern, B. S., S. Walbridge, et al. 2008. A Global Map of Human Impact on Marine Ecosystems. *Science* **319**(5865): 948–52.

Hansen, J. 2008. Testimony to US Congress. <http://www.columbia.edu/~jeh1/2008/TwentyYearsLater_20080623.pdf>.

Homer-Dixon, T. 2008. Complexity, Crisis, and Creativity: Meeting the Challenges of the Age of Nature. *North America 2030: An Environmental Outlook.* Ottawa: Commission for Environmental Cooperation, Joint Public Advisory Committee.

IJC. 2006. *13th Biennial Report on Geat Lakes Water Quality.* Ottawa and Washington, DC: International Joint Commission.

INAC. 2003. *Canadian Arctic Contaminants Assessment Report II: Highlights.* Ottawa: Indian and Northern Affairs Canada, p. 118.

IPCC. 2000. *Emission Scenarios.* Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press.

____. 2007. *Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.* Geneva, IPCC.

ITTO. 2006. *Status of Tropical Forest Management 2005*. ITTO Technical Series No 24. Yokohama, Japan: International Tropical Timber Organization, p. 302.

Karl, T. R., G. A. Meehl, et al., eds. 2008. *Weather and Climate Extremes in a Changing Climate. Regions of Focus: North America, Hawaii, Caribbean, and U.S. Pacific Islands, Synthesis and Assessment Product 3.3.* Washington, DC: Department of Commerce, NOAA's National Climatic Data Center, US Climate Change Science Program and the Subcommittee on Global Change Research.

Kelleher, K. 2005. *Discards in the World's Marine Fisheries: An Update*. Rome: United Nations Food and Agricultural Organization, p. 131.

Kuylenstierna, J. C. I. and T. S. Panwar. 2007. Atmosphere. *Global Environment Outlook 4: Environment for Development.* Nairobi: United Nations Environment Programme, p. 39–80.

Lemmen, D. S., F. J. Warren, et al., eds. 2008. *From Impacts to Adaptation: Canada in a Changing Climate 2007.* Ottawa: Natural Resources Canada, Climate Change Impacts and Adaptation Division.

Lettenmaier, D., D. Major *et al.*, "Water Resources", en P. Backlund, A. Janetos, D. Schimel *et al.*, *The Effects of Climate Change on Agriculture, Land Resources, Water resources, and Biodiversity in the United States. A Report by the US Climate Change Science Program and the Subcommittee on Global Change Research*, US Department of Agriculture, Washington, DC, 2008, pp. 121-150.

Lettenmaier, D., D. Major, et al. 2008. Water Resources. *The Effects of Climate Change on Agriculture, Land Resources, Water Resources, and Biodiversity in the United States. A Report by the US Climate Change Science Program and the Subcommittee on Global Change Research.* P. Backlund, A. Janetos, D. Schimel et al. Washington, DC: US Department of Agriculture, pp. 121–50.

MA. 2005. *Ecosystems and Human Well-being: Synthesis.* Millenium Ecosystem Assessment. Washington, DC: Island Press.

Magrin, G., C. Gay García, et al. 2007. Latin America. *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.* M. L. Parry, O. F. Canziani, J. P. Palutikof, P. J. van der Linden and C. E. Hanson. Cambridge: Cambridge University Press, pp. 581–615.

McBean, G. 2008. Global Environmental Change: A Challenge for North America. *North America 2030: An Environmental Outlook.* Montreal: Commission for Environmental Cooperation , Joint Public Advisory Committee.

Murawski, S., R. Methot, et al. 2007. Biodiversity Loss in the Ocean: How Bad Is It? *Science* **316**(5829): pp. 1281b–1284.

NEB. 2007. *Canada's Energy Future: Reference Case and Scenarios to 2030.* National Energy Board. Calgary, Alberta.

Nowak, D.J. and J.T. Walton. 2005. Projected Urban Growth (2000–2050) and Its Estimated Impact on the US Forest Resource. *Journal of Forestry.* December, pp. 383–89.

OECD. 2008. *OECD Environmental Outlook to 2030.* Paris: Organization for Economic Cooperation and Development.

OECD/IEA. 2008. *World Energy Outlook 2008.* Paris: OECD, International Energy Agency.

Pauly, D., R. Watson, et al. 2005. Global trends in world fisheries: impacts on marine ecosystems and food security. *Philosophical Transactions of the Royal Society B: Biological Sciences* **360**(1453): 5–12.

Rothman, D. S., J. Agard, et al. 2007. The Future Today. *Global Environment Outlook 4: Environment for Development.* Nairobi: United Nations Environment Programme, pp. 397–454.

Ruth, M., D. Coelho, et al. 2007. *The US Economic Impacts of Climate Change and the Costs of Inaction*. College Park, MD: University of Maryland, Center for Integrative Environmental Research (CIER), p. 48.

Ryan, M. G., S.R. Archer, R. Birdsey, C. Dahm, L. Heath, J. Hicke, D. Hollinger, T. Huxman, G. Okin, R. Oren,J. Randerson, and W. Schlesinger. 2008. Land Resources: Forests and Arid Lands. *The Effects of Climate Change on Agriculture, Land Resources, Water Resources, and Biodiversity in the United States. A Report by the US Climate Change Science Program and the Subcommittee on Global Change Research.* P. Backlund, A. Janetos, D. Schimel et al. Washington, DC: US Department of Agriculture, pp. 75–120.

Sala, O. E., F. S. Chapin III, et al. 2000. Global Biodiversity Scenarios for the Year 2100. *Science* **287**(5459): 1770–74.

Sanderson, E. W., M. Jaiteh, et al. 2002. The Human Footprint and the Last of the Wild. *BioScience* **52**(10): 891–904.

Smeets, E. and R. Wetering. 1999. Environmental Indicators: Typology and overview. Copenhagen: European Environmental Agency: p. 19.

Smil, V. 2008. *Global Catastrophes and Trends: The Next Fifty Years.* Cambridge, MA: The MIT Press.

Stratos Inc. and IISD. 2008. North America 2030: An Environmental Outlook—Discussion Paper. Montreal: Stratos Inc. and International Institute for Sustainable Development, p. 25.

Turner II, B. L., W. C. Clark, et al., eds. 1990. *The Earth as Transformed by Human Action: Global and Regional Changes in the Biosphere over the Past 300 Years.* Cambridge: Cambridge University Press.

US EIA. 2008. *International Energy Outlook 2008.* Washington, DC: US Department of Energy, Energy Information Administration, Office of Integrated Analysis and Forecasting.

UNEP. 2007. *Global Environmental Outlook 4: Environment for Development.* Nairobi: United Nations Environment Programme.

UNPD. 2007. *World Population Prospects: The 2006 Revision*, *Highlights*. New York: United Nations Population Division.

____. 2008. *World Urbanization Prospects: The 2007 Revision, Highlights.* New York: United Nations Population Division.

Vadgama, J., W. A. Nitze, et al. 2008. Outlook for the Environment. *The Future of North America 2025: Outlook and Recommendations.* A. B. Peschard-Sverdrup. Washington, DC: The CSIS Press: pp. 1–85.

Wilkening, K. E., L. A. Barrie, et al. 2000. Trans-Pacific Air Pollution. *Science* **290**(5489): 65–67.

Wilson, D. and R. Purushothaman. 2003. *Dreaming with BRICs: The Path to 2050.* New York: The Goldman Sachs Group, Inc. p. 23.

Worm, B., E. B. Barbier, et al. 2006. Impacts of Biodiversity Loss on Ocean Ecosystem Services. *Science* **314**(5800): 787–90.

Worm, B., E. B. Barbier, et al. 2007. Response to Comments on "Impacts of Biodiversity Loss on Ocean Ecosystem Services." *Science* **316**(5829): 1285d.

ANNEX 1
Key Studies

ORGANIZATION FOR ENVIRONMENTAL COOPERATION AND DEVELOPMENT

Environmental Outlook to 2030

The Organization for Economic Cooperation and Development's *OECD Environmental Outlook to 2030* was released in spring 2008 (OECD 2008) and a further background report was released shortly thereafter (Bakkes, Bosch et al. 2008).[28]

The *OECD Environmental Outlook* is built around a baseline reference scenario (OECD Baseline), which is described as:

> a stylised picture of the environmental developments in the next decades. Its hypothesis is no new policies in response to environmental pressures—as well as no new policies on subsidies in agricultural production and on tariffs in agricultural trade. (Bakkes and Bosch et al. 2008, p. 18)

Various policy package (pp) 'variants' are explored that relate to, for example, local and regional air pollution, greenhouse gas emissions, and agricultural support. These include "policy packages with successively broadening participation: OECD only; OECD+BRIC and OECD+BRIC+Rest of the World" and separate climate change options (Bakkes, Bosch et al. 2008, p. 19). In this report we focus on the more stringent variants: the OECD+BRIC+Rest of the World comprehensive policy package, referred to here as OECD ppGlobal, and the climate change option reflecting policies needed to stabilize atmospheric concentration at 450 parts per million by volume of carbon dioxide equivalents, referred to here as OECD 450 ppm, as these provide the largest contrast to the OECD Baseline.

The OECD is careful to note that the OECD ppGlobal scenario:

> does not attempt to reflect an "ideal" or "comprehensive" package of environmental policies. Instead, it reflects a combination of a limited set of policies that: *a)* cut across many of the main environmental challenges identified in the *Outlook*; and *b)* can be simulated in the modelling framework used for the *Outlook*. It does not, however, include any policies explicitly aimed at protecting biodiversity or enhancing agricultural technology uptake, for example. The EO policy package has been designed to be reasonably politically and practically realistic in terms of its scope, phasing the policies in over time, and with some consideration of regional capacity. (OECD 2008, p. 438)

The OECD 450ppm variant is described as follows:

> This policy simulation is chosen to demonstrate the level of effort required to stabilise atmospheric concentrations of GHG at 450 ppm CO_2eq (referred to below as 450 ppm) and limit global mean temperature change to near 2˚C over the long-term. It provides insights into possible mitigation costs for this aggressive mitigation pathway. It simulates an emission reduction pathway across all world regions in a "least-cost" manner across all sources (and sinks) of greenhouse gas emissions. In addition to cost and effectiveness, the simulation also reviews the technologies needed to achieve this aggressive stabilisation target (see Chapter 17). This allows us to understand what technologies and sources of greenhouse gases are expected to offer the most cost-effective means of reducing emissions significantly over the coming decades. The tax that was applied for this simulation increases from US$2.4 per tonne of CO_2eq in 2010 to US$155 in 2050 (in constant 2001 US$). (OECD 2008, p. 155)

The OECD presents a synopsis of key environmental impacts by region for the various policy variants explored (Bakkes, Bosch et al. 2008, p. 29). This is reproduced below.

[28] Special thanks is extended to Rob Visser of the OECD and Jan Bakkes of the Netherlands Environmental Assessment Agency, who provided us with detailed model runs including data not explicitly presented in either of these published reports.

TABLE A1.1: Synopsis of Environmental Impacts by Regional Cluster in OECD Environmental Outlook

		NAM	EUR	JPK	ANZ	BRA	RUS	SOA	CHN	MEA	OAS	ECA	OLC	AFR	World
CLIMATE CHANGE Temperature change and rate of temperature change	*Baseline*	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	ppOECD	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	ppOECD + BRIC	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	ppGlobal	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	450 ppm	Orange	Orange	Orange	Orange	Orange	Red	Red	Orange	Orange	Orange	Orange	Orange	Orange	Orange
ATMOSPHERE Excess mortality attribuable to urban air pollution by PM_{10}	*Baseline*	Orange	Orange	Orange	Green	Orange	Green	Red	Red	Red	Red	Orange	Orange	Orange	Red
	ppOECD	Green	Green	Orange	Green	Orange	Green	Red	Red	Red	Red	Orange	Orange	Orange	Red
	ppOECD + BRIC	Green	Green	Orange	Green	Green	Green	Orange	Orange	Red	Red	Orange	Orange	Orange	Orange
	ppGlobal	Green	Green	Orange	Green	Green	Green	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange
NUTRIENT LOADING Agricultural nitrogen losses and nitrogen load at river mouths	*Baseline*	Orange	Orange	Orange	Orange	Orange	Orange	Red	Red	Red	Orange	Grey	Red	Orange	Orange
	ppGlobal	Green	Green	Green	Orange	Red	Orange	Red	Red	Red	Red	Grey	Red	Red	Orange
BIODIVERSITY Mean Species Abundance	*Baseline*	Red	Red	Red	Orange	Red	Orange	Red	Red	Orange	Red	Red	Red	Red	Red
	ppOECD	Red	Red	Red	Orange	Red	Orange	Red	Red	Orange	Red	Red	Red	Red	Red
	ppOECD + BRIC	Red	Red	Red	Orange	Red	Orange	Red	Red	Orange	Red	Red	Red	Red	Red
	ppGlobal	Red	Red	Red	Orange	Red	Orange	Red	Red	Orange	Red	Red	Red	Red	Red
LAND USE Change in agricultural land area	*Baseline*	Orange	Orange	Green	Orange	Orange	Orange	Red	Orange	Green	Red	Orange	Orange	Red	Orange
	ppOECD	Orange	Orange	Green	Orange	Orange	Orange	Red	Orange	Green	Red	Orange	Orange	Red	Orange
	ppOECD + BRIC	Green	Orange	Green	Orange	Red	Orange	Red	Orange	Green	Red	Orange	Orange	Red	Orange
	ppGlobal	Green	Orange	Green	Orange	Red	Orange	Red	Orange	Green	Red	Orange	Red	Red	Orange
FRESH WATER Population living in areas under severe water stress	*Baseline*	Orange	Orange	Orange	Orange	Orange	Orange	Red	Red	Red	Red	Orange	Orange	Red	Orange
	ppGlobal	Orange	Orange	Orange	Orange	Orange	Orange	Red	Red	Red	Red	Orange	Orange	Red	Orange
FORESTS Change in natural forest area	*Baseline*	Orange	Orange	Orange	Red	Orange	Orange	Red	Red	Grey	Orange	Red	Orange	Red	Orange
	ppOECD	Orange	Orange	Orange	Red	Orange	Orange	Red	Red	Grey	Orange	Red	Orange	Red	Orange
	ppOECD + BRIC	Orange	Orange	Orange	Red	Red	Orange	Red	Red	Grey	Orange	Red	Orange	Red	Orange
	ppGlobal	Orange	Orange	Orange	Red	Red	Orange	Red	Red	Grey	Orange	Red	Orange	Red	Orange

LEGEND

- Red: increase of a large problem in the context of internationally articulated objectives
- Orange: intermediate situations, including hotspots or situations getting worse before getting better
- Green: significant decrease in problem
- Grey: inconclusive

Source: *OECD Environmental Outlook* modelling suite, final output from IMAGE cluster (given in Bakkes and Bosch et al. 2008, p. 29)

Notes: NAM = North America; EUR = OECD Europe; JPK = OECD Asia; ANZ = OECD Pacific; BRA = Brazil; RUS = Russia & Caucasus; SOA = South Asia; CHN = China Region; MEA = Middle East; OAS = Other Asia; ECA = Eastern Europe & Central Asia; OLC = Other Latin America & Caribbean; AFR = Africa; BRIC = Brazil, Russia, India and China.

UNITED NATIONS ENVIRONMENT PROGRAMME

Global Environmental Outlook 4: Environment for Development

The United Nations Environment Programme's *GEO4: Environment for Development* was released in October 2007 (UNEP 2007). Chapter 9 - "The Future Today" was the primary forward-looking chapter in this assessment (Rothman, Agard et al. 2007).[29]

GEO4 does not include a baseline reference scenario. Rather, it presents four scenarios with fundamentally different assumptions about changes in individual behaviour and public policies. These are as follows:

- **Markets First**: the private sector, with active government support, pursues maximum economic growth as the best path to improve the environment and human well-being. Lip service is paid to the ideals of the Brundtland Commission, *Agenda 21* and other major policy decisions on sustainable development. There is a narrow focus on the sustainability of markets rather than on the broader, human-environment system. Technological fixes to environmental challenges are emphasized at the expense of other policy interventions and some tried-and-tested solutions.
- **Policy First**: government, with active private and civil sector support, initiates and implements strong policies to improve the environment and human well-being, while still emphasizing economic development. Policy First introduces some measures aimed at promoting sustainable development, but the tensions between environment and economic policies are biased towards social and economic considerations. Still, it brings the idealism of the Brundtland Commission to overhauling the environmental policy process at different levels, including efforts to implement the recommendations and agreements of the Rio Earth Summit, the World Summit on Sustainable Development (WSSD), and the Millennium Summit. The emphasis is on more top-down approaches, due in part to desires to make rapid progress on key targets.
- **Security First**: government and private sector compete for control in efforts to improve, or at least maintain, human well-being for mainly the rich and powerful in society. Security First, which could also be described as "Me First," has as its focus a minority: rich, national and regional. It emphasizes sustainable development only in the context of maximizing access to and use of the environment by the powerful. Contrary to the Brundtland doctrine of interconnected crises, responses under Security First reinforce the silos of management, and the UN role is viewed with suspicion, particularly by some rich and powerful segments of society.
- **Sustainability First**: government, civil society and the private sector work collaboratively to improve the environment and human well-being, with a strong emphasis on equity. Equal weight is given to environmental and socio-economic policies, and accountability, transparency and legitimacy are stressed across all actors. As in Policy First, it brings the idealism of the Brundtland Commission to overhauling the environmental policy process at different levels, including strong efforts to implement the recommendations and agreements of the Rio Earth Summit, WSSD, and the Millennium Summit. Emphasis is placed on developing effective public-private sector partnerships not only in the context of projects but also that of governance, ensuring that stakeholders across the spectrum of the environment-development discourse provide strategic input to policy making and implementation. There is an acknowledgement that these processes take time, and that their impacts are likely to be more long-term than short-term (Rothman, Agard et al. 2007, pp. 400-401).

UNITED NATIONS, DEPARTMENT OF ECONOMIC AND SOCIAL AFFAIRS, POPULATION DIVISION

World Population Prospects: The 2006 Revision and *World Urbanization Prospects: The 2007 Revision*

Every two years the Population Division of the United Nations Department of Economic and Social Affairs prepares national-level population estimates and projections. Since 1988, it has also provided these data separately for urban and rural populations. The most recent versions are the *World Population Prospects: The 2006 Revision* (United Nations 2007) and *World Urbanization Prospects: The 2007 Revision* (United Nations 2008). The data in the latter are consistent with those in the medium variant of the 2006 global population estimates and projections.

The 2006 Revision includes eight projection variants and three AIDS scenarios (United Nations 2007). These differ with respect to assumptions around fertility, mortality, and international migration. Of these, the most commonly referenced, and the ones presented in the main body of this report, are three variants that differ only in terms of their fertility assumptions:

- Medium-variant: total fertility in all countries is assumed to converge eventually toward a level of 1.85 children per woman.
- High-variant: fertility is projected to remain 0.5 children above the fertility in the medium variant over most of the projection period.
- Low-variant: fertility is projected to remain 0.5 children below the fertility in the medium variant over most of the projection period.

[29] Special thanks is extended to the various modelling groups who have kindly provided detailed model runs including data not explicitly presented in the published report. These groups include the Fisheries Centre at the University of British Columbia, the Netherland Environmental Assessment Agency, the International Food Policy Research Institute, the Centre for Environmental Systems Research of the University of Kassel, the Frederick S. Pardee Center for International Futures at the University of Denver, and the UNEP-World Conservation Monitoring Centre

In these variants, mortality is projected on the basis of models of changing life expectancy produced by the United Nations Population Division. These produce smaller gains over time as higher life expectancy is achieved. The future path of international migration is set on the basis of past international migration estimates and consideration of the policy stance of each country with regard to future international migration flows. In general, though, projected levels of net migration are held constant over most of the projection period (United Nations 2007). The UN indicates that "estimates of the proportion of the population living in urban areas and the population of cities are derived on the basis of national statistics," but is not clear on what the future projections for these proportions are derived (United Nations 2008, p. 1).

INTERNATIONAL ENERGY AGENCY

World Energy Outlook 2008

The International Energy Agency (IEA) is an autonomous body within the framework of the Organisation for Economic Cooperation and Development (OECD). Each year it releases a *World Energy Outlook*. Since 1998, the even–number-year reports present new sets of comprehensive projections and the odd–number-year reports address more specific issues in detail. The results presented in this report are derived from the *World Energy Outlook 2008* (OECD/IEA 2008).

The main projections presented in WEO2008 relate to a Reference Scenario. This scenario indicates "what would happen if, among other things, there were to be no new energy-policy interventions by government beyond those already adopted by mid-2008" (OECD/IEA 2008). These do include policies that may have yet to be fully implemented (OECD/IEA 2008, p. 59). The study does include other analyses related to oil and gas supply prospects and climate policy options, but detailed results are not presented, so they have not been considered in this report.

The principal assumptions underlying the Reference Scenario relate to population, economic activity, energy prices and energy-related technologies. The population assumptions are taken from the most recent UN projections (see description above). Assumptions about economic growth are developed building on information from a number of sources, including the International Monetary Fund and the World Bank. Similarly, assumptions related to energy prices and technology draw upon other, more detailed analyses. These are then used to drive the IEA's World Energy Model to produce the projections presented in the report (OECD/IEA 2008).

US ENERGY INFORMATION ADMINISTRATION

International Energy Outlook 2008

Each year, the Energy Information Administration, an independent statistical and analytical agency within the US Department of Energy produces an *International Energy Outlook*. This complements the US-focused *Annual Energy Outlook*. The results presented in this report are derived from the *International Energy Outlook 2008* (US EIA 2008).

The main projections presented in IEO2008 relate to a Reference Case. This is "based on US and foreign government laws in effect on 1 January 2008. The potential impacts of pending or proposed legislation, regulations, and standards are not reflected in the projections, nor are the impacts of legislation for which the implementing mechanisms have not yet been announced" (US EIA 2008, p. ix). In addition to the Reference Case, four other cases are considered. These differ based upon assumptions related to economic growth and energy prices, reflecting the uncertainty in these parameters. Since the most detailed results are presented for the Reference Case, this is the scenario focused on in this report.

The principal assumptions underlying the Reference Case relate to population, economic activity, energy prices and energy-related technologies. The population assumptions are taken from the most recent UN projections (see description above) for all countries other than the United States; these are provided by US-based studies (US EIA 2008, p. 117). Assumptions about economic growth are drawn from independent studies (p. 106). Similarly, assumptions related to energy prices and technology draw upon other, more detailed analyses. These are then used to drive the a suite of models in order to produce the projections presented in the report.

ANNEX 2
Data Tables

The following tables summarize projections for 2030 from the GEO4 and OECD scenarios, as well as the reference scenarios in the International Energy Agency's *World Energy Outlook 2008* (OECD/IEA 2008), the US Energy Information Administration's *International Energy Outlook 2008* (US EIA 2008), and the high, medium, and low population projections from the United Nations Population Division.

The scenarios are GEO4 MF (Markets First), GEO4 PF (Policy First), GEO4 SeF (Security First), GEO4 SuF (Sustainability First), OECD ppGlobal (comprehensive global policy package), and OECD 450ppm (GHGs stabilized at 450 ppm).

Note: Total may occasionally differ slightly from direct sums because of rounding.

TABLE A2.1: TOTAL POPULATION *(millions of persons)*

		Projections for 2030									
		GEO4				OECD			UNPD		
	2005	MF	PF	SeF	SuF	Baseline	ppGlobal	450ppm	Low	Medium	High
Canada	32	39	38	37	38	39	39	39	37	39	42
USA	300	362	354	347	348	363	363	363	342	366	391
Mexico	104	127	129	130	127	130	130	130	118	128	139
NORTH AMERICA	**436**	**528**	**521**	**514**	**513**	**532**	**532**	**532**	**497**	**533**	**572**

Note: Data normalized to 2005 values from UNPD.

TABLE A2.2: TOTAL GDP *(billions of US dollars)*

		Projections for 2030								
		GEO4				OECD				
	2005	MF	PF	SeF	SuF	Baseline	ppGlobal	450ppm	IEO 2008	WEO 2008
Canada	990	2,184	2,188	1,851	1,961	1,707	1,699	1,702	1,780	1,636
USA	10,996	25,825	25,786	23,432	23,003	20,778	20,746	20,760	20,204	18,551
Mexico	983	2,071	2,104	1,885	1,889	2,459	2,446	2,448	2,534	2,299
NORTH AMERICA	**12,969**	**30,080**	**30,078**	**27,168**	**26,853**	**24,944**	**24,891**	**24,910**	**24,518**	**22,486**

Note: All values in year 2000 US$ using PPP-based exchange rates. Data normalized to 2005 values from WEO 2008. IEO 2008 and WEO 2008 values are from reference scenarios.

TABLE A2.3: GDP PER CAPITA *(thousands of US dollars)*

		Projections for 2030								
		GEO4				OECD				
	2005	MF	PF	SeF	SuF	Baseline	ppGlobal	450ppm	IEO 2008	WEO 2008
Canada	30.7	56.1	57.9	50.3	52.3	43.7	43.5	43.6	45.5	41.8
USA	36.7	71.3	72.8	67.5	66.1	57.3	57.2	57.2	55.2	50.7
Mexico	9.4	16.3	16.3	14.6	14.8	18.9	18.8	18.9	19.8	17.9

Note: All values in year 2000 US$ using PPP-based exchange rates. Data normalized to 2005 values from WEO 2008. IEO 2008 and WEO 2008 values are from reference scenarios.

TABLE A2.4: SECTORAL SHARES OF TOTAL GDP *(%)*

		Projections to 2030			
		GEO4			
	2005	MF	PF	SeF	SuF
Canada					
Agriculture	2.4	1.1	1.2	1.3	1.3
Energy	7.3	4.6	4.1	5.0	4.4
ICTech	4.9	5.5	5.6	5.5	5.7
Manufactures	25.9	26.5	26.6	26.2	26.5
Materials	2.2	3.3	3.2	3.0	3.2
Services	57.4	59.0	59.2	58.9	58.9
USA					
Agriculture	1.6	0.8	0.9	1.0	1.1
Energy	2.2	1.3	1.2	1.3	1.1
ICTech	7.9	8.2	8.3	8.4	8.3
Manufactures	20.3	18.9	18.9	19.8	18.5
Materials	1.2	1.4	1.4	1.6	1.4
Services	66.9	69.3	69.3	68.0	69.7
Mexico					
Agriculture	4.4	2.2	2.5	2.6	3.1
Energy	6.7	3.8	3.5	4.1	3.2
ICTech	6.2	7.5	7.5	7.8	7.8
Manufactures	28.0	30.1	30.2	30.9	30.4
Materials	2.2	3.2	3.1	3.2	3.1
Services	52.5	53.3	53.2	51.5	52.5

TABLE A2.5: PRIMARY ENERGY USE *(petajoules)*

		Projections for 2030								
		GEO4				OECD				
	2005	MF	PF	SeF	SuF	Baseline	ppGlobal	450ppm	IEO 2008	WEO 2008
Canada										
Coal	1,171	716	270	1,054	59	1,343	267	270	1,559	757
Oil	4,077	6,406	5,375	5,820	3,552	4,578	3,887	3,138	4,712	4,270
Natural Gas	3,376	6,728	6,063	5,912	4,580	3,388	2,955	2,711	4,681	5,090
Nuclear	1,004	447	515	576	439	883	668	978	999	1,223
Hydro	1,309	1,695	1,687	1,580	1,579	1,579	1,379	1,444	3,335	1,406
Traditional Biofuels	488	469	404	414	310	310	367	338		496
Modern Biofuels	42	341	580	381	1,459	1,459	621	1,118		475
Solar and Wind	5	160	238	138	280	280	574	274		250
Total	**11,472**	**16,963**	**15,132**	**15,874**	**12,258**	**12,258**	**10,717**	**10,272**	**15,287**	**13,966**
USA										
Coal	23,264	28,847	19,031	36,260	8,646	34,281	16,964	14,608	31,203	26,520
Oil	39,893	58,659	49,517	55,848	36,200	46,006	39,331	31,929	46,483	36,903
Natural Gas	21,328	41,328	39,900	34,265	30,570	23,865	21,374	26,087	22,991	21,682
Nuclear	8,846	3,653	4,221	4,480	3,959	7,846	9,551	8,888	6,971	10,480
Hydro	981	1,269	1,250	1,178	1,176	1,125	1,040	1,083	6,736	1,086
Traditional Biofuels	2,813	2,029	1,794	1,868	1,469	3,229	2,855	2,636		3,831
Modern Biofuels	286	1,055	1,879	895	4,778	3,316	7,389	10,660		3,934
Solar and Wind	483	2,118	3,776	1,300	6,652	4,700	14,879	5,887		2,982
Total	**97,894**	**138,958**	**121,369**	**136,094**	**93,451**	**124,367**	**113,382**	**101,778**	**114,384**	**107,416**
Mexico										
Coal	366	736	438	952	181	746	439	372	509	825
Oil	4,348	8,259	6,914	7,595	4,176	7,140	5,776	5,046	6,900	5,207
Natural Gas	1,850	5,120	4,591	4,171	4,190	4,533	3,337	3,116	4,434	4,443
Nuclear	118	140	187	170	134	164	214	216	87	116
Hydro	100	168	166	183	178	186	171	179	405	135
Traditional Biofuels	326	542	482	511	381	405	364	331		166
Modern Biofuels	22	195	342	161	887	813	1,323	1,387		333
Solar and Wind	266	591	1,078	436	1,377	464	2,257	819		541
Total	**7,395**	**15,750**	**14,198**	**14,180**	**11,505**	**14,450**	**13,882**	**11,467**	**12,336**	**11,766**
NORTH AMERICA										
Coal	24,802	30,299	19,738	38,267	8,886	36,370	17,670	15,251	33,272	28,102
Oil	48,318	73,324	61,807	69,263	43,928	57,724	48,994	40,113	58,095	46,379
Natural Gas	26,554	53,176	50,555	44,348	39,341	31,785	27,666	31,914	32,106	31,216
Nuclear	9,968	4,239	4,923	5,225	4,532	8,892	10,433	10,082	8,058	11,819
Hydro	2,390	3,132	3,102	2,941	2,934	2,810	2,590	2,706	10,477	2,626
Traditional Biofuels	3,627	3,040	2,681	2,793	2,160	4,054	3,585	3,306		4,493
Modern Biofuels	349	1,591	2,801	1,437	7,125	4,530	9,332	13,165		4,742
Solar and Wind	755	2,869	5,092	1,874	8,309	5,437	17,710	6,981		3,772
Total	**116,762**	**171,670**	**150,699**	**166,148**	**117,214**	**151,602**	**137,980**	**123,517**	**142,007**	**133,148**

Note: Data normalized to 2005 values from WEO 2008. IEO 2008 and WEO 2008 values are from reference scenarios. IEO 2008 data for Hydro includes all renewables.

TABLE A2.6: PER CAPITA PRIMARY ENERGY USE *(gigajoules)*

		Projections for 2030								
		GEO4				OECD				
	2005	MF	PF	SeF	SuF	Baseline	ppGlobal	450ppm	IEO 2008	WEO 2008
Canada	355	436	401	432	327	327	274	263	391	357
USA	326	384	343	392	269	343	312	280	312	293
Mexico	71	124	110	109	90	111	107	88	96	92

Note: Data normalized to 2005 values from WEO 2008. IEO 2008 and WEO 2008 values are from reference scenarios.

TABLE A2.7: PRIMARY ENERGY USE PER UNIT GDP *(megajoules)*

		Projections for 2030								
		GEO4				OECD				
	2005	MF	PF	SeF	SuF	Baseline	ppGlobal	450ppm	IEO 2008	WEO 2008
Canada	11.6	7.8	6.9	8.6	6.3	7.5	6.3	6.0	8.6	8.5
USA	8.9	5.4	4.7	5.8	4.1	6.0	5.5	4.9	5.7	5.8
Mexico	7.5	7.6	6.7	7.5	6.1	5.9	5.7	4.7	4.9	5.1

Note: GDP measured in year 2000 US$ using PPP-based exchange rates. Data normalized to 2005 values from WEO 2008. IEO 2008 and WEO 2008 values are from reference scenarios.

TABLE A2.8: FINAL ENERGY USE, BY SECTOR *(petajoules)*

		Projections for 2030						
		GEO4				OECD		
	2005	MF	PF	SeF	SuF	Baseline	ppGlobal	450ppm
Canada								
Industry	2,616	3,351	2,909	2,913	2,302	2,391	2,296	2,057
Residential	1,419	2,001	1,902	1,841	1,558	1,797	1,767	1,627
Services	1,310	1,964	1,801	1,801	1,426	1,654	1,632	1,388
Transportation	2,331	3,889	3,475	3,950	2,763	3,452	3,349	2,773
Other	186	225	199	215	161	238	233	195
Total	**7,862**	**11,431**	**10,286**	**10,721**	**8,210**	**9,532**	**9,277**	**8,040**
USA								
Industry	15,096	20,717	17,339	17,862	12,995	18,322	17,620	15,481
Residential	12,259	16,610	15,558	15,458	12,597	14,990	14,681	13,299
Services	9,033	13,609	12,476	12,763	9,775	12,939	12,694	10,705
Transportation	27,166	40,273	35,552	42,901	28,699	35,974	34,959	28,720
Other	658	906	794	832	580	929	903	744
Total	**64,212**	**92,116**	**81,720**	**89,817**	**64,645**	**83,154**	**80,858**	**68,949**
Mexico								
Industry	1,282	2,857	2,429	2,531	1,875	2,639	2,536	2,217
Residential	815	1,602	1,497	1,428	1,172	1,021	993	879
Services	156	425	407	366	297	715	698	564
Transportation	1,608	3,636	3,221	3,492	2,276	3,473	3,367	2,689
Other	121	286	253	252	187	185	180	143
Total	**3,982**	**8,806**	**7,809**	**8,068**	**5,807**	**8,033**	**7,774**	**6,492**
NORTH AMERICA								
Industry	18,994	26,925	22,677	23,306	17,172	23,352	22,453	19,755
Residential	14,493	20,214	18,958	18,728	15,327	17,808	17,441	15,805
Services	10,499	15,998	14,685	14,930	11,498	15,308	15,024	12,657
Transportation	31,105	47,798	42,248	50,343	33,738	42,899	41,675	34,182
Other	965	1,418	1,247	1,299	928	1,352	1,316	1,082
Total	**76,056**	**112,353**	**99,814**	**108,606**	**78,662**	**100,719**	**97,909**	**83,481**

Note: Data normalized to 2005 values from OECD Baseline.

TABLE A2.9: WATER USE, TOTAL BY SECTOR *(millions of cubic meters)* AND PER CAPITA *(cubic meters)*

		Projections for 2030						
		GEO4				OECD		
	2005	MF	PF	SeF	SuF	Baseline	ppGlobal	450ppm
Canada								
Agriculture	3,929	3,995	3,558	4,677	4,022	4,017	3,999	3,979
Domestic	5,930	6,892	5,115	8,062	4,537	6,638	6,623	6,628
Electricity	30,279	45,077	5,604	48,944	3,314	26,543	19,465	18,892
Manufacturing	6,186	10,076	9,522	10,153	9,691	6,307	6,158	6,178
Total	**46,324**	**66,040**	**23,800**	**71,836**	**21,565**	**43,505**	**36,245**	**35,678**
	(1,435)	**(1,696)**	**(630)**	**(1,953)**	**(575)**	**(1,114)**	**(928)**	**(914)**
USA								
Agriculture	244,572	227,179	175,543	255,180	233,128	237,434	237,409	237,194
Domestic	51,866	61,190	45,678	72,098	39,708	61,221	61,197	61,208
Electricity	211,671	279,124	55,450	323,355	37,538	234,600	190,334	187,025
Manufacturing	27,570	50,967	46,901	55,011	45,835	39,136	38,899	38,902
Total	**535,679**	**618,459**	**323,571**	**705,644**	**356,210**	**572,391**	**527,839**	**524,328**
	(1,787)	**(1,708)**	**(914)**	**(2,034)**	**(1,024)**	**(1,577)**	**(1,455)**	**(1,445)**
Mexico								
Agriculture	35,767	37,073	33,301	54,912	44,819	29,753	29,767	29,721
Domestic	4,996	12,797	9,941	13,321	6,493	17,516	17,345	17,373
Electricity	16,077	39,632	16,943	42,560	11,571	34,501	26,879	24,763
Manufacturing	287	667	635	697	486	582	573	574
Total	**57,127**	**90,169**	**60,820**	**111,490**	**63,369**	**82,352**	**74,563**	**72,431**
	(548)	**(711)**	**(472)**	**(861)**	**(498)**	**(635)**	**(575)**	**(558)**
NORTH AMERICA								
Agriculture	284,268	268,247	212,402	314,769	281,970	271,204	271,175	270,895
Domestic	62,792	80,878	60,734	93,481	50,739	85,375	85,166	85,209
Electricity	258,027	363,833	77,997	414,859	52,423	295,644	236,678	230,680
Manufacturing	34,043	61,710	57,058	65,861	56,012	46,025	45,629	45,654
Total	**639,130**	**774,668**	**408,191**	**888,970**	**441,144**	**698,248**	**638,648**	**632,438**

Note: Data normalized to 2005 values from OECD Baseline. Per capita values in parentheses.

TABLE A2.10: AGRICULTURAL PRODUCTION *(thousands of metric tons)*

		Projections to 2030			
		GEO4			
	2000	MF	PF	SeF	SuF
Canada					
Animal Products	12,098	20,774	19,916	19,329	20,650
Non-Animal Products	77,950	125,547	121,839	127,933	133,958
Total	**90,048**	**146,321**	**141,755**	**147,262**	**154,608**
USA					
Animal Products	112,282	190,990	186,630	182,645	194,750
Non-Animal Products	727,446	1,200,466	1,169,469	1,112,784	1,232,444
Total	**839,728**	**1,391,456**	**1,356,099**	**1,295,429**	**1,427,194**
Mexico					
Animal Products	13,740	30,164	32,394	29,234	31,007
Non-Animal Products	131,490	257,458	256,543	235,851	267,770
Total	**145,230**	**287,622**	**288,937**	**265,085**	**298,777**
NORTH AMERICA					
Animal Products	138,120	241,928	238,940	231,208	246,407
Non-Animal Products	936,886	1,583,471	1,547,851	1,476,568	1,634,172
Total	**1,075,006**	**1,825,399**	**1,786,791**	**1,707,776**	**1,880,579**

TABLE A2.11: AGRICULTURAL DEMAND *(thousands of metric tons)*

		Projections to 2030			
		GEO4			
	2000	MF	PF	SeF	SuF
Canada					
Animal Products	11,310	16,236	16,419	14,908	15,713
Non-Animal Products	63,332	98,293	96,916	90,318	95,752
Total	**74,642**	**114,529**	**113,335**	**105,226**	**111,465**
USA					
Animal Products	109,502	161,724	163,209	148,779	152,204
Non-Animal Products	635,014	958,790	944,833	915,014	928,385
Total	**744,516**	**1,120,514**	**1,108,042**	**1,063,793**	**1,080,589**
Mexico					
Animal Products	15,731	27,033	28,815	24,861	27,183
Non-Animal Products	105,817	187,772	192,902	169,029	183,137
Total	**121,548**	**214,805**	**221,717**	**193,890**	**210,320**
NORTH AMERICA					
Animal Products	136,543	204,993	208,443	188,548	195,100
Non-Animal Products	804,163	1,244,855	1,234,651	1,174,361	1,207,274
Total	**940,706**	**1,449,848**	**1,443,094**	**1,362,909**	**1,402,374**

TABLE A2.12: AGRICULTURAL DEMAND *(kg/person/year)* AND FOOD AVAILABILITY *(kcal/person/day)*

		Projections to 2030			
		GEO4			
	2000	MF	PF	SeF	SuF
Canada					
Total Demand	2,426	2,941	3,001	2,861	2,970 Food
Availability	3,610	4,077	4,114	3,828	4,083
USA					
Total Demand	2,612	3,095	3,129	3,066	3,106 Food
Availability	3,802	4,448	4,487	4,198	4,419
Mexico					
Total Demand	1,229	1,693	1,722	1,497	1,653 Food
Availability	3,173	3,779	3,735	3,333	3,708

TABLE A2.13:PRODUCTION OF WOOD PRODUCTS *(thousands of cubic meters)*

		Projections to 2030			
		GEO4			
	2000	MF	PF	SeF	SuF
Canada	199,285	387,419	395,052	328,606	356,366
USA	542,672	1,006,393	995,730	905,434	920,718
Mexico	33,282	31,480	30,629	30,329	31,079
NORTH AMERICA	**775,239**	**1,425,292**	**1,421,411**	**1,264,369**	**1,308,163**

TABLE A2.14: LANDINGS FROM MARINE FISHERIES *(metric tons)*

		Projections for 2030				
		GEO4				OECD
	2000	MF	PF	SeF	SuF	Baseline
FAO 21 - Northwest Atlantic	45,214,710	29,160,437	28,813,609	29,677,933	20,585,983	22,204,592
FAO 31 - West Central Atlantic	30,113,839	32,565,967	33,768,594	31,570,750	23,327,667	31,785,157
FAO 67 - Northeast Pacific	41,078,411	74,546,821	74,065,241	72,963,461	59,553,825	74,934,509
FAO 77 - East Central Pacific	41,871,201	49,983,896	50,340,469	54,803,132	53,361,712	56,201,079
Total	**158,278,161**	**186,257,121**	**186,987,913**	**189,015,276**	**156,829,188**	**185,125,337**

TABLE A2.15: GREENHOUSE GAS EMISSIONS FROM ENERGY AND LAND USE AND INDUSTRIAL PROCESSES *(petagrams Carbon)* AND Per Capita Emissions *(megagrams Carbon)*

		Projections for 2030						
		GEO4				OECD		
	2005	MF	PF	SeF	SuF	Baseline	ppGlobal	450ppm
Canada								
Energy Use	0.170	0.247	0.199	0.250	0.123	0.182	0.118	0.095
Industrial Processes	0.012	0.016	0.014	0.011	0.009	0.010	0.010	0.009
Land Use	0.022	0.052	0.056	0.054	0.050	0.048	0.034	0.027
Total	**0.204**	**0.311**	**0.263**	**0.311**	**0.173**	**0.240**	**0.163**	**0.132**
	(6.34)	**(9.59)**	**(8.11)**	**(9.61)**	**(4.45)**	**(6.38)**	**(4.46)**	**(3.54)**
USA								
Energy Use	1.877	2.504	1.996	2.670	1.249	2.338	1.647	1.412
Industrial Processes	0.085	0.130	0.104	0.105	0.073	0.105	0.098	0.091
Land Use	0.224	0.316	0.240	0.269	0.229	0.282	0.167	0.152
Total	**2.186**	**2.947**	**2.340**	**3.039**	**1.550**	**2.725**	**1.913**	**1.655**
	(7.48)	**(10.07)**	**(8.00)**	**(10.39)**	**(4.39)**	**(7.70)**	**(5.52)**	**(4.76)**
Mexico								
Energy Use	0.110	0.228	0.180	0.211	0.113	0.194	0.155	0.122
Industrial Processes	0.008	0.015	0.011	0.013	0.008	0.012	0.011	0.009
Land Use	0.068	0.060	0.093	0.060	0.065	0.050	0.046	0.042
Total	**0.186**	**0.281**	**0.279**	**0.260**	**0.184**	**0.256**	**0.212**	**0.171**
	(1.78)	**(2.74)**	**(2.72)**	**(2.54)**	**(1.45)**	**(1.95)**	**(1.61)**	**(1.32)**
NORTH AMERICA								
Energy Use	2.157	2.981	2.376	3.133	1.486	2.714	1.921	1.632
Industrial Processes	0.105	0.160	0.130	0.128	0.089	0.127	0.119	0.109
Land Use	0.314	0.404	0.390	0.365	0.330	0.380	0.249	0.220
Total	**2.576**	**3.544**	**2.899**	**3.609**	**1.920**	**3.221**	**2.289**	**1.960**

Note: Data normalized to 2005 values from OECD Baseline. Per capita values in parentheses.

TABLE A2.16: NO_x EMISSIONS FROM ENERGY USE AND INDUSTRIAL PROCESSES *(teragrams Nitrogen)*, AND PER CAPITA *(megagrams Nitrogen)*

		Projections for 2030						
		GEO4				OECD		
	2005	MF	PF	SeF	SuF	Baseline	ppGlobal	450ppm
Canada								
Energy Use	0.561	0.478	0.404	0.640	0.257	0.317	0.115	0.237
Industrial Processes	0.018	0.022	0.020	0.020	0.018	0.014	0.013	0.014
Total	**0.579**	**0.500**	**0.424**	**0.660**	**0.276**	**0.331**	**0.128**	**0.251**
	(17.94)	**(12.84)**	**(11.22)**	**(17.94)**	**(7.35)**	**(8.49)**	**(3.27)**	**(6.42)**
USA								
Energy Use	5.278	4.375	3.682	6.128	2.308	3.406	1.170	2.565
Industrial Processes	0.125	0.157	0.144	0.145	0.125	0.122	0.109	0.117
Total	**5.403**	**4.532**	**3.827**	**6.273**	**2.433**	**3.528**	**1.279**	**2.682**
	(18.02)	**(12.52)**	**(10.81)**	**(18.08)**	**(6.99)**	**(9.72)**	**(3.53)**	**(7.39)**
Mexico								
Energy Use	0.429	0.552	0.472	0.531	0.248	0.292	0.135	0.230
Industrial Processes	0.034	0.050	0.047	0.050	0.043	0.042	0.041	0.042
Total	**0.463**	**0.602**	**0.518**	**0.581**	**0.291**	**0.335**	**0.176**	**0.272**
	(4.45)	**(4.74)**	**(4.03)**	**(4.49)**	**(2.28)**	**(2.58)**	**(1.35)**	**(2.09)**
NORTH AMERICA								
Energy Use	6.268	5.405	4.558	7.299	2.813	4.016	1.420	3.032
Industrial Processes	0.178	0.229	0.211	0.215	0.186	0.178	0.163	0.173
Total	**6.446**	**5.634**	**4.769**	**7.514**	**2.999**	**4.194**	**1.583**	**3.205**

Note: Data normalized to 2005 values from OECD Baseline. Per capita values in parentheses. There are differences between data provided by the IMAGE model and those that may be extracted from national data sets.

TABLE A2.17: SO_x EMISSIONS FROM ENERGY USE AND INDUSTRIAL PROCESSES *(teragrams Sulfur)*, AND PER CAPITA *(megagrams Sulfur)*

		Projections for 2030						
		GEO4				OECD		
	2005	MF	PF	SeF	SuF	Baseline	ppGlobal	450ppm
Canada								
Energy Use	0.853	0.343	0.220	0.411	0.075	0.374	0.058	0.187
Industrial Processes	0.122	0.053	0.046	0.062	0.032	0.043	0.030	0.037
Total	**0.974**	**0.396**	**0.266**	**0.473**	**0.108**	**0.417**	**0.089**	**0.224**
	(30.20)	**(10.17)**	**(7.04)**	**(12.86)**	**(2.87)**	**(10.67)**	**(2.27)**	**(5.74)**
USA								
Energy Use	5.481	1.397	0.992	2.147	0.521	5.923	1.221	3.472
Industrial Processes	0.177	0.081	0.070	0.097	0.049	0.117	0.110	0.111
Total	**5.658**	**1.479**	**1.062**	**2.245**	**0.570**	**6.040**	**1.331**	**3.583**
	(18.87)	**(4.08)**	**(3.00)**	**(6.47)**	**(1.64)**	**(16.65)**	**(3.67)**	**(9.87)**
Mexico								
Energy Use	0.818	0.707	0.526	0.807	0.179	0.402	0.101	0.263
Industrial Processes	0.467	0.758	0.641	0.803	0.396	0.149	0.061	0.130
Total	**1.284**	**1.465**	**1.167**	**1.610**	**0.576**	**0.552**	**0.162**	**0.393**
	(12.32)	**(11.55)**	**(9.06)**	**(12.43)**	**(4.52)**	**(4.25)**	**(1.25)**	**(3.04)**
NORTH AMERICA								
Energy Use	7.151	2.447	1.738	3.366	0.775	6.700	1.381	3.922
Industrial Processes	0.765	0.892	0.756	0.962	0.478	0.309	0.202	0.278
Total	**7.916**	**3.339**	**2.495**	**4.328**	**1.253**	**7.009**	**1.583**	**4.200**

Note: Data normalized to 2005 values from OECD Baseline. Per capita values in parentheses.

TABLE A2.18: RETURN FLOWS OF TREATED AND UNTREATED WATER, BY SECTOR *(millions of cubic meters)*

			Projections for 2030			
			UNEP-GEO4			
	Treated?	2000	MF	PF	SeF	SuF
Canada						
Domestic	Untreated	93	118	88	338	78
	Treated	4,575	5,781	4,291	6,563	3,806
Manufacturing	Untreated	3,187	5,318	3,382	5,473	3,827
	Treated	2,307	3,851	5,283	3,766	4,993
Total	**Untreated**	**3,280**	**5,436**	**3,470**	**5,811**	**3,904**
	Treated	**6,882**	**9,633**	**9,574**	**10,328**	**8,798**
USA						
Domestic	Untreated	2,374	1,093	816	5,214	709
	Treated	42,410	53,537	39,966	59,155	34,743
Manufacturing	Untreated	7,059	13,218	854	15,326	1,514
	Treated	17,709	33,161	41,826	34,735	40,196
Total	**Untreated**	**9,433**	**14,311**	**1,669**	**20,540**	**2,223**
	Treated	**60,120**	**86,699**	**81,792**	**93,890**	**74,939**
Mexico						
Domestic	Untreated	5,449	12,079	9,383	14,783	5,833
	Treated	2,183	7,577	5,886	5,679	4,141
Manufacturing	Untreated	112	250	224	263	168
	Treated	19	43	56	44	46
Total	**Untreated**	**5,561**	**12,329**	**9,607**	**15,046**	**6,001**
	Treated	**2,202**	**7,621**	**5,942**	**5,723**	**4,187**
NORTH AMERICA						
Domestic	Untreated	7,916	13,290	10,287	20,335	6,620
	Treated	49,168	66,896	50,143	71,397	42,689
Manufacturing	Untreated	10,358	18,787	4,460	21,062	5,508
	Treated	20,036	37,056	47,165	38,544	45,235
Total	**Untreated**	**18,273**	**32,076**	**14,746**	**41,397**	**12,128**
	Treated	**69,204**	**103,952**	**97,308**	**109,941**	**87,924**

TABLE A2.19: RIVER NITROGEN FLUXES, BY SOURCE *(thousands of kilograms)*

		Projections for 2030	
		OECD	
	2000	Baseline	ppGlobal
Canada			
Non-point Agriculture	185	345	271
Sewage	46	47	27
Total	**231**	**392**	**298**
USA			
Non-point Agriculture	1526	1362	1032
Sewage	424	485	299
Total	**1950**	**1847**	**1330**
Mexico			
Non-point Agriculture	170	112	156
Sewage	166	238	200
Total	**336**	**350**	**356**
NORTH AMERICA			
Non-point Agriculture	1881	1819	1458
Sewage	636	770	525
Total	2517	2589	1984

TABLE A2.20: FOREST AREA *(square kilometers)*

		Projections of Changes from 2000 to 2030						
		GEO4				OECD		
	2000	MF	PF	SeF	SuF	Baseline	ppGlobal	450ppm
Canada*								
Mature Forest	5,686,715	-94,852	-14,063	-39,157	-6,350	-89,885	-46,379	-15,919
Regrowth Forest	178,187	138,024	121,181	76,840	92,543	30,499	71,075	97,969
Total	**5,864,902**	**43,173**	**107,119**	**37,683**	**86,193**	**-59,386**	**24,696**	**82,050**
USA								
Mature Forest	2,597,172	-46,667	-125,185	-179,028	-120,964	-95,557	-17,579	-33,077
Regrowth Forest	325,850	217,438	188,766	200,346	110,861	78,980	126,962	45,261
Total	**2,923,022**	**170,771**	**63,581**	**21,318**	**-10,103**	**-16,577**	**109,383**	**12,184**
Mexico								
Mature Forest	427,310	-169,854	-246,287	-170,998	-190,646	-38,256	-42,370	-39,650
Regrowth Forest	17,408	-4,790	-9,417	-1,024	-1,416	-188	110	-6,028
Total	**444,718**	**-174,644**	**-255,704**	**-172,021**	**-192,062**	**-38,444**	**-42,261**	**-45,678**
NORTH AMERICA								
Mature Forest	8,711,197	-311,372	-385,535	-389,183	-317,960	-223,698	-106,328	-88,646
Regrowth Forest	521,445	350,672	300,530	276,162	201,987	109,291	198,146	137,202
Total	**9,232,642**	**39,300**	**-85,005**	**-113,021**	**-115,973**	**-114,407**	**91,818**	**48,556**

Note: Normalized to data from OECD Baseline. Regrowth Forest includes growth on abandoned land and timber plantations.

* *Land cover data and categories will differ between information provided by IMAGE model and national data. For example, the IMAGE forest area for Canada indicates, for 2000, an area 165 million ha larger than the estimated forest and other wooded land (402 million ha) as reflected in Canadian data sets.*

TABLE A2.21: AGRICULTURAL AREA *(square kilometers)*

		Projections of Changes from 2000 to 2030						
		GEO4				OECD		
	2000	MF	PF	SeF	SuF	Baseline	ppGlobal	450ppm
Canada								
Food Crops	522,299	-46,925	-11,194	60,799	10,073	162,833	61,609	16,133
Grass and Fodder	149,355	9,493	12,307	16,998	21,408	23,977	6,761	-3,787
Biofuel Crops	0	0	0	0	4,072	7,657	22,069	26,110
Total	**671,654**	**-37,432**	**1,113**	**77,798**	**35,553**	**194,467**	**90,439**	**38.456**
USA								
Food Crops	1,792,543	-176,110	-52,629	19,987	-60,743	226,365	11,198	9,188
Grass and Fodder	2,289,263	115,679	150,405	121,006	218,101	-77,004	-121,089	-106,965
Biofuel Crops	0	0	0	0	39,394	1,193	20,843	94,070
Total	**4,081,806**	**-60,431**	**97,776**	**140,993**	**196,752**	**150,554**	**-89,048**	**-3,707**
Mexico								
Food Crops	274,255	11,381	16,725	19,846	14,135	30,746	14,477	-1,870
Grass and Fodder	787,793	269,178	391,225	244,964	294,068	7,189	4,802	-7,492
Biofuel Crops	8,265	220	5,942	-2,683	18,688	26,232	54,557	72,183
Total	**1,070,313**	**280,779**	**413,892**	**262,127**	**326,891**	**64,167**	**73,836**	**62,821**
NORTH AMERICA								
Food Crops	2,589,097	-211,654	-47,098	100,633	-36,535	419,944	87,284	23,451
Grass and Fodder	3,226,411	394,350	553,937	382,968	533,577	-45,838	-109,526	-118,244
Biofuel Crops	8,265	220	5,942	-2,683	62,154	35,082	97,469	192,363
Total	**5,823,773**	**182,916**	**512,781**	**480,918**	**559,196**	**409,188**	**75,227**	**97,570**

TABLE A2.22: AGRICULTURAL AREA WITH HIGH RISK OF SOIL EROSION RISK FROM WATER *(millions of square kilometers)*

		Projections for 2030						
		GEO4				OECD		
	2000	MF	PF	SeF	SuF	Baseline	pp Global	450ppm
Canada	3.25	2.92	3.18	3.96	3.14	4.83	4.31	3.64
USA	28.21	27.57	29.38	30.60	28.71	33.60	30.65	29.11
Mexico	8.00	10.12	11.06	10.15	10.27	9.17	9.26	9.06
NORTH AMERICA	**39.47**	**40.61**	**43.62**	**44.70**	**42.13**	**47.61**	**44.22**	**41.81**

Note: Normalized to OECD Baseline in 2000.

TABLE A2.23: ANNUAL MEAN CONCENTRATIONS OF PARTICULATE MATTER AND OZONE IN URBAN AREAS, BY COUNTRY

		Projections for 2030	
		OECD	
	2000	Baseline	ppGlobal
Canada			
Particulate Matter (PM_{10}) (µg per cubic meter)	21.4	11.4	5.9
Ozone (ppb)	34.8	35.7	
USA			
Particulate Matter (PM_{10}) (µg per cubic meter)	25.8	18.8	9.3
Ozone (ppb)	40.2	41.3	
Mexico			
Particulate Matter (PM_{10}) (µg per cubic meter)	47.1	25.4	15.1
Ozone (ppb)	42.5	42.3	
NORTH AMERICA (weighted averages)			
Particulate Matter (PM_{10}) (µg per cubic meter)	29.6	19.5	10.2
Ozone (ppb)	40.2	41.0	

Note: Population-weighted averages across urban areas of more than 100,000 persons (OECD 2030).

TABLE A2.24: NORTH AMERICAN URBAN POPULATION EXPOSED TO VARIOUS LEVELS OF PARTICULATE MATTER AND OZONE

		Projections for 2030	
		OECD	
	2000 (%)	Baseline (%)	ppGlobal (%)
Particulate Matter (PM_{10})			
<20 µg per cubic meter	22	76	93
20-30 µg per cubic meter	51	9	7
30-50 µg per cubic meter	13	15	0
50-70 µg per cubic meter	7	0	0
>70 µg per cubic meter	7	0	0
Ozone (O_3)			
<2 µg per cubic meter	4	1	
2-4 µg per cubic meter	14	12	
4-6 µg per cubic meter	51	57	
6-8 µg per cubic meter	31	30	

Note: Percentage of population living in urban areas of more than 100,000 persons (OECD 2030).

TABLE A2.25: DECLINES IN MEAN TERRESTRIAL SPECIES ABUNDANCE, BY CONTRIBUTING FACTOR

	Historic Decline from 'Natural' State as of 2000	Projections of Changes from 2000 to 2030						
		GEO4				OECD		
		MF	PF	SeF	SuF	Baseline	ppGlobal	450ppm
	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
Canada								
Agriculture	5.9	-0.5	-0.1	0.5	0.1	1.4	0.5	0.1
Climate Change	1.5	2.1	2.1	2.0	2.3	1.7	1.6	1.5
Infrastructure	2.3	1.5	0.4	0.4	0.3	1.2	1.3	1.4
Other	2.1	1.5	1.4	1.3	1.3	0.6	0.7	0.8
Total	**11.9**	**4.6**	**3.7**	**4.2**	**4.0**	**4.8**	**4.1**	**3.8**
USA								
Agriculture	23.3	-1.7	-0.3	0.1	0.0	1.5	-0.4	-0.4
Climate Change	1.7	2.5	2.4	2.3	2.7	1.9	1.9	1.7
Infrastructure	7.6	3.0	0.6	0.9	0.5	2.4	2.9	2.7
Other	5.1	1.1	0.8	2.9	-0.1	0.3	0.2	0.8
Total	**37.6**	**4.9**	**3.5**	**6.2**	**3.1**	**6.0**	**4.6**	**4.8**
Mexico								
Agriculture	18.9	3.5	4.3	3.5	4.8	2.1	1.8	1.7
Climate Change	2.1	2.8	2.7	2.8	3.0	2.3	2.1	1.9
Infrastructure	9.6	3.8	0.1	1.3	-0.1	3.4	3.2	3.2
Other	3.5	-0.2	0.0	0.1	-0.1	0.8	1.6	1.8
Total	**34.1**	**10.0**	**7.1**	**7.7**	**7.6**	**8.6**	**8.7**	**8.5**
NORTH AMERICA (weighted averages)								
Agriculture	14.9	-0.6	0.2	0.6	0.5	1.5	0.2	0.0
Climate Change	1.7	2.4	2.3	2.2	2.5	1.9	1.8	1.6
Infrastructure	5.4	2.4	0.5	0.7	0.4	1.9	2.2	2.1
Other	3.6	1.3	1.1	2.0	0.7	0.5	0.6	0.9
Total (weighted averages)	**25.5**	**5.4**	**4.0**	**5.5**	**4.0**	**5.7**	**4.7**	**4.7**

Note: Normalized to OECD Baseline in 2000.

TABLE A2.26: CHANGES IN THE CALCULATED MARINE SPECIES DEPLETION INDEX FROM HISTORIC LEVELS

		Projections for 2030				
		GEO4				OECD
	2000	MF	PF	SeF	SuF	Baseline
FAO 21—Northwest Atlantic	-47.10	-49.30	-49.20	-49.40	-42.20	-33.80
FAO 31—West Central Atlantic	-17.62	-23.43	-23.90	-22.35	-15.70	-22.60
FAO 67—Northeast Pacific	-36.40	-42.40	-41.80	-40.70	-28.00	-43.00
FAO 77—East Central Pacific	-19.60	-29.90	-29.90	-29.90	-29.80	-29.90

Note: Positive changes in DI indicate reduction in depletion risk while negative changes indicate increase in depletion risk.

TABLE A2.27: WATER STRESS *(millions of persons affected and percentage of total population)*

		Projections for 2030					
		UNEP-GEO4				OECD	
	2005	MF	PF	SeF	SuF	Baseline	ppGlobal
Canada	3.3 (10.2%)	3.9 (10.0%)	0.1 (0.3%)	3.6 (9.8%)	0.1 (0.3%)	4.0 (10.2%)	0.2 (0.5%)
USA	114.4 (38.2%)	150.7 (41.6%)	109.8 (31.0%)	161.1 (46.4%)	108.2 (31.1%)	129.9 (35.8%)	125.6 (34.6%)
Mexico	56.2 (53.9%)	73.9 (58.2%)	71.9 (55.9%)	77.6 (59.9%)	68.7 (54.0%)	71.7 (55.2%)	70.3 (54.2%)
NORTH AMERICA (weighted averages)	**173.9 (39.9%)**	**228.5 (43.3%)**	**181.8 (34.9%)**	**242.3 (47.2%)**	**176.9 (34.5%)**	**205.6 (38.7%)**	**196.1 (36.9%)**

Note: Normalized to OECD Baseline in 2005.

TABLE A2.28: HEALTH IMPACTS OF URBAN AIR POLLUTION

		Projections for 2030	
		OECD	
	2000	Baseline	pp Global
Canada			
PM_{10} Mortality	58	0	0
PM_{10} Morbidity	418	0	0
Ozone Mortality	11	49	
Ozone Morbidity	76	615	
USA			
PM_{10} Mortality	121	58	6
PM_{10} Morbidity	926	379	37
Ozone Mortality	28	85	
Ozone Morbidity	213	997	
Mexico			
PM_{10} Mortality	106	70	17
PM_{10} Morbidity	1135	575	143
Ozone Mortality	9	51	
Ozone Morbidity	97	801	
NORTH AMERICA (weighted averages)			
PM_{10} Mortality	113	56	8
PM_{10} Morbidity	924	388	56
Ozone Mortality	23	75	
Ozone Morbidity	179	926	

Note: Mortality values in deaths per million inhabitants in urban areas. Morbidity values in Disability Adjusted Life Years (DALYs) lost per million inhabitants in urban areas.

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