

Feasibility Analysis for an Environment Outlook for Canada

Dale S. Rothman

June 2008



Prepared for Environment Canada by the
International Institute for Sustainable Development

© 2008 International Institute for Sustainable Development (IISD)

Published by the International Institute for Sustainable Development

The International Institute for Sustainable Development contributes to sustainable development by advancing policy recommendations on international trade and investment, economic policy, climate change, measurement and assessment, and natural resources management. Through the Internet, we report on international negotiations and share knowledge gained through collaborative projects with global partners, resulting in more rigorous research, capacity building in developing countries and better dialogue between North and South.

IISD's vision is better living for all—sustainably; its mission is to champion innovation, enabling societies to live sustainably. IISD is registered as a charitable organization in Canada and has 501(c)(3) status in the United States. IISD receives core operating support from the Government of Canada, provided through the Canadian International Development Agency (CIDA), the International Development Research Centre (IDRC) and Environment Canada; and from the Province of Manitoba. The institute receives project funding from numerous governments inside and outside Canada, United Nations agencies, foundations and the private sector.

International Institute for Sustainable Development

161 Portage Avenue East, 6th Floor

Winnipeg, Manitoba

Canada R3B 0Y4

Tel: +1 (204) 958-7700

Fax: +1 (204) 958-7710

E-mail: info@iisd.ca

Web site: <http://www.iisd.org/>

This paper was prepared for Environment Canada by the International Institute for Sustainable Development. The views contained in this paper do not necessarily reflect those of Environment Canada.

Table of Contents

1. Introduction.....	3
2. Elements of an Environment Outlook for Canada: Existing activities in Canada	4
2.1 Data Collection Efforts	5
2.2 Projection Efforts.....	8
3. The Future of Canada as it Appears in Global Assessments	10
4. Structuring an Outlook Exercise for Canada	15
5. Conclusions	21
6. References.....	23

Table of Figures

Figure 1: Total Population	13
Figure 2: Total GDP.....	13
Figure 3: GDP per capita	13
Figure 4: Total primary energy use.....	14
Figure 5: Total greenhouse gas emissions	14
Figure 6: Declines in mean species abundance, by factor	14
Figure 7: Modelling framework for GEO-4.....	18
Figure 8: Preliminary high-level conceptual framework for the proposed Canada Integrated Assessment Modelling Framework	19

1. Introduction

In June 2006, the Environmental Foresight & Priorities Division (EFPD), formerly a component of the Strategic Information Integration Directorate (SIID) of Environment Canada, initiated a multi-year project with the International Institute for Sustainable Development (IISD) to carry out research, methodology development, capacity building and pilot activities in support of the development of an Environment Outlook for Canada (EOC). The EOC will be tailored to Canadian conditions and priorities, while learning from UNEP's Global Environment Outlook processes as well as other relevant international and national outlooks and assessments.

As part of the Annual Work Plan for 2006–2007, IISD produced a Discussion Paper on an Environment Outlook for Canada.¹ This addressed, in part, the following issues:

- a) Rationale for an Environment Outlook for Canada. (What is an Environment Outlook? For what is it used? By whom? Assessment of its effectiveness for environmental decision-making. Discussion of other jurisdictions' experiences with outlook processes and report development.)
- b) Review of other methodologies and implementation, e.g., the United Nations Environment Programme's Global Environment Outlook (UNEP GEO).
- c) EOC report development framework (including the linkages to indicators work and national environmental objectives).
- d) Assessment of relevance of GEO and other scenarios for Canada, and discussion of adaptation or potential for development of domestic scenarios.
- e) Proposed outlook development process for Canada (including identification of potential partners, possible timeline, possible costs and resources requirements, proposed governance structure for the project and proposed evaluation of EOC impact for decision-making).

Earlier versions of that report were used in bilateral discussions with potential collaborators in, and users of, an Environment Outlook for Canada and as the main background document for a Consultative Scoping Workshop on an Environment Outlook for Canada held on March 1–2, 2007, in Montreal. The objective of the discussions and the workshop was to clarify the structure of, and gauge the overall interest in, an Environment Outlook for Canada. A report presenting the highlights from that workshop was also produced.

The Work Plan for 2007–08 called for a continuation of the effort to explore the development of an Environment Outlook for Canada. In particular, this was to focus on the exploration of the feasibility of an EOC and the development of a formal project proposal. The delayed approval for the 2007–08 agreement (October 2007) resulted in shifting activities originally scheduled for spring/summer 2007 to the fall of 2007. A further shift in priorities within SIID (Environment Canada) in fall 2007 affected the continuation of the EOC work planned for 2007–08. Specifically, a decision and agreement between SIID–EC and IISD was made to utilize IISD's expertise in the area of indicators and measurement to pursue an evaluation of the Canadian Environmental Sustainability Indicators (CESI)

¹ <http://www.iisd.org/measure/knowledge/national/canada.asp>

program. The initiation of the CESI program review by IISD was to be made at the cost of not pursuing activities included in the original Work Plan for the Environment Outlook for Canada project.

At this point, the expected results for 2007–08 relating to the feasibility analysis were to be addressed in a report on the elements for an Environment Outlook for Canada. This was to include:

- a breakdown for Canada of data and findings from UNEP's fourth Global Environment Outlook (GEO-4) and other international/national outlooks (e.g., the second OECD Environmental Outlook), (where possible);
- an assessment of the GEO-4 and other international scenarios for relevance and adaptability to Canadian context;
- a preparation of an inventory of key (federal) models, databases and other sources of information, e.g., sectoral assessments, which can contribute to an Environment Outlook for Canada;
- the identification of key modelling and data gaps potentially limiting the development of an EOC; and
- the development of strategies for and feasibility of connecting an EOC to the UNEP GEO and other outlook processes;

Other items, i.e., those related to a proposal outlining options for conducting an EOC, the pursuit of support for an EOC and capacity building for an EOC, were dropped from the Work Plan. This report presents the results of the feasibility analysis.

2. Elements of an Environment Outlook for Canada: Existing activities in Canada

An EOC would not, and should not, start from a blank slate. There are a number of recent and ongoing activities that could contribute to an EOC. Several of these are international efforts, which will be addressed in Section 3. This section will focus on existing activities in Canada. These can be separated into two broad categories. The first consists of key data collection efforts, which aim to provide a clear picture of historical trends and present conditions. The second, while certainly dependent on the former, includes studies that focus on projecting likely or plausible futures.

Before looking at some of these recent activities in more detail, though, it should be noted that, beginning in 1988, the Sustainable Society Project explored what could be a plausible sustainable future for Canada in the year 2030 (Robinson, 1996). This study examined many of the themes that would be of interest for an EOC, including population growth, energy use and economic activity in key sectors such as agriculture, forestry, mining and fisheries. It would certainly be remiss for an EOC to not review carefully what lessons can be learned from this earlier study.

2.1 Data Collection Efforts

Any effort to explore the future of the environment in Canada should necessarily start with a good understanding of the present state of the environment, as well as recent trends in factors driving environmental change. As Canada's national statistical agency, Statistics Canada is legislated under the *Statistics Act*² to produce statistics related to the population, resources, economy, society and culture of Canada. Other federal, provincial and territorial agencies, as well as independent groups, also work with Statistics Canada and each other to provide additional information on the state and trends of the environment in Canada. The following provides a brief overview of some of the most important nationwide efforts. This is intended to reflect the range of available data, but it is not meant to be comprehensive. Given the joint responsibility of the federal government and the provinces/territories in the area of the environment, significant data are also collected by the latter. These data are not described here, but should be explored in the further development of an EOC. Careful attention will need to be paid to their comparability as part of any such process.

General State of the Environment (SOE) Reporting and Indicators

Since the mid-1980s, the Canadian government has developed and published a series of SOE and environmental indicator reports. The most recent comprehensive SOE report dates back more than a decade, however, to 1996. Since 2000, key publications have been *Tracking Key Environmental Issues* (2001), *Environmental Signals* (2003 and forthcoming), and the 2005, 2006, and 2007 *Canadian Environmental Sustainability Indicators* (CESI) reports. The CESI initiative is currently scheduled to sunset in March 2009, but there are ongoing efforts to consider how to move forward with SOE and environmental indicator reporting after this date.³

Agriculture

Since May 2005, Agriculture and Agri-Food Canada (AAFC) has been leading a collaborative effort to link agri-environmental information from a number of sources and make it available on the Internet. The goal of this National Land and Water Information Service (NLWIS) is to be Canada's source of (geospatial) information, analysis and interpretation of agri-environmental data on land use, soil, water, climate and biodiversity. In addition to providing data, interactive Web-mapping applications, worksheets and calculators designed to assist land-use decision-makers are also being developed. It should be noted that the effort is limited to the area of the country defined as agricultural. The project is scheduled to be completed in 2009.⁴

Forests

In a similar vein to the NLWIS, the Canadian Council of Forest Ministers (CCFM) initiated the National Forest Information System (NFIS) effort in 2000 to provide Canadians and the international community with authoritative information about the state of Canada's forests and how they are being managed. This effort is closely tied to the National Forestry Information Database (NFID), which was established by the CCFM in 1990, as well as the National Forest Inventory (NFI), which is coordinated by Natural Resources Canada. The most recent complete version of the NFI is for 2001, but efforts are currently underway to

² *Statistics Act*, 1970-71-72, c. 15, s. 1., available at <http://www.statcan.ca/english/about/statact.htm>.

³ For more information on these initiatives, see <http://www.environmentandresources.gc.ca/> and <http://www.ec.gc.ca/soer-ree/>.

⁴ For more information on NLWIS, see <http://www.agr.gc.ca/nlwis/>.

produce a new inventory. The Earth Observation for Sustainable Development of Forests (EOSD) initiative, a joint effort of the Canadian Forest Service and the Canadian Space Agency, is contributing to this effort.⁵

Wetlands

Working with a number of other partners, the Canadian Wildlife Service of Environment Canada, the North American Wetland Conservation Council (Canada) and Ducks Unlimited Canada are currently leading an effort to develop a comprehensive and consistent inventory of the nation's wetlands. The Canadian Wetland Inventory (CWI) initiative provides an overarching framework for wetland inventory and monitoring in Canada. Phase 1 of the CWI initiative consisted of demonstration projects in selected study areas across Canada, covering a range of ecological and physical settings. Phase 1, which began in 2002, resulted in improved satellite image analysis for wetland mapping, enhanced expertise in land classification based on remote sensing, progress on digital wetland mapping for selected study areas and an initial partnership base for operational mapping. This phase concluded on March 31, 2007. Phase 2, if implemented, will expand the CWI to a full national wetland inventory and will include the development of a complementary monitoring program.⁶

Biodiversity and Ecosystems

The Canadian Biodiversity Information Facility (CBIF) is a joint effort of Agriculture and Agri-Food Canada, Environment Canada, Health Canada, Natural Resources Canada, the Canadian Food Inspection Agency, Canadian Museum of Nature and Parks Canada. As a participant in the Global Biodiversity Information Facility (GBIF), the CBIF is working to improve the organization, exchange, correlation and availability of primary data on biodiversity in Canada. More formally tied to the UN Convention on Biological Diversity (CBD) and the Canadian Biodiversity Strategy, the Canadian Biodiversity Information Network (CBIN) was established in 1996. The CBIN also maintains a database on various aspects of biodiversity in Canada. At a somewhat more general level, the Ecological Monitoring and Assessment Network (EMAN), coordinated by Environment Canada, was established in 1994 to improve understanding of ecosystem changes in Canada—what is changing and why?—by examining integrated data and knowledge sets. EMAN manages and continues to develop its Database Management System, providing on-line access to data collected by the network.⁷ The Conservation Areas Reporting and Tracking System (CARTS), being developed by the Canadian Council on Ecological Areas (CCEA) and collaborators, will be a Web-based application enabling standardized reporting and mapping for all Canadian public conservation (protected) areas.⁸ Finally, in the context of the Biodiversity Outcomes Framework, approved in 2006 by the Canadian Council of Resource Ministers (CCRM), one of the key requirements is related to assessing biodiversity in Canada. While also having many other important uses, the Ecological Status and Trends Report

⁵ For more information on NFIS, see <http://nfis.org/>; for more information on NFID, see <http://nfdp.ccfm.org/>; for more information on NFI, see <http://www.pfc.cfs.nrcan.gc.ca/monitoring/inventory> and <http://nfi.nfis.org/>; for more information on EOSD, see <http://eosd.cfs.nrcan.gc.ca/>.

⁶ For more information on CWI, see <http://www.cwi-ict.ca/> and http://www.wetkit.net/modules/1/showtool.php?tool_id=1857.

⁷ For more information on CBIF, see <http://www.cbif.gc.ca/>; for more information on CBIN, see <http://www.cbin.ec.gc.ca/>; for more information on EMAN, see <http://www.eman-rese.ca/>.

⁸ For more on CARTS, see <http://www.ccea.org/carts.html>.

(ESTR), currently in development, is a key vehicle for meeting this requirement. ESTR is compiling existing data from disparate sources related to the biological components of ecosystems and will make it available in a format that is useful for non-technical audiences.⁹

Air Pollutants and Greenhouse Gases

Through the National Pollutant Release Inventory (NPRI), the Greenhouse Gas Reporting program and other efforts, Environment Canada and Statistics Canada provide national data on emissions of criteria air contaminants,¹⁰ ammonia, other air pollutants¹¹ and greenhouse gases. Reporting for both the NPRI and the Greenhouse Gas Reporting program is required under the *Canadian Environmental Protection Act, 1999* (CEPA, 1999).¹² Indicators of exposure to ground-level ozone (O₃) and fine particulate matter (PM_{2.5}) during the warm season (April 1 to September 30) are provided as part of the Canadian Environmental Sustainability Indicators initiative run by Environment Canada, Statistics Canada and Health Canada.¹³ On a more continuous basis, Environment Canada and Health Canada have developed and are currently piloting an Air Quality Health Index (AQHI), which reports on the health risk posed by a mixture of pollutants including ground-level ozone, particulate matter and nitrogen dioxide.¹⁴

Freshwater

The Water Survey of Canada provides real-time, current year and historical information for a network of over 2,200 sites in Canada. The data measured are flow, water levels and sediment concentrations. Information on other aspects of water in Canada, e.g., water quality, water availability and links between water and health, is spread among a number of groups across the country. The RésEau initiative, led by Environment Canada in partnership with Natural Resources Canada and Health Canada, is an effort to enable the sharing, discovery, access and use of environmental information.¹⁵

General Geospatial Data

The Canadian Geospatial Data Infrastructure (CGDI), managed by Natural Resources Canada within the GeoConnections program, is an effort to standardize and make accessible a range of geospatial data sets throughout Canada. The GeoConnections Discovery Portal provides access to these data products, as well as tools for both using the data and

⁹ Personal communication, László Pintér, May 15, 2008.

¹⁰ The criteria air contaminants are total particulate matter (TPM), particulate matter with a diameter less than or equal to 10 microns (PM₁₀), particulate matter with a diameter less than or equal to 2.5 microns (PM_{2.5}), sulphur oxides (SO_x), nitrogen oxides (NO_x), volatile organic compounds (VOC), and carbon monoxide (CO).

¹¹ The other air pollutants include heavy metals—Lead (Pb); Cadmium (Cd); and Mercury (Hg)—and persistent organic pollutants: Dioxins and Furans (DF); Benzo(a)pyrene(B(a)P); Benzo(b)fluoranthene (B(b)F); Benzo(k)fluoranthene (B(k)F); indeno(1,2,3-cd)pyrene (i(1,2,3-cd)p); and Hexachlorobenzene (HCB).

¹² For more information on the NPRI, see <http://www.ec.gc.ca/pdb/npri/>; for more information on the Greenhouse Gas Reporting program, see <http://www.ghgreporting.gc.ca/GHGInfo/Pages/page1.aspx>; for general information on the reporting of criteria air contaminants, see <http://www.ec.gc.ca/pdb/cac/>.

¹³ For more information on the CESI initiative, see <http://www.environmentandresources.gc.ca/default.asp?lang=En&n=06B244A5-1>.

¹⁴ For more information on the Air Quality Health Index see <http://www.ec.gc.ca/cas-aqhi/> or http://www.hc-sc.gc.ca/ewh-semt/air/out-ext/air_quality_e.html.

¹⁵ For more information the Water Survey of Canada, see (<http://www.wsc.ec.gc.ca/>); for more information on RésEau, see <http://map.ns.ec.gc.ca/reseau/en/>.

contributing new data. In addition, related efforts such as GeoGratis and GeoBase provide additional portals to geospatial data.¹⁶

Health Information

Although somewhat distinct from the efforts discussed above, it is worth noting the efforts of the Canadian Institute for Health Information (CIHI). CIHI is not-for-profit organization funded by the Federal Government and the provinces. Its role is to be an independent source of health information. They have established a strong data collection infrastructure, including developing standards for health information collection. The data collected, while strongly emphasizing health services, do include data related to the physical environment and health. CIHI's focus is on reporting and analysis; the collected data are integrated with those of Statistics Canada, which focus more on health status and determinants of health. CIHI is currently in the process of producing its ninth annual report.¹⁷

2.2 Projection Efforts

Population

Statistics Canada (StatCan) regularly produces projections of Canada's population. The most recently published projections provide annual data for each province and territory by sex and single year of age for 13 scenarios until 2031. For the period 2032 to 2056, the same detail is provided for all of Canada; for individual provinces and territories only total population is provided (StatCan 2006a, 2006b).

Macroeconomics

It does not appear that there are any stand-alone efforts within Canada to make long-term macroeconomic projections for the Canadian economy. When these are needed for other purposes, though, these are produced using the Computable General Equilibrium model developed and managed by Infometrica Ltd. A joint effort by Finance Canada, Transport Canada, DFO, NRCan, Industry Canada and Environment Canada, however, has been underway to produce a Canadian-specific version of the PACE Computable General Equilibrium model.

Energy

Natural Resources Canada (NRCan, 2006) and the National Energy Board (NEB, 2007) have recently published studies looking at the future of energy in Canada. Each study considers energy production and use, as well as energy-related emissions of greenhouse gases (GHGs). The horizon for the NRCan study is 2020 and only a single reference case is explored. The National Energy Board looks out to 2030, presenting a reference case to the year 2015, but then three distinct scenarios going to 2030. A further significant distinction between the two studies is the choice of quantitative models. Specifically, NRCan uses the *Model to Analyze Policies Linked to Energy in Canada* (MAPLE-C), which has been modified from the U.S. National Energy Modeling System (NEMS) to reflect the Canadian economy and its provincial components. Alternatively, the National Energy Board used a combination of

¹⁶ For more information on GeoConnections, see <http://www.geoconnections.org/Welcome.do>; for more information on GeoGratis, see <http://geogratias.cgdi.gc.ca/>; for more information on GeoBase, see <http://www.geobase.ca/>.

¹⁷ For more information on CIHI, see <http://secure.cihi.ca/cihiweb/splash.html>.

TIM, Informetrica's macroeconomic model of the Canadian economy, and ENERGY2020, an integrated multi-region, multi-sector North American energy model. Together, these form what is commonly referred to as the Energy-Economy-Environment Model for Canada, or E3MC, which is maintained by Environment Canada. E3MC was used to prepare the emissions and economic modelling as part of Turning the Corner, the government of Canada's action plan to reduce greenhouse gases and air pollution (Government of Canada, 2008).

Agriculture – Land Use and Environmental Impacts

Under the auspices of the National Agri-Environmental Health Analysis and Reporting Program (NAHARP), Agriculture and Agri-Food Canada (AAFC) is developing tools that can help to track the environmental performance of Canadian agriculture, both historically and in the future. The three components of this effort focus on Agri-Environmental Indicators; Integrated Economic/Environmental Modelling and Analysis; and Agri-Environmental Valuation.

As part of the Agri-Environmental Indicators, a number of tools have been developed to consider the environmental farm management, soil quality, water quality, air quality, biodiversity at the scale of soil polygons, and even certain environmental impacts of the food and beverage industry (Lefebvre *et al.*, 2005). A key component of the Integrated Modelling has been the development of a Land Use Allocation Model (LUAM – see Gameda *et al.*, 2007), which translates projections from the scale of macroeconomic and policy models, principally the Canadian Regional Agricultural Model (CRAM – see Kulshreshtha *et al.*, 2002) to the scale of soil polygons. This allows AAFC to build a bridge to the biophysical models, ideally the same ones used for the Agri-Environmental Indicators, which will allow for the assessment of the expected environmental impacts of potential policies, or other future developments, at the scale of the landscape.

Climate Change

The Climate Change Impacts and Adaptation Program of NRCan recently released a major study on the current and potential future impacts of, and vulnerabilities to, climate change in Canada, along with options for adaptation (Lemmen *et al.*, 2008). The results presented in this study, but also the tools and approaches described, including global and regional climate models, could be useful for an EOC.

Biotechnology

While not specifically a projection, the Biotechnology, Sustainable Development and Canada's Future Economy (BSDE) Expert Working Party formed by the Canadian Biotechnology Advisory Committee (CBAC) developed a vision for the biotechnology sector in Canada in the year 2020 (BSDE, 2006). This vision was accompanied by discussions of the needs for the assessment, adaptive management and governance of BSDE efforts.

Criteria Air Contaminants and Ammonia

As part of its reporting on criteria air contaminants¹⁸ and ammonia, Environment Canada provides national projections to the year 2015.¹⁹ These are prepared in collaboration with provincial, territorial and regional environmental agencies.

3. The Future of Canada as it Appears in Global Assessments

Most integrated global assessments of the environment, notably UNEP's fourth Global Environment Outlook (GEO-4), the OECD's Environmental Outlook to 2030, and the scenarios of the Millennium Ecosystem Assessment (MA), tend to view the world as a set of large regions, or at least present their key results as such. In GEO-4, Canada was grouped with the United States as North America; in the OECD study, Canada was grouped with the United States and Mexico as OECD-North America; in the MA, it was grouped together with all OECD countries.

Part of the reason for these groupings is to provide some regional detail in what are otherwise primarily global reports, while at the same time keeping the amount of information presented manageable. In UNEP's case, it also reflects the regional structure of the institution. Another common reason, though, is that many of the underlying models used to quantify the scenarios themselves treat the world as a set of large regions for many issues, albeit not necessarily in a consistent fashion. This is starting to change, however, as computing power and available data improve. Luckily, most of the models now treat Canada as a separate entity. This makes it possible to consider issues such as demographic change, economic growth, and energy and water use from a national perspective. Furthermore, results for those issues examined at a grid scale, e.g., land use and temperature changes, can be aggregated to the national scale.

Issues still remain, though, with understanding the outcomes of these studies at a sub-national scale, which an EOC would certainly aim to do. Furthermore, these assessments do not necessarily address those environmental issues that would be of most interest to Canadians as these are defined at a larger scale. Finally, the detail to which Canada's economic, social and environmental systems are understood and explored is almost certainly less than would be desired for an EOC.

Still, there is some value in examining the future of Canada as it appears in these assessments. Happily, the developers of the GEO-4 scenarios and the OECD Outlook have made much of the underlying data, which for the most part do not appear in the published reports, available to us.²⁰ The box below provides some information on these scenarios for background purposes. In the remainder of this section, we present a small sample of the results from these two studies, along with comparisons to similar results from Canadian sources where available. The specific values are not necessarily of importance; of more

¹⁸ See footnote 10 for a list of the criteria air contaminants.

¹⁹ See http://www.ec.gc.ca/pdb/cac/Emissions1990-2015/emissions_e.cfm. At the time of writing, the emission trends and projections were being revised and updated, so they are not available. This process will continue for several months.

²⁰ Special thanks go to Jan Bakkes, Bas Eickhout and Detlef van Vuuren (MNP); Helen Mountford (OECD); Jackie Alder (UBC); Claudia Ringler and Siwa Msangi (IFPRI); Lera Miles (UNEP-WCMC); Martine Flöreke and Joseph Alcamo (CESR); and Barry Hughes (DU) for their provision of the data and assistance in their use.

interest are the basic trends and the differences between scenarios. For this reason, most of the results are presented as percentage changes from 2005.

Scenarios of the fourth Global Environment Outlook and the second OECD Environmental Outlook

The OECD Environmental Outlook is built around a baseline reference scenario (OECD Baseline), in which current policies are maintained but no new policies are introduced, particularly none to protect the environment. Various policy “variants” are explored related to, for example, local and regional air pollution, greenhouse gas emissions and agricultural support. Two that are considered at various points in this report are their more stringent variants: one being a global policy package (OECD pp Global); and the other reflecting policies needed to stabilize atmospheric concentration at 450 parts per million by volume of carbon dioxide equivalents (OECD 450 ppm).

In contrast, the four GEO-4 scenarios have fundamentally different assumptions about changes in individual behaviour and public policies. Briefly, in:

- **Markets First** (GEO4MF) – maximum economic growth is pursued; this emphasizes technological solutions to environmental problems. “Lip service” is paid to sustainable development policies.
- **Policy First** (GEO4PF) – strong policies to improve human and environmental well-being are implemented, primarily in a top-down fashion. Social and economic considerations are biased in favour of environmental considerations.
- **Security First** (GEO4SeF) – or “Me First”; the focus is on power and wealth generation for select groups.
- **Sustainability First** (GEO4SuF) – 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.

Population

Canada’s population is expected to grow by 11–25 per cent between 2005 and 2030, increasing from just over 32 million in 2005 to somewhere between 36 and 41 million in 2030.²¹ The projections provided in GEO-4 and the OECD Outlook all fall within the range projected by Statistics Canada (see Figure 1). In 2030, the growth rate will be close to 0.3 per cent in the lowest scenarios, but still around 0.9 per cent in the highest scenarios. Also of note is that the size of the rural population is expected to fall in all of the scenarios; thus, all of the growth will be in urban areas. Furthermore, the share of the population that is older than 65 is expected to rise from just over 13 per cent to 22–25 per cent of the population.

Economic Activity

Between 2005 and 2030, Canada’s economy is projected to grow, which will potentially increase the pressure on the environment. The level of growth varies significantly, though, by scenario (see Figures 2 and 3). The growth in total GDP ranges from a little over 55 per cent in the NEB Fortified Islands scenario to as much as 125 per cent in the GEO-4 Policy First scenario. This disparity is also reflected in the growth in per capita GDP, which ranges from 31 to 90 per cent, reflecting the similar estimates in total population across the

²¹ The StatCan projections are actually for 2031 and have been adjusted to 2030.

scenarios. All of the GEO-4 scenarios project greater growth; the OECD Baseline resembles the NEB Triple E scenario in terms of economic activity.

Energy Use

Depending upon the scenario, total primary energy use in Canada in 2030 is projected to range from slightly above its level in 2005 to a nearly 50 per cent increase (see Figure 4). These differences reflect the varying projections of population and economic activity, as well as disparate assumptions related to technological developments, particularly related to improvements in energy efficiency.

Greenhouse Gas Emissions

Figure 5 presents various estimates for greenhouse gas emissions in Canada between now and 2030. The scenarios with the highest values, an increase of over 50 per cent between 2005 and 2030, also indicate a continued increase after that time. At the other end are scenarios showing a 15–35 per cent decrease over this same period. As extreme as the latter may seem, none of these meet the latest target set by the Canadian government, which is a reduction of 20 per cent between 2006 and 2020, much less than the original targets set under the Kyoto Protocol. This is not to imply that these targets cannot be met, but rather that they present a significant challenge, one that will require “thinking outside the box” that goes beyond what was done in either GEO-4 or the OECD outlook.

Biodiversity

While it is very difficult to make projections of the loss of specific species, indicators are being developed that consider the more general issue of biodiversity loss. One of these is the notion of mean species abundance. Mean species abundance (MSA) captures the degree to which biodiversity, at a macrobiotic scale, remains unchanged. If the indicator is 100 per cent, 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).

Canada had already seen a decrease in terrestrial biodiversity estimated at just under 12 per cent in the year 2000, using mean species abundance as the measure (see Figure 6). The conversion of natural land for agricultural purposes has been the primary cause, accounting for almost half the decline. The expansion of human infrastructure—urbanization, transportation networks, construction related to resource exploitation and other elements of human settlement—has also played a significant role, with losses due to forestry and climate contributing a smaller share to the loss.²²

Looking to the future, a further loss of another 3–5 per cent is expected by 2030 and up to 10 per cent by 2050. Climate change plays an increasingly important role, irrespective of the scenario, as does infrastructure, although this does vary between scenarios. The impact of forestry also increases, whereas that of agriculture remains fairly constant in most of the scenarios.

²² The “other” category includes forestry, fragmentation, and pollution, specifically nitrogen deposition. The existing tools do not allow the identification of biodiversity loss from such factors as the introduction of invasive species.

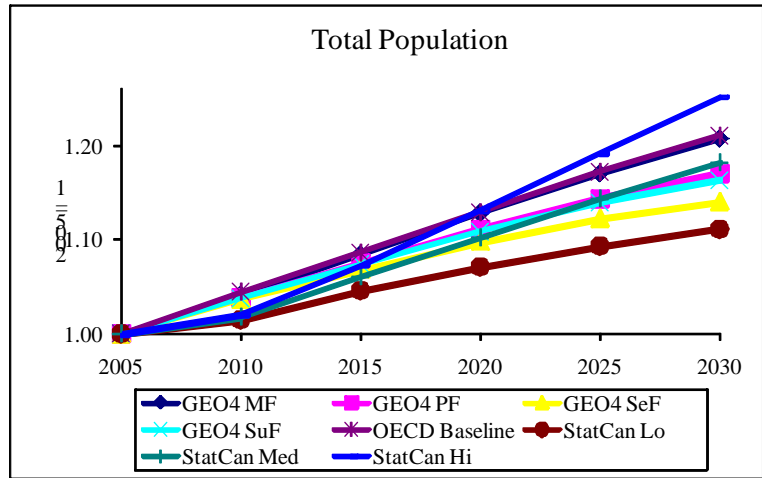


Figure 1: Total Population

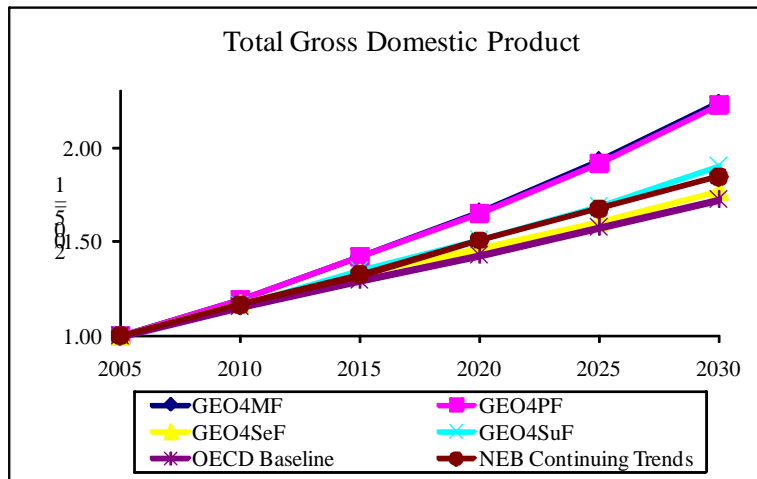


Figure 2: Total GDP

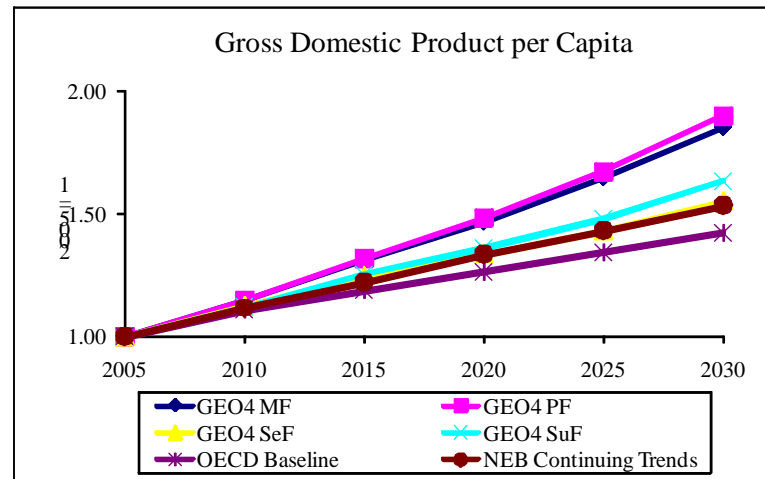


Figure 3: GDP per capita

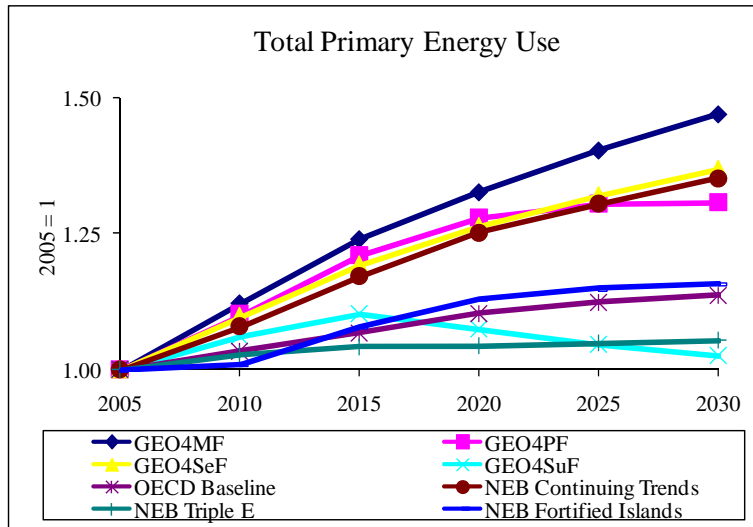


Figure 4: Total primary energy use

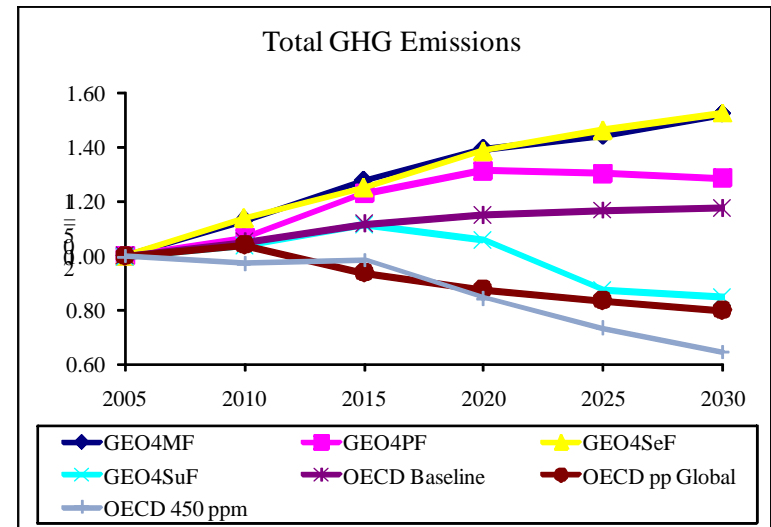


Figure 5: Total greenhouse gas emissions

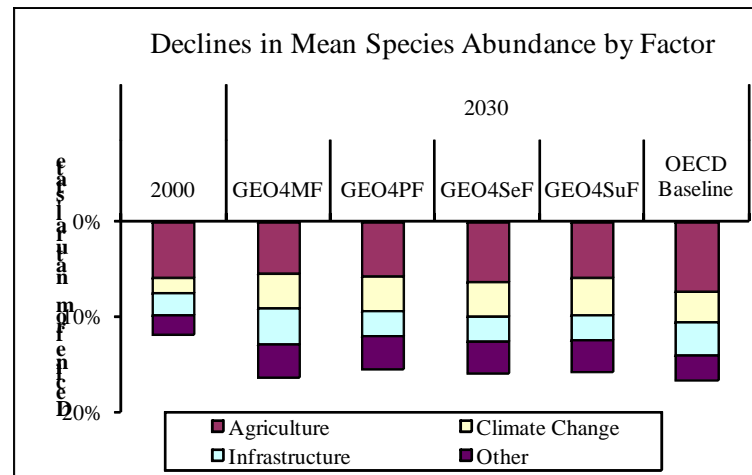


Figure 6: Declines in mean species abundance, by factor

4. Structuring an Outlook Exercise for Canada

As recognized in most recent outlook exercises (e.g., OECD, 2008; UNEP, 2002 and 2007; IPCC, 2000; MA, 2005; Cosgrove and Rijsberman, 2000; Raskin *et al.*, 2002), narratives and modelling complement each other in enriching the overall futures analysis. This can be a daunting effort. Hundreds of people and organizations have been involved in preparing these outlooks and the structure of collaboration followed varies from study to study. The following briefly describes the approach used in developing the scenarios for the fourth Global Environment Outlook.

Three coordinating lead authors (CLAs) and a chapter coordinator from UNEP oversaw the development of the scenarios over a three-year period for GEO-4, published in 2007. Regional team leaders, quantitative modellers and an expert on facilitating participatory processes served as lead authors (LAs) and, together with the CLAs, comprised a chapter expert group (CEG). In addition, primarily for the purpose of providing the regional contributions, a group of about 10 experts per region was chosen by the regional team leaders, in consultation with the regional coordinators of the UNEP Division of Early Warning and Assessment and others. Recognizing the impossibility of the above groups being truly representative or fully versed in all areas required for the development of the chapter, other regional and modelling experts were also invited to provide a broader range of perspectives and specific expertise. Throughout the process, the team was assisted by Bee Successful (<http://www.beesuccessful.com/>), a management consultancy with expertise in scenario thinking and participatory methods.

The CLAs and LAs met several times in 2004 and early 2005 to plan the development of the chapter. During the GEO-4 regional consultations, a strong preference was expressed by participants to retain the basic characteristics of the scenarios, rather than to restart the process. Therefore, the scenarios developed should be seen as revised and updated versions of those from GEO-3, both in terms of the narratives and the quantification (see UNEP and RIVM, 2004).²³ The chapter expert group, along with the seven teams of regional representatives, met in Bangkok in September 2005. This was followed by meetings in each of the regions other than North America, in 2006.

Further smaller meetings of CEG members were held over the next 18 months to further clarify issues and work out potential inconsistencies among the regional narratives and between the narratives and the quantitative results. The seven regional teams developed narrative descriptions of each of the four scenarios from the perspective of each region. Taking the drivers and assumptions of the GEO-3 global scenarios as a starting point, the regional groups worked in parallel to develop rich descriptions of the “journey” and “end state” of the four scenarios from a regional perspective. At the same time, each group carefully considered how events or trends in their region might influence, or be influenced by, developments in other regions and at the global level. Through a series of iterations, storylines were drafted at both the regional and global levels. In parallel, a suite of advanced

²³ The scenarios were influenced by more recent scenario exercises, both those that drew directly from GEO-3, e.g., regional studies in Africa (UNEP, 2006) and Latin America (UNEP, 2004), and those that only marginally considered the scenarios presented in GEO-3, most notably the global and sub-global scenarios developed as part of the Millennium Ecosystem Assessment (MA, 2005; Lebel and others, 2005).

state-of-the-art models was used to develop the quantitative estimates of future environmental change and impacts on human well-being. In order to check the validity and consistency of the scenarios, the narrative teams interacted closely with the global and regional modellers to ensure that the quantitative and qualitative components of the scenarios complemented and reinforced each other. Furthermore, the scenarios were critically reviewed by experts in particular areas, such as energy, many of whom were contributors to other chapters of the final GEO-4 report. A concerted effort was made throughout the process to build regional capacity with respect to scenario development, as well as to make the resulting regional material a central part of the global storylines. In particular, special attention was given to the regional priority issues identified early in the GEO-4 process and discussed throughout the other chapters of the GEO-4 report (UNEP, 2007). Furthermore, through discussions as a regional team, and with the broader chapter working group, each region developed their own storylines and considered the quantitative results for their region as part of the process of developing the final chapter.

Since no single overriding “super model” is available for computing future environmental change and the impacts on human well-being, the most common practice in outlook studies is to assemble suites of models for the task. Before their use in such an integrated manner, the individual models have generally been published in the peer-reviewed scientific literature and shown to be useful for linking changes in society with changes in the natural environment. The models are then “soft-linked,” with output files from one model being used as inputs to other models.

An example of such a framework used in GEO-4 is shown in Figure 7. Briefly, the individual models are as follows (UNEP, 2007):

- International Futures (IFs) is a large-scale integrated global modelling system (Hughes and Hillebrand, 2006). IFs serves as a thinking tool for the analysis of long-term country-specific, regional and global futures across multiple and interacting issue areas. The system draws upon standard approaches to modelling specific issue areas whenever possible, extending those as necessary and integrating them across issue areas. For GEO-4, IFs provided population trends and the development in GDP and GDP per capita as well as additional information on value added, household consumption, health and education.
- IMAGE (Integrated Model to Assess the Global Environment) is a dynamic integrated assessment model for global change developed by the National Institute for Public Health and the Environment (RIVM), The Netherlands (Bouwman *et al.*, 2006). IMAGE is used to study a whole range of environmental and global change problems, particularly in the realm of land use change, atmospheric pollution and climate change. The main objectives of IMAGE are to contribute to scientific understanding and support decision-making by quantifying the relative importance of major processes and interactions in the society-biosphere-climate system. For GEO-4, IMAGE provided estimates of energy use, land use, greenhouse gas emissions, and changes in temperature and precipitation.
- IMPACT (International Model for Policy Analysis of Agricultural Commodities and Trade) is a representation of a competitive world agricultural market for 32 crop and livestock commodities, including all cereals, soybeans, roots and tubers, meats, milk,

- eggs, oils, oilcakes and meals, sugar and sweeteners, fruits and vegetables, and fish. It was developed in the early 1990s as a response to concerns about a lack of vision and consensus regarding the actions required to feed the world in the future, reduce poverty and protect the natural resource base. For GEO-4, IMPACT generated projections for crop area, livestock numbers, yield, production, demand for food, feed and other uses, prices, trade and childhood malnutrition.
- WaterGAP (Water – Global Assessment and Prognosis) is a global model developed at the Center for Environmental Systems Research of the University of Kassel that computes both water availability and water use on a 0.5° global grid (Alcamo *et al.*, 2003a, b; Döll *et al.*, 2003). The model aims to provide a basis for an assessment of current water resources and water uses, and for an integrated perspective on the impacts of climate change and socioeconomic drivers (population, economic growth and technological change) on the future water sector. For GEO-4, WaterGAP provided estimates of water use (for irrigation and in the domestic, manufacturing and electricity production sectors), water availability and water stress.
 - EwE (Ecopath with Ecosim) is an ecological modelling software suite for personal computers of which some components have been under development for nearly two decades. The development is centred at the University of British Columbia's Fishery Centre. The approach is thoroughly documented in the scientific literature, with over 100 ecosystems models developed to date (see <http://www.ecopath.org>). EwE uses two main components: Ecopath – a static, mass-balanced snapshot of marine ecosystems; and Ecosim – a time dynamic simulation module for policy exploration that is based on an Ecopath model. For GEO-4, EwE provided estimates of catch, profits, and quality of marine fisheries.
 - The GLOBIO model simulates the impact of multiple pressures (e.g., land use conversion, climate change and certain air pollutants) on biodiversity (Alkemade *et al.*, 2006). The model relies on a database of field studies relating magnitude of pressure to magnitude of biodiversity impact. This database includes separate measures of mean species abundance (MSA) and of mean species richness (MSR) of original species of ecosystems, each in relation to different degrees of pressure. The entries in the database are all derived from peer-reviewed studies, either of change through time in a single plot, or of response in parallel plots undergoing different pressures. An individual study may have reported species richness, mean species abundance, or both. Rows are classified by pressure type, taxon under study, biome and region. For GEO-4, GLOBIO provided estimates of changes in mean species abundance for terrestrial ecosystems.

The analyses for the OECD Environmental Outlook followed a similar approach, using many of the same tools, e.g., IMAGE, WaterGap and GLOBIO. Perhaps the key difference was the use of the ENV-Linkages economic model. “The ENV-Linkages model is a global economic model built primarily on a database of national economies. The model represents the world economy in 34 countries/regions, each with 26 economic sectors. Each of the 34 countries/regions is underpinned by an economic input-output table (usually published by a national statistical agency). These tables identify all the inputs into an industry and identify all the industries that buy specific products. Some industries explicitly use land, while others, such as fisheries and forestry, also have a ‘natural resource’ input. (OECD, 2008).

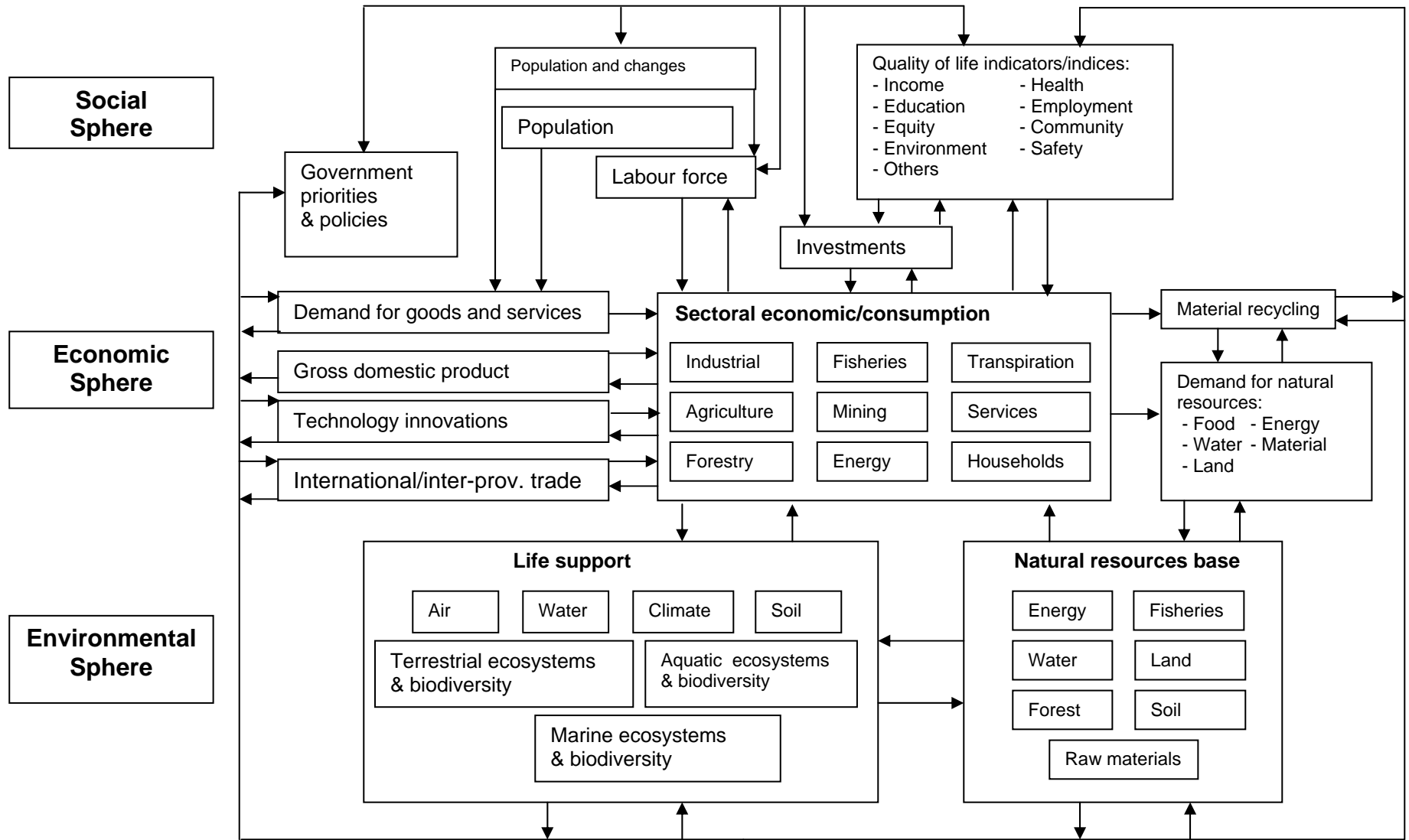


Figure 8: Preliminary high-level conceptual framework for the proposed Canada Integrated Assessment Modelling Framework

A question that arises here is the extent to which these models could be applied in an EOC. The WaterGap, GLOBIO and parts of the IMAGE model operate at a grid-scale level; thus results can be aggregated to the level of Canada. IFs, IMPACT, ENV-Linkages and parts of the IMAGE model operate at a country or multi-country level; Canada is treated separately in each of these models, so specific data can be obtained. EwE uses the marine regions of the UN Food and Agricultural Organization, three of which border on Canada. Thus, although these models can provide a general overview for Canada as a whole, it is questionable whether they could provide results at a sub-national level that would be desired in an EOC. Furthermore, as primarily global models, while they do a good job of placing Canada in the context of the broader world, a further analysis would be required to consider the degree to which they capture specific aspects of the Canadian situation, including the use of more detailed data that might not be included in international databases.

Alternatively, it might be more appropriate as part of an EOC to establish a central coordinating body, a similar modelling framework, sets of regional teams at the provincial/territorial level and, perhaps, sectoral teams. The earlier discussion of the elements of an EOC would seem to indicate that many of the building blocks for such a system may already be in place, at least on the quantitative side, where it would be desirable to assemble such a framework using tools and models that are more Canadian focussed, i.e., that would make use of more specific information on the Canadian economy and environment and could provide greater sub-national detail.

Such a system has actually been considered in the recent past. Earlier in this decade, the creation of a Canadian Integrated Assessment Modelling (CIAM) framework was proposed.²⁴ The proposal was to set up a cross-departmental partnership initiative to develop “a common framework . . . to make existing and emerging sectoral models (social, economic, natural resources, or environmental) and the associated data sets easily accessible to other users, and thereby to enhance departmental as well as federal analytical capacity for informed public policy decision making aimed at sustainable development.”²⁵ The proposed framework was intended to bridge the social, economic and environmental spheres (see Figure 8) and the intention was to draw on a number of federal departments including Agriculture and Agri-Food Canada, Natural Resources Canada, Environment Canada, Finance Canada, Health Canada, Human Resources and Social Development Canada, Industry Canada, Department of Fisheries and Oceans, Statistics Canada and the National Roundtable on the Environment and the Economy. While the actual development of a comprehensive CIAM framework was not pursued, two pilot projects went ahead. One completed pilot dealt with climate change impacts on northern community infrastructure, with a “vertical” integration transforming climate change scenarios into permafrost response, terrain disturbance, risks to infrastructure damage and, finally, to cost scenarios with various adaptation options (Zhou *et al.*, 2007). The other pilot tackles the issue of agricultural resilience to climate change on the Canadian Prairies (Zhang *et al.*, 2004). With a close collaboration between NRCan and AAFC, as well as University of Saskatchewan, this pilot project encompasses three modelling components: a biophysical model to simulate climate change impacts on land productivity; a regional agricultural model (CRAM) to assess the

²⁴ Personal communication from Aining Zhang July 25, 2007.

²⁵ From Zhang, A. and Cihlar, J., 2002. “Creating a Canada Integrated Assessment Modelling (CIAM) Framework”, unpublished draft discussion paper, Natural Resources Canada.

economic cost/benefit of the impacts; and an agent-based land use adaptation model (PF-ABM) to simulate farmers' land use response to these changes. The findings from the biophysical assessment have suggested the need for a thorough economic analysis. An effort is currently underway to expand the framework of analysis to Canada wide and to incorporate the issue of biomass for biofuel development.

5. Conclusions

This document has built upon the previous Discussion Paper on an Environment Outlook for Canada.²⁶ Its focus has been on the feasibility of an Environment Outlook for Canada, with particular emphasis on breakdown for Canada of data and findings from recent international scenario exercises; assessing these efforts for relevance and adaptability to Canadian context; preparing an inventory of key (federal) models, databases and other sources of information, e.g., sectoral assessments, which can contribute to an Environment Outlook for Canada; and identifying key modelling and data gaps potentially limiting the development of an EOC.

Based upon the material presented in this report, what can be said in general about the feasibility of an Environment Outlook for Canada? Is an EOC feasible? This can, perhaps, be best answered by revisiting the original goals for this analysis in the form of a series of questions.

Do the required models, databases and other sources of information, e.g., sectoral assessments, exist within Canada that could be used to develop an Environment Outlook for Canada?

There are numerous ongoing activities related to data collection, model development and sectoral assessments for environmental issues in Canada. Thus, many of the basic building blocks for an EOC already exist. Many of these are still in the development stage, however, which might limit their use in the immediate future. Areas that appear somewhat lacking in coverage include water quality and quantity. More importantly, there is a general lack of coordination across these efforts, which would be a key requirement of an EOC.

What can be learned from other international/national outlooks for the purposes of developing an Environment Outlook for Canada?

Efforts such as the fourth Global Environment Outlook and the second OECD Environmental Outlook can help to paint a general picture of possible environmental futures for Canada, but lack in providing specificity at a national and sub-national level. In addition, the approaches used to develop these outlooks provide models for how an EOC might be pursued. These would need to be modified, however, to make them appropriate for the Canadian situation and to best utilize the existing building blocks discussed above. Most significantly, perhaps, would be the need to consider the plausible environmental futures for Canada (scalable for analysis, interpretation and reporting) at a provincial/territorial, if not a finer geographic level, which is not the case for the existing international studies.

²⁶ <http://www.iisd.org/measure/knowledge/national/canada.asp>.

What are the major issues that need to be considered for the development of an Environment Outlook for Canada?

The development of an EOC appears to be feasible, but would require significant support and commitment in terms of staff time and financial resources, i.e., several years and probably several million dollars. Ideally, such an effort would have federal (multi-department)/provincial/territorial support and buy-in. Furthermore, any effort to develop an EOC should not be seen as a stand-alone exercise, but rather a stimulus to integrate and contribute to the range of existing activities, as well as initiate further activities. An EOC could play a significant role in fulfilling legislative mandates under the *Department of Environment Act*, the *Canadian Environmental Protection Act* (CEPA, 1999) and the *Auditor General Act* related to monitoring and pursuing federal progress on environmental and sustainable development issues.

What is the potential for the development of an Environment Outlook for Canada at this time?

The potential benefits of an EOC—e.g., an integrated modelling system, capacity building and support for sustainable development strategies at multiple levels (national, regional and sectoral)—would almost certainly go beyond any specific products, such as a published report. Unfortunately, based upon the research undertaken to develop this feasibility analysis and the discussions within key federal departments, it would appear that, while there exists the logic for a national Environment Outlook for Canada described in the previous Discussion Paper, the necessary support and commitment does not presently exist.

6. References

Alcamo, J., Döll, P., Henrichs, T., Kaspar, F., Lehner, B., Rösch, T., and Siebert, S. (2003a). Development and testing of the WaterGAP 2 global model of water use and availability. In *Hydrological Sciences* 48 (3):317-337.

Alcamo, J., Döll, P., Henrichs, T., Kaspar, F., Lehner, B., Rösch, T. and Siebert, S. (2003b). Global estimation of water withdrawals and availability under current and 'business as usual' conditions. In *Hydrological Sciences* 48 (3):339-348.

Alkemade, R., Bakkenes, M., Bobbink, R., Miles, L., Nellemann, C., Simons, H. and Tekelenburg, T. (2006). GLOBIO 3: Framework for the assessment of global terrestrial biodiversity. In Bouwman, A.F., Kram, T. and Klein Goldewijk, K. (eds.) *Integrated Modelling of Global Environmental Change: An Overview of IMAGE 2.4*. Netherlands Environmental Assessment Agency, Bilthoven.

Bouwman, A.F., Kram, T. and Klein Goldewijk, K. (2006). *Integrated Modelling of Global Environmental Change: An Overview of Image 2.4*. Netherlands Environmental Assessment Agency, Bilthoven.

BSDE. (2006). *BioPromise? Biotechnology, Sustainable Development and Canada's Future Economy*. Executive and Technical Reports to CBAC (Canadian Biotechnology Advisory Committee) from the Biotechnology, Sustainable Development and Canada's Future Economy (BSDE) Expert Working Party.

Cosgrove, W. J. and Rijsberman, F. R. (2000). *World Water Vision: Making water everybody's business*. Earthscan, London

Döll, P., Kaspar, F. and Lehner, B. (2003). A global hydrological model for deriving water availability indicators: model tuning and validation. In *Journal of Hydrology* 270 (1-2):105-134

Gameda, S., S. Toure, H. Morana, T. Huffman, and D. J. Kroetsch (2007). "Integrated Socio-Economic and Biophysical Modelling to Assess Agricultural Policy Impacts", poster presentation at Farming Systems Design 2007: An International Symposium on Methodologies for Integrated Analysis of Farm Production Systems, 10-12 September, Sicily, Italy.

Government of Canada (2008). *Turning the Corner: Detailed Emissions and Economic Modelling*. Gatineau, Quebec: Inquiry Centre, Environment Canada.

Government of Canada (2007). *Canadian Environmental Sustainability Indicators*. Gatineau, Quebec: Inquiry Centre, Environment Canada.

Hughes, B. and Hillebrand, E. (2006). *Exploring and Shaping International Futures*. Paradigm Publishers, Boulder, CO.

- IPCC (2000). *Emission Scenarios*. Cambridge University Press, Cambridge
- Kulshreshtha, S. N., Gill, R., Junkins, B., Desjardins, R., Boehm, M., and Bonneau, M. (2002). Canadian Economic and Emissions Model for Agriculture (C.E.E.M.A. 2.0): Technical Documentation.
- Lebel, L., Thongbai, P. and Kok, K. (2005). Sub-Global Assessments. In *Millennium Assessment Ecosystems and Human Well-being: Multi-scale Assessments: Findings of the Sub-global Assessments Working Group*. Island Press, Washington, DC
- Lefebvre, A., Eilers, W. and Chunn, B. (eds.) (2005). *Environmental Sustainability of Canadian Agriculture: Agri-Environmental Indicator Report Series – Report #2*. Agriculture and Agri-Food Canada, Ottawa.
- Lemmen, D. S., Warren, F. J., Lacroix, J. and Bush, E. (eds.) (2008). *From Impacts to Adaptation: Canada in a Changing Climate 2007*. Government of Canada, Ottawa.
- MA (2005). *Ecosystems and Human Well-being: Scenarios: Findings of the Scenarios Working Group of the Millennium Ecosystem Assessment Working Group*. Island Press, Washington, DC.
- MA (2005). *Ecosystems and Human Well-Being. Volume 2 Scenarios*. Island Press, Washington, DC.
- National Energy Board (2007). *Canada's Energy Future: Reference Case and Scenarios to 2030*. National Energy Board, Calgary.
- Natural Resources Canada (2006). *Canada's Energy Outlook: The Reference Case 2006*. Natural Resources Canada, Analysis and Modelling Division, Ottawa.
- OECD (2008). *OECD Environmental Outlook to 2030*. Organization for Economic Co-operation and Development, Paris.
- Raskin, P., Banuri, T., Gallopin, G., Gutman, P., Hammond, A., Kates, R. and Swart, R. (2002). *Great Transition: The Promise and Lure of the Times Ahead*. Stockholm Environment Institute, Boston, MA
- Robinson, J. B. (1996). *Life in 2030: Exploring a Sustainable Future for Canada*. UBC Press: Vancouver.
- Statistics Canada (2006a). *Population Projections for Canada, Provinces and Territories 2005-2031*. Statistics Canada, Ottawa
- Statistics Canada (2006b). *Population Projections for Canada, Provinces and Territories, with Detailed Electronic Tables 2005-2051*. CD-ROM, Statistics Canada, Ottawa
- UNEP (2007). *Global Environment Outlook 4: Environment for Development*, United Nations Environment Programme, Nairobi.

UNEP (2006). *Africa Environment Outlook 2: Our Environment, Our Wealth*. United Nations Environment Programme, Nairobi

UNEP (2004). *GEO Latin America and the Caribbean Environment Outlook 2003*. United Nations Environment Programme, Nairobi

UNEP (2002). *Global Environment Outlook 3*. Earthscan, London.

UNEP and RIVM (2004). *The GEO-3 Scenarios 2002-2032. Quantification and analysis of environmental impacts*. Potting, J. and Bakkes, J. (eds.). UNEP/DEWA/RS.03-4 and RIVM 402001022. United Nations Environment Programme, Nairobi and National Institute for Public Health and the Environment (currently MNP), Bilthoven.

UNPD (2007). *World Population Prospects: The 2006 Revision*. UN Population Division, New York, NY, <http://www.un.org/esa/population/unpop.htm>

Zhang, A., C. Goodfellow, K. Sprague, R. Becker, F. Zhou, B. MacGregor, J-W. Ilek, Reinder DeJong, Denise Neilsen, Sam Gameda (2004). "Vulnerability of Prairie Agricultural Systems to Climate Change: A Spatially-explicit Model-based Assessment". In proceeding of 57th CWEA Annual Conference: Water and Climate Change, knowledge for better Adaptation. Montreal, June.

Zhou, F., A. Zhang, R. Li, E. Hove, A. Majid (2007). Potential climate change-induced permafrost degradation and building foundations: An assessment of impacts and costs for five case communities in the Northwest Territories. Natural Resources Canada: Research Report. 115p.