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Environment

A REPORT OF THE CANADIAN INDEX OF WELLBEING (CIW)

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CANADIAN Index OF WELLBEING

Measuring what matters

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Abstract

This is the first edition of the Environment Domain Report for the Canadian Index of Wellbeing. The report provides a snapshot on the state and the trends in Canada's environment using a set of anthropocentric, natural capital-based indicators. It also represents the beginning of a discussion about how the stocks and flows of Canada's natural capital affect human wellbeing. The report therefore highlights some of the choices that policy makers need to consider in order to optimize the long-term wellbeing of Canadians.

Collectively, the indicators from the Environment Domain paint a mixed picture for Canada through both time and space.

- **Air** quality indicators are variable with some improvements and some declines, though pollutants do remain a concern when they peak during poor air quality periods in certain locations. Growing energy demands, largely for fossil fuels, are driving many of the trends, ranging from greenhouse gas emissions to air pollution, with the oil and gas and transportation sectors being the heaviest emitters. While Canada has successfully reduced several of the key drivers of poor air quality, respiratory diseases are still of concern and have grown over the past two decades.
- **Energy** production continues to meet and surpass demand, enabling Canada to maintain the envious position of being a large energy exporter. Of note is the fact that renewable energy sources, while growing, still make up a small proportion of total energy use.
- **Freshwater** quality, which varies throughout Canada, is generally acceptable. While water use rates remain roughly consistent, they are high on an absolute level. However, water supply is trending downwards in Southern Canada, which represents a risk to wellbeing.
- **Non-Renewable resources**, including both energy sources and metals, have declined over the past decades, but both additional discoveries and increased viability, through rises in commodity prices, have stabilized the trends. Waste disposal levels remain high, despite a leveling off of disposal rates in recent years along with increases in diversion rates.
- **Biotic Resource** trends are generally negative in both the marine and terrestrial realms. Marine ecosystems are showing signs of systemic change as catches of large fish make way for smaller species from lower on the food chain. On land, numerous mammals, reptiles and amphibians, and some bird species are showing signs of decline and there have been significant changes in the structure of Canadian food webs, particularly in non-terrestrial systems. Lastly, despite improvements in forestry management practices, our forest resources are not in balance, resulting in a gradual erosion of ecosystem services.

Overall, Canadians face numerous challenges when it comes to the environment and wellbeing, as any policy choice has the ability to prioritize one aspect of wellbeing over another. The challenge remains how to *optimize* wellbeing for both humans and other species, rather than *maximize* one domain of wellbeing (e.g., economic benefits towards living standards).

Lastly, as Canadians, we face a challenge when it comes to the availability of environmental data. Though this issue affects most countries, and notwithstanding the excellent work of government agencies (e.g., Statistics Canada and Environment Canada), Canadians should be concerned about the paucity of information on natural capital. Like other countries, Canada has insufficient funding and capacity when it comes to environmental monitoring, and without much more comprehensive data, it will be impossible fully assess the stocks and flows of Canada's natural capital and ecosystem services, and how they in turn affect our wellbeing.

Executive Summary

> *"When the 20th century began, people still thought of the planet as infinite in its bounty. The highest mountains were still unclimbed, the ocean depths never visited, and vast wildernesses stretched across the equatorial continents. Now we have all but finished mapping the physical world, and we have taken the measure of our dwindling resources. Troubled by what we have wrought, we have begun to turn in our role from local conqueror to global steward."*
>
> — E.O. Wilson, in *Naturalist*

The environment is the foundation upon which human societies are built. From the resources that fuel our economy and the happiness of outdoor enthusiasts, to the medicine that heals us and the lessons that guide our religions, the wellbeing of humans is inextricably dependent on the environment. We are a part of the planet, made up of the same materials and energy as the earth, plants, and animals around us. Indeed, the dictionary defines the environment as: "the complex of physical, chemical, and biotic factors (as climate, soil, and living things) that act upon an organism or an ecological community and ultimately determine its form and survival."[1] Yet despite its fundamental importance to us as a species, and despite estimates that Canada's natural resource wealth exceeds one *trillion* dollars[2], humans often take the environment for granted. We fail to appreciate the various and valuable ecosystem services provided by nature that sustain human wellbeing. To put it another way, the environment can be seen as an asset, or a form of natural capital, which in turn provides the basis for human wellbeing in other domains. Examples would include the relationships between pollution and health, or the cod fisheries and the economy of the East Coast. These types of linkages speak to the importance of the environment, and demonstrate why it is included in the Canadian Index of Wellbeing.

This is the first edition of the Environment Domain Report. It provides a snapshot on the state of and the trends in Canada's environment using a set of natural capital based stock and flow indicators. It is important to note at the outset that this is not a comprehensive analysis of Canada's state of the environment, nor a measure of whether or not Canada's use of its natural capital is, or is not, sustainable. This is not possible given the state of environmental information and our limited understanding of how ecosystems operate. Rather, this report is the beginning of an effort to assess the stocks and flows of Canada's environmental goods and services. "Stock" indicators provide a form of measurement of the standing amounts - reserves if you will - of a given component of natural capital. It could be thought of as a reservoir, for example, of freshwater. "Flow" indicators measure the quantity and quality that are added/removed or enhanced/degraded from that stock of natural capital in a given time period. These could be thought of as the amount of water that is let out of the reservoir or how much is added via precipitation. Another way of thinking about it is as a bank: capital in the bank is "stock", and

[1] Merriam-Webster Dictionary (2011) Environment. Available online: http://www.merriam-webster.com/dictionary/environment Last accessed, March 10, 2011.

[2] Statistics Canada (2008) Canada's natural resource wealth at a glance. Available online at: http://www.statcan.gc.ca/pub/16-002-x/2007003/10454-eng.htm#chart2 Last accessed: March 11, 2011.

the money you put in or remove is the "flow". The conceptual approach is covered in more depth in Section 2 - Methodology under Conceptual Approach.

Lastly, right from the outset, the author wishes to note several important caveats:

1) Due to various limitations (e.g., data availability/accessibility, financial constraints, time, etc.), and because some indicators do not lend themselves well to a strict stock/flow framework (e.g., water quality or habitat), several of the indicators are blended (i.e., the indicators combine aspects of both stock and flow): others simply do not have data. Accordingly, non-idealized proxy indicators have had to be used to compensate for data that simply do not exist.

2) It is also important to note that the report explicitly uses an anthropocentric perspective on the environment that focuses on the aspects that are of importance to life in general and therefore to the wellbeing of Canadians[3]: air (which includes climate), energy, freshwater, non-renewable resources (which includes minerals and metals), and biotic resources (which is consistent with the idea of "biodiversity", and includes space, genetic resources, species and ecosystems).

3) National indicators can be problematic for a country as large and varied as Canada, as significant regional differences do exist. Canada is a very large country with highly concentrated urban populations, as well as large areas with sparse human inhabitation. Accordingly, single national numbers that do not explore regional differences must be interpreted with this in mind.

4) The report is designed to assess the status of stocks and flows against desirable levels. It is not designed to be an international comparison of how Canada fares versus other countries, though other numbers are noted at times. For an international perspective, the author suggests looking to the Environmental Performance Index (EPI).[4] It is recognized that Canada is blessed with a large land mass while being home to a relatively small population, which means that in general, when compared to other countries (via such measures as the Environmental Performance Index or the Conference Board of Canada's environment indicators[5]), Canada fares well. This report does not fully capture the import and export aspects of the environment (including Canadians' ecological footprints that land in other countries), nor does it track the full life cycle of many goods that play a role in Canada's environment. While these are recognized limitations, they were necessary to make the scope of the report manageable.

5) The mandate for the Environment Domain was to be succinct and not exhaustively comprehensive. Accordingly, the report uses 14 primary indicators, along with some additional data sets, to provide insights into the state and trends of Canada's environmental stocks and flows, and how those link to the wellbeing of Canadians. Such a snapshot cannot capture the full picture of Canada's environment, nor a full description of whether our use

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[3] These aspects have been derived from work done by Victor, P., Hanna, J.E. and Kubursi, A. (1995) How Strong is Weak Sustainability? *Economie Appliquée*, 48(2): 75-94. See Section 4 – Methodology – Conceptual Approach for more details.

[4] See Environmental Performance Index at www.epi.yale.edu.

[5] See Conference Board of Canada Report Card on Environment at http://www.conferenceboard.ca/HCP/Details/Environment.aspx Last accessed: September 29th, 2010.

of the environment is "sustainable" or not. However, it does provide clear trends related to our collective natural capital, and in turn, Canadians' wellbeing.

Summary

Collectively, the indicators from the Environment Domain paint a mixed picture for Canada with no clear discernable overarching trends. An overview of the indicators and trends at a glance is provided below, along with some key highlights from the report.

Highlights from the Environment Domain report

The following are some brief highlights from the report. For more details, including additional references and data sources, please see the respective sections in the report noted below.

Air quality is showing mixed signs, but is still problematic and costly to Canadians' health

Although air quality is generally within an acceptable air pollution level, ground-level ozone has risen 11% over the past two decades. Emissions of air pollutants (criteria air contaminants) are variable with general improvement but also some deterioration. As fossil fuel emissions (which are the source of most air contaminants) continue to increase both domestically and from trans-boundary emissions, air quality has the potential to deteriorate. Furthermore, even under current levels, many Canadians in select urban areas are periodically exposed to dangerous air quality levels[6] during the summer which result in disease, death and billions of dollars worth of health care costs to taxpayers.[7] For more details, please see the following sections: AIR: Air Quality, AIR: Air Pollution, and AIR: Greenhouse Gas Emissions.

Greenhouse Gas (GHG) emissions are rising

Absolute GHG emissions continue to rise (up 24% since 1990, the baseline for the Kyoto Protocol) as have per capita GHG emissions, though recently there have been signs of a decrease in the latter. Tackling climate change is a global challenge, and just as Canada needs others to play their part in reducing emissions, so too do we, as Canadians, need to play our part. Canada is far from the trajectory needed to reduce emissions to a rate that avoids dangerous climate change (350ppm CO_2e and a global average 2°C increase in temperature[8,9]). The primary drivers of this increase are the rise in energy use by industries (in particular the oil and gas sector which accounts for 22% of emissions), along with increases in transportation (also 22%), electricity production via utilities (17%) and industry (15%). While the economy is becoming more GHG efficient (i.e., GHG emissions per dollar of GDP is improving), generally

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[6] An estimated 50 percent of the ground-level ozone stems from the United States. Ontario Ministry of the Environment (2005) "Transboundary air pollution in Ontario". Available online at: http://www.ene.gov.on.ca/envision/techdocs/5158e_index.htm Last accessed: October 4th, 2010.

[7] Pandey, M.D. and Nathwani, J.S. (2003) Canada wide standard for particulate matter and ozone: cost-benefit analysis using a Life Quality Index, *Risk Analysis*, 23(1): 55-67.

[8] Meinshausen, M., Hare, W., Wigley, T. M. M., Van Vuuren, D., Den Elzen, M. G. J. and Swart, R. (2006) Multi-gas Emissions Pathways to Meet Climate Targets *Climatic Change* 75: 151–194. http://www.springerlink.com/content/218548170461445/?p=62e04c1bfacc449e929a9f9c61c0ebce&pi=4

[9] Rockström, W.S. et al. (2009) A safe operating space for humanity, Nature, 461: 472-475, September 24, 2009.

we are headed in the wrong direction. Already the types of impacts that dangerous climate change will bring are being seen: increased disease (e.g., West Nile virus), damage from extreme weather events (e.g., droughts and floods) and impacts of invasive species in warmer temperatures (e.g., British Columbia's mountain pine beetle outbreak). While these may not stem only from climate change, these types of events will have a major impact upon the wellbeing of Canadians from our health to our economy to our natural capital and often first impact sections of the population that can ill-afford to pay the costs of adaptation — in particular poorer, rural communities such as First Nations.[10,11] For more details, please see: AIR: Greenhouse Gas Emissions.

Canadians continue to be large consumers, and producers, of hydrocarbon energy

Canada's appetite for energy continues to grow. While energy producers have kept pace with demand and grown availability considerably over the past two decades, virtually all of the growth has come through the exploitation of non-renewable energy reserves. These fossil fuel reserves, which make up some 90% of our primary energy production, are being rapidly converted into energy, chemicals and other refinery products, including for export. Energy use is driven primarily by industry (31%) and transportation (31%), and to a lesser extent, commercial (17%) and residential use (17%). Such voracious energy use is the primary reason for Canada's inability to meet its Kyoto targets and stem the rising tide of GHGs noted above. The last two years, have shown first indications that Canadians may be reducing their energy use: it is imperative that all citizens continue to improve the efficiency of their energy use, as this represents the fastest, cheapest, and most viable solution to reducing energy consumption, and in turn, GHGs. This will conserve energy while also providing policy makers with the flexibility to choose how to manage energy production for the wellbeing of all Canadians. For more details, see: ENERGY: Energy Production and ENERGY: Energy Use.

Decreasing freshwater supplies combined with high demand raise concerns for a future with climate variability

Freshwater supply in Southern Canada has been steadily decreasing since the 1970s and is now down by 8.5%, while water demand remains consistently high. While it is important to recognize that both the supply and demand have considerable variability throughout the country and through time, the combination of declining supplies and increasing demand in the Prairies, the Okanagan, Southern Ontario, and the St. Lawrence valley should be of concern. As Canadians face a future in which climate change impacts will further increase variability and availability of freshwater, policy makers need to proactively address these two disconcerting trends.

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[10] McMichael, A.J. and Githeko, A. (2001) Human Health. In *Climate Change 2001: impacts, adaptations, and vulnerability*. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change. McCarthy, J.J. et al. (Eds). New York, USA: Cambridge University Press.

[11] Rosenzweig, C. and Wilbanks, T.J. (2010) The state of climate change vulnerability, impacts, and adaptation research: strengthening knowledge base and community, *Climatic Change*, 100(1): 103-106

Many Canadian species are struggling, especially freshwater fish, grassland birds, reptiles and amphibians

Since 1970,[12] birds in forests and waterfowl have generally remained healthy, while all other land bird species as well as some seabird populations, have shown marked declines. While freshwater fish, reptiles and amphibians saw increases in abundance in the 1980s, since the 1990s all of these species groups have been in steady decline. Mammals have, for the most part, remained below 1970 levels, which are in turn lower than historical estimates. While recent years have shown some stabilization (except for the continued decline of reptiles and amphibians), more data are required to determine whether this latest trend is significant. Marine ecosystems are undergoing significant changes as larger predatory fish[13] (e.g., sharks and cod), whose stocks are depleted, make way for smaller species that are lower on the food chain (e.g., lobsters and shrimp), which have shown increases in recent years. This so-called trophic collapse is so recent that scientists largely do not yet have a sense of its full consequences for Canada's marine ecosystems which are the basis for millions of dollars in the economy, as well as the cultural and spiritual wellbeing of cultures on all coasts. For more details, please see: BIOTIC RESOURCES: Species Population Trends, and BIOTIC RESOURCES: Fish & Marine Ecosystems.

While Canadians are heavy consumers on an absolute level, recent data may be showing the beginning of a reduction in consumption in various areas.

As a society, Canadians continue to be large consumers of energy (absolute and per capita)[14] and materials (absolute and per capita).[15] The fact that consumption levels continue to be high on a global basis,[16] should be of concern to all Canadians. Not only is higher energy consumption resulting in higher GHG emissions, but more studies[17,18] now suggest that there is a relationship between increased material consumption and decreased happiness, thus raising concerns to the wellbeing of Canadians. Furthermore, additional consumption places further demands on infrastructure (energy and water), as well as land use (recycling facilities, landfill). These demands in consumption, combined with an already ageing infrastructure, have serious economic implications for Canadians that range into the tens of billions of dollars[19]. While it remains early days, several of the indicators have shown decreases in consumption rates in

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[12] A 1970 baseline may already be vastly different from historic levels, but few other data are available.

[13] Myers, R.A., and Worm, B. (2003) Rapid worldwide depletion of predatory fish communities, *Nature*, 423: 280-283

[14] Statistics Canada (2010): Human Activity and the Environment. Available online at: http://www.statcan.gc.ca/pub/16-201-x/2009000/t013-eng.htm Last accessed: September 29, 2010.

[15] Statistics Canada (2010) Environment Accounts and Statistics Division, CANSIM table 153-0041.

[16] World Bank (2010) Data: Canada Energy Use. Available online at: http://data.worldbank.org/data-catalog/world-development-indicators?cid=GPD_WDI. Last accessed: September 29, 2010.

[17] Swinyard, W.R., Kau, A.K., and Phua, H.Y. (2001) Happiness, materialism, and religious experience in the U.S. and Singapore, *Journal of Happiness Studies*, 2(1): 13-32.

[18] Ryan, L. and Dziurawiec, S. (2001) Materialism and Its Relationship to Life Satisfaction, *Social Indicators Research*, 55(2): 185-197.

[19] Infrastructure Canada (2003) The State Of Infrastructure In Canada: Implications for Infrastructure Planning and Policy. Available online: hhttp://www.regionomics.com/infra/Draft-July03.pdf Last accessed: October 5th, 2010.

recent years. If sustained, these are promising trends. For more details, please see: AIR: GHG Emissions, NON-RENEWABLE RESOURCES: Waste, and ENERGY: Energy Use.

Environmental monitoring lacks capacity, while data that do exist are largely inaccessible

Considerable data gaps exist in environmental data in Canada. While poor environmental data is a global trend, Canadians, like citizens in other countries, do not have access to current data (most are at least two to four years old). This lack of data is largely a function of capacity and resources, along with a general lack of strategic integration, and can be seen throughout the country.[20] This situation is in stark contrast with economic data which is readily available, timely and abundant. Statistics Canada and Environment Canada do provide some excellent environmental data, and on very limited resources, which is to be commended. However, there are few robust, multi-year and fully accessible national data sets for public use, making a report such as this very difficult. Areas such as water use,[21] species abundance,[22] land cover,[23] or policy effectiveness have infrequent, incomplete, or non-existent reporting. Even where good data exist (such as for water quality,[24] fisheries[25] and protected areas[26]), access to the raw, primary data is quite restricted. The environmental data sets that relate to the economy (e.g., forestry, oil and gas, and mining) have much larger and better accessible data, which provide examples of what could exist in other areas as a full set of national natural capital accounts. The capacity to undertake environmental monitoring has generally decreased over the years and is badly underfunded. This is a strong call for policy makers to improve investment in monitoring and reporting. Without information to manage our natural capital there is a potential danger for accountability to responsible environmental behaviour to erode.

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[20] For example: Office of the Auditor General of Canada (2010) 2010 Spring Report of the Auditor General of Canada, Chapter 5—Scientific Research—Agriculture and Agri-Food Canada. Available online at: http://www.oag-bvg.gc.ca/internet/English/parl_oag_201004_05_e_33718.html#hd5b Last accessed: October 12, 2010; Office of the Auditor General of Canada (2006) Opening Statement to the Standing Senate Committee on Energy, Environment and Natural, Resources. Available online at: http://www.oag-bvg.gc.ca/internet/English/oss_20060613_e_23770.html Last accessed: October 12, 2010; Office of the Auditor General of Canada (2009) 2009 Fall Report of the Commissioner of the Environment and Sustainable Development, The Commissioner's Perspective—2009, Available online at: http://www.oag-bvg.gc.ca/internet/English/parl_cesd_200911_00_e_33195.html Last accessed: October 12, 2010. Office of the Auditor General of British Columbia (2010) Conservation of Ecological Integrity in B.C. Parks and Protected areas. Available online at: http://www.bcauditor.com/pubs/2010/report3/conservation-ecological-integrity-bc-parks-and-protected- Last accessed: October 12, 2010.

[21] While Statistics Canada released a report on stocks and flows of water in Canada in September, 2010 (http://www.statcan.gc.ca/pub/16-201-x/2010000/part-partie2-eng.htm), the underlying data are not readily accessible, nor does it provide comprehensive coverage of water use.

[22] The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) tracks data related to species that are at risk, however this is not systematic, nor does it cover many species.

[23] Only one comprehensive, freely available Canadian data set on landcover exists, which was created from imagery that is now 10 years old. See GeoBase: http://www.geobase.ca/geobase/en/data/landcover/index.html Last accessed: October 5th, 2010. Also see: Latifovic, R. and Pouliot, D. (2005) Multi-temporal land cover mapping for Canada: Methodology and Products, *Canadian Journal of Remote Sensing*, 31(5): 347-363.

[24] CESI reports on water quality, but only in the aggregate with no primary data being accessible to Canadians.

[25] Numerous data sets are available from Fisheries and Oceans Canada, however, key data sets remain difficult to access for the public and non-governmental organizations. For example, see Ecotrust Canada: http://www.ecotrust.ca/fisheries/accessing-federal-fisheries-data. Last accessed: October 5th, 2010.

[26] CARTS is available online, but there remains no public access to underlying data.

Indicators and Trends at a Glance

The following summary table (Table 2) provides a breakdown of the primary indicators by aspect (air; energy; freshwater; non-renewable resources; and biotic resources). The **current levels (bolded number)** are flagged along with the *earliest dates (italicized)* and the worst (-) and best levels (+) throughout the observed period (denoted with a red - and a green + respectively). The colour indicates the current status (red = poor, yellow = moderate, green = good, as per Table 1 below) based on interpretation of current scientific opinion (from peer reviewed papers), the interpretation of the data sets' creator, and the author of this report, collectively. The arrows indicate the trend (down = deteriorating, horizontal = stable, up = improving; determined via statistical significance tests — see methodology for more details). A target level has also been suggested which is based upon various sources ranging from United Nations targets to logical end points. It should be noted that these are desirable target levels, which in some cases, given current technologies and political priorities, may not be possible to realistically achieve. However, while in most cases these target levels are not formally adopted or recognized by the Canadian Government, in *all* cases, they are logical end points for a sustainable planet. Table 1 is the indicator status and trend legend, and Table 2 provides a summary of the status and trends of the indicators.

Table 1. Dashboard Indicator Legend

Current Status	Deteriorating	Stable	Improving
Poor	↓	→	↑
Moderate	↓	→	↑
Good	↓	→	↑

Table 2. Indicators and Trends at a Glance

Aspect	Indicator	Current, Earliest, Worst and Best Status	Status & Trend	Target	Explanation and Interpretation at a Glance
Air	Population Weighted Ground-level Ozone (parts per billion)	**37.50 (2008)** *35.63 (1990)* 40.90 (2002)- 32.88 (1993)+		<23[27]	Levels have increased by 11%, but despite this increase, it is not yet a significant trend. Air quality, while adequate from a global perspective, is still causing problems in certain parts of the country and could be improved.
	Criteria Air Contaminant Emissions Index	**0.80 (2008)** *1.21 (1985)* 1.25 (1988)- 0.80 (2008)+		As close to 0 as ambient conditions allow[28]	Nearly all CACs are decreasing - both on an absolute and per capita basis (e.g., NO_x, SO_x and CO).
	Absolute GHG emissions (megatons of CO_2e)	**734 (2008)** *592 (1990)* 750 (2006)- 584 (1991)+		119 MT[29]	Greenhouse gas emissions are high and continuing to rise on an absolute basis. Per capita emissions may be showing signs of leveling out, while the emissions intensity of economic output (GHG/GDP) is improving.
Energy	Primary Energy Production (petajoules)	**15,325 (2009)** *11,495 (1990)* 11,495 (1990)- 17,148 (2007)+		N/A[30]	Canada continues to produce considerable amounts of energy from a range of sources, and continues to build additional capacity and production (though the last few years have seen a decrease in this trend). However, the combustion of fossil fuels has implications on wellbeing.
	Energy Use - Final Demand (petajoules)	**7,649.8 (2009)** *6,299.4 (1990)* 7,958.4 (2007)- 6,208.8 (1991)+		N/A[31]	Canadian residents and industries continue to have a voracious appetite for energy with industrial and transportation uses taking up roughly 30% each. This demand is driving the development of additional supply.

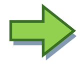
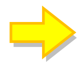
[27] While a level of less than 23ppb is classified as "very good" by the Government of Ontario, levels below 50 are acceptable or "Good" according to both the Government of Ontario and the World Health Organization - Europe (2007) Air Quality Guidelines. Available online at: http://www.euro.who.int/Document/E90038.pdf Accessed: March 11, 2010. However, based upon current air quality driven health concerns (e.g., childhood asthma), higher targets would appear desirable. See Air: Air Quality section for more details.

[28] National ambient air quality objectives are provided here by Health Canada: http://www.hc-sc.gc.ca/ewh-semt/air/out-ext/reg-eng.php#a3

[29] 119 megatonnes (MT) is the value derived from an 80% reduction from 1990 levels, the numbers cited by the IPCC to avoid 450ppm CO_2e, thereby avoiding or at least limiting dangerous climate change.

[30] The level of energy production is a political or economic decision as energy that is in excess of consumption can be (and is) exported.

[31] Energy consumption is an economic decision as energy that is in excess of consumption can be exported.

Freshwater	Water Quality Index	**73.99 (2009)** *73.54 (2005)* 73.54 (2005)- 74.79 (2008)+		>95[32]	Water quality is generally acceptable and, while trend data is difficult to obtain, initial results suggest most freshwater quality is relatively stable. Water quality is spatially variable with some basins being better than others.
	Water Yield in Southern Canada (km^3)	**1,335 (2004)** *1,375 (1971)* 1,165 (1987)- 1,545 (1974)+		Not nationally relevant [33]	Despite considerable annual variability, water yield (supply) is generally in decline (8% since 1970). In some areas, such as the Okanagan, the Prairies, Southern Ontario and Southern Quebec, the mix of low supply and high demand is cause for concern.
	Daily per capita residential water use (litres per day)	**327 (2006)** *341 (1991)* 343 (1999)- 327 (1996)+		Not nationally relevant [34]	Residential water use has decreased slightly in recent years, but in general remains consistently high. Despite data concerns, water use is still high relative to other countries, and can be problematic in water-stressed areas.
Non-Renewable Resources	Viable Non-Renewable Energy Reserves Index	**2.13 (2007)** *1.02 (1976)* 0.99 (1993)- 2.13 (2007)+		No decline[35]	While technically energy reserves have increased in recent years, this is somewhat misleading since the increase is due to additional discoveries and economic viability, rather than absolute amounts (reserve life is down from historical levels). Trends are mixed with some commodities (e.g., bitumen, or oil sands) showing increases, while others (e.g., coal, and natural gas) are decreasing. It is also important to note that use of these non-renewable energy stocks results in large economic benefits, but significant social and environmental impacts as well.

[32] A water quality index of >95 would represent a situation in which the average of all stations were reporting "excellent" water quality according to CCME WQI guidelines. See CCME WQI guidelines for more details. Available at: http://www.ccme.ca/assets/pdf/wqi_techrprtfctsht_e.pdf Last accessed: March 2, 2010.

[33] Freshwater levels are only relevant at a watershed level and thus the target would vary in the local context.

[34] *Ibid.*

[35] Like metals, since non-renewable energy reserves are finite, reserves should ultimately be stable. In such a scenario, non-renewable energy reserves would not undergo combustion (energy would come fully from renewables), but rather they would be used for products and perpetually recycled. See McDonough, W. and Braungart, M. (2002) *Cradle to Cradle: Remaking the Way We Make Things*, North Point Press, for details.

Non-Renewable Resources (continued)	Viable Metal Reserves Index	**0.63 (2006)** *1.69 (1977)* 0.46 (2004)- 1.96 (1980)+		No decline[36]	Metal reserve stocks have been relatively stable in recent years but overall are in decline. The continued liquidation of these stocks brings significant economic benefits, but also social and environmental challenges.
	Combined Per Capita Waste Disposal and Diversion Rate (kilograms per person per year)	**1031 (2008)** *952 (2000)* 1074 (2006)- 952 (2000)+		0[37]	Canadians have begun to decrease their very high levels of waste disposal and diversion after years of increase. Nevertheless, the amount of material sent to landfill, as well as the amount diverted, remains high and thus despite some recently positive signs, the general trend of a "throw-away" approach to materials remains.
Biotic Resources	Canadian Living Planet Index	**0.96 (2003)** *1.00 (1970)* 0.96 (2003)- 1.28 (1990)+		>=1.00[38]	While forest birds continue to do well (post-1970), other species groups such as mammals and freshwater fish are in lower numbers. Overall trends tend to be mixed, with the end result being similar to, but slightly below, 1970 levels and well below 1994 levels.
	Marine Trophic Index	**3.05 (2006)** *3.71 (1950)* 3.02 (2004)- 3.81 (1966)+		>=3.71[39]	Canada continues to "fish down the food chain" as fisheries shift from larger fish like cod to smaller crustaceans like lobster and shrimp. The long term consequences of this alteration to the stock on overall wellbeing are unknown.
	Timber Sustainability Index	**0.73 (2006)** *0.71 (1961)* 0.50 (1989)- 1.02 (1966)+		>=1.00	Albeit relatively stable in recent years, loss of forests through timber harvesting and other factors (fire, insects, etc.) is continuing to outstrip regeneration. Only once since 1960 have we had an increase in the stock of forests in Canada.

[36] Ideally, since most metals can be indefinitely used (if properly used) and are a finite resource, reserves should be stable with existing metals being recycled within the economy. See McDonough, W. and Braungart, M. (2002) *Cradle to Cradle: Remaking the Way We Make Things*, North Point Press, or The Natural Step (www.naturalstep.org) for more on this concept and target.

[37] Ideally, there should be 0 waste and 100% diversion / reuse.

[38] Wildlife populations are naturally variable (e.g., predator-prey cycles). Accordingly there is a natural range of variability, but systemic decreases (or increases beyond an agreed upon baseline) indicate concerns for human use of such resources. Given the historical declines in most species, and given that the LPI does not measure invasive species, an interim target of greater than or equal to a 1970 baseline would represent a logical target.

[39] No "ideal trophic level" exists, but the assumption is that there is a desire to re-establish large predatory species, such as tuna and salmon, and to restore oceans to the levels at, or beyond, those of the 1950s (albeit with the recognition that ecosystem dynamics make such a target difficult and values-based).

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1. Introduction and Background

The Canadian Index of Wellbeing

The Canadian Index of Wellbeing (CIW) is a new initiative that will report on the wellbeing of Canadians: both overall and in specific areas that matter: health, standard of living, time use, education, community vitality, democratic engagement, leisure and culture, and the **environment**. In essence, the CIW is a national index that measures wellbeing in Canada across a wide spectrum of domains. The CIW is designed to be a robust information tool, one that policy shapers, decision makers, media, community organizations and the person on the street will be able to use to get the latest trend information on the wellbeing of Canadians in an easily understandable format. The vision of the project is:

> *To enable **all** Canadians to share in the highest wellbeing status by identifying, developing and publicizing statistical measures that offer clear, valid and regular reporting on progress toward wellbeing goals and outcomes Canadians seek as a nation.*[40]

Indicators are powerful. What we count and measure often influences the policy agendas and decisions of governments. Right now, Canada is lacking a single, national, broad-based and balanced instrument that shows whether our wellbeing, in all of its dimensions, is getting better or worse. The gross domestic product (GDP) is often misused and misinterpreted as a portrait of how well Canada is doing (along with the parallel assumption that a bigger economy is better), but GDP is effectively just a measure of economic output. GDP does measure the use of some ecosystem services (e.g., goods such as timber and fisheries), but it does not capture most ecosystem services. Moreover, additional coal-fired powered plants with CO_2 and mercury capture, more irresponsible logging without reforestation, more fishing of depleted fisheries, more cigarette sales and more crime (and the cost of dealing with it) all increase the GDP, while simultaneously shifting the burdens and costs of environmental and human health degradation onto Canadians. The CIW adopts a different paradigm. It treats beneficial activities like resource conservation and illness prevention as positive, and harmful activities like pollution as negative.

The CIW is rooted in Canadian values identified through cross-country consultations conducted by Canadian Policy Research Networks, Environics, and EKOS: fairness, diversity, equity, inclusion, health, safety, economic security, democracy, and sustainability. These values align with critical national building blocks like the Charter of Rights and Freedoms and the Royal Commission on Health Care: Building on Values. They are being distilled into 64 specific and measurable indicators in eight domains (listed above), and a composite index that will go up or down, much like the TSX or Dow Jones. Besides informing Canadians about the state of wellbeing, the CIW will also help catalyze discussions about what wellbeing goals Canadians aspire to achieve in the future.

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[40] Canadian Index of Wellbeing (2010) Vision, Goals and Objectives. Available online: http://www.ciw.ca/en/AboutTheCIWNetwork/VisionGoalsAndObjectives.aspx Last accessed: May 30th, 2010.

The CIW resides within the Faculty of Applied Health Sciences at the University of Waterloo and is funded through a Funders' Alliance currently led by the Atkinson Charitable Foundation. Development of the CIW is under the leadership of national and internationally renowned experts and indicator practitioners and a national Advisory Board, backed by rigorous Canadian and international peer review, and supported with methodological advice and data sources from Statistics Canada. The CIW is viewed internationally as a global pioneer in developing a holistic, integrated approach to measuring wellbeing at the national level. These connections are important in raising the benchmarks of research and data integrity and changing the global dialogue about genuine progress.

The CIW will be widely promoted through a powerful communications and public engagement strategy. By prominently putting the spotlight on the full range of wellbeing issues, the CIW will help refocus the public discourse in Canada, help reshape the direction of public policy, and give Canadians a tool to promote wellbeing with decision makers to account for why things are getting better or worse.

2. Methodology

> *"Conservation can be defined as the wise use of our natural environment: it is, in the final analysis, the highest form of national thrift – the prevention of waste and despoilment while preserving, improving and renewing the quality and usefulness of all our resources."*
>
> — President John F. Kennedy

Constructing an index that reflects Canada's environment is a daunting task to say the least. The overall work was based upon the conceptual underpinnings of the CIW which is rooted in the notion of the wellbeing of Canadians. While it was imperative that the work be based on robust science, there are nevertheless many normative (value-based) decisions which affect the outcome of the overall index. The mandate of the report was to provide insight into the environment and its linkages to wellbeing, but it was never intended to be a comprehensive analysis of the state of the environment in Canada. From the selection of the framework and indicators, to the weighting and indexing process, the author would like to make it clear that, while based upon credible, robust and objective data, the result is ultimately a value-based view of the environment in Canada. The hope is that in being transparent about the methodology, the foundation is laid for critical evaluation and improvement, as data and knowledge become increasingly available.

A Brief Review of Efforts to Date

There have been many efforts to paint pictures of the state of the environment — in detail and overall — and this is not intended to be a comprehensive review of all efforts to date. Rather, it is intended to be a brief overview of some key efforts. Traditionally the role of monitoring and evaluating the environment has fallen to government agencies at a variety of levels. In Canada, certain agencies have been performing monitoring for decades, and although data still often lack depth and scope, environmental data gathering efforts have grown considerably since 1990 (Appendix A). Since that time, the most notable federal Canadian efforts to understand how Canada's environment are faring include the Government of Canada's State of the Environment reports, Statistics Canada's Human Activity and the Environment and Canada Year Book reports, and more recently, Environment Canada's Canadian Environmental Sustainability Indicators (CESI) work. At a global level, the United Nations (UN) Environment Program via its flagship Global Environment Outlook (GEO) and GEMS-Water, as well as the UN Food and Agriculture Organization (FAO) also have long-standing data gathering and reporting processes through such outlets as the World Conservation Monitoring Centre (WCMC), OECD environmental indicator work, and the FAOSTAT database.[41] The UN Statistical Division is also beginning a new effort to revise the UN Framework for the Development of Environment Statistics. Lastly, also of note is the Millennium Ecosystem Assessment (MEA), a multi-year global effort to develop a sense of the status and trends of the planet's ecosystems, which was completed in 2005.

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[41] FAOSTAT is a database providing time-series and cross sectional data relating to food and agriculture for some 200 countries. It is produced by the Food and Agriculture Organization of the United Nations.

In recent years, however, there has been a proliferation of environmental reporting efforts by non-profit organizations that pull together raw data into distilled indicators and indices. For example, the World Resources Institute began providing data via EarthTrends in 2001, the Heinz Centre published its first State of the Nation's Ecosystems in 2002, and beginning in 2006, a combined group out of Yale and Columbia Universities began to produce the Environmental Performance Index (EPI). Likewise, since 1998, WWF has produced the Living Planet Report which looks at trends in humanity's ecological footprint and compares it to species population trends. In the Canadian context, although various environmental non-governmental organizations (ENGOs) have periodically released environmental monitoring reports, few organizations maintain regular monitoring or reporting efforts. Thus, while there are notable exceptions, such as the Worldwatch Institute's State of the World and Vital Signs reports which have been underway for several decades, ENGOs had, until recently, generally followed the cue of government when it came to data on the environment. Lastly, throughout this whole period, academics and researchers have also endeavoured to assess aspects of the environment and engage in data gathering, though arguably usually within a specific area.

Genuine progress indicator (GPI) work, which has been heavily tied to environmental concerns, has also been a relatively recent development. Beginning in the 1990s, the U.S.-based ENGO Redefining Progress developed the concept of a GPI, an approach which "corrects" GDP upwards or downwards using monetary metrics to account for negative social and environmental impacts. Since that time, the need for broader accounting of wellbeing, or the means to achieve wellbeing, has become increasingly recognized by governments and other organizations (including the OECD[42] and the EU[43]) and there are many efforts underway to supplement or modify the GDP to include environmental aspects (e.g., Stiglitz, Sen and Fitoussi[44]). Canada has been a leader in this space with numerous groups such as GPI Atlantic, GPI Pacific, the Pembina Institute and others developing GPI efforts at community, provincial and regional levels. The CIW represents the first time that an ongoing index, conceptually similar to the GPI in reflecting more than just the GDP, will have been developed and maintained at a national level in Canada.

The reports noted above, along with others, were surveyed for potential frameworks and approaches and the CIW Environment Domain, in turn, reflects some of the thinking from these works.

Conceptual Approach

The Canadian Index of Wellbeing is "a new way of measuring wellbeing." Its purpose is to measure and report nationally on wellbeing overall and in specific areas that matter to Canadians. It is not intended to be an alternative to the GDP but rather a significant complement to the GDP. The CIW's goal is to be a comprehensive and useable measurement

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[42] OECD (2009) OECD welcomes experts' call on need for new measures of social progress. Available online at: http://www.oecd.org/document/9/0,3343,en_2649_34487_43684683_1_1_1_1,00.html Last accessed: March 7, 2010.

[43] Beyond GDP (2010) Measuring progress, true wealth, and the wellbeing of nations. Available online at: http://www.beyond-gdp.eu/news.html Last accessed: March 7, 2010.

[44] Stiglitz, J., Sen, A., and Fitoussi, J-P. (2009) *Report by the Commission on the Measurement of Economic Performance and Social Progress*. Available online at: http://www.stiglitz-sen-fitoussi.fr/documents/rapport_anglais.pdf Last accessed: May 31, 2010.

that tells us whether we are making progress towards wellbeing or away from it. While ideally this would be as locally relevant as possible, given the great variability throughout a country as large as Canada, the starting point for such an effort will be at a national scale.

The framework for the environmental domain should also be as comprehensive as possible. That is to say, it must cover different aspects of the environment that matter to Canadians, including clean air, clean water, available energy and raw materials, wilderness and species, and the goods and services, such as pollination of crops by insects or the enrichment of soils by microfauna, that play a huge underlying role in our economy.[45]

The field of ecological economics has long argued that the economy is in fact a sub-system of the environment.[46] Without ecosystems, there would be no economy and in 1997, rough estimates put the value of the Earth's ecosystems at over $33 trillion dollars per year (see Costanza et al.[47]). Since that time, major international research projects have been developed that have explored the economic value of ecosystems and biodiversity.[48] Despite the recognized monetary value found in these studies, ecosystem services are rarely explicitly monetized through market mechanisms (with some notable exceptions), and accordingly, the economy is driven by consumption rather than the value of conservation. In fact, governmental macroeconomic policy is centered on the notion of economic growth, as measured by GDP, with continual efforts to minimize unemployment, inflation and recessions. This paradigm of continual growth is increasingly under scrutiny as ecological systems, and their "natural capital," reach their points of exhaustion (see Victor[49]). Furthermore, evidence is emerging that indicates that additional consumption is inversely related to wellbeing after a certain point, along with imposing additional social and environmental costs.[50]

Natural capital can be defined as "a stock that yields a flow of valuable goods or services [from today][51] into the future."[52] The Millennium Ecosystem Assessment used four categories of ecosystem services derived from natural capital: provisioning (which generate products or goods), regulating (which control flows and natural processes), cultural (which support human culture, including spiritual, aesthetic and historical aspects), and supporting services (which

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[45] See Daily, G.C. (1997). Introduction: What are ecosystem services? Pages 1-10 in G. Daily, editor. *Nature's Services: Societal Dependence on Natural Ecosystems*. Island Press, Washington, D.C.

[46] See Daly, H. (1977) *Steady-State Economics: The Economics of Biophysical Equilibrium and Moral Growth*, San Francisco, USA: W. H. Freeman.

[47] Costanza, R., d'Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, R.V., Paruelo, J., Raskin, P.S. and van den Belt, M. (1997) The Value of the World's Ecosystem Services and Natural Capital, *Nature*, 387: 253-260.

[48] European Commission (2009) The Economics of Ecosystems and Biodiversity – an interim report. Available online at: http://www.teebweb.org/InformationMaterial/TEEBReports/tabid/1278/Default.aspx Last accessed: October 10, 2010.

[49] Victor, Peter. 2008. *Managing without Growth: Slower by Design, Not Disaster*. Edward Elger Publishing Limited, Cheltenham, U.K.

[50] See Swinyard, W.R., Kau, A.K., and Phua, H.Y. (2001) Happiness, materialism, and religious experience in the U.S. and Singapore, *Journal of Happiness Studies*, 2(1): 13-32; and Ryan, L. and Dziurawiec, S. (2001) Materialism and Its Relationship to Life Satisfaction, *Social Indicators Research*, 55(2): 185-197.

[51] Brackets added.

[52] Costanza, R., d'Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, R.V., Paruelo, J., Raskin, P.S. and van den Belt, M. (1997) The Value of the World's Ecosystem Services and Natural Capital, *Nature*, 387: 253-260.

underpin the other categories and create the conditions for life).[53] Since it is important for Canadians to understand the use of natural capital for human wellbeing, the Environment Domain Report is structured around a framework that attempts to use the notion of stocks of natural capital (air, energy, freshwater, non-renewable resources, and biotic resources) along with how these stocks are changing. An exhaustive and comprehensive system of natural capital accounting in Canada is not possible yet, but it may be one day. It will then be possible to quantitatively demonstrate the trade-offs that result when we convert, or restore, natural capital and ecosystem services into elements of human wellbeing.

There are various frameworks which could have been employed for the Environment Domain report (e.g., state-pressure-response). Ultimately all frameworks have advantages and disadvantages, and a stock-flow framework was adopted for this work in an effort to align with National Economic Accounts work at Statistics Canada.[54] However, a stock-flow framework does have a limitation: it does not work well in cases where the quality of a service is not dependent upon the quantity of the stock. This is particularly true for the biotic resources. For example, flood control may work just as well in an area that has been properly logged as it does in an untouched forest. The ecological economics literature makes the valuable distinction between stock-flow resources and fund-service resources, the latter of which are services that are independent of the amount of physical inflow/outflow of the fund resource.[55] The author acknowledges this weakness, but due to data availability/limitations, alignment as noted above, and the fact that all frameworks and approaches have their caveats, has opted to maintain a stock-flow approach.

In addition to the use of a stock-flow framework, for this research there was a desire to focus on aspects of the environment that are of importance to Canadians: air, energy, freshwater, non-renewable resources, and biotic resources, and the associated ecosystem services. These categories were informed by two CIW pan-Canadian consultations and the thinking of Victor et al.[56] which outlined the "six essentials of life": Air, Energy, Freshwater, Minerals, Space, and Genetic Materials. These aspects were altered slightly for three primary reasons: 1) "Minerals" does not include metals; 2) marine water quantity is somewhat irrelevant, while water quality data are not readily available; and 3) "Space" and "Genetic Resources" data are also not readily available. Accordingly, "Minerals" was re-named "Non-renewable resources," "Water" was specified as "Freshwater," and "Space" and "Genetic Materials" were collapsed into "Biotic Resources "[57] to create the basic framework for the work as seen below (Table 3).

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[53] Millennium Ecosystem Assessment (2005) *Ecosystems and Human Well-Being: Synthesis*. Island Press, Washington.

[54] See Statistics Canada (2010) National Economic Accounts – About the environmental and resource accounts. Avaialble online at: http://www.statcan.gc.ca/nea-cen/about-apropos/env-eng.htm Last accessed: October 10, 2010.

[55] Daly, H.E. and Farley, J.C. (2004) *Ecological Economics, Principles and Applications*, Island Press.

[56] Victor, P., Hanna, J.E. and Kubursi, A. (1995) How Strong is Weak Sustainability? *Economie Appliquée*, 48(2): 75-94.

[57] This simplification was performed because few data that met the necessary requirements exist on either space (which could be thought of as habitat) or genetic materials (the data do not even exist for most species, let alone populations).

Table 3. Initial Conceptual Framework for Environment Domain Report

ASPECT	STOCK	FLOW
Air	Indicator(s)	Indicator(s)
Energy	Indicator(s)	Indicator(s)
Freshwater	Indicator(s)	Indicator(s)
Non-Renewable Resources	Indicator(s)	Indicator(s)
Biotic Resources	Indicator(s)	Indicator(s)

With the framework in place, the process of indicator selection was undertaken. A number of criteria guided the indicator selection process. Specifically, the indicators were required to be:

1) Able to be deemed scientifically reliable and valid via a peer-review process;
2) Able to support benchmarking and monitoring over time, that is, longitudinal or repeated data are available, allowing trend analyses. Essentially this meant that the data must contain multiple (at least two) data points (ideally from at least 1994 to at least 2003 and preferably 2009);
3) Able to be updated on an annual (or at worst biannual) basis;
4) Able to be spatially disaggregated at a later point to speak to "local" conditions (at least sub-provincial, such as at the census, watershed, or ecoregional level);
5) Able to build upon existing data collection efforts, thereby supporting other national initiatives;
6) Clearly defined, measurable, transparent and verifiable (aspects of a good indicator);
7) Sufficiently flexible to capture various aspects of natural capital and to represent both positive (desired) and negative (undesired) activities and outcomes.

Using these requirements and building further upon the basic proposed framework (Table 3), the idea was to develop a "mass-balance" equation of sorts in which there are opening stocks at the beginning of a given year. The various elements are extracted/harvested, then are either removed or added in a national context through trade, before Canadians (and Canadian ecosystems) use some amounts. The system (and humans) then undertake some form of replenishment (continually ongoing), which leaves a "closing stock" at the end of the year. There are also quality considerations for the various stocks which can be degraded (thus often resulting in impacts to the replenishment rates). Missing from this depiction are most of the ecosystem services (aside from provisioning services, and to a lesser extent via quality considerations, some regulating services). The provisioning, regulating, supporting and cultural services[58] are key determinants and constituents of wellbeing for humans when it comes to biotic resources and the role ecosystems play on the other elements. Also missing are some of the very complicated feedback loops, for example, the use of coal, which when not managed properly, releases pollutants that cause acid rain, which in turn affects the health of forests (and in turn the timber, water filtration, and songbird habitat that those forests provide). These

[58] Millennium Ecosystem Assessment (2005) *Ecosystems and Human Well-Being: Synthesis*. Island Press, Washington.

sorts of feedback loops, as can be seen above from a simplified example, can be incredibly complex and are beyond the scope of this work.

In implementing the framework, data limitations quickly began to play out and led to perhaps one of the most important conclusions of this report: while data may be good relative to many countries on a global basis, Canada still lacks good-quality, publicly-available environmental data.

Funding and prioritizing the regular gathering of high-quality environmental data is severely lacking, and cutbacks throughout the late 1990s to water and air monitoring further impaired data gathering efforts.[59] The author would like to emphasize that while Statistics Canada, Environment Canada, and other federal, provincial, territorial and municipal government agencies do their best with limited resources, the result is insufficient to properly inform policy making when it comes to our environment and the broader wellbeing of Canadians. Indeed, this lack of data has been attributed to a lack of capacity and resources, along with a general lack of strategic integration, and is present throughout the country when it comes to environmental monitoring.[60] Data in areas such as agricultural water use and groundwater availability,[61] species abundance and genetics,[62] or detailed and regular land cover[63] have infrequent, incomplete, or non-existent reporting. Even where arguably good data exist (such as for water quality,[64] fisheries[65] and protected areas[66]), access to primary data is quite restricted. The environmental data sets that relate to the economy (e.g., forestry, oil and gas, and mining) are much larger and more accessible; these are examples of what could exist in other areas to complete a full set of

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[59] Savan, B. et al. (2004) Shifts in environmental governance in Canada: how are citizen environment groups to respond? *Environment and Planning C: Government and Policy*, 22:605-619.

[60] For example: Office of the Auditor General of Canada (2010) 2010 Spring Report of the Auditor General of Canada, Chapter 5—Scientific Research—Agriculture and Agri-Food Canada. Available online at: http://www.oag-bvg.gc.ca/internet/English/parl_oag_201004_05_e_33718.html#hd5b Last accessed: October 12, 2010; Office of the Auditor General of Canada (2006) Opening Statement to the Standing Senate Committee on Energy, Environment and Natural, Resources. Available online at: http://www.oag-bvg.gc.ca/internet/English/oss_20060613_e_23770.html Last accessed: October 12, 2010; Office of the Auditor General of Canada (2009) 2009 Fall Report of the Commissioner of the Environment and Sustainable Development, The Commissioner's Perspective—2009, Available online at: http://www.oag-bvg.gc.ca/internet/English/parl_cesd_200911_00_e_33195.html Last accessed: October 12, 2010. Office of the Auditor General of British Columbia (2010) Conservation of Ecological Integrity in B.C. Parks and Protected areas. Available online at: http://www.bcauditor.com/pubs/2010/report3/conservation-ecological-integrity-bc-parks-and-protected- Last accessed: October 12, 2010.

[61] Environment Canada released a report on stocks and flows of water in Canada in September, 2010 (http://www.statcan.gc.ca/pub/16-201-x/2010000/part-partie2-eng.htm), but this was previously unavailable and is not a regularly updated data set.

[62] The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) tracks data related to species that are at risk, however this is not systematic, nor does it cover many species.

[63] Only one comprehensive, freely available Canadian data set on landcover exists, which was created from imagery that is now 10 years old. See GeoBase: http://www.geobase.ca/geobase/en/data/landcover/index.html Last accessed: October 5th, 2010. Also see: Latifovic, R. and Pouliot, D. (2005) Multi-temporal land cover mapping for Canada: Methodology and Products, *Canadian Journal of Remote Sensing*, 31(5): 347-363.

[64] CESI reports on water quality, but only in the aggregate with no primary data being accessible to Canadians.

[65] Numerous data sets are available from Fisheries and Oceans Canada, however, key data sets remain difficult to access for the public and non-governmental organizations. For example, see Ecotrust Canada: http://www.ecotrust.ca/fisheries/accessing-federal-fisheries-data. Last accessed: October 5th, 2010.

[66] CARTS is available online, but there remains no public access to underlying spatial data in a format other than Google Earth (which lacks attributes and is insufficient for analysis in a GIS).

national natural capital accounts. The capacity to undertake environmental monitoring has generally decreased over the years and is badly underfunded.

Measuring ecosystems and the services they provide to humans is even more complex (and arguably more fundamental to human wellbeing) than measuring the economy. However, unlike our understanding of the economy (a parallel, human-created system), where we have strong data and therefore a better understanding of how to manage such a system (for example, the economic stimuli implemented after the global recession of 2008-09), we lack both data and an understanding of our ecosystems. This ranges from knowing how much water we truly have, an ongoing and current measure of how much of each type of land (or sea) cover we possess, or the amount of fish we have in our oceans, let alone how much we are truly using or degrading, or what the impacts of that are on human wellbeing. Arguably the environment should have far more data than the economy, yet it lags far behind. Nevertheless, the data contained herein from various sources represent amongst the best and most robust environmental data in Canada; the fact that Canada has these data is a testament to researchers and statisticians within the government. Therefore, while the results of this study should be considered a preliminary assessment, the report does provide indications, based on reliable data, for policy action.

The data availability issue resulted in difficulties in using the framework as proposed, and ultimately stocks and flows were merged to some extent in the final version. Data also resulted in indices that were, to some extent, data driven rather than concept driven. An example of this is the water use data, which was a choice between residential water use data (a longer data series, relevant to average Canadians, but which has mixed data — both urban and some commercial/industrial, and only represents a small fraction of total water use in Canada) versus industrial water use (a short data series, but which represents a greater portion of water use in Canada). The largest water use (agriculture), along with embedded water in products (the water that goes into growing and processing the ingredients for a latte, for example) are not available, thus resulting in a data driven index. While this is lamentable, it is the reality of the current state of affairs.

This report, with its inherent limitations due to lack of quality data, is a first step towards the ultimate goal of measuring what needs to be measured, that is, an assessment of the interaction of ecosystem functioning and human wellbeing for each watershed in which Canadians live. This initial effort represents the beginning of a journey of continuous improvement in our knowledge of ecosystem functions and the conditions that are directly or indirectly important to human wellbeing. Such a journey would certainly require a common vision, and extensive collaboration with government agencies and other partners, but it is a goal to work towards.

Despite these limitations, numerous potential indicators were considered and underwent two rounds of peer review. Appendix B has a breakdown of various indicators that were considered (for which there were data) along with a rationale for why they were rejected. The set of agreed-upon indicators are presented in Table 4.

Table 4. Set of Indicators for Environment Domain Report

ASPECT	INDICATORS
Air	- Ground-Level Ozone (population weighted national average in ppb) - Criteria Air Contaminant Emissions Index - Greenhouse Gas Emissions (tonnes)
Energy	- Primary Energy Production (petajoules) - Final Demand Energy Use (petajoules)
Freshwater	- Water Quality Index - Water Yield in Southern Canada (km^3) - Residential Water Use (per capita national average in m^3)
Non-Renewable Materials	- Viable Non-Renewable Energy Reserves Index - Metal Reserves Index - Waste Disposal and Diversion Rate (kg per capita)
Biotic Resources	- Canadian Living Planet Index - Marine Trophic Index - Timber Sustainability Index

Composite Index

The CIW framework is based on the notion of a composite index — a single number that moves up or down much like the TSX or Dow Jones Industrial Average, given both the response of the environment and the state of data collection at a given point in time. This will give a quick snapshot of whether the overall quality of life of Canadians is getting better or worse over the years.

For the purposes of calculating and testing the composite index, the plan is to track each domain from the same baseline year. The baseline year is assigned a value of 100. Movement upward from 100 in later years signals improvement in quality of life, while movement downward indicates decline. The baseline year that has been chosen for the CIW is 1994, the first year of the National Population Health Survey. A detailed description of the broader CIW indexing methodology can be found in Michalos, *et al.*[67]

Unfortunately, from the perspective of environmental data, indices and baselines can be challenging to work with. Since natural systems are not only dynamic (with considerable variability), but also often slow-responding, longer-term trends are key to gaining a sense of true environmental patterns. Accordingly, while the CIW composite index will provide some insight into environmental trends since 1994, a far more nuanced picture is gained from an analysis of the raw data going back as far as possible. For example, while the Living Planet Index goes back to 1970, we know that by the start of the last century, humans had already

[67] Please refer to www.ciw.ca

eradicated over 60 million bison and even more passenger pigeons.[68] In the case of greenhouse gas emissions and climate change, the data go back millions of years, providing a very long data set and much better understanding of baselines. This baseline issue, along with an attempt to understand human influence on the environment versus natural variability in environmental trends, looms large in this work. Accordingly, simplified indices must be interpreted with this in mind.

Lastly, while indices are helpful to provide insights, the environment, as a system, is subject to limits, or rather thresholds. Ultimately, a report such as this should aim to determine whether Canada is within its "ecological boundaries." This concept, which was well articulated by Rockstrom et al. in *Nature* last year,[69] is conceptually very logical but practically very difficult to implement in a world where goods, services, pollution and consumption occur on a global basis through imports and exports. National assessments, while able to provide insight to certain aspects, also have recognizable limitations in our globalized world.

The CIW composite index is scheduled for release in the fall of 2011. For more information on the development of the composite index, please refer to www.ciw.ca.

[68] Canadian Bison Association (2010) Bison History. Available online at: http://www.canadianbison.ca/consumer/Resources/bison_history.htm Last accessed: October 10, 2010.

[69] Rockstrom et al. (2009) A safe operating space for nature. *Nature* 461, 472-475

3. The Environment Domain: How Does Canada Measure Up?

> *"We have in the past been concerned about the impacts of economic growth upon the environment. We are now forced to concern ourselves with the impacts of ecological stress – degradation of soils, water regimes, atmosphere, and forests – upon our economic prospects."*
>
> — Gro Harlem Brundtland, *Our Common Future*[70]

The remainder of the report walks through the 14 indicators for the Environment Domain (Table 4). For each environmental aspect and its stock/flow indicator(s), the report comments on the following:

1) **The issue**: what it is and why it is important to wellbeing (along with *direct linkages to other domains of the CIW* and the *considerations and trade-offs* given the current status and trends).[71]
2) **Understanding the indicator**: what the indicator is, why it was selected and how to interpret the results.
3) **Current trends and significance**: what the trends in the headline (and associated) data are, and how they are significant to Canada's environment and Canadians' wellbeing.

The Environment Domain is a key foundation to many of the other domains in the CIW as numerous ecosystem services are the basis for human wellbeing. These other domains include: Community Vitality, Democratic Engagement, Education, Healthy Populations, Leisure & Culture, Living Standards, and Time Use. There is a rich amount of potential content exploring the linkages between the environment and each of these domains of wellbeing, and this report only explores these linkages in a superficial manner. It is the hope that in the future, the CIW can continue to foster an understanding and awareness of how wellbeing is intricately linked both within, and between, these domains.

While these indicators provide a rough image of the trends in Canada's environment as of the spring of 2011, they do not address all of the nuances and should be recognized for what they are: indicators. Each of these aspects requires much more in-depth analysis, including increased spatial and temporal resolution where available, in addition to additional data sets, to provide the details and subtleties that come with understanding complex systems. Such a comprehensive review would require hundreds of pages, millions of dollars, and years of time. Rather, the intention of this report is to provide insights on the environment and its linkages to the wellbeing of Canadians in a relatively succinct and accurate fashion.

The full set of data tables may be found in Appendix C.

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[70] Bruntland, G. (ed.). (1987). *Our common future: The World Commission on Environment and Development*, Oxford: Oxford University Press.

[71] Note: the issue of linkages was not explored in depth in this report and represents an area which could be investigated further.

AIR: Air Quality (Ground-Level Ozone)

Issue: What is the issue and why is it important to wellbeing?

Good air quality is critical to the health of all Canadians. Smog is one of the most recognizable air quality problems in Canada and is a major contributor to respiratory diseases. Two key components of smog are particulate matter (PM)[72] and ground-level ozone. Ground-level ozone (O_3) is a secondary pollutant, formed in sunlight from precursor gases such as NO_x and VOC, which come from the combustion of fossil fuels in motor vehicles, power plants and industrial processes.[73] It is also important to distinguish ground-level ozone from atmospheric ozone, which is a layer of gas 10 to 50 kilometres from the Earth's surface that helps to protect the planet from radiation.

While both ground-level ozone and PM are tracked by Environment Canada,[74] the data set for ground-level ozone has a longer time series and accordingly, was selected as the primary air quality stock indicator at present.

Poor air quality is a driver of adverse human health impacts, including premature mortality[75] and respiratory diseases,[76] and it also adversely affects vegetation.[77] These adverse health impacts impose billions of dollars of unaccounted for costs on society,[78] especially in large municipalities with high traffic congestion[79] like Toronto, Montreal, and Vancouver.[80] In particular, childhood asthma rates have been linked to ground-level ozone and PM, and have risen dramatically over the past twenty years — affecting up to 20% of all boys and 15% of all girls (8 to 11 years old).[81]

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[72] Particulate matter (PM) is emitted to the atmosphere from sources like cars, trucks, factories and wood burning. PM can also be formed in the air from precursor gases such as nitrogen oxides (NO_x), volatile organic compounds (VOC), sulphur dioxide (SO_2), and ammonia. In addition to those substances listed above, Criteria Air Contaminants (CACs as they are collectively known), also include carbon monoxide (CO). Total particulate matter (TPM) is a combination of particulate matter with a diameter less than or equal to 10 micrometres (PM_{10}), and particulate matter with a diameter less than or equal to 2.5 micrometres ($PM_{2.5}$).

[73] Environment Canada. (2007) *Government of Canada Five-Year Progress Report: Canada-wide Standards for Particulate Matter and Ozone*. Available online: http://www.ec.gc.ca/Publications/default.asp?lang=En&xml=31B2381E-56BF-44CC-8D65-BF6FDB7125AD Last accessed: March 6, 2011.

[74] Environment Canada (2010) Canadian Environmental Sustainability Indicators (CESI). Available online at: http://www.ec.gc.ca/indicateurs-indicators/default.asp?lang=En&n=A073189E-1 Last accessed: October 9, 2010.

[75] Burnett RT, Cakmak S, Brook JR. (1998) The effect of the urban ambient air pollution mix on daily mortality rates in 11 Canadian cities. *Canadian Journal of Public Health.* 89(3):152–156.

[76] Goldberg, M.S., Burnett, R.T., Brook, J., Bailar, J.C. Valois, M-F, and Vincent, R. (2001) Associations between Daily Cause-specific Mortality and Concentrations of Ground-level Ozone in Montreal, Quebec, *American Journal of Epidemiology* 154(9):817-826.

[77] Lefohn, A.S. (1992) *Surface level ozone exposures and their effects on vegetation*. Lewis Publishers: Boca Raton, Florida.

[78] Canadian Medical Association (2008) Illness cost of Air Pollution. Available online at: http://www.cma.ca/index.php/ci_id/86830/la_id/1.htm Last accessed: October 11, 2010.

[79] Transport Canada (2006) The cost of urban congestion in Canada. Available online at: http://www.gatewaycouncil.ca/downloads2/Cost_of_Congestion_TC.pdf Last accessed: October 10, 2010.

[80] Lindsey, C.R. (2007) *Congestion relief: Assessing the case for road tolls in Canada*, CD Howe Institute: Toronto.

[81] Commission on Environmental Cooperation (2006) Children's Health and the Environment in North America. Available online: http://www.cec.org/Storage/27/1799_CEC_Children_and_Health_en.pdf Last accessed: October 10, 2010.

Direct linkages to other domains: ***Healthy Populations*** (Poor air quality affects human respiratory tracts, causing various diseases), ***Leisure and Culture*** (Poor air quality affects our ability to get outside and keep active, like playing sports), ***Living Standards*** (Good/poor air quality can affect the desirability of living in a given city, which in turn affects property values).

Considerations and trade-offs: Reducing ground-level ozone levels provides a number of wellbeing benefits, in particular to human health, as noted above. However, in order to do so, we must first reduce fossil fuel combustion (the source of the precursor gases that drive ground-level ozone), and therefore energy use (since most of our energy presently comes from hydrocarbons).

Understanding the Indicator: What is this indicator, why was it selected and how do I interpret the results?

Ground-level ozone is a colourless, odourless gas that is a major component of smog. As noted above, it is not directly emitted, but rather produced through a reaction between NO_x and VOCs in sunlight. It is recognized that some other aspects of air quality, in particular SO_X, have been greatly improved since levels in the 1970s.[82] However, ground-level ozone was selected as a headline indicator as it is strongly correlated with the elements that contribute to poor air quality, it has readily available high-quality data, and because ground-level ozone can also be directly linked to human health and ecosystem degradation. Ground-level ozone is typically measured as a concentration in parts per billion (ppb) and is reported as such in this indicator. The data, available from 1990 to 2007, were gathered by Environment Canada (CESI) and represent a population-weighted average for Canada (which is preferable, and available for this data set unlike most others). This means that data in larger populated areas are given a higher weight than those in less populated areas to adjust for the differences in populated versus less populated areas. Ambient air quality data are collected through the National Air Pollution Surveillance Network, a joint federal, provincial, territorial and municipal program. Data from ozone monitors are operated by the Canadian Air and Precipitation Monitoring Network which is operated by Environment Canada.

In the future it may be desirable to see if the newly-created national Air Quality Health Index,[83] which is suitable for daily assessments of local conditions, can be combined with existing data suitable for annual averages and multi-year analysis, but this is not yet possible. Ground-level ozone is one of two indicators used by the Canadian Environmental Sustainability Indicators (CESI), the other being $PM_{2.5}$ (fine particles of 2.5 micrometres in diameter or less); thus the Environment Domain aligns and supports federal government efforts. Ground-level ozone is also used as an indicator in the Environmental Performance Index (EPI), thereby allowing for international comparisons through time.

The ground-level ozone data are relatively simple to interpret: in the lower atmosphere (i.e., at ground level) the lower the concentration level of ground-level ozone, the better it is for humans, animals and plants. From an absolute basis, the U.S. Environmental Protection Agency

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[82] Environment Canada (2008) Air Quality Trends in Canadian Cities 1979-1992. Available online: http://www.etc-cte.ec.gc.ca/organization/aaqd/aqfact_e.html Last accessed: October 10, 2010.

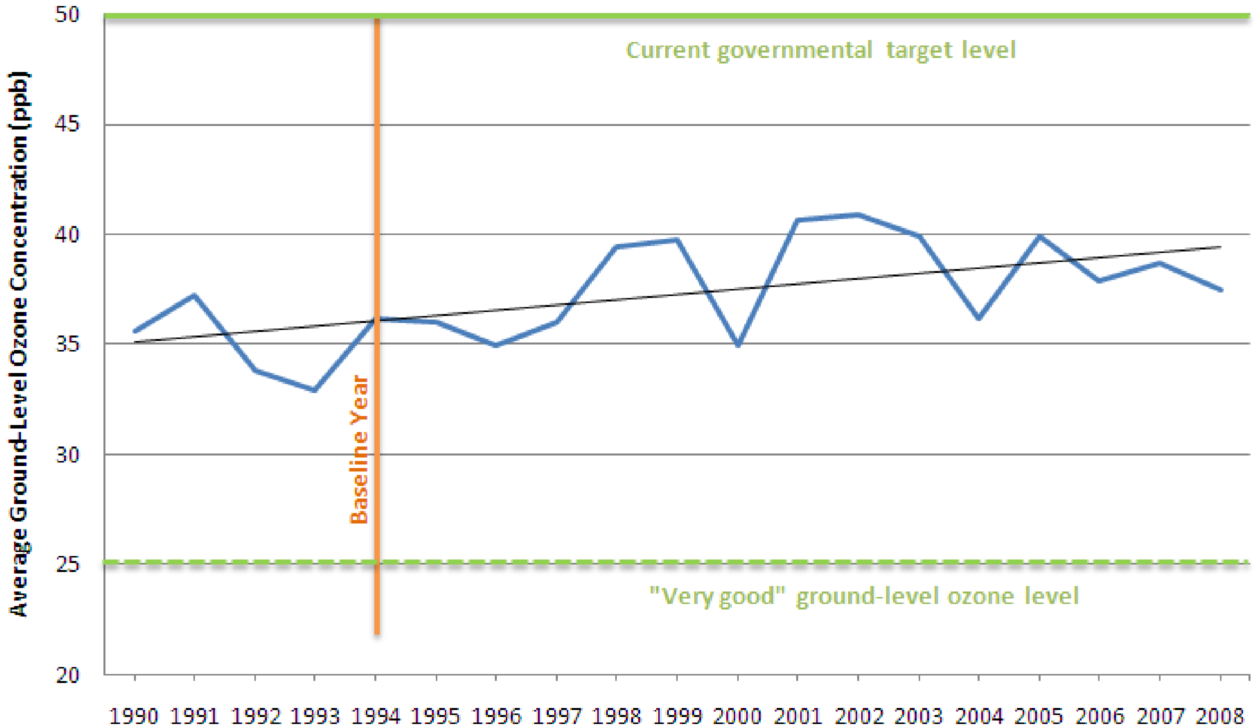
[83] See http://www.ec.gc.ca/cas-aqhi/default.asp?Lang=En for more details on the Air Quality Health Index

recommends that ground-level ozone levels be lower than 75 ppb,[84] while WHO recommends levels of less than 100 ppb,[85] Canadian National Ambient Air Quality Objectives identifies the "maximum desirable level" as below 50 ppb, while the Government of Ontario labels "very good" levels as those below 23 ppb.[86]

Current Trends and Significance: What are the trends in the data and how are they significant to environmental and human wellbeing?

Figure 1. Indicator – Ground-Level Ozone

Population-weighted national average ground-level ozone exposure index, Canada, 1990-2008[87]



The data in Figure 1 illustrate a general (11%), increase that is not statistically significant with 95% certainty.[88] While it would suggest that air quality is gradually getting worse, additional data

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[84] See U.S. Environmental Protection Agency (2010) Ozone Air Quality Standards. Available online at: http://www.epa.gov/air/ozonepollution/standards.html Accessed: March 11, 2010.

[85] World Health Organization (2008) Air quality and health: fact sheet number 313. Available online at: http://www.who.int/mediacentre/factsheets/fs313/en/index.html Accessed: March 11, 2010.

[86] Ontario Ministry of the Environment (2010) Gound-level Ozone. Available online at: http://www.airqualityontario.com/science/pollutants/ozone.cfm Accessed: March 11, 2010.

[87] . Environment Canada. Air Quality Data. National ground-level ozone indicator, Canada, 1990 to 2008. Available online at: http://www.ec.gc.ca/indicateurs-indicators/default.asp?lang=en&n=B1385495-1#aq_chart1_o3_en Accessed: March 6, 2011.

[88] See Environment Canada (2008) CESI – Air Quality – Data Sources and Methods. Available online at: http://www.ec.gc.ca/indicateurs-indicators/default.asp?lang=En&n=DCC798B8-1&offset=6&toc=show Accessed: April 27, 2010.

are necessary before making this definitive conclusion, including data on PM and other criteria air contaminants.

The absolute levels, while not poor from a global perspective, do raise some concerns for the wellbeing of Canadians. Air quality already affects the health of urban populations, in particular older people and children, who are particularly susceptible to poor air quality. In fact research indicates that the costs of poor air quality, when aggregated through time, can reach into the billions of dollars with respiratory diseases accounting for nearly 10 percent of all hospital visits.[89] Although average levels remain below "recommended levels," the evidence is that despite meeting these "good" air quality levels on average, we are failing to protect the health of some Canadians. The fact that nearly 20% of our children — a four-fold increase over the past twenty years — are now experiencing respiratory diseases such as asthma should signal that air quality is not optimal for the wellbeing of all Canadians.[90] The suggested explanation for this apparent discrepancy between recommended levels and health impacts is spatial and temporal variation in levels. Ultimately, both the current levels and the general trend are of concern to the health of both humans and other species, such as lichens[91].

Ground-level ozone levels are described as annual averages and numerous populations are exposed to dangerous amounts of ground-level ozone (> 50 ppb) at certain times of the year. For example, daytime in the summer is much worse than evenings and winters, while southern Ontario (which averaged 47.6 ppb in 2002) has much higher ground-level ozone levels than British Columbia's Fraser Valley (28.0 ppb in 2002)[92] and cities have much higher levels that often exceed the 50ppb threshold. These "spikes" of poor air quality in select areas may indeed be responsible for much of the increase in asthma rates, and may be cause to reconsider how policies target ground-level ozone. While it is recognized that reducing summertime ground-level ozone spikes is challenging, due to the fact that reducing precursor gases does not guarantee decreases in ground-level ozone, refining policy to ensure the wellbeing of our children does represent a logical place to begin.

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[89] Pandey, M.D. and Nathwani, J.S. (2003) Canada wide standard for particulate matter and ozone: cost-benefit analysis using a Life Quality Index, *Risk Analysis*, 23(1): 55-67; and Health Canada (2010) Health Effects of Air Pollution. Available online at: http://www.hc-sc.gc.ca/ewh-semt/air/out-ext/effe/health_effects-effets_sante-eng.php Last accessed: April 24, 2010.

[90] Sahsuvaroglu, T. et al (2009) Spatial analysis of air pollution and childhood asthma in Hamilton, Canada: comparing exposure methods in sensitive subgroups, *Environmental Health*, 8:14. Available online at: http://www.ehjournal.net/content/8/1/14, Last accessed: October 10, 2010; and Commission on Environmental Cooperation (2006) *Children's Health and the Environment in North America*. Available online: http://www.cec.org/Storage/27/1799_CEC_Children_and_Health_en.pdf Last accessed: October 10, 2010

[91] Conti, M. E. and Cecchetti, G. (2001) Biological monitoring: lichens as bioindicators of air pollution assessment — a review, *Environmental Pollution*, 114(3): 471-492.

[92] CESI (2008) Ground-level ozone exposure indicators by region, 1990-2006. Available online at: http://ec.gc.ca/indicateurs-indicators/default.asp?lang=en&n=89B1C598-1#AIRchart3E Last accessed: March 7, 2010.

AIR: Air Pollution (Criteria Air Contaminant Emissions Index)

Issue: What is the issue and why is it important to wellbeing?

Air pollution is a function of the emissions of criteria air contaminants, a suite of harmful airborne emissions that derive from various industrial processes and the combustion of fossil fuels, such as driving a car or running a coal-fired power plant. These emissions include total particular matter under 2.5 micrometres in diameter ($PM_{2.5}$); sulphur oxides (SO_x), a family of sulphur-based compounds; nitrous oxides (NO_x), a family of nitrogen-based compounds; volatile organic compounds (VOCs); and ammonia (NH_3). Also often included (but not reported by Environment Canada, nor this index) are Total Particulate Matter (TPM), and Carbon Monoxide (CO). Collectively, these compounds are responsible for various impacts, including smog, acid rain and other health hazards, all of which are important to wellbeing. These compounds differ from ground-level ozone, which is a by-product of CACs, but not directly emitted like CACs. CACs are largely produced through the burning of fossil fuels.[93]

Direct linkages to other domains: **Healthy Populations** (air pollution has significant impacts upon the health of populations by increasing the prevalence of respiratory disorders[94]), **Leisure and Culture** and **Time Use** (poor air quality restricts some people's ability to engage in certain forms of recreation), **Living Standards** (poor air quality can increase the number of hospital visits, as well as negatively impact tourism, both of which have economic costs on society[95]).

Considerations and trade-offs: Like addressing ground-level ozone, reducing air pollution emissions requires a reduction in fossil fuel burning activities. Alternative forms of energy are needed to reduce dependence upon fossil fuels. However, technologies such as wind, solar, biomass, and tidal are, for the most part, more costly than traditional fossil fuels, and therefore the question of subsidy allocation is a key policy decision. Without reductions, it is likely that health impacts (disease, mortality and costs) will continue to impact wellbeing.

Understanding the Indicator: What is this indicator, why was it selected and how do I interpret the results?

The CAC Emissions Index provides trend information on the emissions of the seven CACs noted above. While the indicator is an indexed value of absolute emissions, the data presented below cover absolute emissions (in tons), indexed emissions (to 1994 levels), and a per capita index (to 1994 levels) to get a sense of how we are doing collectively as a growing country. An index was employed in order to compare between substances that differ dramatically in levels (as seen below), as well as by their impacts. Since subjective endpoints are required to determine impacts (and therefore weightings), indexed values were used instead. The data were indexed to 1994 levels and then averaged with equal weighting to provide an aggregate index.

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[93] Environment Canada (2010) Criteria Air Contaminants and Related Pollutants http://www.ec.gc.ca/Air/default.asp?lang=En&n=7C43740B-1 Last accessed: October 9, 2010.

[94] Canadian Medical Association (2008) Illness Cost of Air Pollution. Available online at: http://www.cma.ca/index.php/ci_id/86830/la_id/1.htm Last accessed: October 11, 2010.

[95] Ibid.

For per capita values, each substance was converted to a per capita level based upon population data from Statistics Canada.

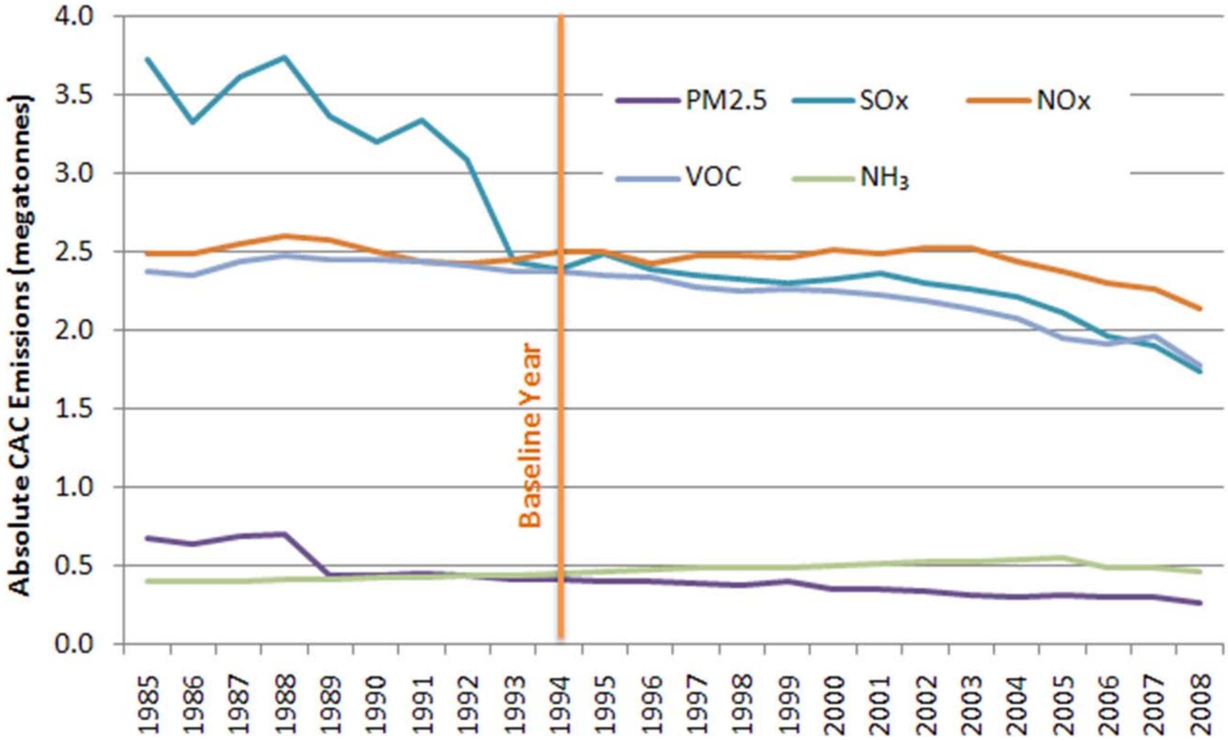
NO_x, SO_x and VOCs are all a part of the EPI, and are tracked by Environment Canada's CESI program as well. Globally these data are well established and monitored, thus providing a rich basis for comparison through time and space.

If the index number is greater than 1.00, then emissions are rising relative to 1994 levels, while if the number is less than 1.00, then emissions are below 1994 levels.

Current Trends and Significance: What are the trends in the data and how are they significant to the environment and human wellbeing?

Figure 2. Indicator – Criteria Air Contaminants

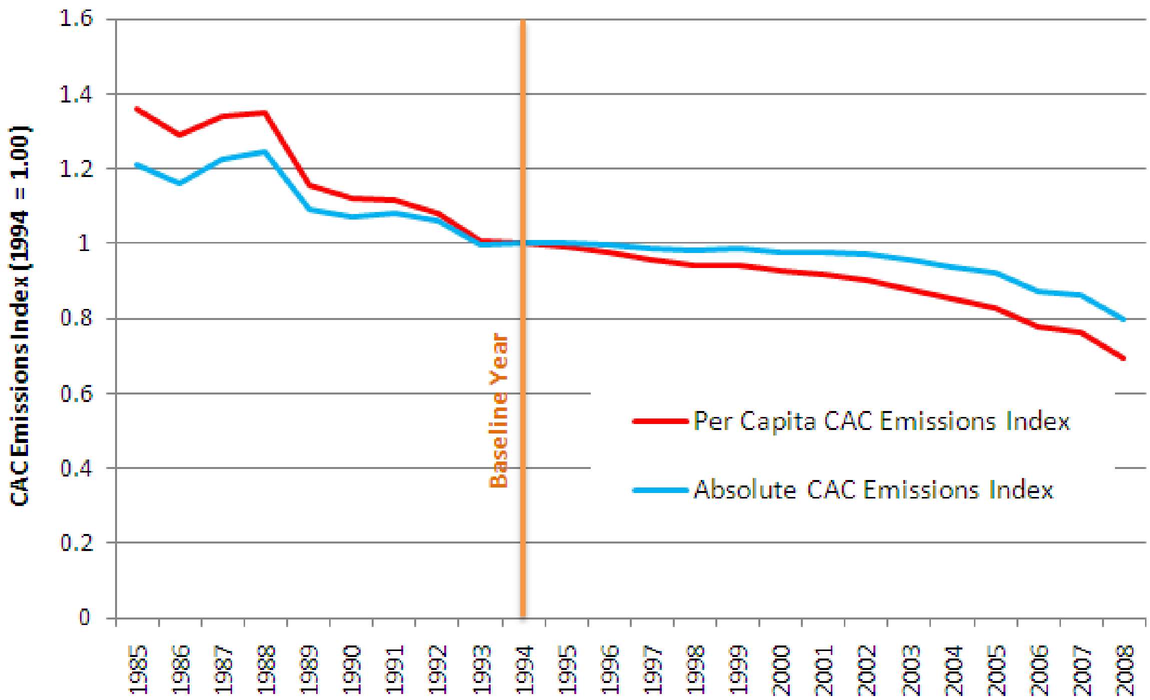
Absolute CAC emissions by type, Canada 1985-2008[96]



[96] Environment Canada. Air Pollutant Emissions Data. Main air pollutants emissions trends for Canada, 1985 to 2008. Available online at: http://www.ec.gc.ca/indicateurs-indicators/default.asp?lang=en&n=C09D502F-1#ae_chart1_en Accessed: March 6, 2011.

Figure 3. Absolute and Per Capita CAC Emissions Indices

Canada 1985-2008[97]



CAC individual trends (Figure 2) indicate a downward trend in four of the five CAC air pollutants while Ammonia emissions have increased slightly during this period. Both the per capita and absolute indices (Figure 3) also indicate a downward trend.

Deeper analysis (Figure 4) reveals that the primary factors behind each of the different CACs vary considerably. For example, dust from construction and roads is the primary contributor to PM2.5, while smelting and refining of non-ferrous materials and petroleum contribute the majority to SO_x emissions. NO_x emissions are largely a function of heavy-duty diesel vehicles and off-road use of diesel, while VOCs are dominated by natural sources[98].

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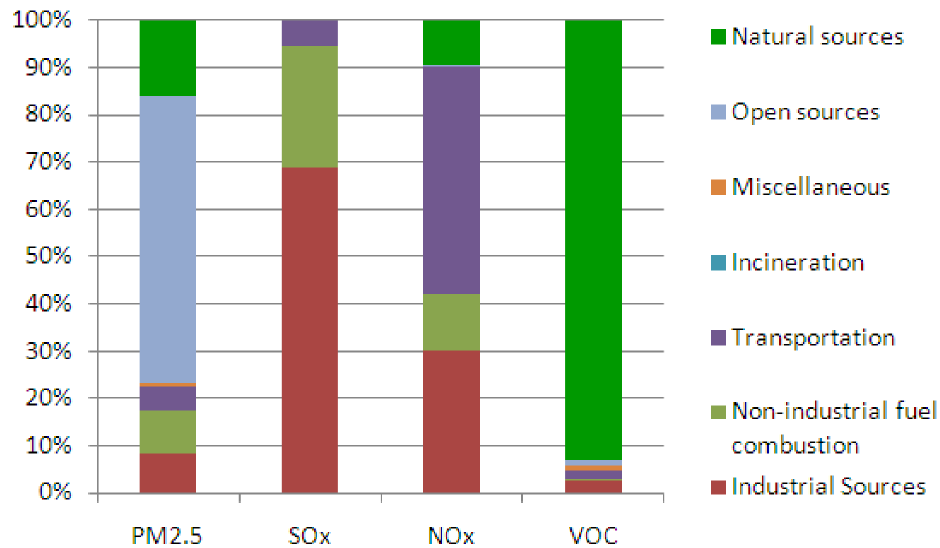
[97] *Ibid.*

[98] Statistics Canada (2009) Human Activity and the Environment, Catalogue no. 16-201-X. Table 3.46. Available online at: http://www.statcan.gc.ca/pub/16-201-x/16-201-x2009000-eng.pdf Last accessed: March 4, 2011.

Figure 4. Contribution of Total by CAC

Canada 2006[99]



Of all of the CAC decreases it is worth noting the story behind the SO_x reduction in particular. Both SO_x and NO_x were subject to North American emissions trading schemes under the U.S. Clean Air Act which began in 1990.[100] The combination of technological improvements, reputational concerns and the use of an emissions trading scheme provided companies with sufficient incentives to reduce CAC emissions. These reductions in fact led to the realization of secondary sulphur markets (sulphuric acid) created from the SO_x that was "scrubbed" out of emissions in smelters.[101] While levels still need to be reduced to eliminate issues such as smog, acid rain and particulate-driven human respiratory diseases, the CAC indicator is heading in the right direction and is a good demonstration of how effective policy[102] can reduce environmental impacts, and ultimately benefit human wellbeing.

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[99] Statistics Canada (2009) Human Activity and the Environment. Table 3.46. Available online at: http://www.statcan.gc.ca/pub/16-201-x/16-201-x2009000-eng.pdf Accessed: March 5, 2011.

[100] Gehring, M. W. and Streck, C. (2005) Emissions trading: lessons from SO_x and NO_x emissions allowance and credit systems legal nature, title, transfer, and taxation of emissions allowances and credits. *Environmental Law Reporter*, 35: 10219.

[101] Caterpillar Global Mining (2008) The reclamation of Sudbury: the greening of a moonscape. *Viewpoint*, Issue 4. Available online at: http://www.cat.com/cda/files/1060442/7/ Last accessed: March 15, 2010.

[102] Some of these include: Canada-Wide Standard for Particulate Matter and Ozone, Canada Wide Acid Rain Strategy, Ozone Annex of the 1991 Canada-U.S. Air Quality Agreement, Convention on the Long Range Transport of Air Pollutants, Development of Ambient Air Quality Objectives, The International Joint Commission, The United Nations Economic Commission for Europe.

AIR: Greenhouse Gas Emissions

Issue: What is the issue and why is it important to wellbeing?

A small group of greenhouse gases — mainly carbon dioxide, methane, nitrous oxide, and water vapour — help to regulate the Earth's climate by trapping solar energy that reradiates from the Earth's surface as heat. The International Panel on Climate Change (IPCC) has strongly stated that anthropogenic GHG emissions are significantly contributing to climate change.[103]

Already, atmospheric concentrations of GHGs are reaching a level not seen in thousands of years, with a trajectory for levels not seen in millions of years. While many people see climate change as "warmer winters and a few bad storms," dangerous climate change will affect wellbeing perhaps more significantly than any other factor within the CIW. It has the potential to disrupt democratic engagement, erode communities through violent conflict, drive drought and its associated costs, increase disease and incidences of heat-related illnesses, and profoundly alter both time use and living standards. It will change patterns of water and species movement, and thereby alter the ways of life of not only aboriginal communities, but potentially cities as well. The Canadian scholar Thomas Homer-Dixon provides a good overview of the linkages between climate change, environmental degradation and human conflict in several of his works[104] as does the major European-UNEP report on The Economics of Ecosystems and Biotic Resources.[105] From purely an economic perspective, climate change is expected to *decrease global GDP by up to twenty percent.* The 2007 Stern report[106] recommends an investment of at least one percent of GDP in an effort to reduce GHG emissions.[107]

Direct linkages to other domains: **Leisure and Culture** (the impacts of climate change will significantly affect leisure activities, and may affect aboriginal cultures, such as those of the Inuit), **Democratic Engagement** (some researchers suggest that under the stresses of climate change, civil strife increases and democratic engagement may decrease),[108] **Community Vitality** (communities can be significantly affected by extreme weather and other impacts of climate change), **Healthy Populations** (climate change has been shown to affect disease, ranging from respiratory disorders and heat impacts, to vector-based infections), **Living Standards** (climate change impacts can significantly affect the economy via such things as

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[103] See IPCC Fourth Assessment Report: Climate Change 2007. Available online at: http://www.ipcc.ch/publications_and_data/publications_and_data_reports.htm#1 Last accessed: March 2, 2010.

[104] Homer-Dixon, T.F. (2001) *Environment, Scarcity and Violence*, Princeton University Press: New Jersey, and Homer-Dixon, T.F. (2009) *Carbon Shift: how the twin crises of oil depletion and climate change will define the future*, Random House: Toronto.

[105] European Commission (2009) *Mainstreaming the Economics of Nature: A synthesis of the approach, conclusions and recommendations of TEEB*. Available online at: http://www.teebweb.org/LinkClick.aspx?fileticket=bYhDohL_TuM%3d&tabid=1278&mid=2357 Last accessed: March 11, 2011.

[106] The Stern Report (see citation below) is a 700 page report, written by British economist Nicholas Stern that discusses the economic impacts of climate change, the costs of stabilization, and the policy challenges to do so.

[107] Stern, N. (2007) *The Economics of Climate Change: the Stern Review*, Cambridge Press.

[108] Homer-Dixon, T. (2000) *The Ingenuity Gap*, Knopf.

droughts, floods and invasive species) and **Time Use** (climate change will likely alter people's time use as they are forced to address impacts).

Considerations and trade-offs: As with the other aspects in the realm of air, greenhouse gases also arise from fossil fuel use. Since carbon is a global gas, Canada has various options for reduction ranging from purchasing carbon credits, to reducing energy demand and shifting to less carbon-intensive sources of energy (such as wind). Should GHG levels not go down, Canada will face penalties under Kyoto, as well as large impacts to all aspects of wellbeing for future generations.

Understanding the Indicator: What is this indicator, why was it selected and how do I interpret the results?

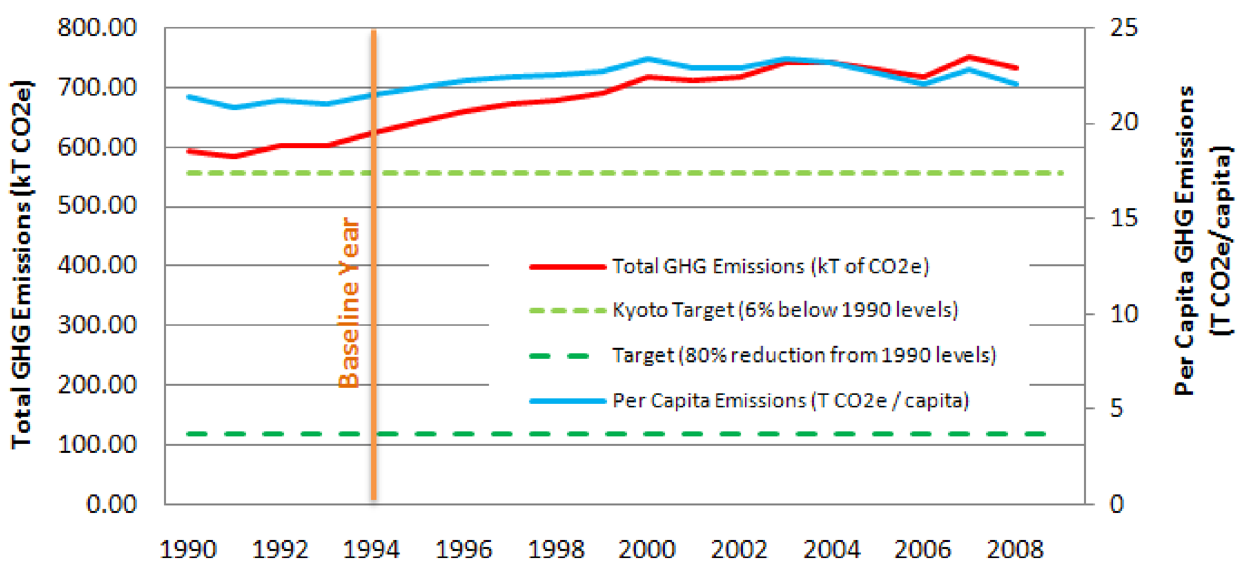
The greenhouse gas (GHG) emissions indicator reports the trend in anthropogenic (human-made) greenhouse gas emissions at a national level for the six main greenhouse gases in Canada: carbon dioxide, methane, nitrous oxide, sulphur hexafluoride, perfluorocarbons and hydrofluorocarbons, in equivalent tonnes of CO_2 (referred to as CO_2e)[109] (see Appendix D for more details).

Greenhouse gas emissions are perhaps the single most important (and widespread) environmental indicator in use. As an indicator, it is used by virtually every environmental reporting program including CESI, EPI, the OECD, the EU and others (Appendix E).

Current Trends and Significance: What are the trends in the data and how are they significant to the environment and human wellbeing?

Figure 5. Indicator – GHG Emissions

Canada 1990-2008[110]



[109] See Appendix E for more details on the warming potential of various greenhouse gases and CO_2e.
[110] Environment Canada. Greenhouse Gas Emissions Data. National greenhouse gas emissions, Canada 1990 to 2008. Available online: http://www.ec.gc.ca/indicateurs-indicators/default.asp?lang=en&n=BFB1B398-1#ghg1_en Accessed: March 6, 2011

GHG emissions have increased in Canada both in overall absolute and per capita terms since 1994, though recent years have shown a decline in per capita use rates: between 2003 and 2008 emissions decreased absolutely by 0.08%[111]. Nevertheless, the graph above illustrates the 24.1% increase in absolute GHG emissions since 1990, along with both the Kyoto target (6% below 1990 levels by 2012) and the longer term target of 80% below 1990 levels by 2050. Such levels would be required to achieve Canada's component towards the long term target of 350ppm of CO_2e, which many suggest is the level necessary to avoid dangerous climate change impacts.[112,113] Furthermore, in addition to absolute emission levels, Canada is amongst the highest per capita emitters in the world (second only to the United States), and unlike the U.S., has shown an increasing trend in per capita emissions, though this has leveled off in recent years and, while it is too early to tell for certain, may be showing signs of decline. While the economy is increasingly less GHG intensive (not shown on graph), Canada's performance in "de-carbonizing the economy" is average when compared to other industrialized countries.[114]

The specific sectors of the economy that contributed the greatest amounts to Canada's GHG emissions are highlighted below.

Table 5. GHG Emission Changes by Sector

Canada 1990-2008[115]

Economic Sector	1990	2008	Change from 1990-2008 (megatonnes)	Change from 1990-2008 (%)
Fossil fuel industries	103	160	57	55%
Electric utilities	97	121	24	24%
Transportation	121	162	40	33%
Heavy industry and manufacturing (includes construction)	123	110	-13	-10%
Service industries	40	59	19	47%
Residential	52	52	0	1%
Agriculture	56	71	15	27%
Total	**592**	**734**	**142**	**24%**

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[111] Environment Canada. Greenhouse Gas Emissions Data. National greenhouse gas emissions, Canada 1990 to 2008. Available online at: http://www.ec.gc.ca/indicateurs-indicators/default.asp?lang=en&n=BFB1B398-1#ghg1_en Accessed: March 6, 2011

[112] Meinshausen, M., Hare, W., Wigley, T. M. M., Van Vuuren, D., Den Elzen, M. G. J. and Swart, R. (2006) Multi-gas Emissions Pathways to Meet Climate Targets, *Climatic Change* 75: 151–194. http://www.springerlink.com/content/218548170461445/?p=62e04c1bfacc449e929a9f9c61c0ebce&pi=4

[113] Rockström, W.S. et al. (2009) A safe operating space for humanity, *Nature*, 461: 472-475, September 24, 2009.

[114] Environment Canada (2010) National Inventory Report – Part 1: 1990-2008. Available online at: http://www.ec.gc.ca/ges-ghg/default.asp?lang=En&n=0590640B-1 Last accessed: April 28, 2010.

[115] Environment Canada (2010) Table 2-11: Summary of emissions and economic activity by sector, 1990 and 2008 http://www.ec.gc.ca/ges-ghg/default.asp?lang=En&n=0590640B-1 Last accessed: April 28, 2010.

What is significant about these statistics is that residential energy-related emissions were virtually unchanged over the period 1990-2008. While residential transportation is included within transportation emissions (which have increased by 33%), the primary areas of growth are related to energy and non-renewable energy reserves (fossil fuels). Oil, gas and coal industries, along with downstream transportation emissions, are now responsible for nearly half of Canada's emissions. Thus the most important contributors to increasing GHG emissions in Canada are not average Canadian households, per se, but rather certain industries, in particular oil and gas along with transportation, electricity and heat generation facilities. It is important to note that while households do in turn consume some of the energy and goods produced by industry, a considerable amount is exported. Meanwhile, some sectors, such as industrial processes, have managed to reduce their absolute emissions below 1990 levels. These facts raise some questions around issues of equity when it comes to emissions reductions: how do we hold sectors responsible for meeting (or failing to meet) the challenge of GHG emissions and climate change?

There are numerous implications of these trends for the wellbeing of Canadians. Carbon represents a liability to Canadians; not only to their businesses, but to the wellbeing of future generations. In the short term, should an emissions trading scheme be put in place and carbon become a tradable commodity, Canadian companies will be at a disadvantage due to the carbon-intensive nature of our economy. Carbon has a price both figuratively and literally, and the externality that Canada is currently forcing upon the rest of the planet via its carbon emissions could indeed come back to impact us more than we realize. Canada's Arctic has already experienced a warming of more than 1.7°C and an increase of 4 or 5°C is projected.[116] This will have very large ramifications for infrastructure, communities and species throughout the Arctic, causing disruption to cultural, economic and general wellbeing. GHG emissions don't only impact Canada either; climate change is a global issue in which we affect, and are in turn affected by, others. Lastly, it is important to bear in mind that the impacts of climate change are only just starting to be felt. The true costs will be borne in the future, and thus we are making policy decisions that will affect the wellbeing of future generations.

[116] International Arctic Science Committee (2010) Arctic climate change scenarios for the 21st century projected by the ACIA-designated models. Available online at: http://www.eoearth.org/article/Arctic_climate_change_scenarios_for_the_21st_century_projected_by_the_ACIA-designated_models Last accessed: October 11, 2010; and Natural Resources Canada (2007) Geological Survey of Canada – Permafrost Communities and Climate Change. Available online at: http://gsc.nrcan.gc.ca/permafrost/communities_e.php Last accessed: October 12, 2010.

ENERGY: Energy Production (Primary)

Issue: What is the issue and why is it important to wellbeing?

While the theoretical stock of energy on Earth is nearly limitless (the energy from the sun, combined with energy contained within the Earth, is far in excess of anything that humans could use at this time), the amount of energy humans can produce with current technology is far more restricted. Nevertheless, primary energy production is a key element to wellbeing, factoring heavily into the Canadian economy, and powering other aspects that affect other elements of wellbeing. In the Canadian context, roughly 4% of our GDP derives from the energy sector alone[117] which is worth in excess of $50 billion dollars.[118]

Direct linkages to other domains: **Leisure and Culture** (energy production can alter land and water use considerably, resulting in changes to leisure and cultural uses of the land and water, in both a negative and positive manner. For example, setting up a coal-fired power plant beside a park may take away from some people's enjoyment, while setting up a hydropower reservoir may provide new recreational opportunities for sailing), **Education** (energy production is a driver of innovation in Canada, which is a leader in nuclear and hydroelectric technologies), **Living Standards** (energy production plays a key role in our economy, as noted above), **Time Use** (the production of energy through utilities saves us from having to gather energy sources such as fire wood ourselves), and **Environment** (energy production has a number of implications for virtually all other aspects within the Environment domain including air pollutants and GHG emissions, water use, non-renewable resource use, and biotic resources impacts through habitat conversion/degradation).

Considerations and trade-offs: Energy production is a major source of employment and revenue for Canada and its populace, which has high energy demands. However, most of our current primary energy production comes via fossil fuels, which are contributing to climate change. The impacts of primary energy production (via development, extraction and operation) can be significant to both the environment and to human wellbeing. If Canada is to develop a reduced carbon pathway, it will need to determine a way of shifting primary energy production from fossil fuels to green energy.

Understanding the Indicator: What is this indicator, why was it selected and how do I interpret the results?

Primary energy production is the harnessing of energy from various sources including coal, crude oil, natural gas, natural gas liquids, hydro and nuclear electricity and steam.[119] Production is measured in petajoules, and according to Statistics Canada, "one petajoule contains energy equivalent to about 30 million litres of gasoline, enough to power Canada from all sources for a

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[117] Statistics Canada (2010) Table 379-0027 – Gross domestic product (GDP) at basic prices, by North American Industry Classification System (NAICS), monthly (dollars) (table), CANSIM (database), http://cansim2.statcan.gc.ca/cgi-win/cnsmcgi.exe?Lang=E&CNSM-Fi=CII/CII_1-eng.htm, Accessed: March 15, 2010.

[118] Industry Canada (2010) Canadian Industry Statistics (CIS) Available online at: http://www.ic.gc.ca/eic/site/cis-sic.nsf/eng/h_00013.html Last accessed: March 10, 2011.

[119] Statistics Canada (2009) Table 2.1-1: Total energy – primary energy, by type – Production. Available online at: http://www.statcan.gc.ca/pub/57-601-x/2008004/t020-eng.htm Last accessed: October 11, 2010.

little more than an hour." [120] A large proportion of this production is exported,[121] primarily to the United States, while Canada also engages in a limited amount of energy importing as well.[122] Furthermore, some of this energy is consumed by the producers, while other aspects of it are taken up by non-energy use, such as the production of chemicals and refinery products.

The indicator was selected as it is a key variable that is readily available (reported on a quarterly basis by the Canadian government) and represents an important aspect of how the environment is used. Canadians are heavy users of energy on a global basis,[123] in part because of our extreme climate fluctuations and geography, and in part because of our high levels of consumption and standard of living.

The higher the amount of primary energy production, the more energy Canada is generating from various sources. There is no judgment as to whether this is "good energy" or 'bad energy" (i.e., there is no discrimination between sources due to their secondary impacts), though the makeup of the various sources of primary energy are illustrated within the indicator. Impacts, such as CO_2 emissions, are captured in Air: GHG Emissions.

[120] Statistics Canada (2009) Heavy Fuel Oil Consumption in Canada. Available online at: http://www.statcan.gc.ca/pub/11-621-m/11-621-m2007062-eng.htm Last accessed: October 11, 2010.

[121] Statistics Canada (2009) Table 2.1-2: Total energy – primary energy, by type – Exports. Available online at: http://www.statcan.gc.ca/pub/57-601-x/2008004/t021-eng.htm Last accessed: October 11, 2010.

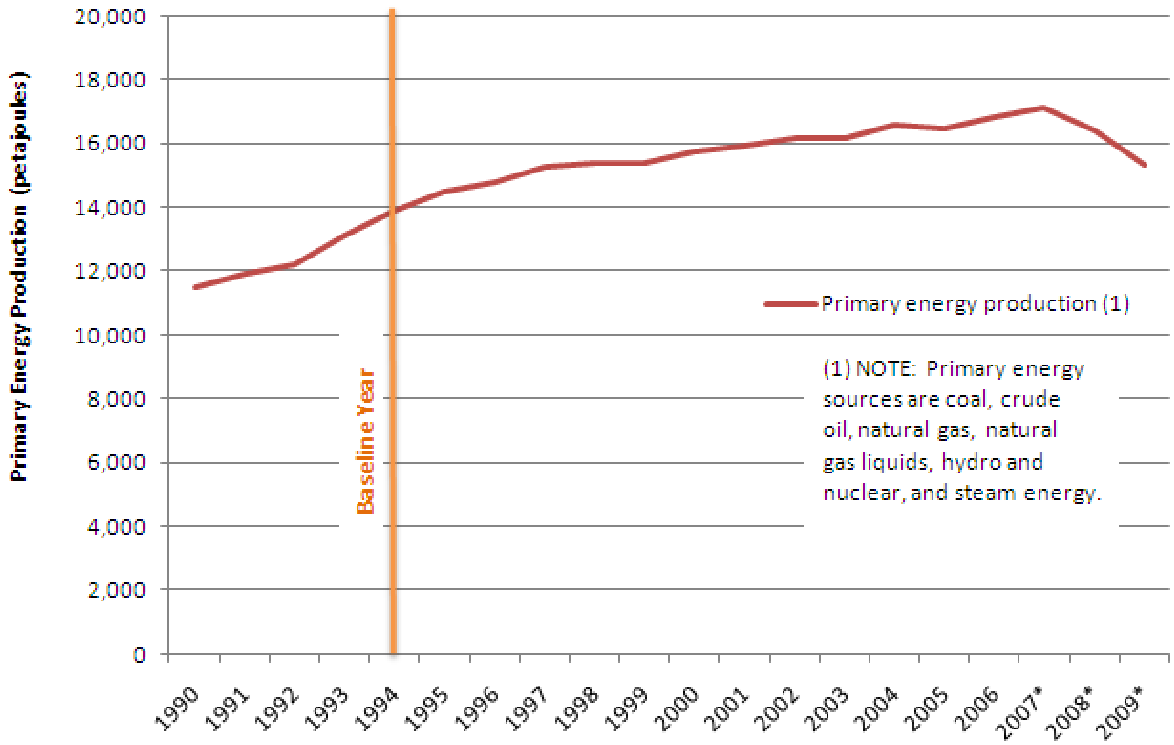
[122] Statistics Canada (2009) Table 2.1-3: Total energy – primary energy, by type – Imports. Available online at: http://www.statcan.gc.ca/pub/57-601-x/2008004/t022-eng.htm Last accessed: October 11, 2010.

[123] U.S. Energy Information Administration (2006) International Total Primary Energy Consumption and Energy Intensity. Available online at: http://www.eia.doe.gov/emeu/international/energyconsumption.html Last accessed: October 11, 2010.

Current Trends and Significance: What are the trends in the data and how are they significant to Canadians' wellbeing?

Figure 6. Indicator – Primary Energy Production

Canada 1990-2009 (1994 baseline)[124]



*Note: 2007-09 were updated using the latest available data.[125]

Figure 6 shows the levels of primary energy production in Canada since 1990. As is seen, there has been a general increase in production since 1990, though levels dipped since 2007. Much of this decrease was a function of lower demand for energy production, which has somewhat flexible capacity in order meet the demands of users, such as the manufacturing and transportation sectors.[126]

[124] Statistics Canada (2011). Table 2.1-1. Total energy – Primary energy, by energy type – Production. Available online: http://www.statcan.gc.ca/pub/57-601-x/2010003/t020-eng.htm Accessed: March 6, 2011.

[125] Statistics Canada (2010) Energy Supply and Demand. Available online at: http://www40.statcan.ca/l01/cst01/prim71-eng.htm Last accessed: October 11, 2010.

[126] Statistics Canada (2010) Energy and Supply 2008. Available online: http://www.statcan.gc.ca/daily-quotidien/091124/dq091124c-eng.htm. Last accessed: October 11, 2010.

Figure 7. Composition of Primary Energy Production

By Type, Canada 1990-2009[127]

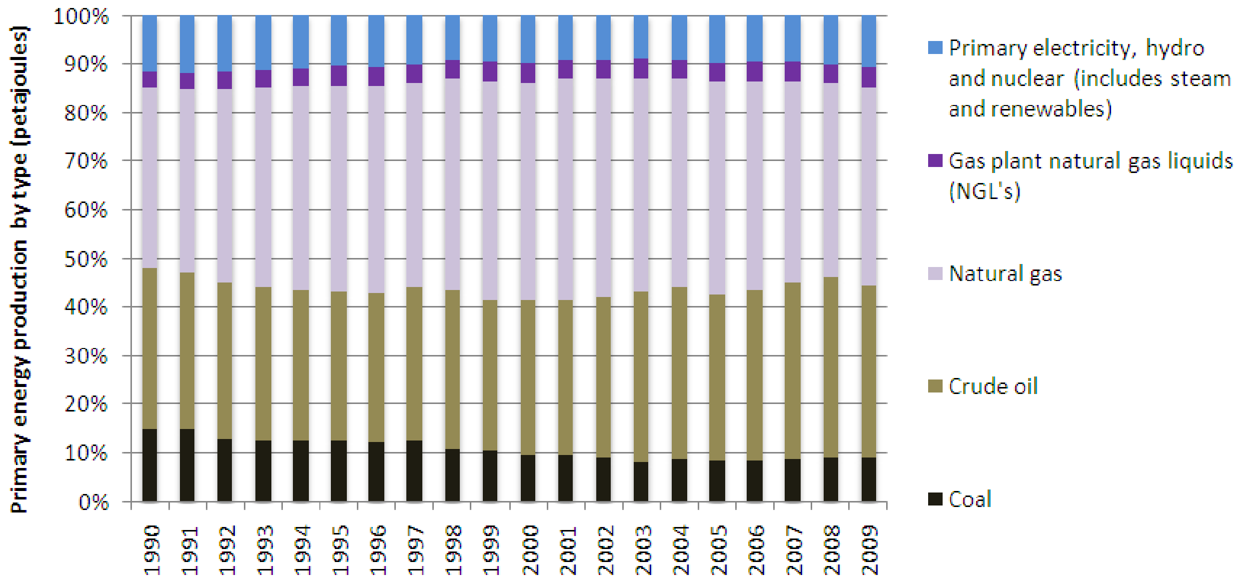


Figure 7 provides a breakdown of energy production from various sources. As can be seen, the reliance upon coal is steadily decreasing, while crude oil and natural gas have increased. Hydro, nuclear, and now renewables, have remained relatively steady over the years. According to Statistics Canada, "Hydro generation accounted for 60% of electric power in 2008, the largest source. Nuclear energy provided about 15%. (In Ontario, nuclear power accounted for more than 53% of total electricity generation.) Although electricity generation from wind, solar and tidal sources is rising, total generation from these sources represented less than 0.5% of total generation. Over the period from 2000, when wind generation capacity was only 137 megawatts, to 2008, capacity has increased to 2,369 megawatts, and grew over 26% from 2007-2008 alone. According to the Canadian Wind Energy Association, Canada ranked 10th in the world in terms of new wind energy capacity at the end of 2008."[128]

These data suggest that significant amounts of primary energy production capacity in Canada is made up of non-renewable energy reserves. These sources have (or could have) significant impacts on both the environment and on human health (e.g., carbon emissions, SO_x/NO_x/mercury emissions,[129] habitat conversion/inundation, sour gas,[130] radioactive wastes, etc.). This issue also arises in the context of non-renewable energy reserves, which is explored

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[127] Statistics Canada (2011). Table 2.1-1. Total energy – Primary energy, by energy type – Production. Available online: http://www.statcan.gc.ca/pub/57-601-x/2010003/t020-eng.htm Accessed: March 6, 2011.

[128] Statistics Canada (2010) Energy and Supply 2008. Available online: http://www.statcan.gc.ca/daily-quotidien/091124/dq091124c-eng.htm. Last accessed: October 11, 2010.

[129] U.S. Environmental Protection Agency (2010) *Human Health and Environmental Effects of Emissions from Power Generation*. Available online at: http://www.epa.gov/capandtrade/documents/power.pdf Last accessed: October 11, 2010.

[130] Energy Resources Conservation Board (2010) Health Effects of Sour Gas. Available online at: http://www.ercb.ca/portal/server.pt/gateway/PTARGS_6_0_320_0_0_43/http;/ercbContent/publishedcontent/publish/ercb_home/public_zone/sour_gas/the_public_interest/HealthEffects.aspx Last accessed: October 11, 2010.

later in this report. While no primary energy source is without its impacts, minimizing or eliminating impacts, and simultaneously maintaining high levels of energy production, is a key challenge facing both the private and public sectors. Renewable forms of primary energy production represent one potential pathway to lowering impacts, though even these technologies still have potential social and environmental consequences on human wellbeing.

ENERGY: Energy Use (Final Demand Energy Use)

Issue: What is the issue and why is it important to wellbeing?

Canada is a nation that is connected to its energy. We are a vast nation with extreme temperature fluctuations (in the case of the Prairies, from -40 to +40°C). As a result we use considerable amounts of energy — to move around, to shift goods, to provide services over long distances, to power our urban areas, and to heat our homes and workplaces. In fact, Canada ranks quite high on a global level in terms of energy use.[131]

Energy is used throughout the Canadian economy; in fact, without energy there would be no economy.[132] Energy consumption is not a "bad thing" per se — it provides us with many benefits listed below — but rather, since energy production has impacts and externalities, we need to be aware that our consumption has implications for other areas of wellbeing as noted below.

Direct linkages to other domains: **Leisure and Culture** (energy use is a key aspect to many recreational and cultural pursuits), **Education** (energy use plays a role in powering technology and many electronic devices that enable learning, from the internet to home computers), **Healthy Populations** (energy use underpins modern medical technology and is critical for an array of devices such as x-ray machines), **Living Standards** (energy use is critical in powering both homes and businesses – from natural gas to electricity to fueling cars; oil and gas also currently play a key role in our economy), **Time Use** (energy use has the ability to save time by performing work, thereby freeing up our time for other pursuits), **Environment** (energy use fuels energy production, which in turn has numerous environmental implications).

Considerations and trade-offs: Canada will always be a heavy energy user by virtue of our climate and our general standard of living. However, we must ensure that we use energy resources wisely. The more Canadians do not use, the less damage is caused and the more these non-renewable resources are kept for future uses. Improving efficiency and reducing demand will be key to not continually increasing our energy needs and therefore our CO_2 emissions and other impacts on wellbeing.

Understanding the Indicator: What is this indicator, why was it selected and how do I interpret the results?

Final demand energy use is the energy supplied to the final consumer for all energy uses. It is calculated as the sum of final energy use for all sectors of the Canadian economy including industrial, transportation, agriculture, residential, public administration, and commercial/other institutional. Use is measured in petajoules, and according to Statistics Canada, "one petajoule contains enough energy to power the Montreal subway system for one year."[133]

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[131] U.S. Energy Information Administration (2006) International Total Primary Energy Consumption and Energy Intensity. Available online at: http://www.eia.doe.gov/emeu/international/energyconsumption.html Last accessed: October 11, 2010.

[132] Ayres, R.U. and Warr, B. (2009) *The Engine of Economic Growth: how energy and work drive material prosperity*, Edward Elgar Publishing.

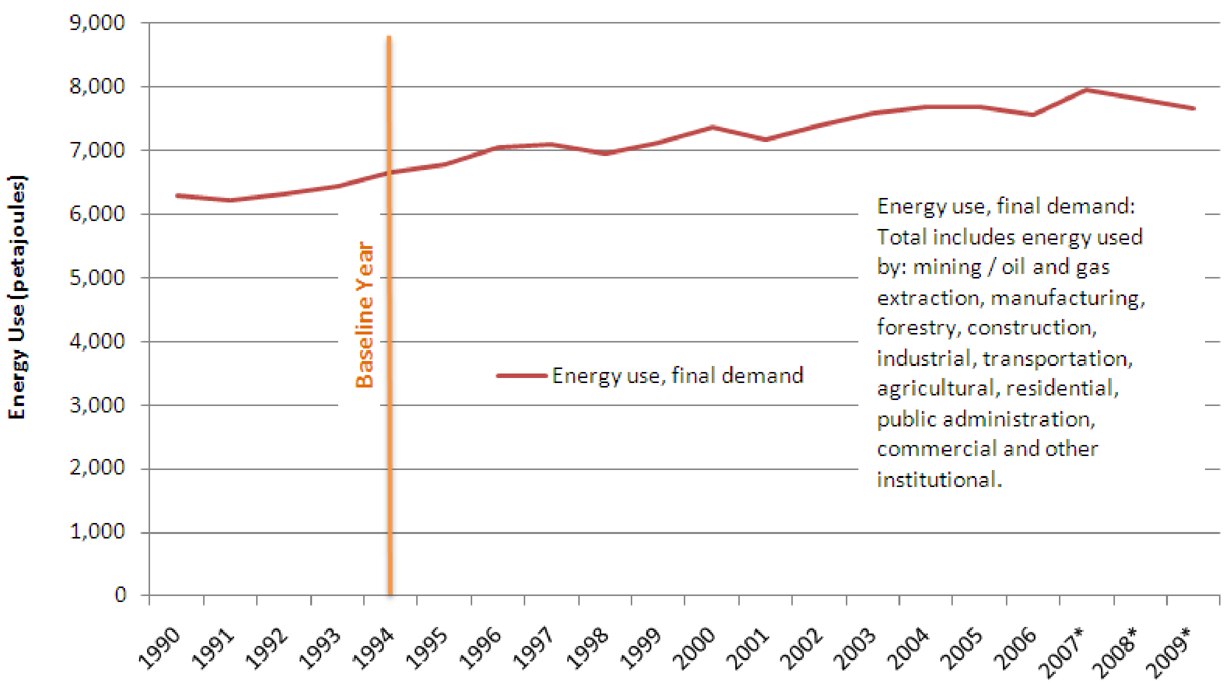
[133] Statistics Canada (2010) Report on Energy Supply and Demand in Canada 2008. Available online at: http://www.statcan.gc.ca/pub/57-003-x/2008000/part-partie1-eng.htm Last accessed: October 11, 2010.

The indicator was selected as it is readily available (reported on a quarterly basis by the Canadian government), can be disaggregated in numerous ways, and represents an important aspect of how the environment is used. The interpretation of the data is relatively simple: the more energy used, the more Canada as a nation is consuming to power our lifestyle — be it cars, factories, stoves, or laptops.

Current Trends and Significance: What are the trends in the data and how are they significant to Canadians' wellbeing?

Figure 8. Indicator – Final Demand Energy Use

Canada 1990-2009[134]



*Note: 2007-09 were updated using the latest available data.[135]

Figure 8 shows the gradual increase in final demand energy use in Canada since 1990. Use decreased in 2008 and 2009 largely due to lower demand in the manufacturing and transportation sectors.[136] The makeup of energy use by sector has remained remarkably consistent over the years, with industrial and transportation dominating energy use at nearly 60%. Residential energy use has decreased slightly on a per capita basis (though it has still

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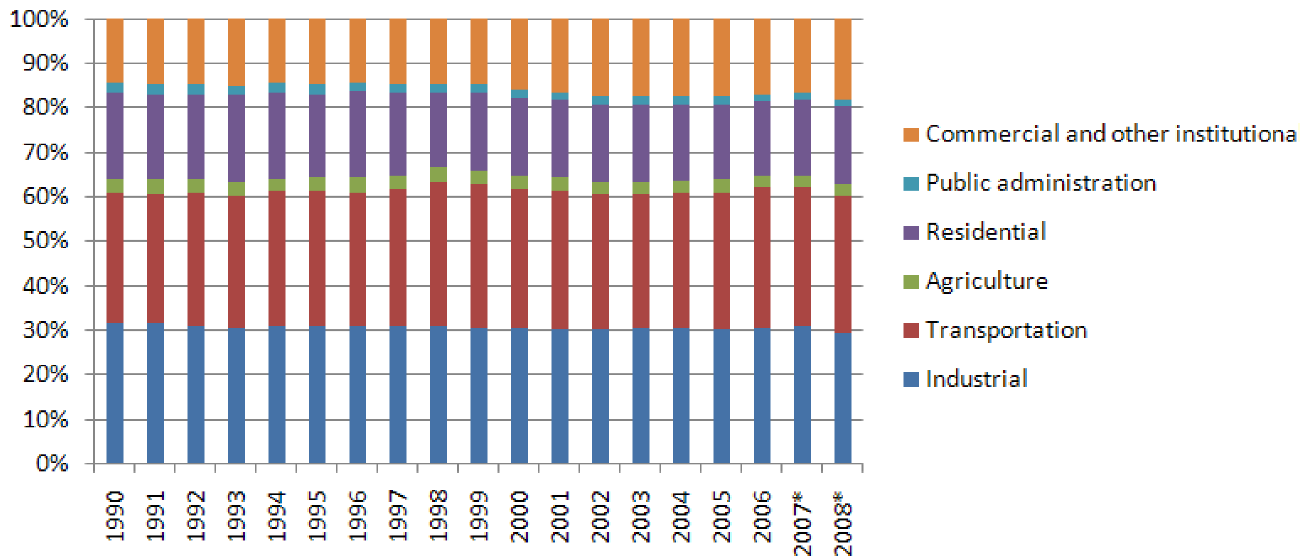
[134] Statistics Canada (2011) Table 2.1-1. Total energy – Primary and secondary energy, by energy type, in terajoules – Final demand. Available at: http://www.statcan.gc.ca/pub/57-601-x/2010003/t029-eng.htm Accessed: March 6, 2011.

[135] Statistics Canada (2009) Table 2.4-1 Total Energy – Total primary and secondary energy – Domestic demand by sector. Available online at: http://www.statcan.gc.ca/pub/57-601-x/2008004/t030-eng.htm Last accessed: October 12, 2010; and Statistics Canada (2010) Energy Supply and Demand. Available online at: http://www40.statcan.ca/l01/cst01/prim71-eng.htm Last accessed: October 11, 2010..

[136] Statistics Canada (2010) Energy and Supply 2008. Available online: http://www.statcan.gc.ca/daily-quotidien/091124/dq091124c-eng.htm. Last accessed: October 11, 2010.

increased on an absolute basis), while commercial energy use has increased on a per capita basis, and even more so on an absolute basis (Figure 9).

Figure 9. Final Demand Energy Use, Proportional Makeup by Sector



*Note: 2007-08 were updated using other data.[137]

The implications of all of these data suggest that the burden to decrease energy use (or conversely, increase energy efficiency) lies with all sectors of the economy. While the industrial and transportation sectors might provide the biggest gains, select sub-sectors also have an important role, as there is a considerable range of efficiency improvement between sectors. For example, manufacturing and construction have largely maintained 1990 levels of energy use, whilst still growing considerably. Conversely, and in part due to large growth, energy use in oil and gas extraction has increased tremendously since 1990. It is imperative for all industries, as well as other sectors, to improve efficiency, as this represents the fastest, cheapest, and most viable solution to reducing energy use. Not only will this free up energy production, it will provide policy makers with the flexibility to choose how to manage energy production for the wellbeing of all Canadians.

[137] Statistics Canada (2009) Table 2.4-1 Total Energy – Total primary and secondary energy – Domestic demand by sector. Available online at: http://www.statcan.gc.ca/pub/57-601-x/2008004/t030-eng.htm Last accessed: October 12, 2010; and Statistics Canada (2010) Energy Supply and Demand. Available online at: http://www40.statcan.ca/l01/cst01/prim71-eng.htm Last accessed: October 11, 2010.

FRESHWATER: Water Quality (Water Quality Index)

Issue: What is the issue and why is it important to wellbeing?

Water quality for both surface water (e.g., rivers, lakes and streams) and groundwater in Canada is under pressure from a range of sources, including agriculture, industrial activities and household behaviour. Degraded water quality can affect both aquatic life and human uses of water for drinking, recreation, industry and agriculture.

Direct linkages to other domains: **Healthy Populations** (poor water quality can cause impacts on health, such as infection from *E. coli*[138]), **Living Standards** (poor quality water is more costly to treat and use, resulting in additional costs to the public and private sectors; it has even been shown to affect land value[139]), **Leisure and Culture** (poor water quality limits opportunities to use freshwater bodies for swimming, angling and other forms of recreation), **Environment** (water quality can affect biotic resources as much as it does human health).

Considerations and trade-offs: Improving water quality is, for the most part, a matter of environmental management practices. While policy measures can be effective, monitoring and enforcement are essential, and other voluntary measures can be helpful to encourage progress. However, water quality improvements can bolster numerous areas of wellbeing from leisure to health and biotic resources.

Understanding the Indicator: What is this indicator, why was it selected and how do I interpret the results?

The Canadian Council of the Ministers of the Environment (CCME) through Environment Canada has developed the Water Quality Index (WQI) which tracks overall surface water quality based on an analysis of several chemical and physical parameters as these relate to the health of aquatic life (e.g., fish, invertebrates and plants). It does not assess the quality of water on the basis of whether water is potable or safe for human consumption and use. Indeed, most of the water we drink from natural sources like rivers and groundwater aquifers must be filtered or treated to ensure it is safe to drink, since even very clean water can have natural parasites that are harmful to humans.

The WQI uses ratings from poor to excellent with attributes as listed in Table 6.

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[138] The water contamination incident of Walkerton, Ontario, in 2000 provides a poignant reminder of the serious health impacts of poor water quality.

[139] Leggett, C.G. and Bockstael, N.E. (2000) Evidence of the effects of water quality on residential land prices, *Journal of Environmental Economics and Management*, 39(2): 121-144.

Table 6. CCME Water Quality Index Values and Descriptions

Category	CCME WQI Values [140]	Description[141]
Excellent	95-100 (97.5)	Water quality is protected with a virtual absence of threat or impairment; conditions very close to natural or pristine levels. These index values can only be obtained if all measurements are within objectives virtually all of the time.
Good	80-94 (87)	Water quality is protected only with a minor degree of threat or impairment; conditions rarely depart from natural or desirable levels.
Fair	65-79 (72)	Water quality is usually protected but occasionally threatened or impaired; conditions sometimes depart from natural or desirable levels
Marginal	45-64 (54.5)	Water quality is frequently threatened or impaired; conditions often depart from natural or desirable levels
Poor	0-44 (22)	Water quality is always threatened or impaired; conditions usually depart from natural or desirable levels

The WQI data from Environment Canada (CESI) is available for only a portion of all of Canada's watersheds, namely only for major rivers and communities. The data are calculated on a three year average to minimize large variations and are only available for 2005-2008 as a frequency distribution (number of stations in a given category). Since no national number is created by CESI or CCME, and station values are not available, a single metric was created by using the mid-point of the station rating (the number in brackets in Table 6), multiplying this against the percentage of stations falling into a given category, and then totaling the numbers to create an aggregate score for a given year (represented by the red line in Figure 10). For example, 41.95% of the stations fell into the "good" category in 2008, and therefore 41.95% was multiplied with the "good" midpoint (87). While this process does degrade the numbers considerably, it does allow for a short-term national trend line. The author acknowledges that CESI does not consider the full data set sufficient enough to determine valid long term trends, and that CESI will be working on such efforts, but until such an approach exists, this method does inform a trendline. It should be noted that the indicator does not measure groundwater quality — a national database for this has not yet been constructed. The WQI (stations by category, not annual averages) is used by CESI, while an alternate version, which relies upon a limited set of parameters and using stations only from the UNEP-GEMS database, is employed by the EPI. Figure 10 also captures the data from CESI via the bars (which shows the number of stations reporting any given water quality rating).

[140] This report has added mid-point values (noted in brackets), but these value are not used by CCME's WQI.

[141] CCME (2009) CCME Water Quality index FAQs. Available online at: http://www.ccme.ca/initiatives/waterfaqs.html#11 Accessed: October 7, 2010.

Current Trends and Significance: What are the trends in the data and how are they significant to Canadians' wellbeing?

Figure 10. Indicator – Water Quality Index

Canada 2005-2009[142]

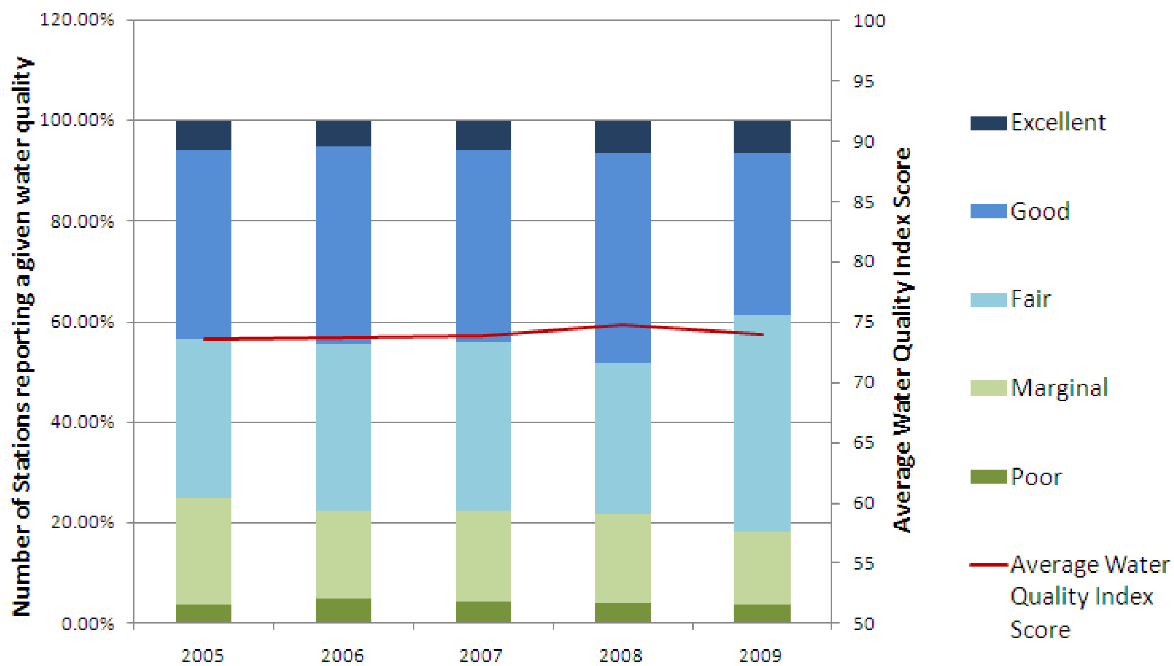

Figure 10 provides a representation of the status of freshwater quality in Canada. The figure demonstrates two aspects of the data: first, that aggregate scores are relatively stable; and second, that nearly half of the stations reported good to excellent water quality, with fewer than 5% reporting poor water quality in any given year. The increase seen between 2005 and 2008 is not likely to be statistically significant, but unlike other indicators, there are an insufficient number of data points to determine any sort of long-term trends. Of the sites tested from 1990 to 2006, the CESI data reported no change or an improvement in water quality levels in 79% (phosphorus) and 72% (nitrate-nitrite) of sites.[143]

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[142] a) Environment Canada (2011) Water Quality Data. Status of freshwater quality for protection of aquatic life at monitoring sites in Canada, 2005-2007. Available online: http://www.ec.gc.ca/indicateurs-indicators/default.asp?lang=en&n=BFB1B398-1#ghg1_en Accessed: March 6, 2011; b) Environment Canada. (2011) Water Quality Data. Status of freshwater quality for protection of aquatic life at monitoring sites in selected river basin regions, Canada, 2005 to 2007. Available online: http://www.ec.gc.ca/indicateurs-indicators/default.asp?lang=en&n=ADFCFBAB-1#wq2_en Accessed: March 6, 2011.

[143] "Of the 76 sites tested for phosphorus trends between 1990 and 2006, 22 sites (29%) show a decrease in the amount of phosphorus in rivers and lakes in Canada, 16 sites (21%) show an increasing trend; and 38 sites (50%) show no change. Of the 83 sites monitored for nitrate-nitrite trends between 1990 and 2006, 10 sites (12%) show a decrease, 23 sites (28%) show an increasing trend and 50 sites (60%) show no change." Source: Environment Canada (2010) Canadian Environmental Sustainability Indicators (CESI). Available online at: http://www.ec.gc.ca/indicateurs-indicators/default.asp?lang=En&n=68DE8F72-1 Last accessed: October 9, 2010.

According to Environment Canada,[144] hundreds of different substances are discharged, directly or indirectly, into rivers and lakes, affecting water quality. The fact that two-thirds of Canada's population, and their water needs, are concentrated in a relatively small, urban area (less than 1% of Canada's land), means that water quality impacts are concentrated.[145] Pollutants discharged to the air and onto land also find their way indirectly into water bodies. Runoff of fertilizers, herbicides and pesticides from agricultural lands and household pollutants (e.g., antibiotics and personal care products) from urban areas results in high concentrations of nitrogen and phosphorous which can degrade water quality and affect species, including humans.[146] In addition, natural phenomena like the spring snow melt and heavy rainfall can result in significant and often temporary declines in water quality due to increased amounts of suspended sediments, which are often high in nutrients and metals. The magnitude or frequency of these natural events may be exacerbated by climate change.[147]

Like air quality, water quality conditions vary considerably through space and time. Of particular note, from 2005 to 2007, water quality was poorer in the St. Lawrence (where 37.5%, or 9 out of 24 stations, were rated as poor or marginal) compared to other select basins. Conversely, the Ottawa river basin (67%, or 8 out of 12 stations) along with the Saint John–St.Croix river basin (80%, or 8 out of 10 stations), were generally of better quality (reporting either good or excellent water quality).[148] Furthermore, a number of the sites where poorer water quality was found were associated with agricultural and/or urban areas, while remote monitoring stations generally had much higher quality water (Figure 11). While not entirely unexpected, this highlights concerns for water quality in the southern portions of Canada where lie not only our agricultural regions, but also our large population centres. That is not to say that rural areas are free from water quality concerns — issues in recent years with First Nations communities in Canada[149] have indicated that poor water quality can occur nearly anywhere — but rather that spatial variation in water quality is a significant issue that requires data from local conditions to be fully understood.

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[144] Environment Canada (2007) *Canadian Environmental Sustainability Indicators 2007*, 4.

[145] Statistics Canada (2006) 2006 Census. Government of Canada.

[146] Richter, B.D., Braun, D.P., Mendelson, M.A., and Master, L.L. (2003) Threats to imperiled freshwater fauna, *Conservation Biology*, 11(5): 1081-1093.

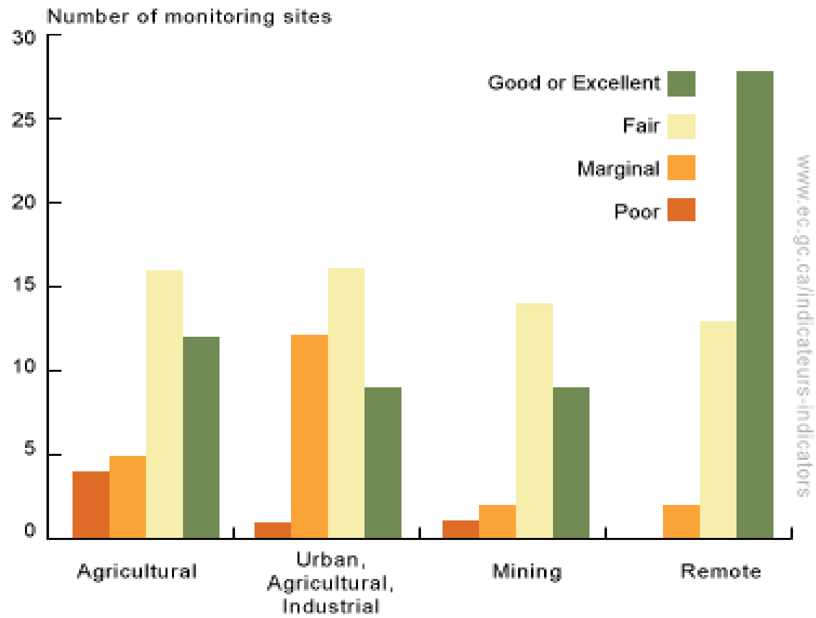
[147] Arnell, N.W. (1999) Climate change and global water resources, *Global Environmental Change*, 9(1): S31-49.

[148] CESI (2010) Water QualityData Tables. Available online at: http://www.ec.gc.ca/indicateurs-indicators/default.asp?lang=en&n=ADFCFBAB-1#wq1_en Last accessed: October 11, 2010.

[149] See: http://www.canadians.org/water/issues/First_Nations/index.html for more details.

Figure 11. Water Quality Index ratings by land use category

Canada 2005-2007[150]



Water of sufficient quality and quantity is fundamental to human health and the proper functioning of ecosystems. The accumulated impacts of increasing industrial development and human settlement that result in increasing demands for water and more pollutant loading on rivers, streams, lakes and groundwater aquifers can lead to the degradation of water quality that affects both aquatic life and the quality of water for human use. Degradation of water quality can also affect economic activities such as tourism and agriculture, or recreational use of water such as swimming and fishing.

[150] Environment Canada (2010) CESI – Water Quality – Pollution Sources and Impacts. Available online at: http://www.ec.gc.ca/indicateurs-indicators/default.asp?lang=En&n=88872F95-1 Last accessed: October 8, 2010.

FRESHWATER: Water Supply (Water Yield for Southern Canada)

Issue: What is the issue and why is it important to wellbeing?

With large lakes, extensive wetlands, numerous glaciers and mighty rivers, at first glance, Canada appears to have lots of freshwater. However, when it comes to freshwater, it is not a matter of quantity alone, but quantity in conjunction with space and time. Since water is not always available when and where it is needed, nor is nature always factored into the environmental flow requirements, the stock of water is critical to the wellbeing of Canadians. Water is essential not only for life and basic health (sanitation and drinking water), but indeed essential to all aspects of wellbeing. Food, transportation, energy, clothing, recreation, and biotic resources are all intimately dependent upon water supplies.

Direct linkages to other domains: **Leisure and Culture** (a lack of water can significantly affect numerous recreational pursuits, as well as impact cultural landscape features), **Community Vitality** (water use restrictions can affect public spaces, such as community pools, thereby affecting community vitality), **Democratic Engagement** (the threat of losing access to water supplies can be a major driver of civic protest and political engagement), **Healthy Populations** (water is essential for life and therefore its availability is central to health), **Living Standards** (a lack of water can have significant economic impacts on things such as crops, energy, or industrial processing), **Environment** (nature, like humanity, depends upon water for life and thus everything from trees to fish need an available water supply).

Considerations and trade-offs: When water supply is greater than the demands of both humans and other species, the considerations are much simpler. However, given that water supply is highly variable, when water is less abundant, there is a need to prioritize where we allocate our water. While inter-basin transfers have been performed in a number of areas in Canada to bolster supply, this can lead to numerous ecological and political implications, especially when these transfers are across borders (provincial, territorial, or international). Taking water for certain economic activities, such as large scale hydroelectric power production, can have considerable energy benefits, but also has major consequences for habitat conversion through flooding. The trade-offs that policy makers make between ecosystem services and traditional economic activity must consider the array of impacts on wellbeing, as well as how to prioritize through space and time.

Understanding the Indicator: What is this indicator, why was it selected and how do I interpret the results?

The water yield is based upon the results of a study[151] estimating Canada's annual average water renewal. This estimate (freshwater yield), which is coherent through space and time, was created by Statistics Canada to allow accounting and analysis of the monthly regional renewal of water resources in Canada. Water yield (or supply) is a critical measure of quantity and in particular, how much is available at times of the year (e.g., August) when supply is low (while demand is high). While it is recognized that too much water can indeed be problematic, too

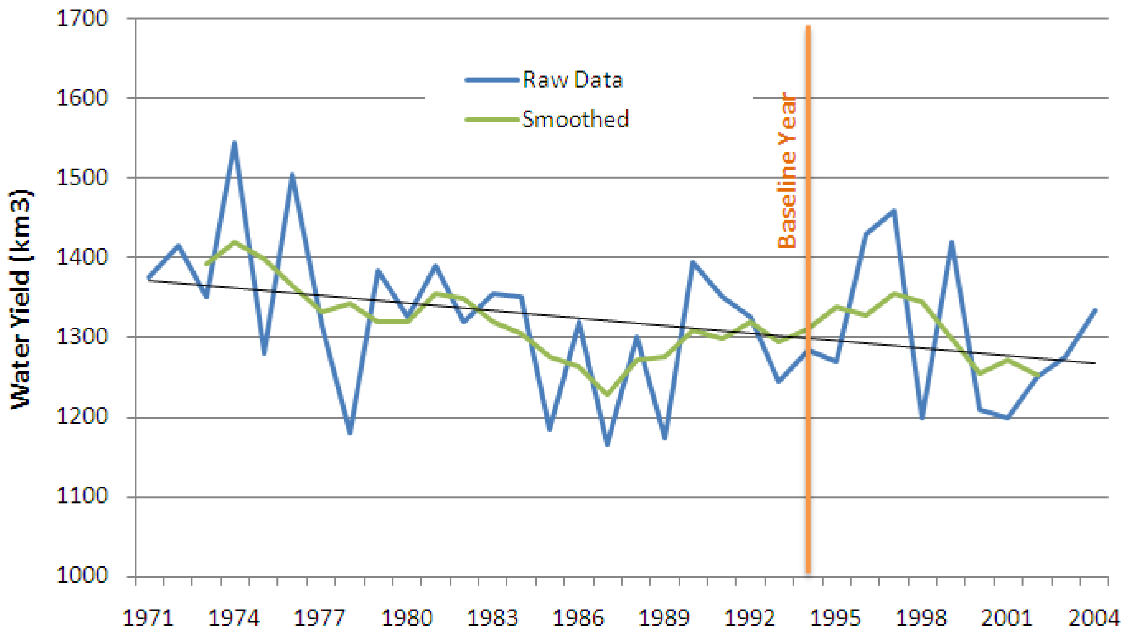
[151] R. Bemrose , L. Kemp, M. Henry, and F. Soulard, (2009) The Water Yield for Canada as a Thirty-year Average (1971 to 2000): Concepts, Methodology and Initial Results, *Environment Accounts and Statistics Analytical and Technical Paper Series*, Statistics Canada Catalogue no. 16-001-MWE2009007.

little water is perhaps even more disconcerting. In other words, a systematic increase or decrease is cause for concern, but perhaps more so in the latter case.

Current Trends and Significance: What are the trends in the data and how are they significant to the environment and human wellbeing?

Figure 12. Indicator – Water Yield for Southern Canada[152]

Trends in Water Yield, Southern Canada 1971-2004[153]



Canada's average annual renewable freshwater supply (water yield) is 3,472 km^3, which is about as much water as is found in Lake Huron (3,540 km^3) [154]. Over the course of the past 30 years, the supply of water in Southern Canada has decreased some 8.5% (Figure 12), which represented an average loss of 3.5 km^3 per year, which is the equivalent of all of Canada's residential water use for a year (3.8 km^3)[155]. These trends are not consistent through space and time, however. As Figure 12 indicates, there is considerable variability year-to-year, and select

[152] Since raw data were unavailable, the indicator was adapted from information found in: Statistics Canada (2010) Freshwater Supply and Demand in Canada. Available online at: http://www.statcan.gc.ca/daily-quotidien/100913/dq100913b-eng.htm Last accessed: March 11, 2011. Smoothed data uses a 5-year moving average. "Southern Canada" is delineated by the North-line which separates Canada into two regions based on 16 social, biotic, economic and climatic variables; and includes all major cities below 54°N which captures the vast majority of the Canadian population. See: McNiven C., and H. Puderer, 2000, "Delineation of Canada's North: An Examination of the North-South Relationship in Canada", Geography working Paper Series, Statistics Canada Catalogue no. 92F0138M2000003. Statistics Canada, Environment Accounts and Statistics Division and Business Survey Methodology Division, 2010, special tabulation.

[153] Statistics Canada (2010). Publications. Human Activity and the Environment. Section 2. Canada's water supply – stocks and flows. Chart 2.2 Trends in water yield for Southern Canada, 1971 to 2004. Available online: http://www.statcan.gc.ca/pub/16-201-x/2010000/ct005-eng.htm Accessed: March 6, 2011.

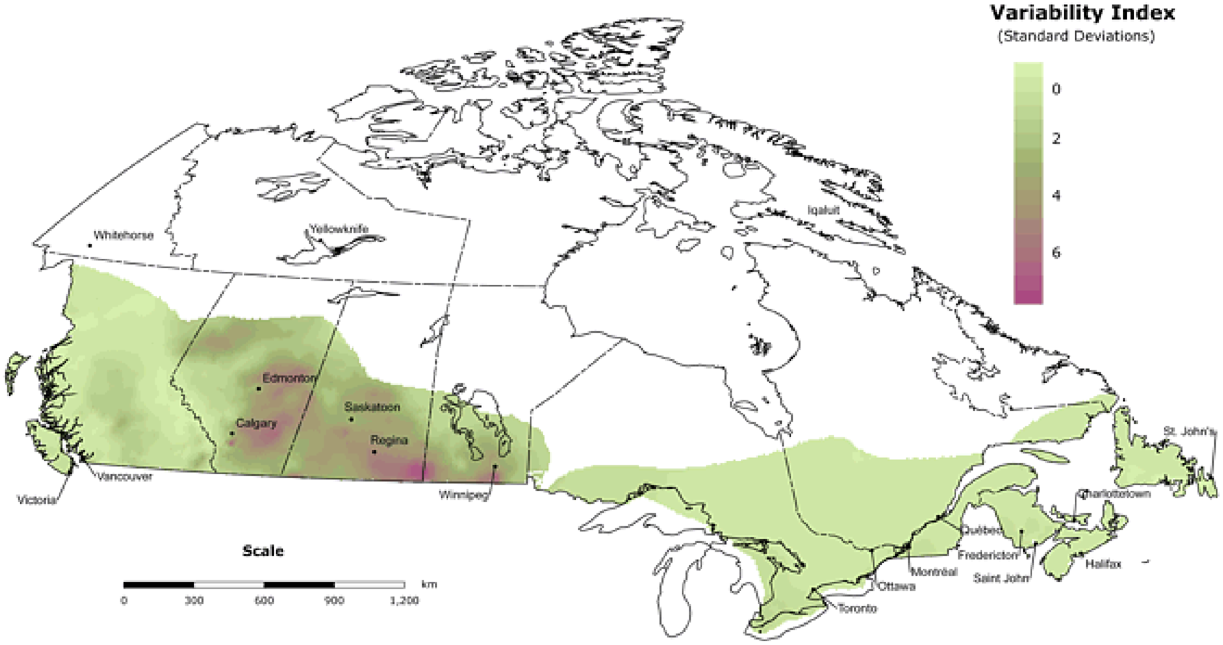
[154] Statistics Canada (2010) Human Activity and the Environment – Freshwater Supply and Demand in Canada. Available online at: http://www.statcan.gc.ca/pub/16-201-x/16-201-x2010000-eng.pdf Last accessed: October 15, 2010.

[155] *Ibid.*

regions have greater variability (Figure 13), notably throughout the prairies where supply can go from extreme scarcity (drought) to extreme abundance (flooding), both of which have impacts on human wellbeing.

Figure 13. Water Supply Variability in Canada

Water Asset (Yield) Variability throughout Canada, 1971-2004[156]



Water is a form of natural capital that is extremely valuable, and Canada is fortunate to have so much given the global shortages that affect billions of people[157]. This is not to say that water supply is not a concern in Canada; water is not equally distributed and region to region and year to year, certain communities already face water shortages. Climate change predictions suggest increasing variability in terms of both temperature and precipitation, and it is likely that certain parts of the country will increasingly face challenges associated with water supply[158]. Yet such challenges, and the tradeoffs that policy makers and Canadians must contemplate, will not only be a function of supply, but also of use and demand, which are considered next.

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[156] Since raw data were unavailable, the indicator was adapted from information found in: Statistics Canada (2010) Human Activity and the Environment – Freshwater Supply and Demand in Canada. Available online at: http://www.statcan.gc.ca/pub/16-201-x/16-201-x2010000-eng.pdf Last accessed: October 15, 2010. Smoothed data uses a 5-year moving average. "Southern Canada" in delineated by the North-line which separates Canada into two regions based on 16 social, biotic, economic and climatic variables; and includes all major cities below 54°N which captures the vast majority of the Canadian population. See: McNiven C., and H. Puderer, 2000, "Delineation of Canada's North: An Examination of the North-South Relationship in Canada", Geography working Paper Series, Statistics Canada Catalogue no. 92F0138M2000003. Statistics Canada, Environment Accounts and Statistics Division and Business Survey Methodology Division, 2010, special tabulation.

[157] The Millennium Development Goals indicate that billions still lack access to basic sanitation. See: United Nations (2010) Millennium Development Goals Report - Target 7.C. Available online at: http://www.un.org/millenniumgoals/environ.shtml Last accessed: October 15, 2010.

[158] E.g., see the final report to the Canadian Parliament, Standing Senate Committee on Agriculture and Forestry (2003) Climate Change: We are at risk. Available online: http://www.parl.gc.ca/37/2/parlbus/commbus/senate/Com-e/agri-e/rep-e/repfinnov03-e.htm Accessed: March 5, 2010.

FRESHWATER: Water Use (Residential Water Use Rate)

Issue: What is the issue and why is it important to wellbeing?

The available supply of freshwater is critically important to the wellbeing of Canadians, but given the finite nature of water, so too is demand. Canadians are among the highest water users in the world, using roughly twice as much per person as in other industrialized countries, with the exception of the United States.[159] According to recent work completed by the Water Footprint Network, Canada ranks 12th in the world when total water use is combined (2,049 m^3/person/year, or 5,619 litres/person/day).[160]

A sustainable supply of clean drinking water is vital for everyday human life in cities. Water is also used to clean our streets, fight house fires, wash clothes, fill public swimming pools, flush toilets and water gardens. Moreover, water is also critical for agricultural production and industrial use, and for extracting oil from Alberta's oil sands. Although water cannot easily be destroyed, it can easily be shifted and re-located — a natural process that happens via the water cycle, and one that humans can affect through water use. When there is insufficient (or too much) water at a local level, it can have significant ramifications upon health (disease, drowning), property (flooding), and the economy (agricultural droughts, their effects on food supplies and the associated insurance).

Direct linkages to other domains: See Water Supply.

Considerations and trade-offs: Water use is very much a function of water availability in a given watershed. Integrated watershed resource management helps to balance various wellbeing needs and ensure that there is enough water for both humans and nature. Without such approaches, shortages occur which in turn leads to conflict and a general loss of wellbeing in various ways.

Understanding the Indicator: What is this indicator, why was it selected and how do I interpret the results?

While tracking household water use by municipalities is perhaps meaningful to everyday Canadians, it is arguably more important to track changes in agricultural and industrial water use, the latter of which represents the vast majority of water use in Canada (Figure 14).[161] In fact, arguably a more comprehensive indicator would be a water footprint which measures the water used both domestically and abroad by accounting for water that is contained in products, or consumed in their production. However, since such data are unavailable in a time series that

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[159] Environment Canada (2009) Average daily domestic water use. Available online at: http://www.ec.gc.ca/eau-water/1806BB6C-90A6-471A-AC27-AFA2F0F3C605/daily-domestic-use.gif Last accessed: October 12, 2010.

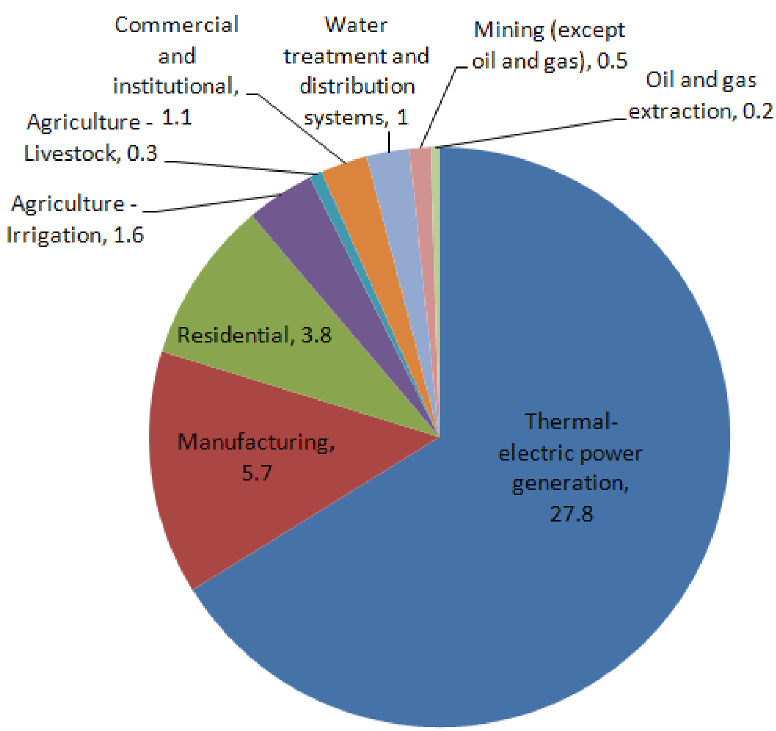
[160] The water footprint of a nation is defined as the total amount of water that is used to produce the goods and services consumed by the inhabitants of the nation. Since not all goods consumed in one particular country are produced in that country, the water footprint consists of two components: water use inside the country and water use outside the country that is imported via goods. For more information see: Chapagain, A.K. and Hoekstra, A.Y. (2004) *Water Footprint of Nations: Volume 1*. UNESCO-IHE: Institute for Water Education, Research Report Series No. 16. Available online at: http://www.waterfootprint.org/Reports/Report16Vol1.pdf Last accessed: April 23, 2010.

[161] Statistics Canada (2005) Industrial Water Use Survey. Available online at: http://www.statcan.gc.ca/pub/16-401-x/2008001/5003964-eng.htm Last accessed: March 14, 2010.

meets the data requirements for this report and neither are industrial water use rates available in a time series, residential water use is employed instead. Accordingly, this was the indicator selected, and will be used until such time as improved data are available.

Figure 14. Indicator – Breakdown of Water Use In Canada

Water Use, Canada 2005 (in km^3) [162]



The Residential Water Use indicator is a measure of average total water used per person per day in litres within the household. Water use data comes from Environment Canada, Municipal Water Use, 2004 Statistics.[163]

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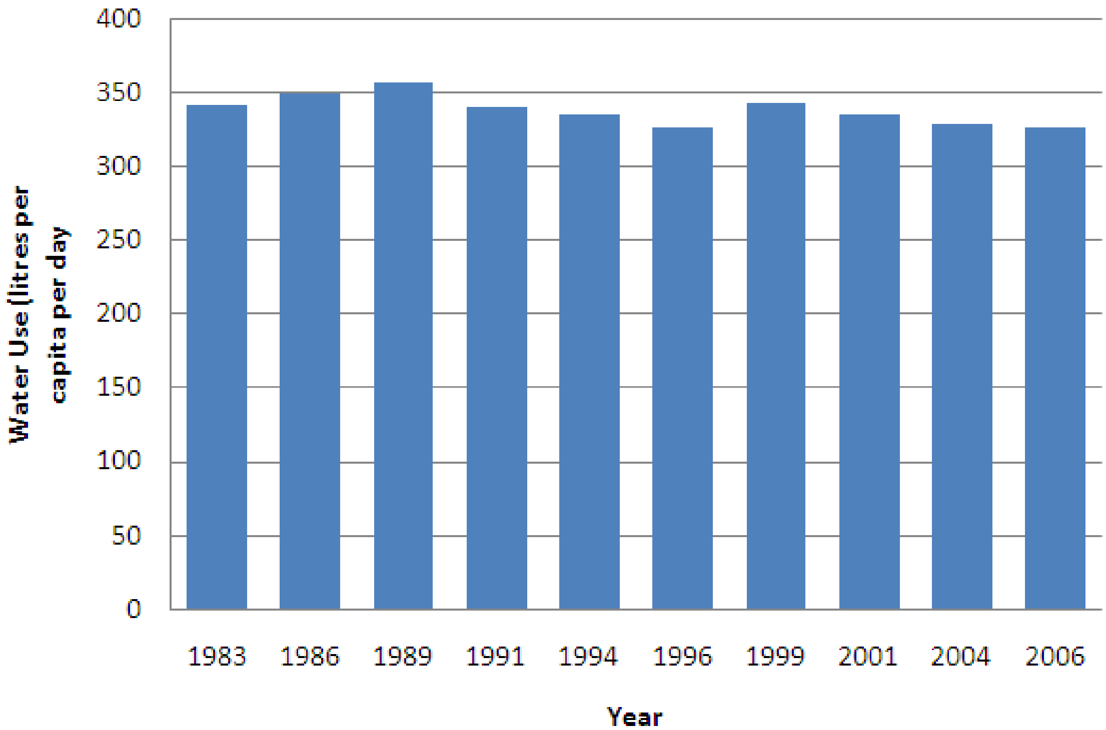
[162] Statistics Canada (2010) Water use in Canada, by Sector, 2005. Available online at: http://www.statcan.gc.ca/daily-quotidien/100913/t100913b1-eng.htm Last accessed: October 15, 2010.

[163] Environment Canada (2010) Municipal Water and Wastewater Survey. Available online at: http://www.ec.gc.ca/eau-water/default.asp?lang=En&n=ED0E12D7-1Last accessed: October 12, 2010.

Current Trends and Significance: What are the trends in the data and how are they significant to the environment and human wellbeing?

Figure 15. Indicator – Residential Water Use Rate[164]

Daily Per Capita Use, Canada 1983-2006[165]



Average daily per capita residential water use has varied over the years around 330 litres per day (Figure 15). While there has been an 8.4% decline since1989 (357 to 327 litres per day), this does not represent a significant decrease given the variability in the trend. The latest use levels equal the lowest per capita water use (1996). Despite this positive signal, Canadians remain large water users in the global context, and more importantly, in many watersheds that are stressed. Canadians use more than twice as much water per day as the average global citizen who uses 156 litres of water per day. Even industrialized nations tend to consume less than Canadians with the average British citizen using a mere 106 litres of water per day.[166] There is also a great deal of regional variability within the nation (Table 7); residents of Saint

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[164] Note: reviewers expressed some concerns about these data. EC has changed its methodology considerably over the years. The jump from 1996 to 1999 is suspected of being a methodological artifact. Furthermore, the 2009 National Water and Wastewater Benchmarking Initiative studied residential water use in large Canadian cities where water is metered and found that the residential figure is closer to 243 litres per capita per day. This suggests that there may be some overestimation in the data presented here.

[165] . Environment Canada. Publications. (2010) 2010 Municipal Water Use Report. Municipal Water Use, 2006 Statistics. Pp.32. Available online: http://www.ec.gc.ca/Publications/default.asp?lang=En&xml=596A7EDF-471D-444C-BCEC-2CB9E730FFF9 Accessed: March 6, 2011.

[166] Hoeskstra, A.Y. and Chapagain, A.K. (2007) Water footprints of nations: Water use by people as a function of their consumption pattern. *Water Resource Management*, 21:35-48.

John, New Brunswick used more than five times the average amount, or over 200,000 litres per year. While Saint John may not be a water-stressed area, the prairies, the interior of British Columbia, and several other areas experience drought conditions, suggesting that residents in cities like Saskatoon (510 L/day) ought to reconsider their water use.

Figure 16 provides some perspective on the emerging challenge between water supply (the previous indicator) and demand or water use. We can see that during August (the month when water supply is lowest and demand is highest), supplies and demands have become increasingly an issue for watersheds in southern Canada. This is an emerging trend which is likely to only be further exacerbated under climate change. Given the importance of water to a variety of aspects of wellbeing – from health to recreation to the economy – lowering water demand should be a priority to the public and policy makers alike.

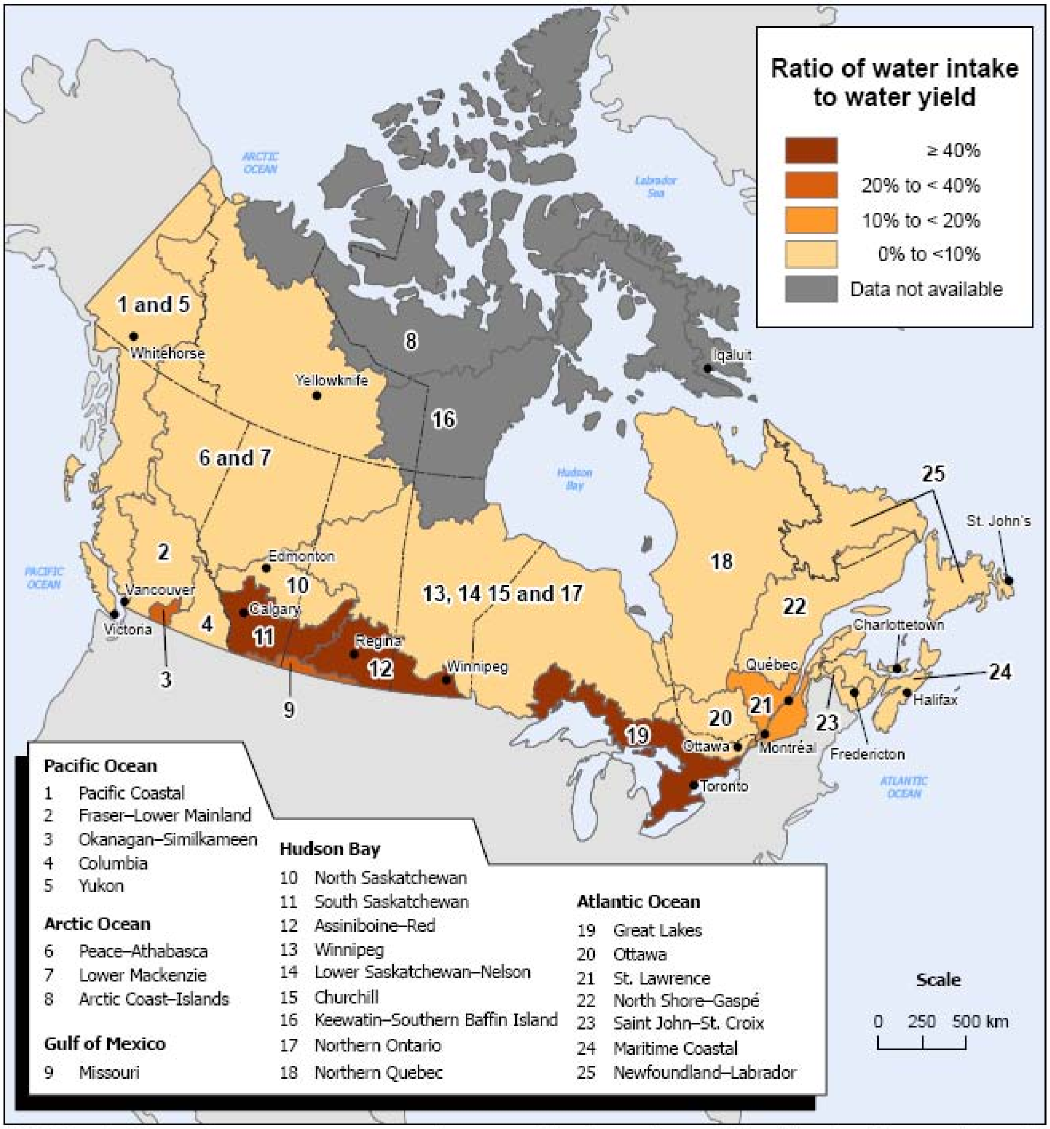
Table 7. Municipal Residential Water Use

By major municipality in Canada. Ranked lowest to highest.

Municipality	Water use (litres/day/capita)	Municipality	Water use (litres/day/capita)
St. John's, NF	157	Fredericton	298
Regina	162	Québec	300
Charlottetown	164	Vancouver	358
Winnipeg	187	Moncton	372
Toronto	219	Victoria	405
Edmonton	227	Montreal	503
Ottawa	235	Saskatoon	510
Calgary	257	Saint John, NB	564
Halifax	296		

Figure 16. Ratio of Water Intake to Water Yield

Average Ratio for August[167]



[167] Note(s): The following drainage regions were aggregated to protect confidentiality Pacific Coastal (1) with the Yukon (5) Peace-Athabasca (6) with the Lower Mackenzie (7) and the Winnipeg (13), Lower Saskatchewan-Nelson (14), Churchill (15) and Northern Ontario (17). Data that contributed to intake volumes (demand) were compiled from Statistics Canada: Industrial Water Survey, 2005 Households and the Environment Survey, 2006 Survey of Drinking Water Plants, 2005 to 2007 and Agricultural Water Use Survey 2007. Data from Agriculture and Agri-Food Canada and Canada Mortgage and Housing Corporation were used to help allocate and derive some intake volumes. Water yield volumes (supply) used for each drainage region are a 34-year median (1971 to 2004) for the month of August. Source(s): Canada Mortgage and Housing Corporation, 2007, Household Guide to Water Efficiency, Product number 61924. Statistics Canada, Environment Accounts and Statistics Division, 2010, special tabulation.

NON-RENEWABLE RESOURCES: Viable Non-Renewable Energy Reserves Index

Issue: What is the issue and why is it important to wellbeing?

Energy stems from various sources in Canada, but one important form for both the economy, and powering our electricity grid, are non-renewable energy reserves. As noted earlier under the Primary Energy Production indicator, energy is a key sector of the economy, and a significant portion of this is made up through non-renewable energy. Non-renewable energy resources are made up of hydrocarbons that are portable, and can be converted into energy as well as other materials (e.g., plastics). Furthermore, although the percentage of power that comes from non-renewables varies from province to province,[168] without these non-renewable energy supplies, there would be significant implications for our energy grid and our economy, as several provinces rely heavily upon non-renewable resources for their power and economic output (e.g., Alberta and the Atlantic provinces).

Non-renewable energy reserves represent an interesting policy debate for Canadians: when energy is available from both renewable (typically more costly, but with arguably fewer environmental and social impacts) and non-renewable forms (typically cheaper, but with greater environmental and social impacts),[169] how should non-renewable energy reserves be used?

Direct linkages to other domains: **Healthy Populations** (both energy and derived products are essential components to modern medical operations, from sterilized plastics to MRIs, but conversely, sour gas from wells, or mercury bioaccumulation or particulate matter from the combustion of non-renewables, can have negative human health impacts), **Living Standards** (plastics and combusted non-renewable resources underpin much of how we move about, heat and build our homes, and operate our industrial machinery), **Time Use** (energy has the ability to save time by performing work, thereby freeing up our time for other pursuits), **Democratic Engagement** (extractive industries have both provided revenues to assist governments function, and conversely, at times, eroded local governance capacity[170]) **Leisure and Culture** (non-renewable energy resources can power leisure activities as well as make materials such as plastics that are used in everything from kitchens to sports equipment), **Education** (hydrocarbon derived chemicals, energy and plastics all play roles in chemistry, physics, and the tools and equipment that drive science, and in today's computing age, even the arts), and to other aspects within the **Environment** domain (e.g., biotic resources impacts via habitat conversion from bitumen mining, climate change impacts from CO_2 emissions, or water quality impacts from NO_x/SO_x-driven acid rain).

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[168] Coal-fired electricity generation, as an example, ranges from over 50% in some provinces to 0% in others, with a Canadian average of roughly 13%. Source: National Energy Board (2008) Coal-Fired Power Generation - An Overview - Energy Brief. Available online at: http://www.neb-one.gc.ca/clf-nsi/rnrgynfmtn/nrgyrprt/lctrcty/clfrdpwrgnrtn2008/clfrdpwrgnrtnnrgybrf-eng.html Last accessed: October 8, 2010.

[169] Note: this simplification of the issue does not factor in the complicated array of subsidies applied to all forms of energy.

[170] World Bank (2004) World Bank Extractive Industries Review. Available online at: http://web.worldbank.org/WBSITE/EXTERNAL/TOPICS/EXTOGMC/0,,contentMDK:20306686~menuPK:592071~pagePK:148956~piPK:216618~theSitePK:336930,00.html Last accessed: October 11, 2010.

Considerations and trade-offs: Like the considerations on primary energy production, the debate as to how to use our non-renewable energy resources pits present day energy and economic benefits against future wellbeing. Balancing these decisions is critical for policy makers.

Understanding the Indicator: What is this indicator, why was it selected and how do I interpret the results?

The Viable Non-Renewable Energy Reserve Index is a measure derived from the Government of Canada's (Statistics Canada) national natural resource stock accounts. These are annual inventories of the amounts of the following substances: coal (bituminous, sub-bituminous, and lignite; in megatonnes), crude oil (millions of cubic metres), crude bitumen (thousands of cubic metres), natural gas liquids (ethane, butane, propane and pentanes; millions of cubic metres), and uranium (billions of kilotonnes of uranium metal[171]). These stocks account for the reserves as well as any annual depletions (extracted) or additions (discovery of new deposits) and accordingly, this indicator combines aspects of stock and flow. It should be noted that the reserve quantities are price related. That is to say, the available quantities are the amounts available given a certain market price (which makes extraction economically viable). As prices change, so too do the quantities available until such time as either financial requirements dictate that they are unrecoverable, or the reserves are completely exhausted.

To prepare the use of this index in the CIW environment domain, each of these substances was converted into an indexed value using the 1994 values (in accordance with the CIW baseline year). These five indexed substances were then averaged to form one single value for energy reserves with equal weighting to account for energetic equivalence. By not converting to a single energy unit, each given energy type can be evaluated without being overwhelmed by the values of the others .

This indicator was selected because it is one of the only environmental data sets in Canada that has robust stock and flow accounting. Members of the CIW Management Team wanted to not only take advantage of this robust data set from Statistics Canada, but also lend support to this sort of approach to natural capital accounting.

For the index itself, values greater than 1.00 mean that the reserves have been increased since 1994 (whether via new discovery, or economic viability due to price changes), while values less than 1.00 mean a declining reserve stock (for the same reasons noted above).

Current Trends and Significance: What are the trends in the data and how are they significant to the environment and human wellbeing?

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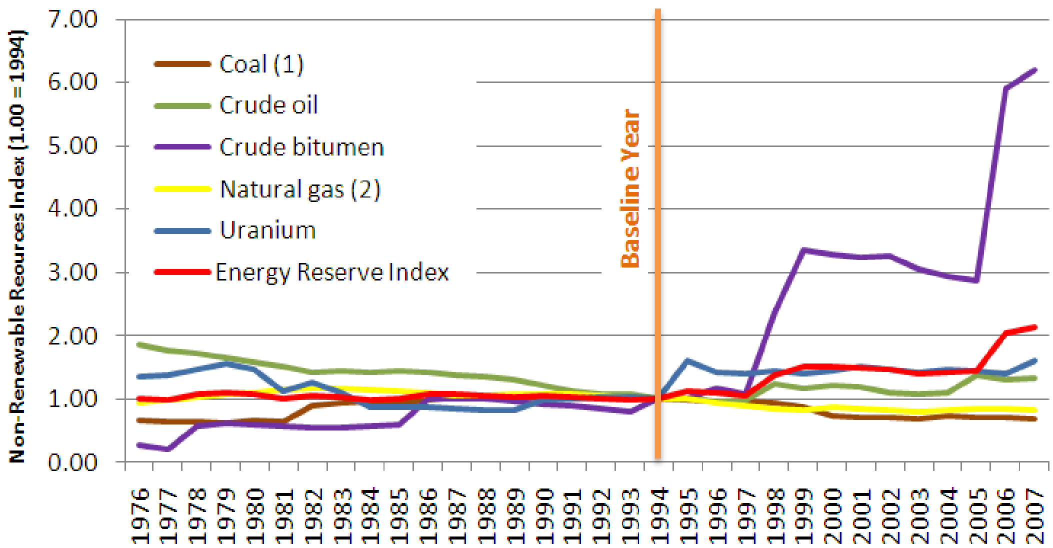
[171] See NRCan (2010) Canadian Minerals Yearbook (CMY) 2008 – Uranium. Available online at: http://www.nrcan.gc.ca/smm-mms/busi-indu/cmy-amc/2008revu/htm-com/ura-ura-eng.htm Last accessed: October 11, 2010. Note, of this roughly 0.7% would be U-235, which is used for enrichment and ultimately fuel for nuclear reactors. Given that the levels are relatively consistent, and the available data, general uranium metal amounts were used.

Figure 17. Indicator – Viable Non-Renewable Energy Reserve Index

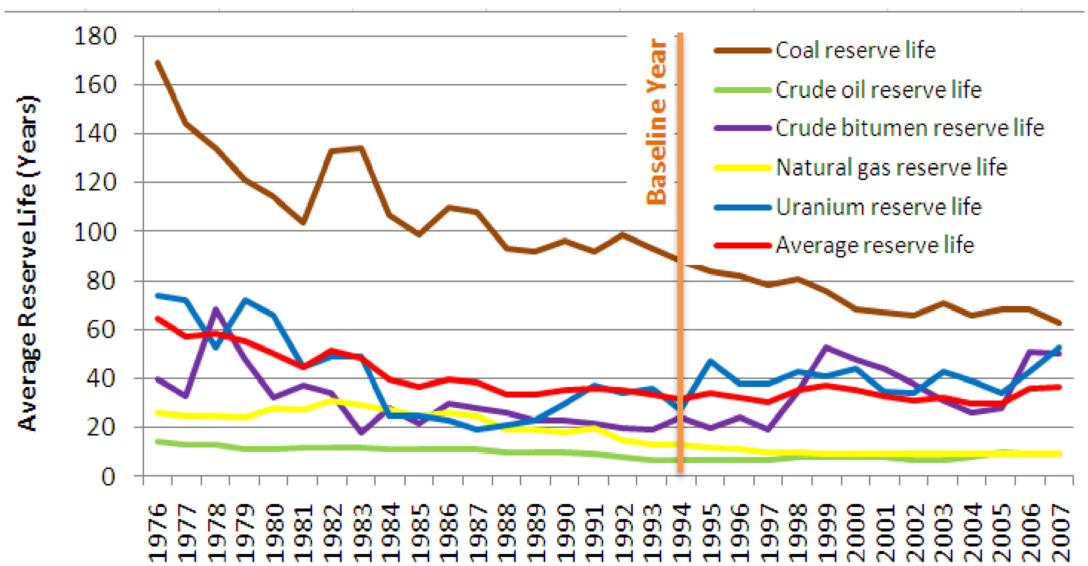
Canada 1976-2007 (1994 baseline)[172]



(1) Coal includes bituminous, sub-bituminous and lignite coal; (2) Natural gas includes ethane, butane, propane and pentanes.

Figure 18. Estimated Average Reserve Life for Viable Non-Renewable Energy Reserves

Reserve Life for Select Commodities in Canada, 1976-2007[173]



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[172] Statistics Canada (2009) Human Activity and the Environment. Annual Statisitics. Table 3.39 Established energy resource reserves. Available online: http://www.statcan.gc.ca/pub/16-201-x/2009000/t182-eng.htm Accessed: March 6, 2011.

[173] *Ibid.*

Overall, given that non-renewable energy reserves are, by definition, limited, the trend in Figure 17 is somewhat positive. While some resources are declining, others such as crude bitumen, oil and uranium have shown growth through continual discoveries of new viable deposits.

It is likely that some of this increase in reserve life has been driven in recent years by the increased price of oil (which rose from below $20/barrel in 1999 to over $130 in 2008, before coming back down again to around $100 at present). This increase in price has made further oil sands development economically feasible and therefore driven up the lifespans of the various commodities (as seen Figure 18). Even without including crude bitumen in the index, overall the reserve levels remain relatively stable.

However, if the concept of reserve life is also used (in other words, how many years is left before the reserve is exhausted given the supply and demand at the time), it paints a slightly less optimistic picture (Figure 18). Reserve life can be seen to be in general decline since 1976, and while again it has stabilized (or even increased) for some resources (such as uranium and bitumen), it is exhibiting steady declines in other areas (such as coal or natural gas). Over the course of 30 years we have exported 70 years worth of coal reserve lifespan. Similarly, natural gas reserves have been in fairly steady decline, which is of concern given the extent to which this "clean" fossil fuel makes up a significant portion of our energy mix.[174]

Energy resources are not only foundational to the size of our economy (and even the value of our dollar), they also provide numerous benefits to Canadians, as the energy that powers our machines — from copiers to cars — largely comes from non-renewable energy resources. Furthermore, as emerging economies such as China, India, and Brazil continue to grow and demand more goods and greater services, these energy reserves will be increasingly valuable.

However, extraction and use of these non-renewable energy reserves comes at a significant cost to other aspects of wellbeing. Environmental degradation (e.g., CO_2, air pollution, water quantity and quality impacts, land conversion), and democratic governance concerns, human health impacts, corruption issues and other concerns[175] have followed extractive industries. As extraction has increased, so too have the impacts on other aspects of wellbeing.

Given the combination of these being finite reserves, and the impacts that using such reserves currently has, a key question facing policy makers is whether to draw down the stock of this finite natural capital asset to convert into energy, to use it for conversion into non-energy uses (such as chemicals and other refinery products), or to preserve it. Put another way, do we, as Canadians, choose to cash in on these resources today (along with the negative externalities that come with burning hydrocarbons), save them for trade in the future, or keep them in the ground? While such a decision would have implications on our international responsibilities if we chose to conserve our own energy resources and sourced power from other nations, it is an important discussion. Regardless of the answer, when we consider our Non-Renewable Energy Reserves, along with the Primary Energy Production data covered earlier, it highlights the large reliance Canada currently has on non-renewable energy reserves to meet our energy needs. How we spend down this natural capital is a key public policy debate of our time.

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[174] See ENERGY – Primary Energy Production.

[175] World Bank (2004) World Bank Extractive Industries Review. Available online at: http://web.worldbank.org/WBSITE/EXTERNAL/TOPICS/EXTOGMC/0,,contentMDK:20306686~menuPK:592071~pagePK:148956~piPK:216618~theSitePK:336930,00.html Accessed: October 11, 2010.

NON-RENEWABLE RESOURCES: Viable Metal Reserves Index

Issue: What is the issue and why is it important to wellbeing?

The Earth provides numerous substances that are critical to modern living. From energy minerals such as coal and uranium to precious metals such as gold and silver, the resources that come from the Earth's surface are very important inputs into the economy and contribute to our current standard of living. Roughly 2% of the Canadian economy (GDP) derives from the mining sector.[176] Metals are the foundation of technology: computers, electrical wiring, batteries, cars, and even our buildings and schools are all forged from metals. Like energy reserves, metal reserves contribute to many of the goods and services that underpin the quality of life of Canadians.

Direct linkages to other domains: **Leisure and Culture** (metals, like energy, play a key role in many recreational pursuits as well as the arts; their extraction has the potential to convert or degrade areas that are used for leisurely or cultural pursuits), **Education** (metals are not only an essential component in technology that enables education, but are heavily used in the construction of educational facilities), **Healthy Populations** (metals go into various medical devices, but extraction can also release pollutants that are toxic to human health), **Democratic Engagement** (several instances have occurred in which extractive industries have impaired or eroded the ability of Aboriginal peoples to self-govern; however, mining also provides funds for numerous government activities), **Living Standards** (metals are used extensively in daily life and go into a huge array of products from cars to pens; metals also are important for jobs via the mining and manufacturing sectors), **Time Use** (metals go into various machines that help us save time), and **Environment** (extraction often results in habitat conversion and/or degradation, which in turn has biotic resources impacts).

Considerations and trade-offs: Metal reserves provide Canadians with economic benefits, including jobs and revenues, as well as needed materials for manufacturing and industry. However, the extraction of such resources can come at the cost of other areas of wellbeing — from the loss of cultural landscapes to the conversion and degradation of critical habitat. Governments must balance these trade offs for the greater wellbeing of Canadians.

Understanding the Indicator: What is this indicator, why was it selected and how do I interpret the results?

The Viable Metals Reserve Index is a measure derived from the Government of Canada's (Statistics Canada) national natural resource stock accounts. While Canadian mines are largely polymetallic, these are annual inventories of the amounts (thousands of tonnes) of the following substances: copper, nickel, lead, zinc, gold, molybdenum and silver. These stocks account for the reserves as well as any annual depletions (extracted) or additions (discovery of new deposits). It also takes into account reserves that have become economically viable (or non-

[176] Statistics Canada (2010) Table 379-0027 - Gross domestic product (GDP) at basic prices, by North American Industry Classification System (NAICS), monthly (dollars) (table), CANSIM (database), http://cansim2.statcan.gc.ca/cgi-win/cnsmcgi.exe?Lang=E&CNSM-Fi=CII/CII_1-eng.htm, Accessed: March 15, 2010.

viable)[177].To prepare the Metal Reserve Index, each of these substances was converted into an indexed value using the 1994 values (in accordance with the CIW baseline year). These six indexed substances were then averaged to form one single value for metal reserves with equal weighting.

This indicator was selected because it is one of the only environmental data sets in Canada that has robust stock and flow accounting. Members of the CIW Management Team wanted to not only take advantage of this solid data set from Statistics Canada, but also to lend support to this sort of an approach to natural capital accounting.

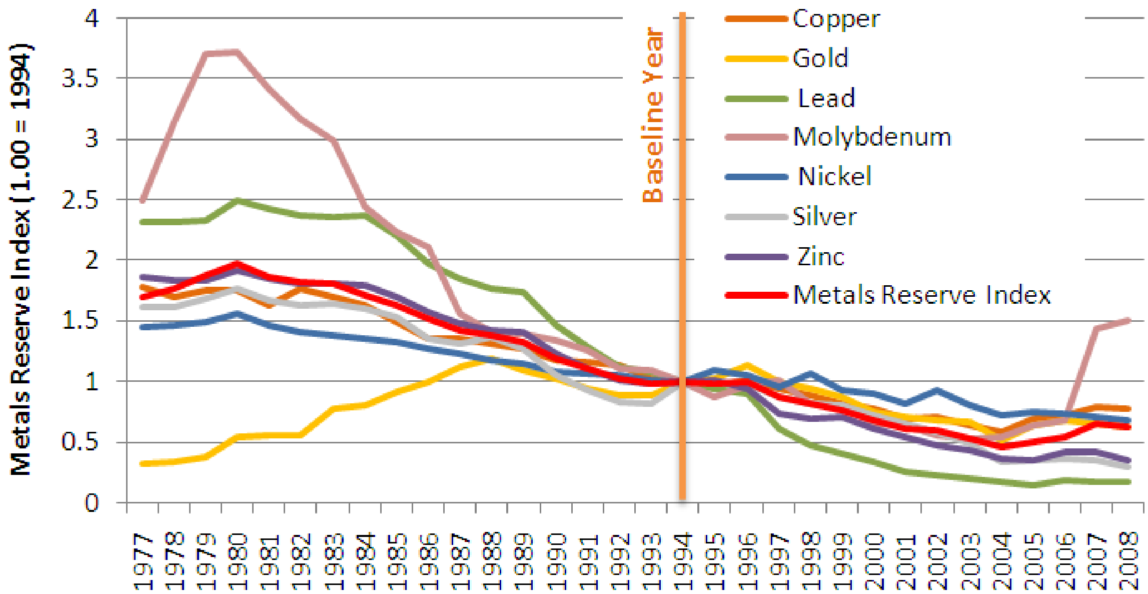
When interpreting the data, values of greater than 1.00 mean that the reserves have been increased since 1994, likely due to the discovery of new deposits, while values of less than 1.00 mean a declining reserve stock.

[177] The specific explanation provided by NRCan is as follows: "The annual aggregate change in Canadian reserves is the net result of three main factors affecting individual mines, additions to reserves, deletions to reserves, and production. Additions to reserves are the result of new discoveries; new geological, metallurgical, production or other information; a decrease in production costs; or a rise in commodity prices, all of which increase the quantity of mineral resources that is profitable to mine. Deletions to reserves are the result of new geological, metallurgical, production or other information; increases in costs; or decreases in commodity prices, all of which reduce the quantity of mine reserves that are now expected to be mined at a profit."
Natural Resources Canada. Business and Market Information. Canadian Mineral Exploration. Overview of Trends in Canadian Mineral Exploration. Canadian Reserves of Selected Major Metals and Recent Production Decisions. Page 6 Canadian Reserves of Selected Major Metals as at December 31 of Each Year, 1977-2008. Available online at: http://www.nrcan.gc.ca/mms-smm/busi-indu/cme-ome/2009/cha-03-eng.htm Accessed: March 6, 2011.

Current Trends and Significance: What are the trends in the data and how are they significant to the environment and human wellbeing?

Figure 19. Indicator – Viable Metals Reserve Index

Canada 1976-2008 (1994 baseline)[178]



Unlike the Viable Non-Renewable Energy Reserve Index, the Metals Reserve Index is universally declining (Figures 19 and 20). While in the last few years the rate of decline has slowed and for now appears stable, reserves are at or near historic lows for virtually all metals. This is despite rising prices, which, as for other extractive industries, determine which reserves are economically viable. Mining has been going on in Canada for many decades now and most of the large and easily accessible deposits have been depleted. In fact, many trends are emerging globally to suggest that metal and mineral reserves are in decline and that mining companies need to use ever greater amounts of water and energy to access those that remain.[179] For the time being, the declining reserves in Canada are balanced through international trade from developing countries. Canadian junior mining companies are global leaders when it comes to the discovery and development of metal resources. Like other metals, gold has declined relative to 1994 levels. However, unlike other metals, it has increased relative to earlier baselines, with a rise of 115% relative to 1980 reserves: declines started in 1988. Overall, most reserves are at less than half of the known ore reserves relative to 1980[180]. In absolute terms the apparent

[178] Natural Resources Canada. Business and Market Information. Canadian Mineral Exploration. Overview of Trends in Canadian Mineral Exploration. Canadian Reserves of Selected Major Metals and Recent Production Decisions. Table 3.6 Canadian Reserves of Selected Major Metals as at December 31 of Each Year, 1977-2008. Available online at: http://www.nrcan.gc.ca/mms-smm/busi-indu/cme-ome/2009/cha-03-eng.htm Accessed: March 6, 2011.

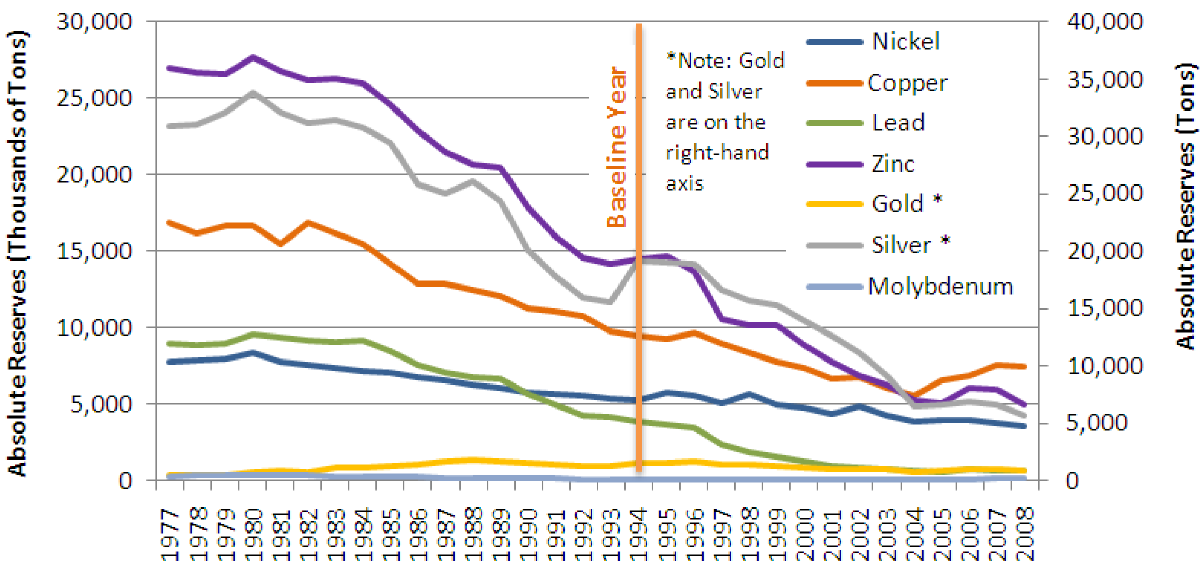
[179] Mudd, G M, 2007, Global Trends in Gold Mining: Towards Quantifying Environmental and Resource Sustainability? *Resources Policy*, 32 (1-2): 42-56.

[180] Natural Resources Canada. Business and Market Information. Canadian Mineral Exploration. Overview of Trends in Canadian Mineral Exploration. Canadian Reserves of Selected Major Metals and Recent Production Decisions. Table 3.6 Canadian Reserves of Selected Major Metals as at December 31 of Each Year, 1977-2008.

reserves relative to the end of 2008 were 12 years for nickel, 10 years for copper, 9 years for gold, 7 years for molybdenum, 6 years for zinc, 6 years for silver and 4 years for lead. Reserve estimates may be overestimated for a number of reasons[181].

Figure 20. Absolute Levels of Non-Renewable Metal Reserves

Canada 1977-2008 (1994 baseline)[182]



On the one hand, this trend signals unsustainable extraction in Canada that will impact jobs and communities. On the other hand, it means that extraction is likely to increasingly shift abroad thereby lowering the burden on Canada's environment. In other words, the trend is negative from an economic wellbeing perspective, but from a health and ecosystem perspective, it may be interpreted as positive. Ultimately the aim is not to stop using metals, but rather to use metals as many times as possible through downcycling (or even perpetual recycling if possible). Metals do not degrade through time per se, but rather just end up dispersed. Rather than mining, dispersing, and accumulating (the current trend of 'cradle-to-grave'), there is a need to circulate these "technical nutrients" in recycling loops, from "cradle-to-cradle".[183] Doing so not only protects us from dispersed substances such as lead that can be dangerous to our health, but also prevents the degradation of our forests, atmosphere and water bodies (associated with mineral extraction practices) both here and abroad.

Available online at: http://www.nrcan.gc.ca/mms-smm/busi-indu/cme-ome/2009/cha-03-eng.htm Accessed: March 6, 2011.

[181] According to the source noted in Footnote 165, ""Furthermore, life indices tend to overstate the apparent life of reserves when, for example, annual production is abnormally low due to strikes, cutbacks, or suspensions at large establishments, or when significant increases in capacity resulting from new production decisions will be coming on stream, but only several years hence."

[182] Natural Resources Canada. Business and Market Information. Canadian Mineral Exploration. Overview of Trends in Canadian Mineral Exploration. Canadian Reserves of Selected Major Metals and Recent Production Decisions. Table 3.6 Canadian Reserves of Selected Major Metals as at December 31 of Each Year, 1977-2008. Available online at: http://www.nrcan.gc.ca/mms-smm/busi-indu/cme-ome/2009/cha-03-eng.htm Accessed: March 6, 2011.

[183] See McDonough, W. and Braungart, M. (2002) *Cradle-to-Cradle: remaking the way we make things*, Northpoint press: New York.

NON-RENEWABLE RESOURCES: Waste (Per Capita Waste Disposal Rate)

Issue: What is the issue and why is it important to wellbeing?

Whereas renewable materials tend to break down into organic nutrients, non-renewable resources tend be transformed and accumulate. We tend to think of waste as either sewage (excreted human nutrients), recycling (select plastics, glass and metals with a market value) and garbage (everything else). However, when we look at how nature operates, waste equals food.[184] To put it another way, one organism's waste is another organism's lunch — or one man's garbage is another man's gold. Western society has become a throw-away society where take-out meals and disposable handkerchiefs are second nature. However, this high consumption rate comes at a cost: continued resource extraction from the landscape resulting in the loss of habitats and species; pollution; large, overflowing landfill sites that nobody wants in their backyards; and in general, a society where individuals must work longer hours to obtain more "stuff". While high levels of consumption are not necessarily a bad thing, it becomes detrimental when it is coupled with a one-way flow of materials to the landfill. To achieve more sustainable production and consumption patterns, we must continue to strive towards the 3Rs: reduce our consumption, re-use in order to throw less away, and recycle the rest. Once the materials loop has been closed, with fully established technical streams and organic nutrient streams,[185] we can achieve a society in which extraction is minimal while resource provision is kept at high levels.

Direct linkages to other domains: **Community Vitality** (landfills are divisive issues that affect communities), **Living Standards** (consumption and waste diversion both materially affect our standard of living; from disposable income to taxes), **Time Use** (in order to consume more, we must earn more income which requires more time; it also takes time to operate, store, and maintain the "stuff" we bought), **Environment** (habitat is converted into landfill, while incineration can have emissions problems if not properly managed).

Considerations and trade-offs: Most people can agree that waste should be reduced, but the challenge is figuring out how, given that nobody wants a landfill in their backyard, and there is often reluctance to incinerate waste to energy. Therefore, policy challenges revolve around providing "sticks" and "carrots" to encourage Canadians to minimize their waste. Our throw-away lifestyle will not only have impacts on our land-use and taxes, but our happiness as well.

Understanding the Indicator: What is this indicator, why was it selected and how do I interpret the results?

The per capita waste disposal and diversion rate is an indicator of the material throughput in society — how much stuff we're putting into landfill versus how much is being repurposed. It is a measure of both the amount flowing through the system, as well as progress towards a closed-loop, steady-state economy. It also indicates the extent to which we are engaging in throw away behaviour – the tendency to use non-renewable resources one time before dispersing them into landfills and other end points. In theory, waste should be separated out

[184] Benyus, J. (2002) *Biomimicry: Innovation inspired by nature*, Harper Perennial.

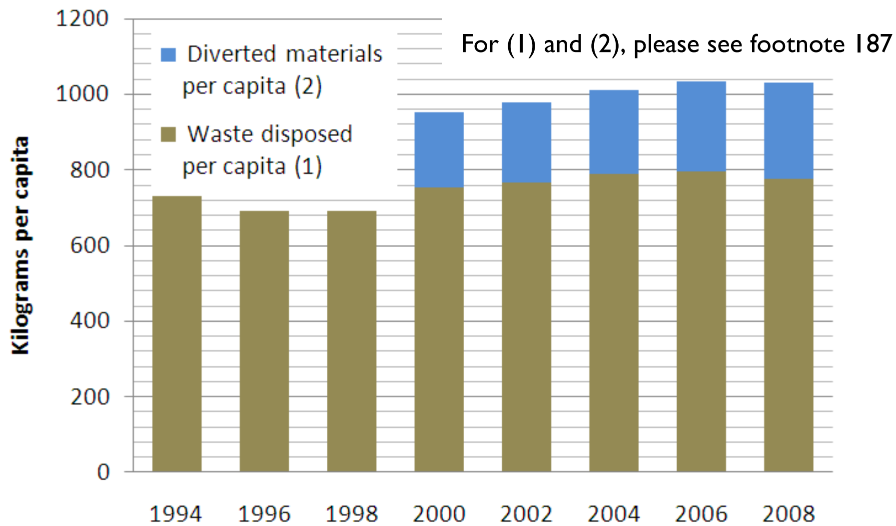
[185] McDonough, W. and Braungart, M. (2002) *Cradle-to-Cradle: remaking the way we make things*, North Point press: New York.

into either organic nutrients (as the popular Green Bin program has started doing in many municipalities in Canada), or non-renewable resources (as parts of the Blue Bin program do at present). Waste, per se, should not really exist (after all, no other species create landfill sites) and therefore a waste indicator is a suitable flow measure for the loss of potentially reusable non-renewable resources.

Current Trends and Significance: What are the trends in the data and how are they significant to the environment and human wellbeing?

Figure 21. Indicator – Per Capita Waste Disposal and Diversion Rates[186]

Annual Per Capita, Canada 1994-2008



Unfortunately, the trend for waste is not generally positive (Figure 21). With the exception of a decrease in waste disposal between 1994 and 1996, Canadians have, until very recently, exhibited a trend towards greater waste production (up 6% from 1994 and 11% since 1996). While the amount of diverted material is also increasing, it has done so in a consistently proportional manner, indicating that recycling rates are not increasing through time. However, the latest data point for 2008 does show some promise with waste production rates having decreased, along with an increasing amount of material diversion. While making assertions from single data points is not possible, we can hope that the trends of less waste disposal and a greater percentage of waste diversion continue.

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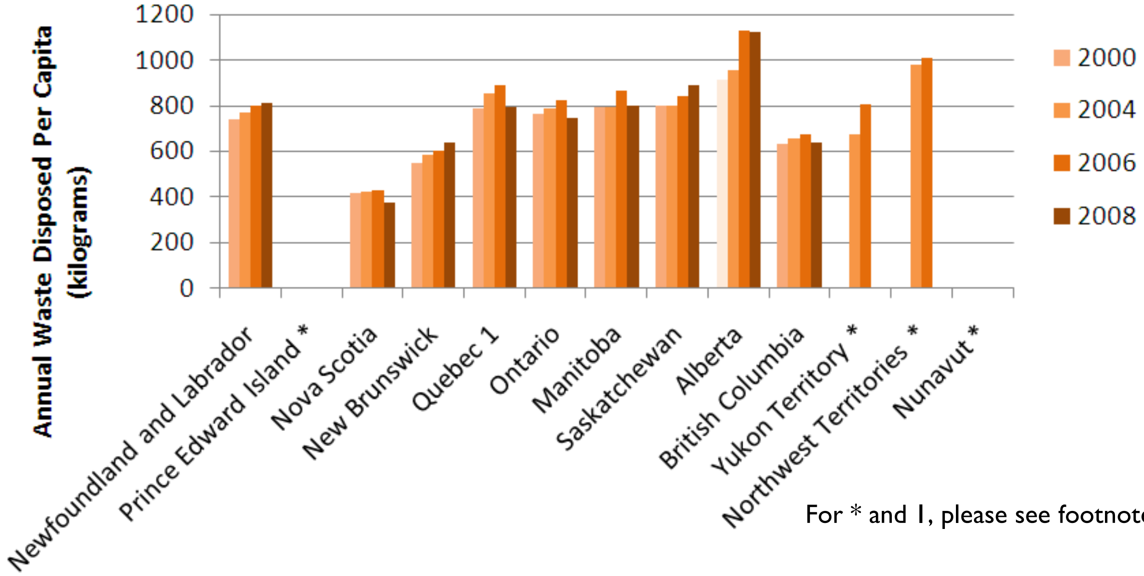
[186] Source: Statistics Canada (2010) Waste Management Industry Survey: Business and Government Sectors. Available online: http://dsp-psd.pwgsc.gc.ca/Collection/Statcan/16F0023X/16F0023XIE.html Last accessed: March 6, 2011 (1) Total amount of non-hazardous waste disposed of in public and private waste disposal facilities includes waste that is exported out of the source province or of the country for disposal. This does not include wastes disposed in hazardous waste disposal facilities or wastes managed by the waste generator on site. Diversion data are not available for 1994, 1996, and 1998.

(2) This information covers only those companies and local waste management organizations that reported non-hazardous recyclable material preparation and refers only to that material entering the waste stream and does not cover any waste that may be managed on-site by a company or household. Additionally, these data do not include those materials transported by the generator directly to secondary processors, such as pulp and paper mills while bypassing entirely any firm or local government involved in waste management activities.

In addition to the national trends, waste disposal also varies considerably across Canada (Figure 22).

Figure 22. Waste Disposal Rates by Province and Territory[187]

Waste Disposal in Canada for Select Jurisdictions, 2000, 2004, 2006, and 2008[188]



For * and 1, please see footnote 188

Figure 22 indicates that Albertans and individuals from the Northwest Territories (NWT) are amongst the highest waste creators in the country. While nearly all provinces and territories have seen waste disposal rates increase, Alberta and the Yukon increased the most over the period of 2000 to 2008, raising particular concerns for Alberta in particular which disposes nearly three times the amount of waste as Nova Scotia. In 2008, Nova Scotia, Quebec, Ontario, Manitoba and British Columbia exhibited strong decreases in waste disposal, a fact that is beyond the scope of this report, but merits deeper investigation.

Increased material consumption is of concern to Canadians for several reasons. Not only is higher energy consumption resulting in higher GHG emissions, but researchers have long known that increased consumption and wealth do not equate to higher levels of reported happiness.[189] To quote one study "…workers who are earning a lot of money because they work long hours provide the market for the very goods they are producing, and never mind if they do not really need the goods in question. The consumption becomes the reward for the hard work and the long hours. Nevertheless, it cannot be a very satisfying reward: the conditions of dissatisfaction must be maintained, or markets for useless products would disappear under a gale of common sense. We become addicted to consumption, which

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[187] Note: data for PEI and Nunavut are suppressed to meet the confidentiality requirements of the Confidentiality Act. (1) The 2004 waste disposal data are derived from a survey administered by RECYC-QUÉBEC. In 2006, disposal data were derived from Statistics Canada's 2006 Waste Management Industry Survey.

[188] Statistics Canada (2010) Waste management industry survey: business and government sectors. Available online: http://dsp-psd.pwgsc.gc.ca/Collection/Statcan/16F0023X/16F0023XIE.html Accessed: March 2,2011.

[189] Source: Carley, M. and Spapens, P. (1998) *Sharing the World: Sustainable Living and Global Equity in the 21st Century*, Earthscan, London, 142.

provides no lasting satisfaction."[190] Indeed, some studies[191,192] now suggest that there is in fact a relationship between increased material consumption and decreased happiness, thus raising concerns for the wellbeing of Canadians.

Growing consumption also has economic implications for the country and impacts to living standards since consumption places further demands on infrastructure (energy and water) as well as land use (recycling facilities, landfill). These demands in consumption, combined with an already ageing infrastructure, have very large economic implications for Canadians that reach into the tens of billions of dollars.[193] In summary, waste is not good for wellbeing; it impacts various areas of wellbeing and should be a concern to the public and policy makers alike.

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[190] Ibid., 143.

[191] Swinyard, W.R., Kau, A.K., and Phua, H.Y. (2001) Happiness, materialism, and religious experience in the U.S. and Singapore, *Journal of Happiness Studies*, 2(1): 13-32.

[192] Ryan, L. and Dziurawiec, S. (2001) Materialism and Its Relationship to Life Satisfaction, *Social Indicators Research*, 55(2): 185-197.

[193] Infrastructure Canada (2003) The State Of Infrastructure In Canada: Implications for Infrastructure Planning and Policy. Available online: http://www.infc.gc.ca/research-recherche/results-resultats/rs-rr/rs-rr-2003-03-eng.html#T1 Last accessed: October 5th, 2010.

BIOTIC RESOURCES: Species Population Trends (Living Planet Index)

Issue: What is the issue and why is it important to wellbeing?

Biodiversity is sometimes considered synonymous with the environment and all life on Earth, including humans.[194] The ecosystems, species and genetics (or "biotic resources") that make up all of the living things on our planet provide a huge array of benefits to humans. The Millennium Ecosystem Assessment, published in 2005, provides a complete overview of the various ecosystem services that nature provides to humanity.[195] A small subset of services include: the provision of seafood, timber, and energy; carbon sequestration, crop pollination, disease, and pest control; nutrient cycling and seed dispersal; cultural, intellectual and spiritual inspiration; and recreational experiences. Biotic resources are at the very foundation of human wellbeing, and our societies, our cultures, our lives would cease to exist without them.

Beyond the goods and services that nature provides, it is also the template for sustainability and wellbeing. When the planet loses species, it not only loses valuable genetic materials that have taken thousands of years to evolve, it loses a design masterpiece capable of teaching us a great deal. Humans are heavily dependent upon our fellow plants and animals.

For this section we used three Biotic Resource indicators, chosen as proxies for overall species health, the status of marine systems, and the status of terrestrial systems. Surprisingly few indicators are available to assess biotic resources nationally in Canada. Environment Canada's recent *Canadian Biodiversity: Ecosystem Status and Trends 2010* report shows that while many indicators (see Appendix E) can be used at regional or local scales, few datasets with multi-year time series comprehensively span the country.

Direct linkages to other domains: **Leisure and Culture** (species play important roles in First Nations culture and contribute to various outdoor pursuits, such as bird watching), **Community Vitality** (trees are a key element in driving the vitality of community spaces), **Education** (biotic resources provide not only direct opportunities for learning about species and ecosystems, but also inform design and provide information about various systemic processes), **Healthy Populations** (numerous drugs along with various traditional medicines are derived from plants and animals, birds reduce the numbers of mosquitoes which can carry disease, trees filter the air in our cities, and insects and microorganisms decompose pollutants and enrich our soils), **Living Standards and Environment** (biotic resources provide a large array of ecosystem services, many of which contribute the equivalent of billions of dollars to the economy).

Considerations and trade-offs: Species are important for all of the various roles that they play in our lives — the array of ecosystem services is vital to our wellbeing in all domains. However preserving biotic resources means improving biodiversity management at a minimum and can, at

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[194] The official definition of biodiversity is: "The variability among living organisms from all sources, including, INTER ALIA, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems" (Convention on Biological Diversity, 1992).

[195] See Reid et al. (2005) *Ecosystems and Human Well-being: synthesis report.* Millennium Ecosystem Assessment. Available online at: http://www.millenniumassessment.org/documents/document.356.aspx.pdf Last accessed: March 14, 2010.

times, mean forgoing development opportunities altogether in areas where species cannot tolerate disturbance. In essence it means ensuring that lands and waters are managed to ensure that both species and humans receive a portion of the benefits.

Understanding the Indicator: What is this indicator, why was it selected and how do I interpret the results?

A measure of the "amount of biotic resources" does not exist at present. While rough measures exist of the amount of habitat or the amount of genetic variation in a given species, we gather very limited data when it comes to species and habitats. The Living Planet Index (LPI) does however represent one metric that assesses the population levels (or stocks) of select species. The LPI is an index of species population abundance developed by WWF and the Zoological Society of London (ZSL). It tracks vertebrate species and makes the assumption that changes in the population abundance in key species, throughout terrestrial, freshwater and marine realms, are reflective of overall trends in biotic resources. It uses 1970 as a baseline (largely due to data limitations pre-1970), which while being restrictive in terms of determining absolute species levels (i.e., species may have been at an all-time low/high in 1970), it does tell us about recent trends. Good biological baseline data are lacking; therefore we do not know whether a given species is just skirting extinction but showing an increase, or whether a decline is from their most abundant levels of all time. Furthermore, the LPI only reflects those species that we immediately think of: other vertebrates. Missing from the list are the huge numbers of invertebrates, plants, fungi, protists and bacteria. The LPI also does not speak to changes in species richness (the number of species); it is solely a metric of abundance. Other metrics that were considered included the percentage of protected land/water, percentage of land converted, relative protection of critical habitat, changes in the number of invasive species and changes in the number of SARA-listed species (see Appendix E for the full list of indicators considered). The LPI species abundance indicator was chosen as the most direct representation of faunal health, which is assumed to also act as an indirect proxy for habitat health.

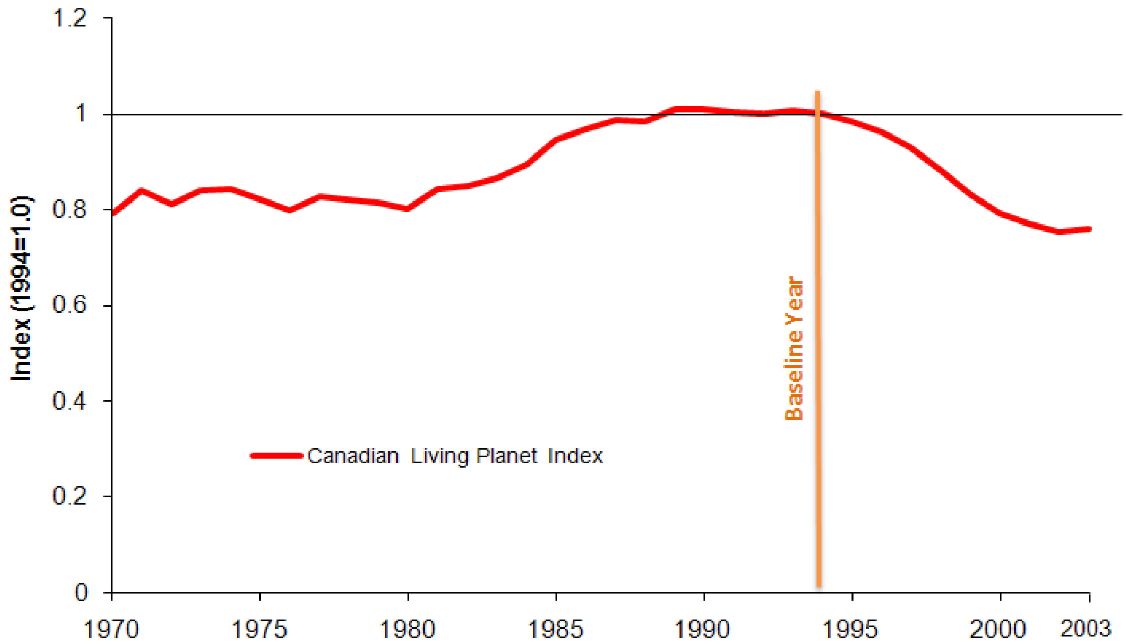
The LPI is used by WWF in their Living Planet Report, thus allowing for international comparisons through time, and is also being explored for use by the UN Convention on Biological Diversity. It was chosen as a direct representation of vertebrate health, which is assumed to also act as an indirect proxy for habitat health. Had a habitat measure been selected, it may have had a less direct relationship with vertebrate health.

For the index, the original baseline year of 1970 has been shifted to 1994 and set equal to 1.00 to align it with other data in this report. All species are aggregated into taxonomic groups before being combined into three realms (freshwater, marine and terrestrial) and then into the overall index. If the index number is increasing, then species are generally becoming more abundant, while the opposite is true if the number is in decline. The Canadian data were generated by WWF-Canada and ZSL in 2006, and use between 800 (2003) and 963 (1980) species abundance data points (i.e., N values range from 800 to 963). Note that there is a predominance of bird data within this data set, which is corrected for by aggregating by taxonomic group. For more details on the methodology, please see the Living Planet Index website.[196]

Current Trends and Significance: What are the trends in the data and how are they significant to the environment and human wellbeing?

Figure 23. Indicator – Living Planet Index

Canada 1970-2003 (1994 baseline)[197]



The trends exhibited by the Living Planet Index require considerable interpretation and have both good and bad news stories. First, the good news: the index is relatively close to the same levels as it was in 1970 suggesting that on balance, species abundance levels have not changed considerably since that time. Moreover, as seen in Figure 24, both birds, and reptiles and amphibians are above their 1970 levels some of which may have to do with the elimination of certain pesticides (e.g., the ban on DDT was beneficial to birds — and humans).

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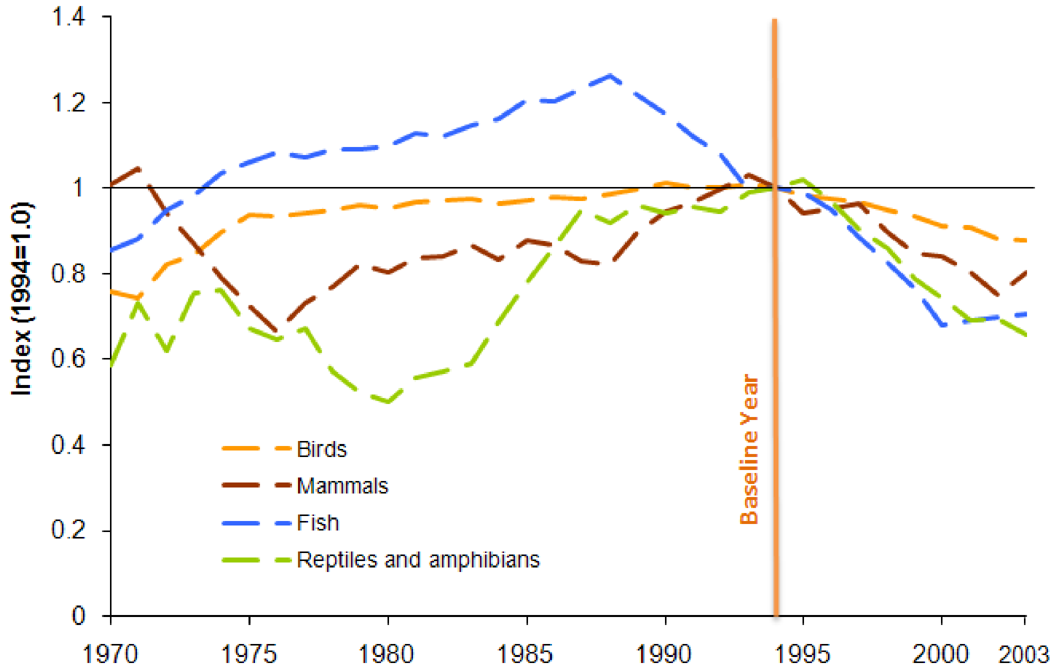
[196] Zoological Society of London – Institute of Zoology (2010) WWF/ZSL Living Planet Index. Available online at: http://www.zsl.org/science/research/research-projects/lpi,1162,AR.html Last accessed: October 11, 2010.

[197] McRae, L., Loh, J., Collen, B., Holbrook, S., Amin, R., Latham, J., Tranquilli, S. and Baillie, J. (2007) Living Planet Index. Canadian Living Planet Report 2007 (ed. By S. Mitchell and A. Peller), WWF-Canada, Toronto, Canada.

Figure 24. Living Planet Index for select taxa

Canada 1970-2003 (1994 baseline)[198]



However, there is bad news: since the mid 1990s, the index has been in decline on all fronts, with reptiles and amphibians showing the greatest decrease, along with fish. An estimated 20% of native frogs, toads and salamanders are at risk of extinction, while18% of non-marine fishes are listed as Endangered or Threatened in all parts of their range[199]. Certain bird groups have also suffered badly, while others appear to be holding stable. In particular, birds of grasslands and other open habitats lost 40% of their populations, 35% of shorebirds have experienced recent declines somewhere in their range, and seabirds also show a greater number of populations in decline since the 1980s. Waterfowl are mainly healthy, as are forest birds[200].

Habitat degradation, predation, competition, natural selection and direct human harvesting all contribute to these trends, but ecologists are still trying to understand various patterns. Some explanations are readily available, such as the declines in groundfish stocks due to overfishing, as well as the effects of habitat degradation/loss, abstraction, and invasives on freshwater aquatic species. Others impacts, such as increases in shellfish and marine mammals, are less well understood. Unfortunately, species abundance and range data in Canada (and throughout the world) is very deficient. With the exception of birds, rare species, and commercially valuable species such as polar bear, whales and salmon, we lack good estimates of numbers (and in many cases other aspects of basic biology, such as how fast and often a given species reproduces).

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[198] McRae, L., Loh, J., Collen, B., Holbrook, S., Amin, R., Latham, J., Tranquilli, S. and Baillie, J. (2007) Living Planet Index. Canadian Living Planet Report 2007 (ed. By S. Mitchell and A. Peller), WWF-Canada, Toronto, Canada.

[199] Federal, Provincial and Territorial Governments of Canada (2010) Canadian Biodiversity: Ecosystem Status and Trends 2010. Canadian Councils of Resource Ministers. Ottawa, ON. Available online: www.biodivcanada.ca/ecosystems Accessed: March 4, 2011.

[200] *Ibid.*

Basic data such as abundance and range are insufficient relative to the data needed to document the complex and fundamental relationships among species in food webs. We know that the loss or reduction of species in food webs has already greatly altered some Canadian ecosystems, and there is a pressing need to document not only patterns, but also the processes that are foundational to Canadian biodiversity.

Even when only considering the abundance of vertebrate species, the implications of declining species stocks are of concern. One need only consider the widespread impacts on wellbeing that the cod-stock collapse had in Atlantic Canada — from living standards to community vitality, the echoes of the disappearance of that single species will ring for many decades in the small towns of Newfoundland. Similar stories exist in other parts of Canada, from the Fraser River salmon to the woodland caribou of the boreal forests. There are species which define the wellbeing of many communities in Canada. Species are typically sentinels of trouble, and if the decline in Canada's species continues, would we all not be well advised to listen?

BIOTIC RESOURCES: Fish and Marine Ecosystems (Marine Trophic Index)

Issue: What is the issue and why is it important to wellbeing?

Marine ecosystems are often ignored because not only are they not a part of the daily lives of most Canadians, but also because it is sometimes difficult to sense the wellbeing of an ocean — even for individuals who reside in close proximity — given its vastness and depth. However, our oceans *are* essential aspects to our wellbeing. Obviously they provide us with food in the form of seafood, but in addition, they are an inspiration to the arts, form the basis of numerous cultures in the east, west and north coasts, and are the centrepoint of numerous port cities in which many people use them for commercial and recreational purposes. Seafood is a key part of the diet of over a billion people on the planet[201] and is also a healthy source of protein, providing omega fatty acids and lean protein, both of which help to maintain good health. We are still learning about our oceans; the Census of Marine Life only began in 2000 and released its first report in 2010.

Unfortunately, the last several decades have not been kind to marine ecosystems. In all parts of the world, our oceans have been overfished, polluted, their habitats converted through coastal development or damaged by fishing gear (e.g., bottom trawling). As we empty out the larger, more desirable species, the demand for protein turns to increasingly small, short-lived species lower down the food chain. This process of fishing down the food web has been well-documented across the planet. David Suzuki speaks of a time when he was a child when he could jig for halibut near his house in Vancouver[202]. Any hope of restoring such opportunities will be lost forever, along with the heritage, beauty and economic value of the species that share our coastal waters, if the process of ocean degradation does not end.

Direct linkages to other domains: **Leisure and Culture** (fishing is a significant recreational activity in Canada, while various species, such as salmon and oolichan, have cultural value to First Nations), **Community Vitality and Living Standards** (the entire existence of certain coastal communities, such as some of those in Newfoundland, Nunavut, and British Columbia, is based upon marine ecosystems), **Education** (marine fisheries provide opportunities to learn about the biotic resources in the oceans), **Healthy Populations** (numerous products that benefit human health, such as omega-3 fatty acids from various fish species, are derived from the oceans), **Environment** (marine species not only affect other species, but play a role in nutrient cycling, pollution filtration, food provision and other ecosystem services).

Considerations and trade-offs: A changing Marine Trophic Index (MTI) signifies a different balance of species. Raising the MTI to its historical levels would involve restoration of the diversity and ecological integrity of systems that once provided abundant marine resources. However, the current status of the MTI in has increased some species that provide considerable economic value. While economically beneficial in the short run, fishing down our food webs is risky given that we do not know what the long term wellbeing impacts will be of an altered trophic level.

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[201] Tidwell, J.H. and Allan, G.L. (2001) Fish as food: aquaculture's contribution - Ecological and economic impacts and contributions of fish farming and capture fisheries, *EMBO Reports*, 2(11): 958–963

[202] Suzuki, D. (2007) *David Suzuki: the autobiography*, page 376. Vancouver: Greystone Books, 405 pp.

Understanding the Indicator: What is this indicator, why was it selected and how do I interpret the results?

The MTI is an indicator that measures the mean trophic level of landed marine species.[203] In simple terms, it is a measure of how many big, predatory fish (e.g., swordfish) we are catching versus small, herbivorous or omnivorous species (e.g., clams). Technically, "the term 'MTI' is in fact the CBD's name for the mean trophic level (TL) of fisheries landings, originally used by Pauly *et al.* (1998)[204] to demonstrate that fisheries, since 1950, are increasingly relying on the smaller, short-lived fishes and on the invertebrates from the lower parts of both marine and freshwater food webs."[205] As used by UBC's Sea Around Us Project, the MTI used here is a "cut" MTI, meaning that only mean trophic levels of 2.0 or greater are considered as this makes for a more powerful indicator[206].

The MTI for fisheries landings by region and globally is expressed as an index ranging from a value of 1 for primary producers (e.g., phytoplankton) up to a level of 5 for top-level carnivores (e.g., marine mammals).[207] In addition to being an indicator of the sustainability of fisheries, the MTI provides a measure of ecosystem integrity. Declining mean trophic levels suggest that food chains are becoming shorter, leaving ecosystems less able to cope with natural or human-induced change. The long-term sustainability of fisheries is, in turn, directly linked to human livelihoods and wellbeing. A young fishery (i.e., one that is just starting up in a new location) is likely to encounter a higher mean MTI. As the fishery matures, the MTI, and the size of the fish caught, is likely to decline, which indicates the altered trophic structure. In fact, the MTI reveals that, as the world's fisheries mature, the mean trophic level of catches is in steady decline — humanity is fishing down marine food webs. All else being equal, the lower the mean trophic level, the younger the fish in the catch: conversely, the higher the mean trophic level, the older and larger the fish. According to the United Nations, current data quality is sufficient for global and regional level analyses.[208] As a result, the MTI is recognized and used by both the UN Convention on Biological Diversity, and the Environmental Performance Index, as an indicator of marine biotic resources.

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[203] Trophic level is defined as the position of an organism in the food chain, determined by the number of energy-transfer steps to that level. A fish's role within an ecosystem is largely a function of its size: small fish are more likely to have a greater number of predators than very large fish. Trophic levels change with the life history of fishes, for example, growth enables the juveniles to consume larger, predatory zooplankton and small fishes which leads to an increase in trophic level, often culminating in values around 4.5 in large fishes. For more details, see: Pauly D. and R. Watson. (2005) Background and interpretation of the 'Marine Trophic Index' as a measure of biodiversity, *Philos. Trans. R. Soc. Lond B* 360 (1454): 415-423.

[204] Pauly D, Froese R, Christensen V. (1998) How pervasive is 'Fishing down marine food webs': response to Caddy et al. *Science*. 282 (5393): 1383

[205] Pauly, D. and Watson, R. (2005) Background and interpretation of the 'Marine Trophic Index' as a measure of biodiversity, *Philos Trans R Soc Lond B*, 360 (1454): 415–423.

[206] *Ibid.*

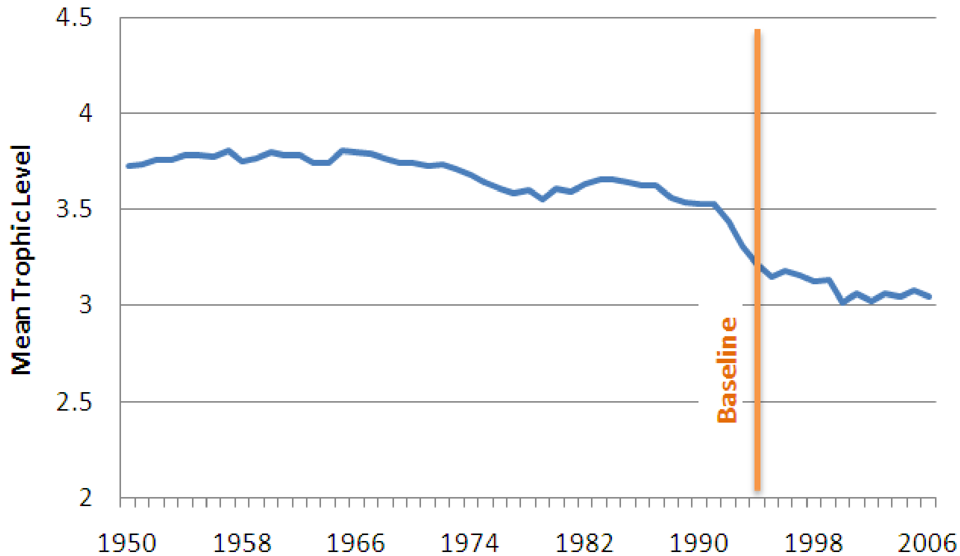
[207] In Canada, the extremes of the MTI are represented by Atlantic halibut (with a trophic Level of 4.5) at the top end, and scallops (with a trophic level of 2.0) at the lower end. Sea Around Us Project (2010) Available online at: http://www.seaaroundus.org/eez/124/200.aspx# Last accessed: October 12, 2010.

[208] United Nations, Marine Trophic Index http://www.un.org/esa/sustdev/natlinfo/indicators/methodology_sheets/oceans_seas_coasts/marine_trophic_index.pdf Mean Trophic Index for Canada and other international fisheries has been calculated by the Sea Around Us Project based at the University of British Columbia; data are available at http://www.seaaroundus.org/TrophicLevel/EEZTrophicIndex.aspx?eez=124&fao=0&c|

Current Trends and Significance: What are the trends in the data and how are they significant to the environment and human wellbeing?

Figure 25. Indicator – Marine Trophic Index

Canada 1950-2006 (1994 baseline)[209]



The mean trophic level (TL) of marine species landed has declined dramatically since the early 1990s (Figure 25) from a mean level of 3.7 in 1951 to 3.05 in 2006. A declining trophic level (i.e., MTI) suggests a general decline in larger fish stock towards smaller marine species. According to Professor Daniel Pauly, a professor in the Fisheries Centre at the University of British Columbia, who compiles the data, the decline in Canada's mean trophic levels is amongst the largest in the world[210].

However, there is more to the story. While larger, predatory species are being fished out (large, predatory pelagic and groundfish species), fishers and scientists have noticed an increase in the number of shellfish (including shrimp, crab and lobster). These species have grown considerably not only in stock estimates, but also in value as a portion of landed catch value (Figure 26). These data are backed by estimates of mean maximum fish length which have also decreased from an average of 111cm in 1950, to 55cm in 1994, to a current (2006) value of 46cm. All of these data indicate that not only are we steadily removing large fish, but we are also not fully replacing them with the same amount of other, small species (whether through choice, bycatch – the discarding of unwanted fish, or unavailability).

While catch per unit effort data are unavailable, vessel numbers, which are a proxy for general fleet capacity, have dropped by roughly half since 1990,[211] suggesting at least some reduced pressure on fish species. Fishing gear, catch-per-unit effort, time at sea and bycatch are all

[209] Sea Around Us Project. (2010) Analyses and Visualization. Marine Trophic Index in the Waters of Canada. Available online: http://www.seaaroundus.org/eez/124/200.aspx Accessed: March 6, 2011.

[210] Pauly, D. (2010) Pers. Comm., January 20, 2010.

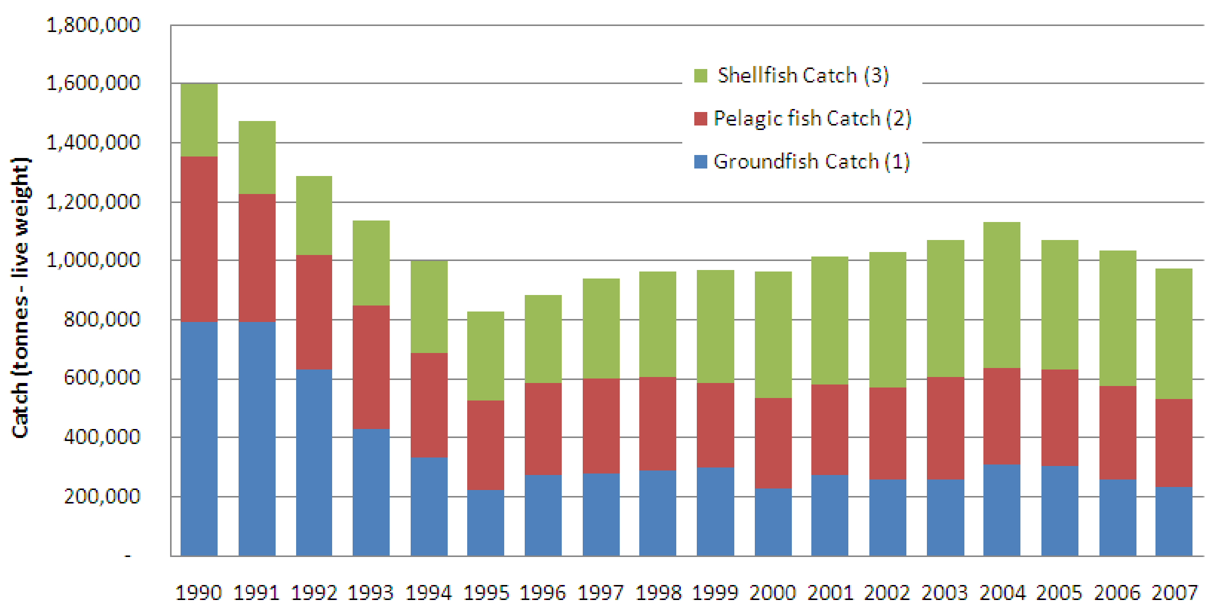
[211] Hsu, T.C.T. (2003) Simple capacity indicators for peak-to-peak and data envelopment analyses of fishing capacity — a preliminary assessment, in *Measuring capacity in fisheries*, Eds. Pascoe, S.; Gréboval D., FAO Fisheries Technical Paper T445.

additional factors that are driving these trends, however, there is no question that there has been a shift in the trophic structure of Canada's oceans. Figure 26 also illustrates the effect of "fishing down the food web"; where the abundance of lower trophic level species (such as shellfish) increases due to reduced predation of higher trophic level species (such as sharks). While lobsters, shrimp, clams and scallops may be economically beneficial as a replacement for lost groundfish species such as cod, the long term implications of this trophic shift are unknown and may have as-yet unforeseen implications on the wellbeing of Canadians. Furthermore, many of the species that are of cultural, recreational and economic benefit to Canadians, such as halibut (TL 4.53), tarpon (4.5), Atlantic/Chinook salmon (4.53/4.4), swordfish (4.49), bluefin tuna (4.43) and Atlantic/Pacific cod (4.01), are all amongst the highest trophic levels. In other words, the data suggest these species are no longer being caught and that instead, we are catching smaller species. Scientific evidence suggests that we have turned to smaller, lower trophic level species out of necessity as stock levels of these larger predatory fish decline.[212] Such a loss represents a loss of wellbeing (economic, recreational, cultural) in coastal communities, sport fishers, naturalists, aboriginal peoples, and for seafood lovers in Canada and the rest of the world.

Marine scientists do not have all of the answers to solve these decreases in natural capital. However, researchers suggest that for marine species, reducing fishing fleet capacity is one aspect of helping to rebuild fish stocks and ensure sustainability, while reducing subsidies and policy enforcement also remain key elements.[213] These sorts of actions will enable Canadians to maximize the stock of biotic fisheries resources, and in doing so, optimize wellbeing.

Figure 26. Total Landed Catch for Marine Species

Canada 1990-2007[214]



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[212] Myers, R.A., and Worm, B. (2003) Rapid worldwide depletion of predatory fish communities, *Nature*, 423: 280-283

[213] Pauly, D. et al. (2002) Towards sustainability in world fisheries, *Nature* 418, 689-695.

[214] Statistics Canada (2010) Summary Tables. Sea fisheries landed catch. Retrieved March 6, 2011. Available online: http://www40.statcan.ca/l01/cst01/envi37a-eng.htm Accessed: March 6, 2011.

BIOTIC RESOURCES: Forest Ecosystems (Timber Sustainability Index)[215]

Issue: What is the issue and why is it important to wellbeing?

Sustaining Canada's forests means that the annual harvest (and deforestation) in cubic metres should not exceed the annual growth in cubic metres of standing timber while the reproductive capacity and resilience of the forest ecosystems stays equal. For a renewable resource like timber, a constant stock size indicates that annual harvesting and other losses, including losses due to fire, insects and other industrial development, are offset by annual growth. Sustaining Canada's timber resources is critical to the forest industry, local economies and to Canada's carbon balance sheet.

Direct linkages to other domains: **Leisure and Culture** (forests are important elements in numerous First Nations cultures, and also play a role in recreation), **Democratic Engagement** (forests are valued; their destruction has sparked protests, such as at Clayquot Sound in British Columbia, and directly driven democratic engagement), **Community Vitality** and **Living Standards** (like ocean resources, forest resources are key to the existence of many rural communities in Canada, providing jobs and defining the nature of the place), **Educated Populace** (healthy forests are laboratories for learning and have taught Canadians much about forest ecology and harvesting practices), **Healthy Populations** (forests provide an array of ecosystem services that directly and indirectly affect human health).

Considerations and trade-offs: Timber reserves are a stock of capital, which when we spend down, result in less "interest" to live off of. By not allowing timber resources to return to sustainable levels, not only are we not maximizing economic yield in the medium to long term, we are also losing out on various ecosystem services provided by those forests. Improving forestry management practices, both through regulatory means and supporting voluntary mechanisms, can help to ensure that forests are managed for the broad array of services they provide for human wellbeing.

Understanding the Indicator: What is this indicator, why was it selected and how do I interpret the results?

The Timber Sustainability Index (TSI) is used as an indicator of the sustainability of Canada's forests measured as the ratio of annual growth of standing timber (by volume) to the total volume of harvesting, other industrial development losses, forest fires and insect mortality. In this sense, it is a net of various flows. A TSI that is equal to or greater than 1.00 implies that timber resources are sustainable; that is, the growth rate is in harmony with, or exceeding, the annual depletion rate. A TSI of less than 1.00 implies that the timber capital stock is being depleted at unsustainable rates.

The TSI is comprised of data on estimated annual growth rates, harvest volume, natural mortality, impact of roads and fire losses. Timber supply, harvest, and fire statistics comes from the National Forest Database maintained by Natural Resources Canada (with input from provincial government forestry agencies), which is comprised of provincial forest inventory data. Statistics Canada's Environmental Accounts and Statistics Division, in turn, constructs a

[215] This indicator, and the associated text, are taken from Phase I; this section was written almost entirely by Mark Anielski.

timber supply model to build the Physical Timber Asset Account (PTAA) in which growth in a given year is estimated as: closing stock - (opening stock + fire + harvest + roads + mortality).

The TSI is constructed using data contained in the PTAA.[216] Most of the data, namely timber harvest and fire statistics, contained in this account comes from the Canadian Forest Inventory and the National Forestry Database maintained by the Canadian Council of Forest Ministers with data input from provincial forestry agencies. Other factors including the impacts of roads, natural mortality and annual growth rates are derived using mathematical models developed by Statistics Canada. Unfortunately, accurate statistics on the loss of timber due to linear disturbance and industrial development that includes roads and oil and gas activity is not very robust; these impacts must be modeled.[217]

Lastly, it is important to note that the TSI does not measure quality of forest. It is simply a measure of timber. Accordingly, it does not treat virgin forest differently from re-forestation plots or plantations. This is important as the virgin forest tends to provide greater ecological and human wellbeing benefits (e.g., better ecosystem services).[218]

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[216] Source: Statistics Canada. Econnections. Catalogue 16-200, XKE, p. 40-50. Note : The Canadian Forest Inventory 1991 upon which Statistics Canada's Physical Timber Asset Account (PTAA) is based is no longer being maintained. It has been replaced by the new, plot-based National Forest Inventory recently released by NRCan (www.nfi.nfis.org) which is a more dynamic measure showing annual allowable cut (as the maximum sustainable harvest) compared to total cut. The new NFI differs significantly in method from the old CANFI91. Statistics Canada is still investigating how to integrate the NFI into its timber accounts. It is very unlikely there will be an update of the PTAA beyond 2003 using the old method. The trend in standing timber volume that will result when the new NFI is integrated into the PTAA is unknown at this moment. It may differ significantly from the trend currently represented in the PTAA. Accordingly, this indicator will need to be changed in the future.

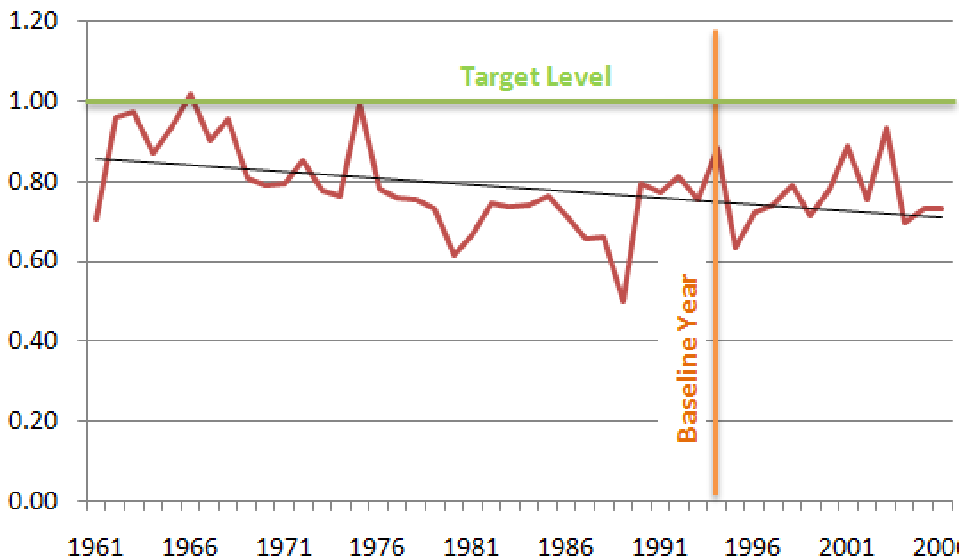
[217] The Physical Timber Asset Accounts (PTAA) is based on forest resource inventories produced by provincial and territorial forest departments/ministries. Although these inventories are conducted regularly, they often use different land bases from one period to the next. As a result, consistent stock data are not available as an annual time series. The provincial/territorial inventories are aggregated by the Canadian Forest Service of Natural Resources Canada to form Canada's Forest Inventory. This national inventory is available for both 1986 and 1991, although the differences between the 1986 and 1991 inventories do not reflect the actual changes that occurred between these points in time; the 1991 inventory is only a partial update of the 1986 inventory. To overcome the lack of consistent, annual forest data, the stock/flow time series of the PTAA is estimated using a simulation model. Beginning with inventory data for a single year (1991), this model simulates the impact of growth, harvesting, natural loss and other changes to timber stocks over the period 1961 to 2003. This type of simulation is similar to the timber supply analyses done by provincial forest managers when determining the annual allowable cut — the amount of timber that can be harvested annually on a sustainable basis.

[218] Bunker, D.E. et al. (2005) Species Loss and Aboveground Carbon Storage in a Tropical Forest, *Science*, 310(5750):1029-1031.

Current Trends and Significance: What are the trends in the data and how are they significant to the environment and human wellbeing?

Figure 27. Indicator – Timber Sustainability Index

Canada, 1961-2006 (1994 baseline)



The Canadian TSI (Figure 27) has been less than 1.00 for the majority of years in the period 1961-2006, which means that the total stock of Canada's timber resources were declining due to harvesting, fires, natural mortality (e.g., due to insect infestations) or industrial development (e.g., roads[219]) at a rate faster than the annual growth rate of the forests. It should be noted that 2004-2006 figures are estimated based on historical trends using current timber harvest and fire statistics from the National Forestry Database maintained by the Canadian Council of Forest Ministers. The bottom line is that the TSI remains at levels that suggest unsustainable timber resource consumption.

According to Statistics Canada's PTAA, Canada's timber has declined from an estimated 14.637 billion cubic metres in 1961 to 12.647 billion cubic metres in 2006, a 13.6% net loss of standing timber over this time period. While total growth in timber has been healthy at 7,653 million cubic metres in total between 1961-2006, this has been exceeded by the combined volumes of timber harvested (6,957 million m^3) plus losses due to natural mortality (1,974 million m^3), wild fires (832 million m^3), and roads (205 million m^3), for a total of 9,969 million m^3. Fragmentation in the northern boreal is minimal due to relatively little human impact. In contrast, the southern boreal forest has become increasingly fragmented through human disturbance. Forest ranges are also shifting, particularly in northern and treeline zones: forest ranges are expanding northward in coastal Labrador and both growth and density of forests are increasing near treeline in the Yukon and Quebec[220].

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[219] Note: the PTAA does not account for losses due to oil and gas activity such as seismic lines or pipelines.

[220] Federal, Provincial and Territorial Governments of Canada (2010) Canadian Biodiversity: Ecosystem Status and Trends 2010. Canadian Councils of Resource Ministers. Ottawa, ON. Available online: www.biodivcanada.ca/ecosystems Accessed: March 4, 2011.

Canadian Forest Service notes that forest harvest levels have steadily increased over the past decade. Overall, 0.01-0.02% of Canadian forests are ceded annually to other types of land cover – corresponding to a loss of approximately 150 000 km^2 of Canada's forests per year[221]. Since 1994, more than a million hectares a year have been cut — an area almost twice the size of Prince Edward Island. Forest losses at the regional scale have been meaningful in some areas. For example, 45% of the Douglas fir zone in B.C. has been converted to other land use. Since 1990, there has been an average of over 8,200 forest fires per year; in 2000, 600,000 hectares of forest were burned. There is, however, no obvious increase in the number of forest fires between 1970 and 2000. Insects such as spruce budworm and the mountain pine beetle affect huge swaths of forest, with estimates being in the order of 14 million hectares per year for the spruce budworm[222] and a cumulative of 16 million hectares for the mountain pine beetle, an area some five times the size of Vancouver Island.[223]

The cumulative impact of sustained pine beetle infestation in central British Columbia and increasingly, in Alberta, is expected to have devastating effects on the forests of these two provinces. According to research scientist Allan Carroll at Pacific Forestry Centre in Victoria, the spread of the beetle is happening in lock step with warmer winters. Historically, cold winters killed the pine beetle larvae that infect lodgepole pine stands. However, rapid warming — the average winter temperatures have risen by more than 4°C in the last century — means the pine beetle population has grown exponentially in the past six years, turning a sea of green pine trees into a broad swath of rust-red forest.[224]

Tracking changes in the stock of growing trees is only part of the picture when evaluating the ecological integrity of a forest. Well-structured, healthy forests provide economic goods, wildlife habitat, carbon sequestration, soil stabilization, water filtration and regulation, and recreational opportunities for Canadians that we consider factors of wellbeing. Forest structure is determined by factors such as the diversity and population structure (how many trees are young, middle aged or old growth) of trees and other plants as well as animals (e.g., forest birds and woodland caribou). Findings from the latest Environment Canada Ecosystem Status and Trends Report indicate that in some regions of Canada, old forests have shifted to young forests (e.g., Atlantic Maritime areas and Boreal Plains, see [225]). Nonetheless, old forests continue to make up 40% of Newfoundland and Labrador's boreal forest and BC's coastal forests[226].

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221 Federal, Provincial and Territorial Governments of Canada (2010) Canadian Biodiversity: Ecosystem Status and Trends 2010. Canadian Councils of Resource Ministers. Ottawa, ON. Available online: www.biodivcanada.ca/ecosystems Accessed: March 4, 2011.

222 Duchesne, L. and Ouimet, R. (2008) Population dynamics of tree species in southern Quebec, Canada: 1970-2005, *Forest Ecology and Management*, 255(7): 3001-3012.

223 British Columbia Ministry of Forests and Range (2010) Beetle Facts. Available online at: http://www.for.gov.bc.ca/hfp/mountain_pine_beetle/facts.htm Last accessed: October 11, 2010.

224 Struck, Doug. '*Rapid Warming' Spreads Havoc in Canada's Forests. Washington Post Foreign Service*. March 1, 2006. Page A01. Available at http://www.washingtonpost.com/wp-dyn/content/article/2006/02/28/AR2006022801772.html

225 Federal, Provincial and Territorial Governments of Canada (2010) Canadian Biodiversity: Ecosystem Status and Trends 2010. Canadian Councils of Resource Ministers. Ottawa, ON. Available online: www.biodivcanada.ca/ecosystems Accessed: March 4, 2011.

226 *Ibid.*

4. Conclusion

> *"Conservation is sometimes perceived as stopping everything cold, as holding whooping cranes in higher esteem than people. It is up to science to spread the understanding that the choice is not between wild places or people, it is between a rich or an impoverished existence for [hu]Man[ity]"*
>
> — Thomas E. Lovejoy, quoted in *Balancing on the Brink of Extinction*

The Environment Domain paints a mixed picture of Canada's environment. Some aspects of Canada's environment are improving while others are degrading. The choices we make in terms of protecting, managing or restoring these aspects of the environment will dictate not only the state of our lands and waters, but also play a significant role in determining our wellbeing as Canadians.

The indicators suggest that air quality is a concern, especially in some locations, and greenhouse gas emissions are increasing for the country, while air pollution emissions appear to be headed, for the most part, in the right direction.

Energy aspects remain a major concern and highlight the supply-side management mentality that Canada has tended to adopt for many of its natural capital assets: "More energy demand? No problem, we will create more supply". However, this increased demand, using the fossil fuel sources available, has direct implications on our ability to change the status of air quality and pollution emissions.

The indicators for freshwater paint a picture of a country of heavy water users who generally have acceptable water quality, though water yield is of concern in some locations and showing signs of decline.

The consumption of non-renewable resources and associated waste has good news and bad news stories: while the conversion of non-renewables is economically beneficial in the short-term (revenue, taxes and livelihoods), the resulting externalities on biotic resources (habitat conversion and degradation), air, freshwater, and human health are not always factored into decision making. The linear "extract and consume" model seen in our high waste generation rates, is showing promising signs of decreasing at a time when researchers continue to further explore whether in fact consumption has made people happier.

Lastly, our biotic resources, while generally stable, are showing disconcerting signs of decrease and unsustainable patterns in both the forests and oceans. If our biotic resources are further impaired and ecosystem services begin to degrade, the wellbeing implications for Canadian society will become far more apparent. The ecosystem services that our provided by biotic resources are significantly undervalued as natural capital.

All in all, the report concludes that while Canada is not a country in crisis, there are warning signs that not all is well when it comes to the environment and wellbeing. With enviable natural capital resources, Canada, unlike many countries in the world, has the fortunate position of having a buffer before system limits are reached. However, given that there is an increasingly large global population with a voracious and growing demand for our natural capital, it is critical that policy makers assess the consequences of how we use the environment to better the wellbeing of all Canadians. Given not only its recognized value that is in excess of a trillion dollars, but also its unrecognized value in the form of ecosystem services, the environment needs to be central in the debate on improving wellbeing.

The path towards ensuring resilient and sustainable ecosystem services is ultimately a human choice. It begins with individual citizens, but it must also be manifest in government actions. We must begin to recognize the true value of our environment through policies, pricing, and cultural attitudes.

The Millennium Ecosystem Assessment,[227] combined with the latest assessments of biodiversity,[228] suggests that we are headed down the wrong path. Should we fail to alter the course of environmental degradation, we will encounter a poorer (and less beautiful) world with an increased likelihood of civil strife.[229] As we enter into the era of resource scarcity, global economic competitiveness and heightened interest in community health, general wellbeing will be dictated not by more, but by less; not by quantity, but by quality; not by tradition, but by innovation. We must think about the value of natural capital and the definition of the good life to not only address environmental concerns, but to provide a stable foundation for human wellbeing.

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[227] See http://www.millenniumassessment.org for more details.

[228] Butchart, S.H.M. et al (2010) Global Biodiversity: indicators of recent decline. *Science*, DOI: 10.1126/science.1187512

[229] Homer-Dixon, T. (2000) *The Ingenuity Gap*. Knopf. .

5. Areas for Future Development

> *"Human kind still has much to learn about the nature of Value, and the value of Nature."*
>
> — The Economics of Ecosystems and Biodiversity

This report would be remiss if it did not flag areas that need further efforts and/or analysis. Scattered throughout this report have been numerous notes that identified data and/or knowledge gaps. The following is a summary of those areas that need further development.

1) **Aspects missing from this report:**[230] Ideally stock and flow indicators should be developed for missing areas including those noted below. Please note that in some cases data were not available, while in others, data were available but not appropriate for the report at this time.

   - **Land cover:** Data exist, but little in the way of land-cover change through time. Further efforts could build upon work completed in 2005 by Natural Resources Canada.[231]
   - **Material consumption**: Material consumption accounts could be built upon existing economic data (National Accounts), along with the use of the Consumer Price Index to provide "consumption baskets". This in turn could ultimately generate a national input-output model of consumption. This is similar to the notion of the Ecological Footprint, which uses national input-output tables for calculations.
   - **Toxic chemicals**: At present toxic chemicals are a notable gap within the indicators. NPRI data are likely the best bet, but there would need to be some kind of weighting applied to the emissions, since toxins have differential impacts that are target-dependent. There is work being done in the EU on a chemical risk index which could act as a means of weighting various chemicals based upon toxicity.
   - **Food and food security**: This is also currently missing from the report. Considerable amounts of data are available on food and agriculture in Canada (e.g., Class 1 prime agricultural lands, organic farming, area under cultivation via Agricultural Census). Statistics Canada also completed a report several years ago on food and the environment,[232] but ultimately food and agriculture was set aside in this report (in part due to the complications of international trade). It could be added in future versions.
   - **Policy Compliance**: Though not a natural capital stock-flow *per se*, compliance is an important aspect affecting policy, since usually policy enforcement, not legislation, is the critical driver of performance. Analysis around compliance as it relates to key environmental policy, such as CEPA, the Ocean Act, or CITES, would be interesting and

[230] Also see Appendix C.

[231] See: Latifovic, Rasim and Darren Pouliot, 2005, "Multi-temporal land cover mapping for Canada: Methodology and Products," *Canadian Journal of Remote Sensing*, 31(5):347-363. Natural Resources Canada, Canada Centre for Remote Sensing.

[232] See: http://www.statcan.gc.ca/pub/16-201-x/2009000/part-partie1-eng.htm

informative for the wellbeing of Canadians. Some provinces have begun to track compliance information, and these efforts should be encouraged.

- **Renewable energy**: This is another missing component within the indicator suite at present. Data exist, via Simon Fraser University, but would need to be compiled and checked if desired.
- **Subsidies**: There are no data compiled related to subsidies and the general realm of ecological fiscal reform. This would be interesting to pursue, though it does represent a policy response, similar to protected areas, rather than a stock or flow of natural capital *per se*.
- **Noise**: There are no data available on noise as an important environmental variable that has significant potential impacts upon human hearing/health.

2) **Improved data access**: In many cases, data exist, but are not accessible for one reason or another. Restrictions on access to information are a key challenge in Canada and environmental data access needs improvement.
   - Data on fisheries pressure exist, but are restricted in terms of access at present. In particular, insightful flow indicators could be developed around the following data sets: Fish trawl data; Catch per unit effort data; Spawning biomass.
   - Protected areas data is another area that needs improved access for the public and decision makers, although some steps have been taken to improve data gathering and access (e.g., CARTS[233]).
3) **Additional data analysis**: Certain data sets are available (or under development) but need further work (e.g., updating, completion, extension, methodological concerns, etc.) prior to use. Of note are the following indicators (and associated institutions/people) which should be considered for future versions of this work:
   - Water Footprint (Water Footprint Network / Arjen Hoekstra and Ashok Chapagain)
   - Ocean Health Index (NCEAS / Ben Halpern)
   - Ecological representation analysis of protected areas by ecoregion (WWF-Canada / Steven Price and James Snider)
   - Ecological Footprint (Global Footprint Network / Mathis Wackernagel)
4) **Further research on the explicit linkages between environment and wellbeing**: This area has certain aspects that have been well developed and others that are still very much in their infancy. Ecological integrity and its ties to human health is a largely unexplored space that merits considerable attention for its potential in transforming medicine from a reactive discipline into one that proactively tackles drivers of disease at their root causes. Along these lines, some of the possible environmental quality of life indicators could include areas such as:
   - Premature deaths/hospital visits due to air pollution[234]

[233] While CARTS does provide accessible numbers and Google-based data, raw GIS data is still not readily available, making robust analysis difficult.

[234] There is considerable work in this area, including ongoing efforts by Environment Canada and Health Canada to develop an air health indicator.

- Costs of climate change impacts and adaptations
- Health impacts of climate change (disease)
- Water borne disease incidents
- Cost of water (water treatment)[235]
- Cumulative soil and landscape remediation costs of extractive industries
- Cost of invasive species[236]
- Impacts on "nature deficit disorder" and its impacts on childhood creativity[237]
- Social impacts of time lost due to commuting (and urban sprawl)

Such costs and impacts need to be understood as they impact life satisfaction, future options in ways of living, happiness, etc. that go beyond monetary costs.

5) **Alter timing of updates/release:** Given the large extent to which this report relies upon governmental data, and especially census data, it is suggested that the next version of the CIW report be completed during the summer months (it is noted that CESI is moving to a rotating quarterly set of releases, which is commended), and in particular around two years after the Census is completed (i.e., 2013, 2018, 2021, etc.). Doing so will maximize the timeliness of the data.

6) **Refine Existing Indicators**: Some of the indicators used in this work could use refinements both in terms of methods as well as updating data. In particular, the following are noted:
   - **Weighting**: At present, equal weights have been assigned to indicators within the index, aside from the inclusion (or exclusion) of certain variables. It is recommended that the weighting of these variables be done either via a Delphi method (expert weighting) or alternatively, via public opinion polling, which could be updated through time, or both.
   - **Timber Sustainability Index**. This indicator will need an overhaul once the PTAA is incorporated into the new, plot-based National Forest Inventory recently released by NRCan (www.nfi.nfis.org).
   - **Waste**: Hazardous wastes is another aspect of waste that was not covered here, along with other industrial waste. Where data are available, these could be added.
   - **Water Quality Index**: It is recognized that at present the methodology associated with the Water Quality Index is not ideal. One possibility would be to use phosphorus as a proxy; this has been done by Environment Canada in the past, but the data set is not ongoing.
   - **Water supply/demand data**: There are several options here, but ideally the data should either be switched to a cumulative figure of total water use from agricultural,

[235] Environment Canada is working on a water treatability indicator and Statistics Canada's survey of environment protection expenditures measures some of this. See http://www.statcan.gc.ca/bsolc/olc-cel/olc-cel?catno=16F0006XWE&lang=eng

[236] Environment Canada is seeking to develop an indicator with partners over the next two years.

[237] See Louv, R. (2005) *Last Child in the Woods: saving our children from nature deficit disorder*. Algonquin Books.

industrial and residential use, or alternatively some form of water footprinting, which captures embedded water as well as import/export issues.

- **Living Planet Index**: These data need to be updated. In addition, there is no indicator around species at risk. One possibility on this front would be to use the Red List Index calculation or possibly use improved data from COSEWIC.

7) **Explore Conceptual Underpinnings**: The very premise of this report could be explored in further depth. For example, the following issues could be explored in greater detail to provide additional clarity and scope:

- Definition of a "Canadian ecosystem"
- Whether management is a necessary pre-condition for the contribution to wellbeing
- Defining the time horizon of "sustainability"
- Exploring how to determine an "optimum" level of resource use
- Further refining the scope of "ecological goods and services"
- Whether wellbeing should be defined in terms of "human needs" or whether the concept needs to be expanded to the wellbeing and "needs" of nature as well.

6. References

Arnell, N.W. (1999) Climate change and global water resources, *Global Environmental Change*. 9(1): S31-49.

Ayres, R.U. and Warr, B. (2009) *The Engine of Economic Growth: how energy and work drive material prosperity*, Edward Elgar Publishing: Northampton, MA, USA

Bemrose, R.,Kemp, L., Henry, M. and Soulard, F. (2009) The Water Yield for Canada as a Thirty-year Average (1971 to 2000): Concepts, Methodology and Initial Results, *Environment Accounts and Statistics Analytical and Technical Paper Series*, Statistics Canada Catalogue no. 16-001-MWE2009007.

Benyus, J. (2002) *Biomimicry: Innovation inspired by nature*, Harper Perennial: New York, NY, USA

Beyond GDP (2010) Measuring progress, true wealth, and the wellbeing of nations. Available online at: http://www.beyond-gdp.eu/news.html Last accessed: March 7, 2010.

British Columbia Ministry of Forests and Range (2010) Beetle Facts. Available online at: http://www.for.gov.bc.ca/hfp/mountain_pine_beetle/facts.htm Last accessed: October 11, 2010.

Bruntland, G. (ed.). (1987). *Our common future: The World Commission on Environment and Development* Oxford University Press: Oxford, UK

Bunker, D.E. DeClerck, F., Bradford, J.C. colwell, R.K. Perfecto, I. Phillips, O.I., Sankaran, M. Naeem, S. (2005) Species Loss and Aboveground Carbon Storage in a Tropical Forest, *Science*. 310(5750):1029-1031.

Burnett R.T., Cakmak S., Brook J.R. (1998) The effect of the urban ambient air pollution mix on daily mortality rates in 11 Canadian cities. *Canadian Journal of Public Health.* 89(3):152–156.

Butchart, S.H.M Walpole, M., Collen, B. Van Strien, A. Scharlemann, J.P.W. et al. (2010) Global Biodiversity: indicators of recent decline. *Science*. 328(5982): 1164-1168

Canadian Bison Association (2010) Bison History. Available online at: http://www.canadianbison.ca/consumer/Resources/bison_history.htm Last accessed: October 10, 2010.

Canadian Index of Wellbeing (2010) Vision, Goals and Objectives. Available online at: http://www.ciw.ca/en/AboutTheCIWNetwork/VisionGoalsAndObjectives.aspx Last accessed: May 30, 2010.

Canadian Medical Association (2008) Illness Cost of Air Pollution. Available online at: http://www.cma.ca/index.php/ci_id/86830/la_id/1.htm Last accessed: October 11, 2010.

Canadian Parliament, Standing Senate Committee on Agriculture and Forestry (2003) Climate Change: We are at risk. Available online at: http://www.parl.gc.ca/37/2/parlbus/commbus/senate/Com-e/agri-e/rep-e/repfinnov03-e.htm Last accessed: March 5, 2010.

Carbon Dioxide Information Analysis Center (2011) Recent Greenhouse Gas Concentrations. Available online at: http://cdiac.ornl.gov/pns/current_ghg.html Last accessed: March 6, 2011.

Carley, M. and Spapens, P. (1998) *Sharing the World: Sustainable Living and Global Equity in the 21st Century*, Earthscan: London, UK

Caterpillar Global Mining (2008) The reclamation of Sudbury: the greening of a moonscape. *Viewpoint*, Issue 4. Available online at: http://www.cat.com/cda/files/1060442/7/ Last accessed: March 15, 2010.

CCME (2009) CCME Water Quality index FAQs. Available online at: http://www.ccme.ca/initiatives/waterfaqs.html#11 Accessed: October 7, 2010.

CCME Water Quality Index 1.0 Techical Report. Canadian Water Quality Guidelines for the Protection of Aquatic Life. Available online at: http://www.ccme.ca/assets/pdf/wqi_techrprtfctsht_e.pdf Last accessed: March 2, 2010.

Chapagain, A.K. and Hoekstra, A.Y. (2004) *Water Footprint of Nations: Volume 1. Main Report.* UNESCO-IHE: Institute for Water Education, Research Report Series No. 16. Available online at: http://www.waterfootprint.org/Reports/Report16Vol1.pdf Last accessed: April 23, 2010.

Commission on Environmental Cooperation (2006) Children's Health and the Environment in North America. A Final Report on Available Indicators and Measures. Available online at: http://www.cec.org/Storage/27/1799_CEC_Children_and_Health_en.pdf Last accessed: October 10, 2010.

Conference Board of Canada Report Card on Environment (2011). Environment. Key Messages. Available online at: http://www.conferenceboard.ca/HCP/Details/Environment.aspx Last accessed: September 29, 2010.

Conti, M. E. and Cecchetti, G. (2001) Biological monitoring: lichens as bioindicators of air pollution assessment - a review, *Environmental Pollution*, 114(3): 471-492.

COSEWIC Status Reports (2010) Available online at: http://www.cosewic.gc.ca/eng/sct2/index_e.cfm Last accessed: March 9, 2011

Costanza, R., d'Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, R.V., Paruelo, J., Raskin, P.S. and van den Belt, M. (1997) The Value of the World's Ecosystem Services and Natural Capital, *Nature*, 387: 253-260.

Daily, G.C. (1997). Introduction: What are ecosystem services? Pages 1-10 in G. Daily, editor. *Nature's Services: Societal Dependence on Natural Ecosystems*. Island Press: Washington, USA

Daly, H. (1977) *Steady-State Economics: The Economics of Bi-ophysi-cal Equilibrium and Moral Growth*, W. H. Freeman and Co.: San Francisco, USA

Daly, H.E. and Farley, J.C. (2004) *Ecological Economics, Principles and Applications*. Island Press: Washington, USA

Duchesne, L. and Ouimet, R. (2008) Population dynamics of tree species in southern Quebec, Canada: 1970-2005, *Forest Ecology and Management*, 255(7): 3001-3012.

Ecotrust Canada (2011) Accessing Federal Fisheries Data. Available online at: http://www.ecotrust.ca/fisheries/accessing-federal-fisheries-data Last accessed: March 11, 2011.

Energy Resources Conservation Board (2010) The Public Interest. Health Effects of Sour Gas. Available online at: http://www.ercb.ca/portal/server.pt/gateway/PTARGS_6_0_320_0_0_43/http;/ercbContent/pub lishedcontent/publish/ercb_home/public_zone/sour_gas/the_public_interest/HealthEffects.aspx Last accessed: October 11, 2010.

Environment Canada. (2008) Ground-level ozone exposure indicators by region, 1990-2006. Available online at: http://ec.gc.ca/indicateurs-indicators/default.asp?lang=en&n=89B1C598-1#AIRchart3E Last accessed: March 7, 2010.

Environment Canada. (2010) Water Quality Data. Available online at: http://www.ec.gc.ca/indicateurs-indicators/default.asp?lang=en&n=ADFCFBAB-1#wq1_en Last accessed: October 11, 2010.

Environment Canada (2008) Air Quality Trends. Air Quality Trends in Canadian Cities 1979-1992. Available online: http://www.etc-cte.ec.gc.ca/organization/aaqd/aqfact_e.html Last accessed: October 10, 2010.

Environment Canada (2008) Air Quality Indicator: Data Sources and Methods. Available online at: http://www.ec.gc.ca/indicateurs-indicators/default.asp?lang=En&n=DCC798B8-1&offset=6&toc=show Last accessed: April 27, 2010.

Environment Canada (2009) Average daily domestic water use. Available online at: http://www.ec.gc.ca/eau-water/1806BB6C-90A6-471A-AC27-AFA2F0F3C605/daily-domestic-use.gif Last accessed: October 12, 2010.

Environment Canada (2010) Measuring Sustainability: Canadian Environmental Sustainability Indicators. Available online at: http://www.ec.gc.ca/indicateurs-indicators/default.asp?lang=En&n=A073189E-1 Last accessed: October 9, 2010.

Environment Canada (2010) National Freshwater Quality. Available online at: http://www.ec.gc.ca/indicateurs-indicators/default.asp?lang=En&n=68DE8F72-1 Last accessed: October 9, 2010.

Environment Canada (2010) Sources of Water Pollution. Available online at: http://www.ec.gc.ca/indicateurs-indicators/default.asp?lang=En&n=88872F95-1 Last accessed: October 8, 2010.

Environment Canada (2010) Criteria Air Contaminants and Related Pollutants. Available online at: http://www.ec.gc.ca/Air/default.asp?lang=En&n=7C43740B-1 Last accessed: October 9, 2010.

Environment Canada (2010) Data and Publications. Municipal Water and Wastewater Survey. Available online at: http://www.ec.gc.ca/eau-water/default.asp?lang=En&n=ED0E12D7-1 Last accessed: October 12, 2010.

Environment Canada (2010) National Inventory Report – Part 1: 1990-2008. Available online at: http://www.ec.gc.ca/ges-ghg/default.asp?lang=En&n=0590640B-1 Last accessed: April 28, 2010.

Environment Canada (2010) Table 2-11: Summary of emissions and economic activity by sector, 1990 and 2008 Available online at: http://www.ec.gc.ca/ges-ghg/default.asp?lang=En&n=0590640B-1 Last accessed: April 28, 2010.

Environment Canada (2010) Annual National Pollutant Release Inventory (NPRI) Quality Assurance / Quality Control (QA/QC) Process. Available online at: https://www.ec.gc.ca/inrp-npri/default.asp?lang=en&n=40EED52A-1. Last accessed: March 9, 2011.

Environment Canada (2010) Air Quality Health Index. Available online at: http://www.ec.gc.ca/cas-aqhi/default.asp?Lang=En. Last accessed: March 9 2011.

Environment Canada. (2007) *Government of Canada Five-Year Progress Report: Canada-wide Standards for Particulate Matter and Ozone*. Available online: http://www.ec.gc.ca/Publications/default.asp?lang=En&xml=31B2381E-56BF-44CC-8D65-BF6FDB7125AD Last accessed: March 6, 2011.

Environment Canada (2010) Air Pollutant Emissions Data. Main air pollutants emissions trends for Canada, 1985 to 2008. Available online at: http://www.ec.gc.ca/indicateurs-indicators/default.asp?lang=en&n=C09D502F-1#ae_chart1_en Last accessed: March 6, 2011.

Environment Canada (2010) Air Quality Data. National ground-level ozone indicator, Canada, 1990 to 2008. Available online at: http://www.ec.gc.ca/indicateurs-indicators/default.asp?lang=en&n=B1385495-1#aq_chart1_o3_en Last accessed: March 6, 2011.

Environment Canada (2010) Greenhouse Gas Emissions Data. National greenhouse gas emissions, Canada 1990 to 2008. Available online at: http://www.ec.gc.ca/indicateurs-indicators/default.asp?lang=en&n=BFB1B398-1#ghg1_en Last accessed: March 6, 2011

Environment Canada. Publications (2010) 2010 Municipal Water Use Report. Municipal Water Use, 2006 Statistics. Available online at: http://www.ec.gc.ca/Publications/default.asp?lang=En&xml=596A7EDF-471D-444C-BCEC-2CB9E730FFF9 Last accessed: March 6, 2011.

European Commission (2009) *Mainstreaming the Economics of Nature: A synthesis of the approach, conclusions and recommendations of TEEB*. Available online at: http://www.teebweb.org/LinkClick.aspx?fileticket=bYhDohL_TuM%3d&tabid=1278&mid=2357 Last accessed: March 11, 2011.

Environment Canada (2010) Water Quality Data. Status of freshwater quality for protection of aquatic life at monitoring sites in selected river basin regions, Canada, 2005 to 2007. Available online at: http://www.ec.gc.ca/indicateurs-indicators/default.asp?lang=en&n=ADFCFBAB-1#wq2_en Last accessed: March 6, 2011.

Environmental Performance Index 2010 (2010) Available online at: www.epi.yale.edu. Last accessed: September 29th, 2010.

FAOSTAT (2011) Available online at: http://faostat.fao.org/ Las accessed: March 9, 2011

Federal, Provincial and Territorial Governments of Canada (2010) Canadian Biodiversity: Ecosystem Status and Trends 2010. Available online at: www.biodivcanada.ca/ecosystems Last accessed: March 4, 2011.

Gehring, M. W. and Streck, C. (2005) Emissions trading: lessons from SO_x and NO_x emissions allowance and credit systems legal nature, title, transfer, and taxation of emissions allowances and credits, *Environmental Law Reporter*, 35: 10219.

GeoBase (2009) Land Cover. Available online at: http://www.geobase.ca/geobase/en/data/landcover/index.html Last accessed: October 5th, 2010.

Goldberg, M.S., Burnett, R.T., Brook, J., Bailar, J.C. Valois, M-F, and Vincent, R. (2001) Associations between Daily Cause-specific Mortality and Concentrations of Ground-level Ozone in Montreal, Quebec, *American Journal of Epidemiology* 154(9):817-826.

Health Canada (2010) Health Effects of Air Pollution. Available online at: http://www.hc-sc.gc.ca/ewh-semt/air/out-ext/effe/health_effects-effets_sante-eng.php Last accessed: April 24, 2010.

Hoeskstra, A.Y. and Chapagain, A.K. (2007) Water footprints of nations: Water use by people as a function of their consumption pattern,*Water Resource Management*, 21:35-48.

Homer-Dixon, T. (2001) *The Ingenuity Gap*, Knopf Canada. Toronto

Homer-Dixon, T.F. (2001) *Environment, Scarcity and Violence*, Princeton University Press: New Jersey, and Homer-Dixon, T.F. (2009) *Carbon Shift: how the twin crises of oil depletion and climate change will define the future*, Random House: Toronto.

Hsu, T.C.T. (2003) Simple capacity indicators for peak-to-peak and data envelopment analyses of fishing capacity — a preliminary assessment, in *Measuring capacity in fisheries*, Eds. Pascoe, S.; Gréboval D., FAO Fisheries Technical Paper T445.

Infrastructure Canada (2003) The State Of Infrastructure In Canada: Implications for Infrastructure Planning and Policy. Available online: http://www.regionomics.com/infra/Draft-July03.pdf Last accessed: October 5 2010.

The Encyclopedia of Earth (2010) Arctic climate change scenarios for the 21st century projected by the ACIA-designated models. Available online at: http://www.eoearth.org/article/Arctic_climate_change_scenarios_for_the_21st_century_projected_by_the_ACIA-designated_models Last accessed: October 11, 2010

Intergovernmental Panel on Climate Change. IPCC Fourth Assessment Report: Climate Change 2007. Available online at: http://www.ipcc.ch/publications_and_data/publications_and_data_reports.htm#1 Last accessed: March 2, 2010.

Latifovic, R. and Pouliot, D. (2005) Multi-temporal land cover mapping for Canada: Methodology and Products, *Canadian Journal of Remote Sensing*, 31(5): 347-363.

Lefohn, A.S. (1992) *Surface level ozone exposures and their effects on vegetation*. Lewis Publishers: Boca Raton, Florida, USA

Leggett, C.G. and Bockstael, N.E. (2000) Evidence of the effects of water quality on residential land prices, *Journal of Environmental Economics and Management*, 39(2): 121-144.

Lindsey, C.R. (2007) *Congestion relief: Assessing the case for road tolls in Canada*, CD Howe Institute (Issue 248): Toronto, Canada

Louv, R. (2005) *Last Child in the Woods: saving our children from nature deficit disorder*. Algonquin Books. Chapel Hill: NC, USA

McDonough, W. and Braungart, M. (2002) *Cradle to Cradle: Remaking the Way We Make Things*, North Point Press: New York, USA

McMichael, A.J. and Githeko, A. (2001) Human Health. In *Climate Change 2001: impacts, adaptations, and vulnerability*. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change. McCarthy, J.J. et al. (Eds). New York, USA: Cambridge University Press.

McNiven C., and H. Puderer (2000), "Delineation of Canada's North: An Examination of the North-South Relationship in Canada", Geography working Paper Series, Statistics Canada Catalogue no. 92F0138M2000003. Statistics Canada, Environment Accounts and Statistics Division and Business Survey Methodology Division, 2010, special tabulation.

McRae, L., Loh, J., Collen, B., Holbrook, S., Amin, R., Latham, J., Tranquilli, S. and Baillie, J. (2007) Living Planet Index. Canadian Living Planet Report 2007 (Eds) S. Mitchell and A. Peller), WWF-Canada, Toronto, Canada.

Meinshausen, M., Hare, W., Wigley, T. M. M., Van Vuuren, D., Den Elzen, M. G. J. and Swart, R. (2006) Multi-gas Emissions Pathways to Meet Climate Targets. *Climatic Change* 75: 151–194.

Michalos, A.C. *et al.* (2010). An Approach to the Canadian Index of Wellbeing. Available online at: http://www.ciw.ca/Libraries/Documents/An_Approach_to_the_CIW.sflb.ashx. Last accessed May 30, 2010.

Millennium Ecosystem Assessment (2010). Overview of the Millennium Ecosystem Assessment . Available online at: http://www.millenniumassessment.org/en/About.aspx#1 Last accessed March 14, 2010.

Mudd, G.M. (2007) Global Trends in Gold Mining: Towards Quantifying Environmental and Resource Sustainability? *Resources Policy* 32 (1-2): 42-56.

Myers, R.A., and Worm, B. (2003) Rapid worldwide depletion of predatory fish communities, *Nature* 423: 280-283

Health Canada (2010) National Ambient Air Quality Objectives (NAAQOs). Available online at: http://www.hc-sc.gc.ca/ewh-semt/air/out-ext/reg-eng.php#a3 Last accessed: March 9, 2011.

National Energy Board (2008) Coal-Fired Power Generation - An Overview - Energy Brief. Available online at: http://www.neb-one.gc.ca/clf-nsi/rnrgynfmtn/nrgyrprt/lctrcty/clfrdpwrgnrtn2008/clfrdpwrgnrtnnrgybrf-eng.html Last accessed: October 8, 2010.

National Forest Inventory. NRCan (2010) Available online at: www.nfis.org Last accessed: March 8, 2011

Natural Resources Canada (2007) Geological Survey of Canada – Permafrost Communities and Climate Change. Available online at: http://gsc.nrcan.gc.ca/permafrost/communities_e.php Last accessed: October 12, 2010.

Natural Resources Canada (2009) The Atlas of Canada. Available online at: http://atlas.nrcan.gc.ca/site/english/maps/peopleandsociety/population/population2006/PopDist06/1. Last accessed: March 11 2011.

Natural Resources Canada (2010) Overview of Trends in Canadian Mineral Exploration. Available online at: http://www.nrcan.gc.ca/mms-smm/busi-indu/cme-ome/2009/cha-03-eng.htm Last accessed: March 6, 2011.

Natural Resources Canada (2010) Canadian Minerals Yearbook (CMY) 2008 – Uranium. Available online at: http://www.nrcan.gc.ca/smm-mms/busi-indu/cmy-amc/2008revu/htm-com/ura-ura-eng.htm Last accessed: October 11, 2010.

OECD (2009) OECD welcomes experts' call on need for new measures of social progress. Available online at: http://www.oecd.org/document/9/0,3343,en_2649_34487_43684683_1_1_1_1,00.html Last accessed: March 7, 2010.

Office of the Auditor General of British Columbia (2010) Conservation of Ecological Integrity in B.C. Parks and Protected areas. Available online at: http://www.bcauditor.com/pubs/2010/report3/conservation-ecological-integrity-bc-parks-and-protected- Last accessed: October 12, 2010.

Office of the Auditor General of Canada (2006) Opening Statement to the Standing Senate Committee on Energy, Environment and Natural, Resources. Available online at: http://www.oag-bvg.gc.ca/internet/English/oss_20080304_e_30182.html Last accessed: October 12, 2010

Office of the Auditor General of Canada (2009) 2009 Fall Report of the Commissioner of the Environment and Sustainable Development, The Commissioner's Perspective—2009. Available online at: http://www.oag-bvg.gc.ca/internet/English/parl_cesd_200911_00_e_33195.html Last accessed: October 12, 2010.

Office of the Auditor General of Canada (2010) 2010 Spring Report of the Auditor General of Canada, Chapter 5—Scientific Research—Agriculture and Agri-Food Canada. Available online at: http://www.oag-bvg.gc.ca/internet/English/parl_oag_201004_05_e_33718.html#hd5b Last accessed: October 12, 2010.

Ontario Ministry of the Environment (2005) "Transboundary air pollution in Ontario". Available online at: http://www.ene.gov.on.ca/environment/en/resources/STD01_076512.html Last accessed: October 4th, 2010.

Ontario Ministry of the Environment (2010) Ground-level Ozone. Available online at: http://www.airqualityontario.com/science/pollutants/ozone.cfm Last accessed: March 11, 2010.

Pandey, M.D. and Nathwani, J.S. (2003) Canada wide standard for particulate matter and ozone: cost-benefit analysis using a Life Quality Index, *Risk Analysis*, 23(1): 55-67.

Pauly D, Froese R, Christensen V. (1998) How pervasive is 'Fishing down marine food webs': response to Caddy et al. *Science*. 282 (5393): 1383

Pauly, D. and Watson, R. (2005) Background and interpretation of the 'Marine Trophic Index' as a measure of biodiversity, *Philos Trans R Soc Lond B*, 360 (1454): 415–423.

Pauly, D., Christensen, V., Guenette, S., Pitcher, T.J., Sumaila, R., Walters, C.J., Watson, R. and Zeller, D. (2002) Towards sustainability in world fisheries, *Nature* 418, 689-695.

Reid, W.V., H. A. Mooney, A. Cropper, D. Capistrano, S. R. Carpenter, K. Chopra, P. Dasgupta, T. Dietz, A. K. Duraiappah, R. Hassan, R. Kasperson, R. Leemans, R. M. May, A. J. McMichael, P. Pingali, C. Samper, R. Scholes, R. T. Watson, A.H. Zakri, Z. Shidong, N. J. Ash, E. Bennett, P. Kumar, M. J. Lee, C. Raudsepp-Hearne, H. Simons, J. Thonell, and M. B. Zurek (2005) *Ecosystems and Human Well-being: synthesis report.* Millennium Ecosystem Assessment. Available online at: http://www.maweb.org/documents/document.356.aspx.pdfLast accessed: March 8, 2011.

Richter, B.D., Braun, D.P., Mendelson, M.A., and Master, L.L. (2003) Threats to imperiled freshwater fauna, *Conservation Biology* 11(5): 1081-1093.

Rockström, J., Steffen, W., Noone, K., Person, A., Chapin III, S., Lambin, E.R., Lenton, T.M., Sceffer, M., Folke, C., Schellnhuber, H.J., Nykvist, B., de Wit, C.A., Hughes, T., van der Leeuw, S., Rodhe, H., Sorlin, W., Snyder, P.K., Costanza, R., Svedin, U., Falkenmark, M., Karlberg, L., Corell, R.W., Fabry, V.J., Hansen, J., Walker, B. Liverman, D., Richardson, K., Crutzen, P., and Foley, J.A. (2009) A safe operating space for humanity, *Nature*, 461: 472-475.

Rosenzweig, C. and Wilbanks, T.J. (2010) The state of climate change vulnerability, impacts, and adaptation research: strengthening knowledge base and community, *Climatic Change* 100(1): 103-106

Ryan, L. and Dziurawiec, S. (2001) Materialism and Its Relationship to Life Satisfaction, *Social Indicators Research* 55(2): 185-197.

Sahsuvaroglu, T., Merrett, M., Sears, M.R., McConnell, R., Finkelstein, N., Arain, A., Newbold, B., and Burnett, R.(2009) Spatial analysis of air pollution and childhood asthma in Hamilton, Canada: comparing exposure methods in sensitive subgroups, *Environmental Health*, 8:14

Savan, B., C. Gore and Morgan. A. (2004) Shifts in environmental governance in Canada: how are citizen environment groups to respond? *Environment and Planning C: Government and Policy* 22:605-619.

Sea Around Us Project. (2010) Marine Trophic Index in the Waters of Canada. Available online: http://www.seaaroundus.org/eez/124/200.aspx Last accessed: March 6, 2011.

Statistics Canada (2010) About the environmental and resource accounts. Availble online at: http://www.statcan.gc.ca/nea-cen/about-apropos/env-eng.htm Last accessed: October 10, 2010.

Statistics Canada (2010) Section 1: Food in Canada. Available online at: http://www.statcan.gc.ca/pub/16-201-x/2009000/part-partie1-eng.htm Last accessed March 11, 2011.

Statistics Canada (2010) Section 2: Canada's Water Supply – Stocks and Flows. Available online at: http://www.statcan.gc.ca/pub/16-201-x/2010000/part-partie2-eng.htm Last accessed: March 9, 2011.

Statistics Canada (2005) Human Activity and the Environment – Solid Waste in Canada. Available online at: http://www.statcan.gc.ca/pub/16-201-x/16-201-x2005000-eng.pdf Last accessed: October 14, 2010.

Statistics Canada (2005) Industrial Water Use Survey. Available online at: http://www.statcan.gc.ca/pub/16-401-x/2008001/5003964-eng.htm Last accessed: March 14, 2010.

Statistics Canada (2008) Canada's natural resource wealth at a glance. Available online at: http://www.statcan.gc.ca/pub/16-002-x/2007003/10454-eng.htm#chart5 Last accessed: October 9, 2010.

Statistics Canada (2009) Heavy Fuel Oil Consumption in Canada. Available online at: http://www.statcan.gc.ca/pub/11-621-m/11-621-m2007062-eng.htm Last accessed: October 11, 2010.

Statistics Canada (2009) Human Activity and the Environment: Annual Statistics 2009. Available online at: http://www.statcan.gc.ca/pub/16-201-x/16-201-x2009000-eng.pdf Last accessed: March 4, 2011.

Statistics Canada (2009) Energy Statistics Handbook. Fourth Quarter 2008. Available online at: http://www.statcan.gc.ca/pub/57-601-x/57-601-x2008004-eng.htm Last accessed: October 11, 2010.

Statistics Canada (2010) Energy Supply and Demand. Available online at: http://www.statcan.gc.ca/daily-quotidien/101214/dq101214b-eng.htm Last accessed: October 11, 2010.

Statistics Canada (2010) CANSIM. Available online at: http://cansim2.statcan.gc.ca/ Last accessed: March 11, 2011.

Statistics Canada (2010) Freshwater Supply and Demand in Canada. Available online at: http://www.statcan.gc.ca/daily-quotidien/100913/dq100913b-eng.htm Last accessed: March 11, 2011.

Statistics Canada (2011) Report on Energy Supply and Demand in Canada 2008. Available online at: http://www.statcan.gc.ca/bsolc/olc-cel/olc-cel?catno=57-003-X&CHROPG=1&lang=eng Last accessed: March 11, 2011.

Statistics Canada (2010) Landed catch and value. Sea fisheries landed catch. Available online at: http://www40.statcan.ca/l01/cst01/envi37a-eng.htm Last accessed: March 6, 2011.

Statistics Canada (2010) Waste Management Industry Survey: Business and Government Sectors. Available online at: http://dsp-psd.pwgsc.gc.ca/Collection/Statcan/16F0023X/16F0023XIE.html Last accessed: March 6, 2011.

Statistics Canada (2010) Water use in Canada, by Sector, 2005. Available online at: http://www.statcan.gc.ca/daily-quotidien/100913/t100913b1-eng.htm Last accessed: October 15, 2010.

Statistics Canada (2010). Canada's water supply—stocks and flows. Available online at: http://www.statcan.gc.ca/pub/16-201-x/2010000/part-partie2-eng.htm Last accessed:

Stern, N. (2007) *The Economics of Climate Change: the Stern Review*, Cambridge Press: Cambridge, UK.

Stiglitz, J., Sen, A., and Fitoussi, J-P. (2009) *Report by the Commission on the Measurement of Economic Performance and Social Progress*. Available online at: http://www.stiglitz-sen-fitoussi.fr/documents/rapport_anglais.pdf Last accessed: May 31, 2010.

Struck, D. 'Rapid Warming' Spreads Havoc in Canada's Forests. Washington Post Foreign Service. March 1, 2006. Page A01. Available online at http://www.washingtonpost.com/wp-dyn/content/article/2006/02/28/AR2006022801772.html Last accessed: March 11, 2011.

Swinyard, W.R., Kau, A.K., and Phua, H.Y. (2001) Happiness, materialism, and religious experience in the U.S. and Singapore, *Journal of Happiness Studies* 2(1): 13-32.

Suzuki, D. (2007) *David Suzuki: the autobiography*, Vancouver: Greystone Books, 405 pp.

Ryan, L. and Dziurawiec, S. (2001) Materialism and Its Relationship to Life Satisfaction, *Social Indicators Research* 55(2): 185-197.

The Council of Canadians. Safe water for First Nations Available online at: http://www.canadians.org/water/issues/First_Nations/index.html Last accessed: March 5, 2011.

United Nations (2010) Millennium Development Goals Report -.Goal 7: Ensure Environmental Sustainability. Available online at: http://www.un.org/millenniumgoals/environ.shtml Last accessed: October 15, 2010.

The Natural Step (2011) Available online at: www.naturalstep.org Last accessed: March 9, 2011.

Tidwell, J.H. and Allan, G.L. (2001) Fish as food: aquaculture's contribution - Ecological and economic impacts and contributions of fish farming and capture fisheries, *EMBO Reports* 2(11): 958–963.

Transport Canada (2006) The cost of urban congestion in Canada. Available online at: http://www.gatewaycouncil.ca/downloads2/Cost_of_Congestion_TC.pdf Last accessed: October 10, 2010.

U.S. Energy Information Administration (2006) International Total Primary Energy Consumption and Energy Intensity. Available online at: http://www.eia.doe.gov/emeu/international/energyconsumption.html Last accessed: October 11, 2010.

U.S. Environmental Protection Agency (2010) *Human Health and Environmental Effects of Emissions from Power Generation*. Available online at: http://www.epa.gov/capandtrade/documents/power.pdf Last accessed: October 11, 2010.

U.S. Environmental Protection Agency (2010) Ozone Air Quality Standards. Available online at: http://www.epa.gov/air/ozonepollution/standards.html Accessed: March 11, 2010.

United Nations (2011) Marine Trophic Index. Available online at: http://www.un.org/esa/sustdev/natlinfo/indicators/methodology_sheets/oceans_seas_coasts/marine_trophic_index.pdf Last accessed: October 17, 2010.

Victor, P., Hanna, J.E. and Kubursi, A. (1995) How Strong is Weak Sustainability? *Economie Appliquée* 48(2): 75-94.

Victor, P. (2008) *Managing without Growth: Slower by Design, Not Disaster*. Edward Elger Publishing Limited: Cheltenham, U.K.

World Bank (2004) World Bank Extractive Industries Review. Available online at: http://web.worldbank.org/WBSITE/EXTERNAL/TOPICS/EXTOGMC/0,,contentMDK:20306686~menuPK:592071~pagePK:148956~piPK:216618~theSitePK:336930,00.html Last accessed: October 11, 2010.

World Bank (2010) World Development Indicators. Available online at: http://data.worldbank.org/data-catalog/world-development-indicators?cid=GPD_WDI. Last accessed: September 29, 2010.

World Health Organization (2008) Air quality and health: fact sheet number 313. Available online at: http://www.who.int/mediacentre/factsheets/fs313/en/index.html Accessed: March 11, 2010.

Zoological Society of London – Institute of Zoology (2010) WWF/ZSL Living Planet Index. Available online at: http://www.zsl.org/science/research/research-projects/lpi,1162,AR.html Last accessed: October 11, 2010.

Appendix A: Notable National and International Environmental Reporting Initiatives

Report Title	Organization	Description	Link / Citation	Organizing Framework
Canadian Environmental Sustainability Indicators	Environment Canada (Government)	Through the Canadian Environmental Sustainability Indicators (CESI) initiative, the federal government reports on environmental indicators that track the long-term trends for issues of key concern to Canadians	http://www.ec.gc.ca/indicateurs-indicators/default.asp	Air Quality, Greenhouse Gas Emissions, Water Quality, Water Levels, Protected Areas
The State of the Nation's Ecosystem 2008	The Heinz Center (U.S. non-profit)	The report aims to provide a national perspective on the condition of the nation's ecological assets, one that is not limited by specific geographic boundaries, not focused on a specific problem or pollutant, and not aligned with any specific policy agenda.	The Heinz Center (2008) The State of the Nation's Ecosystems 2008: Measuring the Lands, Waters, and Living Resources of the United States	Core and habitat based indicators; divided across four main areas (extent and pattern, chemical and physical, biological components, and goods and services)
Human Activity and the Environment	Statistics Canada (Government)	This report has an emphasis on human activity and its relationship to natural systems-air, water, soil, plants and animals. Its aim is to paint a statistical portrait of Canada's environment.	Human Activity and the Environment: Annual Statistics. Available online at: www.statcan.gc.ca/bsolc/olc-cel/olc-cel?catno=16-201-XWE&lang=eng	State – pressure – response model
State of the Environment (1991, 1996)	Environment Canada (Government)	State of the Environment was originally created in 1990 to track the status of Canada's environment. It has been replaced by the Canadian Environmental Sustainability Indicators work by Environment Canada.	Environment Canada (1991) State of the Environment, Government of Canada: Ottawa, 750pp	State – pressure – response model
Biodiversity Indicators Partnership	United Nations (Gov't)	Twentyten.net is the biodiversity monitoring effort created under the Convention on Biological Diversity to determine whether the convention has begun to achieve its aims of stemming the loss of biodiversity.	www.twentyten.net	Biomes, habitats and ecosystems; Species; Protected areas; threatened species; genetic diversity (similar to Reed Noss's framework[16])

Report Title	Organization	Description	Link / Citation	Organizing Framework
Millennium Ecosystem Assessment	Various	The Millennium Ecosystem Assessment (MA) was started in 2001. The findings of over 1,360 experts provide an "appraisal of the condition and trends in the world's ecosystems and the services they provide (such as clean water, food, forest products, flood control, and natural resources) and the options to restore, conserve or enhance the sustainable use of ecosystems."[238]	www.millenniumassessment.org	Ecosystem services framework
World Resources Report	World Resources Institute (U.S. non-profit think tank) and various other institutions	The World Resources Report analyzes major environmental and development issues primarily for a policymaker audience. The most recent publications examine the correlation of development, the environment and government.	www.wri.org/project/world-resources-report	Various
Vital Signs	Worldwatch Institute (U.S. independent research organization)	Vital Signs is an annual report that tracks and analyzes trends. The number of trends changes from report to report, but these trends are divided into several categories which may include: food, agriculture, energy, transportation, environment, climate, global economy, resources, population, health and disease, and others.	www.worldwatch.org/taxonomy/term/39 or vitalsigns.worldwatch.org/	Energy and Transportation; Environment and Climate; Food and Agriculture; Economy and Resources; Population and Society

[238] Source: Millennium Ecosystem Assessment (2010). Overview of the Millennium Ecosystem Assessment . Available online at: http://www.millenniumassessment.org/en/About.aspx#1 Last accessed March 14, 2010.

Appendix B: Indicators Considered but Not Used

The following is a list of indicators for which data were available and considered, but ultimately rejected. A brief rationale is provided which briefly summarizes why the indicator was rejected:

ELEMENT	INDICATOR	RATIONALE FOR REJECTION
Air	Temperature deviations from norm	Data are sufficient, but other data sets were preferred given the limited number of stock and flow indicators to be included.
	% of commuters walking, biking, carpooling and using public transit	Insufficient data (time series is not yet sufficiently long to warrant inclusion).
Energy	# of LEED certified buildings	An insensitive indicator that considers only certified buildings; many buildings are built to standards but not certified.
Freshwater	Industrial water use	Insufficient data quality (no time series). Ultimately this data source should probably replace municipal water use as it is far more significant than residential water use.
	Water footprint	Insufficient time series and general data (e.g., industrial and agricultural water use) to fully generate quality data sets at present.
	Nutrient loading	Agricultural census data existed, but this represented a limited subset of data. Furthermore, nutrient loading was already captured to some extent in water quality index.
Non-Renewable Materials	Ecological Footprint	The earlier version of this report discussed inclusion of the Ecological Footprint and opted to not include it as a indicator.
	National Pollutant Release Inventory Index	While there are protocols in place to optimize the quality of NPRI data[239], the self-reporting nature of the information raises some concerns over the quality of this data set.
Biotic Resources	Species at Risk (numbers and changes by category)	Although data is available from COSEWIC,[240] a lack of systematic assessments creates biases in the data set.
	Mean maximum fish size	Inclusion of Living Planet Index (which

[239] Environment Canada, Annual National Pollutant Release Inventory (NPRI) Quality Assurance / Quality Control (QA/QC) Process https://www.ec.gc.ca/inrp-npri/default.asp?lang=en&n=40EED52A-1.

[240] COSEWIC Status Reports, http://www.cosewic.gc.ca/eng/sct2/index_e.cfm.

		contains information on marine species already) means that marine species would be biased in the index with the inclusion of another marine index.
	Area treated by pesticides	Data are available for agricultural and forestry lands, though unavailable in an urban context. Could have been added and is a strong candidate for future versions.
	Percent protected by ecoregion	At the time of publication, data were unavailable on an ecoregion basis and as such, total land area was used instead.
	Forest area under FSC Management	While FSC is generally recognized as the highest environmental management standard for forest management, it does not account for some other practices and does not provide a clear picture of overall forestry practices in the Canadian landscape. While some of these data are available, weightings would need to be applied to create a comprehensive index.
	Urban density	Urban density is often linked to compact, low-energy, walkable/bikeable areas (therefore low GHG), and also indicates a control on sprawl (which takes away land from native land cover). Given the limited space available in the report, other indicators were selected, but this could represent a good indicator in future reports.
	Government (Federal / Provincial / Territorial) spending on the environment as a percentage of total expenditures	Data existed, but more money is not necessarily money better spent. Since little could be inferred from the spending amounts (aside from the priority that environment played within a certain administration), the indicator was not selected.
	Environmental Management Practices	Statistics Canada has begun to gather significant amounts of environmental data in recent years, including data on environmental management practices. At present there is an insufficient time series to warrant inclusion, but this should change in time. It will not, however, solve the issue of implementation vs. effectiveness of those management practices.

Appendix C: Environment Domain Data

	AIR			ENERGY		FRESHWATER		
YEAR	Ground-Level Ozone (population weighted in parts per billion)	Criteria Air Contaminant Emissions Index	Absolute GHG Emissions (megatons of CO_2e / year)	Primary Energy Production (petajoules)	Energy Use - Final Demand (petajoules)	Water Quality Index	Water Yield in Southern Ontario (km^3)	Residential Water Use Rate (litres / person / day)
1980							1,325	
1981							1,390	
1982							1,320	
1983							1,355	342
1984							1,350	
1985		1.21					1,185	
1986		1.16					1,320	350
1987		1.22					1,165	
1988		1.25					1,300	
1989		1.09					1,175	357
1990	35.63	1.07	592	11,495.37	6,299.40		1,395	
1991	37.27	1.08	585	11,887.93	6,208.83		1,350	341
1992	33.81	1.06	602	12,196.17	6,327.59		1,325	
1993	32.89	1.00	604	13,077.80	6,447.44		1,245	
1994	36.17	1.00	624	13,913.30	6,654.75		1,285	335
1995	36.03	1.00	641	14,489.20	6,785.04		1,270	
1996	34.96	1.00	659	14,800.30	7,040.45		1,430	327
1997	36.05	0.99	672	15,284.40	7,095.48		1,460	
1998	39.44	0.98	678	15,368.70	6,956.18		1,200	
1999	39.76	0.99	691	15,358.20	7,132.50		1,420	
2000	34.94	0.98	717	15,768.40	7,375.97		1,210	
2001	40.66	0.98	711	15,894.90	7,175.44		1,200	335
2002	40.90	0.97	717	16,171.00	7,384.68		1,250	
2003	39.93	0.96	741	16,170.90	7,586.49		1,275	329
2004	36.22	0.94	741	16,553.70	7,681.58		1,335	
2005	39.90	0.92	731	16,489.90	7,688.48	73.54		
2006	37.88	0.87	718	16,815.50	7,552.43	73.68		327
2007	38.73	0.87	750	17,147.90	7,958.38	73.82		
2008	37.50	0.80	734	16,379.97	7,802.34	74.79		
2009	N/A	N/A	N/A	15,325.65	7,649.79	73.99		

	NON-RENEWABLE RESOURCES			BIOTIC RESOURCES		
YEAR	Viable Non-Renewable Energy Reserves Index	Viable Metal Reserves Index	Combined Per Capita Waste Disposal and Diversion Rate (tons / person / year)	Canadian Living Planet Index	Timber Sustainability Index	Marine Trophic Index
1980	1.480	1.966		1.02	0.617	3.61
1981	1.133	1.859		1.06	0.665	3.59
1982	1.253	1.816		1.07	0.743	3.63
1983	1.110	1.808		1.10	0.738	3.66
1984	0.867	1.713		1.13	0.740	3.65
1985	0.877	1.626		1.20	0.761	3.64
1986	0.883	1.519		1.22	0.714	3.63
1987	0.860	1.416		1.25	0.655	3.62
1988	0.827	1.377		1.25	0.661	3.56
1989	0.830	1.331		1.28	0.500	3.54
1990	0.983	1.195		1.28	0.793	3.53
1991	1.017	1.107		1.27	0.773	3.53
1992	1.030	1.018		1.27	0.812	3.43
1993	1.043	0.982		1.27	0.755	3.31
1994	1.000	1.000		1.26	0.882	3.22
1995	1.613	0.987		1.25	0.634	3.15
1996	1.433	1.000		1.22	0.724	3.18
1997	1.397	0.874		1.18	0.743	3.15
1998	1.443	0.814		1.11	0.788	3.13
1999	1.390	0.681		1.05	0.714	3.13
2000	1.457	0.615	952	1.00	0.780	3.02
2001	1.507	0.593		0.97	0.888	3.06
2002	1.463	0.534	980	0.95	0.753	3.02
2003	1.430	0.463		0.96	0.932	3.06
2004	1.480	0.508	1013		0.977	3.04
2005	1.437	0.542			1.022	3.08
2006	1.410	0.647	1074		1.066	3.05
2007	1.607	0.627				
2008			1031			
2009						

Baseline year highlighted in grey.

Appendix D: Greenhouse Gases that Contribute to Climate Change

The following are the primary greenhouse gases and their global warming potential.[241]

GREENHOUSE GAS	DESCRIPTION	GLOBAL WARMING POTENTIAL (carbon dioxide equivalents)
Carbon dioxide (CO_2)	A naturally occurring gas produced by living organisms and fermentation, CO_2 is also produced by the burning (combustion) of hydrocarbon-based fuels, deforestation, biomass burning, and industrial processes such as aluminum smelting and lime production.	1
Methane (CH_4)	A naturally occurring, flammable gas emitted by geological coal formations and by the decomposition of organic matter. Landfills are a major source of CH_4 emissions in Canada. Other sources include enteric fermentation, manure management, biomass burning, production and processing of oil and natural gas, and coal mining.	25
Nitrous oxide (N_2O)	Naturally occurring from microbial action in soil, N_2O is also produced by the application of nitrogen fertilizers, soil cultivation, production of nitric acid and adipic acid, and the combustion of fossil fuels and wood.	298
Sulphur hexafluoride (SF_6)	A colourless gas soluble in alcohol and slightly soluble in water. It is mainly applied as cover gas in the production of magnesium. It can also be used as insulating material for high-voltage transformers and circuit breakers.	22,800
Per-fluorocarbons (PFCs)	Synthetic chemicals composed of carbon and fluorine with high global warming potentials and atmospheric lifetimes of up to 50 000 years. PFCs are principally emitted as by-products during aluminum smelting.	4,750 to 10,900
Hydro-fluorocarbons (HFCs)	Synthetic chemicals containing carbon, hydrogen and fluorine. HFCs are used in various applications such as air-conditioning systems, refrigeration systems, firefighting agents, aerosols and foam-blowing agents.	725 to 2,310

[241] Carbon Dioxide Information Analysis Center (2010) Recent Greenhouse Gas Concentrations. Available online at: http://cdiac.ornl.gov/pns/current_ghg.html Last accessed: March 14, 2010.

Appendix E: Assessment of Indicators from Other Reporting Efforts

ESTR = Ecosystem Status and Trends Report (Environment Canada); CESI = Canadian Environmental Sustainability Index (Environment Canada); Phase I – CIW = Phase I of the Canadian Index of Wellbeing; UNCSD = United Nations

Victor's Six Essentials of Life	Indicator	ESTR	CESI	Phase I-CIW	UNCSD	OECD	EPI	MDG	EU	Conf Board of Can	COUNT
Air	Air Quality Health Index (made up of ground-level ozone, $PM_{2.5/10}$, and NO_2)			Yes		Yes?					2
	Ground-level ozone levels/emissions		Yes				Yes		Yes?		2
	$PM_{2.5}$ levels/emissions		Yes				Yes		Yes	Yes	3
	NO_x levels/emissions					Yes			Yes	Yes?	3
	SO_x levels/emissions					Yes	Yes		Yes	Yes?	4
	Ozone depleting substances				Yes	Yes	Yes	Yes	Yes		5
	Per capita VOC emissions					Yes				Yes?	2
	Exceedance of air quality limit values in urban areas								Yes		1
	Ecosystem exposure to acidification, eutrophication and ozone								Yes		1
	Carbon monoxide					Yes					1
	Atmospheric concentrations of ozones depleting substances					Yes					1
	Stratospheric ozone levels					Yes					1
	Ground level UV-B					Yes					1
	CFC recovery rate					Yes					1
	Percentage of cars equipped with catalytic converters					Yes					1
	Capacity of SO_x/NO_x abatement equipment at stationary sources					Yes					1

	Urban traffic density					Yes					1
	Urban car ownership					Yes					1
	Asthma / heat deaths?										
	Water Quality Index		Yes	Yes			Yes			Yes	2
	Groundwater? Index?										0
	Per capita water demand? Water intensity?		Yes			Yes				Yes	2
	Water withdrawals as a percentage of total water resources used		Yes			Yes	Yes?	Yes	Yes?		4
	Adequate sanitation / urban wastewater treatment					Yes?		Yes	Yes		3
Freshwater	Drinking water							Yes			1
	Oxygen consuming substances in rivers (and lakes)				Yes?	Yes?			Yes		3
	Nutrients in water bodies					Yes?			Yes		2
	Bathing water quality								Yes		1
	Exceedance of critical loads of pH levels in water (and soils)					Yes					1
	Concentration of heavy metals in rivers					Yes					1
	Water shortages					Yes					1
	Water pricing					Yes					1
	Per capita energy demand					Yes?			Yes?	Yes	3
	Renewable energy (emissions per MJ)						Yes?		Yes	Yes	3
Energy	GHG emissions (per capita) - also by source; absolute/intensity/GDP;		Yes		Yes	Yes?	Yes	Yes	Yes?	Yes	6
	GHG emissions - carbon intensity		Yes			Yes?	Yes		Yes?		3
	Passenger transport demand								Yes		1

	Projections of greenhouse gas emissions and removals								Yes		1
	Atmospheric greenhouse gas concentrations					Yes			Yes		2
	Use of cleaner / alternative fuels								Yes		1
	Energy efficiency / energy intensity of GDP				Yes	Yes					2
	Distance travelled					Yes					1
	Carbon budget			Yes							0
	Carbon-related economic and fiscal instruments					Yes					1
Minerals	Per capita (municipal) waste production and recycling				Yes	Yes?			Yes?	Yes	4
	Average urban recycling rates? Diversion rates?				Yes	Yes?					2
	Timber Sustainability Index? FSC area (broken by type/jur)?			Yes		Yes?	Yes?			Yes	3
	Hazardous waste					Yes					1
	Road vehicles					Yes					1
	Nuclear waste					Yes					1
	Emissions of heavy metals					Yes					1
	Emissions of organic compounds					Yes					1
	Changes of toxic content of in products and production processes					Yes					1
	Market share of unleaded petrol					Yes					1
	Intensity of use of material resources				Yes	Yes					2
	Economic and fiscal instruments					Yes					1
	Brownfields reclaimed										

	Toxicity (NPRI and contaminant levels in select individuals in country)										
	Wetland extent (area)	Yes		Yes							0
	Agricultural land availability (area)			Yes		Yes?					1
	Agricultural area under organic farming (area)								Yes	Yes	2
	Forest cover (area)				Yes	Yes		Yes		Yes	4
	Urban density? / Urbanization				Yes	Yes					2
	Global and Canadian temperature					Yes			Yes		2
	Land take								Yes		1
	Progress in management of contaminated sites								Yes		1
	Fragmentation	Yes									
Space	% of hectares using zero-till seeding practices	Yes									
	Area of occupancy	Yes									
	Seagrass extent	Yes									
	Grassland extent	Yes									
	Extent of disturbances - fire	Yes									
	Extent of defoliation	Yes									
	Extent affected – pine beetle	Yes									
	Peatland extent (wetlands with >40cm organic soil)	Yes									
	Forest patch integrity	Yes									
	Range shift (distance/year)	Yes									
	Wildlife habitat capacity on agricultural land	Yes									
Genetic	COSEWIC listings (% At risk,	Yes			Yes	Yes	Yes?	Yes?	Yes	Yes	6

Resources	may be at risk, sensitive, secure)										
	Fisheries - Total catch/production? CPUE? Trawling intensity? L index/secondary productivity?	Yes			Yes	Yes?	Yes?				3
	Fisheries - MTI?						Yes			Yes	2
	Fisheries - Proportion/% of fish stocks within safe biological limits? Mean Max Fish Length (MMFL)? # of stocks declining? OHI?							Yes	Yes?		2
	Size of spawning stocks	Yes				Yes					1
	Bird index (Xmas bird count?)	Breedin g Bird Survey abundan ce index									0
	Abundance and dist of selected species / Wild Commodity Index										0
	Protected areas (area by IUCN category)		Yes	Yes	Yes	Yes	Yes	Yes	Yes		5
	Environmental Burden of disease (DALY)					Yes?	Yes				2
	Species diversity								Yes		1
	Soil quality								Yes?		1
	Degree of topsoil losses					Yes					1
	Aquaculture production								Yes		1
	Fertilizer use				Yes	Yes					2
	Livestock					Yes					1
	Pesticide use / consumption of pesticides				Yes	Yes					2

	Fishing fleet capacity / quotas					Yes			Yes		2
	Ecosystem integrity			Yes		Yes?					1
	Area of key ecosystems				Yes	Yes					2
	Grassland health	Yes	Yes								
	Within-species abundance	Yes									
	Plankton abundance (CPUE)	Yes									
	Abundance (Productivity index (returns/spawner), return numbers, biomass, number of individuals, tonnes caught, density, juvenile production)	Yes									
	Coastal erosion	Yes									
	Recovery (number of sites occupied, abundance)	Yes									
	Changes in contaminant concentration	Yes									
	Changes in nutrient concentration	Yes									
	Algal blooms (changes in number/density (biomass), changes in number of water bodies with blooms, changes in bloom composition)	Yes									
	Changes in community composition (vegetation categories)	Yes									
	Primary productivity	Yes									
	Changes in timing of bird migration and nesting	Yes									
	Population status (% increasing, stable, decreasing)	Yes									
	Forest composition (age/size class distributions)	Yes									

	Annual occurrence index (% stations present)	Yes									
Other	Timing of sea ice freeze-up	Yes									
	Lake level	Yes									
	Water body temperature	Yes									
	Changes in seasonal flow rates	Yes									
	Changes in lake pH	Yes									
	Sea temperature	Yes									
	Ocean acidification	Yes									
	Oxygen depletion	Yes									
	Sulfate emissions	Yes									
	Changes in temperature	Yes									
	Changes in precipitation	Yes									
	Sea-level rise	Yes									
	Change in permafrost temperatures	Yes									
	Change in time of spring melt	Yes									
	Change in glacier mass/ ice thickness	Yes									
	Sea-ice/Lake ice extent	Yes									
	Concentrations of contaminants	Yes									
	Concentration of nutrients	Yes									
	Percentage growth in land trusts	Yes									
	Number of registered conservation easements present	Yes									
	Growth of conservation-based tax incentive structures	Yes									
	Value in dollars	Yes									
	Population growth and density				Yes	Yes					2

	Official Development Assistance (ODA)				Yes	Yes					2
	Growth and structure of GDP				Yes	Yes					2
	Private and government final consumption expenditure					Yes					1
	Industrial production					Yes					1
	Structure of energy supply				Yes	Yes					2
	Road traffic; volumes					Yes					1
	Stock of road vehicles					Yes					1
	Agricultural production					Yes					1
	Environmental expenditure					Yes					1
	Pollution abatement and control expenditure					Yes					1
	Public opinion					Yes					1
	Invasive species (extent/range)	Yes									

Based in the Faculty of Applied Health Sciences at the University of Waterloo, the Canadian Index of Wellbeing Network is an independent, non-partisan group of national and international leaders, researchers, organizations, and grassroots Canadians. Its mission is to report on wellbeing at the national level and promote a dialogue on how to improve it through evidence-based policies that are responsive to the needs and values of Canadians.

The Network's signature product is the Canadian Index of Wellbeing (CIW). The CIW measures Canada's wellbeing and tracks progress in eight interconnected categories. It allows us, as Canadians, to see if we are better off or worse off than we used to be — and why. It helps identify what we need to change to achieve a better outcome and to leave the world a better place for the generations that follow.

The Honourable Roy J. Romanow, Chair
The Honourable Monique Bégin, Deputy Chair

Measuring what matters

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