

Canadian Environmental Sustainability Indicators

2006

Greenhouse Gas Emissions Indicator Data Sources and Methods

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Environment Canada
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1. Introduction

Canadians' health and their social and economic well-being are fundamentally linked to the quality of their environment. Recognizing this, in 2004, the Government of Canada committed to establishing national indicators of air quality, greenhouse gas emissions, and freshwater quality. The goal of these indicators is to provide Canadians with more regular and reliable information on the state of their environment and how it is linked with human activities. Environment Canada, Statistics Canada, and Health Canada are working together to develop and communicate these indicators. Reflecting the joint responsibility for environmental management in Canada, this effort has benefited from the cooperation and input of the provinces and territories.

This report is part of a suite of documents released under the Canadian Environmental Sustainability Indicators (CESI) initiative.¹ Each indicator reported in a given year under CESI has an associated "data sources and methods" report to provide technical detail and other background that will facilitate interpretation of the indicator or allow others to conduct further analysis using the CESI data and methods as a starting point.

This report deals with the underlying methods and data for the greenhouse gas emissions indicator as published in the 2006 CESI report.

2. Description of the indicator

The greenhouse gas (GHG) emissions indicator reports the trend in human-made greenhouse gas emissions at a national, provincial/territorial, and sectoral level for the six main greenhouse gases in Canada: carbon dioxide, methane, nitrous oxide, sulphur hexafluoride, perfluorocarbons, and hydrofluorocarbons.

The indicator is based on GHG emissions data taken directly from the 2006 National Inventory Report (NIR) prepared by Environment Canada, entitled *National Inventory Report: 1990–2004, Greenhouse Gas Sources and Sinks in Canada*. As an Annex I Party (developed countries) to the United Nations Framework Convention on Climate Change (UNFCCC), Canada is required to prepare and submit a national inventory of anthropogenic sources and sinks of greenhouse gases on an annual basis.

Since direct measurement of emissions from all sources is not practical, the UNFCCC requires that countries develop, update, publish, and maintain national inventories using comparable emissions estimation methods.

Descriptions of the six greenhouse gases estimated and their main Canadian sources are outlined in Text table 1. Emissions from natural sources (material decay, plant and animal respiration, volcanic and thermal venting, etc.) and absorption of emissions by natural sinks (forests, oceans) are not measured by this indicator.

1. www.environmentandresources.ca and www.statcan.ca

Text table 1 Greenhouse gas descriptions and main sources

Greenhouse gas	Description
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 aluminium smelting and lime production.
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 of CH ₄ emissions include enteric fermentation, ² manure management, biomass burning, production and processing of oil and natural gas, and coal mining.
Nitrous oxide (N ₂ O)	Naturally occurring from microbial action in soil, N ₂ O is also emitted by the application of nitrogen fertilizers, soil cultivation, production of nitric acid and adipic acid, and the combustion of fossil fuels and wood.
Sulphur hexafluoride (SF ₆)	A colorless 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.
Perfluorocarbons (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 aluminium smelting.
Hydrofluorocarbons (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.

Sources: Derived from the Global Development Research Centre: Urban Environmental Management – Urban Waste Management GHG definitions (www.gdrc.org/uem/waste/waste-gases.html) and the United Nations Framework Convention on Climate Change glossary, (http://unfccc.int/resource/cd_roms/na1/ghg_inventories/english/8_glossary/Glossary.htm)

Estimates are provided at the national level, the provincial/territorial level, and the sectoral level for five economic sectors: energy, industrial processes, solvent and other product use, agriculture, and waste. Provincial and territorial emission totals do not include emissions from consumption of halocarbons, or from fugitive refinery emissions, since the activity data associated with these sources are only available at the national level. Emission estimates for use of mineral products, such as limestone, dolomite, soda ash, and magnesite, are also not available at provincial and territorial levels. Ammonia production-related process emissions are included under “Undifferentiated Production” at the provincial level (Environment Canada, 2006).

Text table 2 provides a description of the main sources of the greenhouse gas emissions included in the indicator, broken down by economic sector.

Although the greenhouse gas emissions indicator is quite comprehensive, some emission sources have not been included as a result of exclusions within the NIR. Owing to their relatively small contributions to the total emissions, these exclusions do not significantly affect the overall completeness of the inventory. A detailed discussion of the emission sources not included can be found in Annex 5 of the NIR (Environment Canada, 2006).

2. The digestion of carbohydrates by organisms in livestock.

Data from the land use, land-use change and forestry sector are excluded from the national totals in the NIR and therefore are not included in the CESI report. The National Round Table on the Environment and the Economy's *Environment and Sustainable Development Indicators for Canada* report recommended that the GHG indicator exclude sources and sinks from land-use change and forestry (National Round Table on the Environment and the Economy, 2003).

Text table 2 Sources of greenhouse gas emissions by sector

Source Categories	Description
ENERGY	
a) Stationary fuel combustion	
Electricity and heat generation	Emissions from fuel consumed by:
Electricity generation	Utility and industry electricity generation
Heat generation	Steam generation (for sale)
Fossil fuel industries	Emissions from fuel consumed by:
Petroleum refining and upgrading	Petroleum refining industries (including upstream facilities)
Fossil fuel production	Conventional and non-conventional oil and gas production industries (some refining is included)
Mining	Emissions from commercial fuel sold to:
	Metal and non-metal mines, stone quarries, and gravel pits
	Oil and gas extraction industries
	Mineral exploration and contract drilling operations
Manufacturing industries	Emissions from fuel consumed by the following industries:
	Iron and steel (steel foundries, casting and rolling mills)
	Non-ferrous metals (aluminium, magnesium, and other production)
	Chemical (fertilizer manufacturing, organic and inorganic chemical manufacturing)
	Pulp and paper (primarily pulp, paper, and paper product manufacturers)
	Cement production
	Other manufacturing industries not listed (such as automobile manufacturing, textiles, food and beverage industries)
Construction	Emissions from fuels consumed by the construction industry – buildings, highways, etc.
Commercial and institutional	Emissions from fuel consumed by:
	Service industries related to mining, communication, wholesale and retail trade, finance and insurance, real estate, education, etc.
	Federal, provincial, and municipal establishments
	National Defence and Canadian Coast Guard
	Train stations, airports, and warehouses
Residential	Emissions from fuel consumed for personal residences (homes, apartment hotels, condominiums, and farmhouses)
Agriculture and forestry	Emissions from fuel consumed by:
	Forestry and logging service industry
	Agricultural, hunting and trapping industry (excluding food processing, farm machinery manufacturing and repair)
b) Transportation	Emissions resulting from combustion and/or fugitive releases due to moving passengers, freight, and commodities throughout Canada
Domestic aviation	Emissions resulting from the consumption of fossil fuels by Canadian-registered airlines flying domestically
Road transportation	Emissions resulting from the consumption of fossil fuels by vehicles licensed to operate on roads
Railways	Emissions resulting from the consumption of fossil fuels by Canadian railways
Domestic marine	Emissions resulting from the consumption of fossil fuels by Canadian-registered marine vessels fuelled domestically

Source Categories	Description
Others – off-road	Emissions resulting from the consumption of fossil fuels by combustion devices not licensed to operate on roads
Others – pipelines	Emissions resulting from the transportation and distribution of crude oil, natural gas, and other products
c) Fugitives	Intentional and unintentional releases of greenhouse gases from the following activities:
Coal mining	Underground and surface mining
Oil and natural gas	Conventional and unconventional oil and gas exploration, production, transportation, and distribution
INDUSTRIAL PROCESSES	Emissions resulting from the following process activities:
a) Mineral production	Production of cement and lime; use of soda ash, limestone and dolomite, and magnesite
b) Chemical industry	Production of ammonia, nitric acid, and adipic acid
c) Metal production	Production of aluminium, iron, and steel; magnesium production and casting
d) Consumption of halocarbons and SF₆	Use of HFCs and/or PFCs in air-conditioning units, refrigeration units, fire extinguishers, aerosol cans, solvents, foam blowing, semi-conductor manufacturing, and electronics industry; use of SF ₆ in electrical equipment and semi-conductors
e) Other and undifferentiated production	Non-energy use of fossil fuels
SOVENT AND OTHER PRODUCT USE	Emissions resulting from the use of N ₂ O as an anaesthetic and propellant
AGRICULTURE	Emissions resulting from:
a) Enteric fermentation	Livestock
b) Manure management	Livestock waste management
c) Agricultural soils	
Direct N ₂ O emissions	Emissions resulting from synthetic fertilizer, crop residue, and cultivation of organic soils, and summer-fallow and conservation tillage practices
N ₂ O emissions from manure on pasture, range and paddock	Emissions resulting from manure nitrogen on pasture and cropland
Indirect N ₂ O emissions	Emissions from volatilization, leaching, and runoff of animal manure nitrogen and synthetic fertilizer nitrogen
WASTE	Emissions resulting from:
a) Solid waste disposal on land	Municipal solid waste and wood waste landfills
b) Wastewater handling	Domestic and industrial wastewater treatment
c) Waste incineration	Municipal solid waste and municipal wastewater treatment sludge incineration

Source: Environment Canada, 2006

3. How the indicator is used

The greenhouse gas emissions indicator is used to track progress in Canada’s efforts to lower emissions and reach our environmental performance objectives. Measuring the greenhouse gas emissions indicator in conjunction with economic performance indicators such as the gross domestic product (GDP) will help to support national-level decision making on sustainable development. Sectoral and geographic breakdowns have been used to inform policy development and emissions reduction plans.

4. How the indicator is calculated

Data used to produce the greenhouse gas emissions indicator come directly from the NIR and do not undergo any further manipulation. The inventory follows the internationally approved methods developed by the Intergovernmental Panel on Climate Change (IPCC) to estimate emissions for the six greenhouse gases outlined in Text table 1. The IPCC guidelines (www.ipcc-nggip.iges.or.jp/public/gl/invs1.htm) are approved and developed through an international process that includes comments from national experts, testing of methods through preliminary inventory development, country studies, technical and regional workshops, and informal expert groups (IPCC, 1997).

4.1 Methods

In general, the same approach to estimating emissions is applied across the various gases and human activities. Emissions are estimated by multiplying activity data³ by specific emission factors.⁴ At a simple level, the calculation is:

$\text{Emissions} = \text{activity data} \times \text{emission factor}$

The IPCC guidelines provide various methods for calculating a given emission. The methods for estimating the gases are divided into “tiers” encompassing different levels of activity and technological detail. The same general structure is used, but the level of detail at which the calculations are carried out can vary. “Tier 1” methods are generally very simple, requiring less detail and expertise than the most complicated “Tier 3” methods. For example, electricity and heat generation could be measured using three different methods. A Tier 1 method would entail mass-balance calculations based on aggregated country-wide (or regional) statistics on consumption of basic fuels. A Tier 2 method would involve emission calculation by source types, based on fuel use for each industry and sector of the economy. A Tier 3 method would utilize source-specific data and could be used for only a small number of principal emission sources.

The intention of this tiered structure is to encourage countries to work at the most detailed level possible, while ensuring that for those countries that do not have detailed

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3. Activity data refers to the quantitative amount of human activity resulting in emissions during a given period of time. The annual activity data for fuel combustion sources, for example, are the total amounts of fuel burned. In the agriculture sector, annual activity data for methane emissions from enteric fermentation are the total number of animals, by species.
 4. Based on samples of measurement data, emission factors are representative rates of emissions for a given activity level under a given set of operating conditions. They are the estimated average emission rate of a given pollutant for a given source, relative to units of activity.

data, estimates can be made. The Tier 2 and Tier 3 methods are expected to produce more accurate emission estimates, but are more resource-intensive, as they usually require collection of more detailed data and a more thorough understanding of technologies.

Text table 3 describes the methods used to estimate some of Canada's greenhouse gas emissions. This table illustrates that the selection of IPCC method type is highly dependent on the availability of data for emission factor development.

Text table 3 Types of methods employed in estimating selected sources for Canada's GHG emissions

Category	IPCC method type	Notes
Energy – fuel combustion	Tier 2	Emission estimations are based on detailed fuel/technology information covering stationary and mobile sources.
Energy – fugitive emissions	Tier 2/Tier 3 hybrid	A hybrid approach is appropriate in situations when specific measurement data are available for only a subset of the data (i.e. coal-specific emissions).
Industrial processes – ammonia production	Tier 1	Based on the use of national production data and an average national emission factor.
Industrial processes – nitric acid production	Tier 2	Uses Canada-specific emission factors based on the type of abatement technology employed at individual plants.
Industrial processes – adipic acid production	Tier 3	Based on direct observation reports of facility-specific emissions data.
Agriculture – enteric fermentation	Tier 1/Tier 2	Uses domestic animal population data and average emission factors for all animal categories except cattle, where country-specific emission factors are applied.
Agriculture – manure management	Tier 1/Tier 2	Uses domestic animal population data and average emission factors for manure N ₂ O (Tier 1), and country-specific emission factors for manure CH ₄ (Tier 2) for all animal categories.
Agriculture – soil emissions of nitrous oxide	Tier 1/Tier 2	All emissions in this category are calculated using the Tier 2 emission factors, except for N ₂ O emissions from cultivation of organic soils (Tier 1).
Waste – solid waste disposal on land	Tier 2	Uses a model to produce an emission profile that reflects the pattern of the degradation of waste over time.

Source: Derived from Environment Canada (2006) and IPCC (1997)

To better understand the variation and complexities that arise in estimation methods, the following two sections provide examples of the methods used to calculate greenhouse gas emissions. The first example provides an overview of the methods used to estimate emissions from fuel combustion, while the second illustrates how methane gas is estimated for Canadian dairy and beef cattle.

4.1.1 Example of estimating emissions: fuel combustion

The energy sector includes emissions of all greenhouse gases from the production and use of fuels for the primary purpose of delivering energy. Emissions in this sector are classified as either fuel combustion or fugitive releases.⁵

Emissions from fuel combustion for all energy sub-sectors are estimated using the following equation:

$$\text{Emissions} = \text{quantity of fuel combusted} \times \text{emission factor per physical unit of fuel}$$

The fuel energy-use data used to estimate the combustion emissions are taken from Statistics Canada's annual energy supply and demand report (Statistics Canada, 2005). The fuel- and technology-specific emission factors used to estimate the emissions can be found in Annex 13 of the NIR (Environment Canada, 2006). These factors are based upon the physical quantity of fuel combusted and are subdivided by the type of fuel used.

The equation above applies to all source sectors; however, more detailed methods are often used. Fuel combustion emissions attributed to the transport sector, for example, are calculated using Canada's Mobile Greenhouse Gas Emission Model (MGEM05). This model is used to disaggregate fuel statistics into 23 categories that represent the estimated amount of fuel consumed by vehicles of similar emission characteristics determined as a function of their model year, fuel, and vehicle type. A detailed discussion of this specific method can be found in Section 3.1.3 of the NIR (Environment Canada, 2006).

5. These are intentional or unintentional releases of gases from fuel production activities. In particular, they may arise from the production, processing, transmission, storage, and use of fuels and include emissions from combustion only when it does not support a primary activity, e.g., flaring of natural gases at oil and gas production facilities (Environment Canada, 2006).

4.1.2 Detailed example of applying the method: methane gas from enteric fermentation

National methane gas emission estimations for dairy and beef cattle are derived using methodologies provided by the IPCC and use the following calculation:

Methane emission estimates for Canadian dairy and beef cattle

$$CH_4 = \sum_{l=1}^n (P_l \times EF_l)$$

where

CH_4	=	Enteric fermentation methane emissions for all animal categories
P_l	=	Animal population (P) for each specific livestock category or sub-category (l)
EF_l	=	Methane emissions factor for each specific livestock category (l)

Methane emission estimates for Canadian cattle are calculated using the following steps:

- Step 1:** Cattle are divided into two sub-categories based on the IPCC Tier-2 methodology, along with specific information on animal sub-category, physiological status, age, gender, weight, rate of gain, level of activity, and production environment.
- Step 2:** Emission factors are calculated for each cattle sub-category (dairy cows, dairy heifers, beef cows, bulls, calves <1 year, heifer replacement, heifers >1 year, and steers >1 year) by province and then combined to produce a weighted national average emission factor.
- Step 3:** National enteric emissions are calculated by multiplying the emission factor with its cattle sub-category population, and by summing up estimates for all cattle sub-categories.

For more detailed information on the methods used to estimate emissions in each source category, refer to Chapters 3 through 8 and Annexes 2 and 3 in the NIR (Environment Canada, 2006).

4.2 Reporting units

The greenhouse gas emissions indicator uses the same source categories as are used in the NIR, following the same sub-sector breakdown. This reporting format is agreed upon internationally, and groups emissions into the following six sectors: energy; industrial processes; solvent and other product use; agriculture; land use, land-use change and forestry; and waste. Each of these categories is further subdivided and follows UNFCCC sector and sub-sector divisions closely, with some minor differences. As previously discussed, the indicator does not include data from the land use, land-use change and forestry category. Refer to Text table 2 for a list of all source categories for which greenhouse gas emissions are estimated by the indicator.

Greenhouse gases differ in their ability to absorb heat in the atmosphere based on their chemical properties and lifetime in the atmosphere. For example, over a period of 100 years, methane is 21 times as powerful as carbon dioxide in terms of its potential to trap heat in the atmosphere, so it is considered to have a “global warming potential” of 21. Therefore, greenhouse gas emissions are reported in terms of “carbon dioxide equivalents,” determined by multiplying the amount of emissions of a particular gas by

the global warming potential of that gas. The IPCC publishes the global warming potentials for each greenhouse gas (Text table 4).

Text table 4 Global warming potentials and atmospheric lifetimes

Greenhouse gas	Formula	100-year global warming potential	Atmospheric lifetime (years)
Carbon dioxide	CO ₂	1	variable
Methane	CH ₄	21	12 ± 3
Nitrous oxide	N ₂ O	310	120
Sulphur hexafluoride	SF ₆	23 900	3 200
Hydrofluorocarbons (HFCs)			
HFC-23	CHF ₃	11 700	264
HFC-32	CH ₂ F ₂	650	5.6
HFC-41	CH ₃ F	150	3.7
HFC-43-10mee	C ₅ H ₂ F ₁₀	1 300	17.1
HFC-125	C ₂ HF ₅	2 800	32.6
HFC-134	C ₂ H ₂ F ₄ (CHF ₂ CHF ₂)	1 000	10.6
HFC-134a	C ₂ H ₂ F ₄ (CH ₂ FCF ₃)	1 300	14.6
HFC-143	C ₂ H ₃ F ₃ (CHF ₂ CH ₂ F)	300	1.5
HFC-143a	C ₂ H ₃ F ₃ (CF ₃ CH ₃)	3 800	3.8
HFC-152a	C ₂ H ₄ F ₂ (CH ₃ CHF ₂)	140	48.3
HFC-227ea	C ₃ HF ₇	2 900	36.5
HFC-236fa	C ₃ H ₂ F ₆	6 300	209
HFC-245ca	C ₃ H ₃ F ₅	560	6.6
Perfluorocarbons (PFCs)			
Perfluoromethane	CF ₄	6 500	50 000
Perfluoroethane	C ₂ F ₆	9 200	10 000
Perfluoropropane	C ₃ F ₈	7 000	2 600
Perfluorobutane	C ₄ F ₁₀	7 000	2 600
Perfluorocyclobutane	c-C ₄ F ₈	8 700	3 200
Perfluoropentane	C ₅ F ₁₂	7 500	4 100
Perfluorohexane	C ₆ F ₁₄	7 400	3 200

Source: Environment Canada, 2006

5. Data sources

The greenhouse gas emissions indicator comes directly from the NIR and has not undergone any further manipulation. Data used to develop the NIR come from published as well as non-published sources from various government departments, scientific papers, and internationally accepted IPCC reference documents.

The sections below provide a brief outline of the data sources that were used to calculate emissions for each source category. A comprehensive detailing of all data

sources used can be found in Chapters 3 through 8 of the NIR (Environment Canada, 2006), disaggregated by sector and sub-sector.

5.1 Energy

Many of the data used to estimate stationary and mobile fuel combustion emissions are acquired from Statistics Canada.

Certain sub-sectors require data from additional sources to assess emissions more completely. Some of the data sets used to estimate emissions from road transport activities, for example, are found in Text table 5.

Text table 5 Data sets and sources: Road transport activities

Data set	Source
Vehicle population data	Desrosiers Automotive Consultants; Environment Canada; R.L. Polk and Co.; Statistics Canada
Fuel consumption ratios	Transport Canada; U.S. Environmental Protection Agency
Vehicle kilometres travelled	Environment Canada; Statistics Canada
Road taxed fuel	Statistics Canada

An inventory of fugitive emissions from Canadian coal mining operations is used as the basis for estimating emission factors for releases associated with the mining of solid fuels (King, 1994). These emission factors are multiplied by coal production data from Statistics Canada. Fugitive emission estimates from the oil and natural gas industry are based on two studies (Radian International, 1997; Canadian Association of Petroleum Producers, 1999), using data collected from various sources, such as the Alberta Energy and Utilities Board, Natural Resources Canada, Statistics Canada and provincial energy ministries.

5.2 Industrial processes

Activity data used to develop estimates of greenhouse gas emissions from some of Canada's industrial processes, using either default IPCC or industry-specific emission factors are outlined in Text table 6.

Text table 6 Data sets and sources: Industrial processes

Data set	Source
Cement production; lime production; limestone and dolomite use	Natural Resources Canada, <i>Canadian Minerals Yearbook</i> , Annual.
Cement production	Statistics Canada, <i>Cement</i> , 1990–2004, Monthly, 44-001-XIB.
Ammonia production; nitric acid production	Statistics Canada, <i>Industrial Chemicals and Synthetic Resins</i> , Monthly, 46-002-XIE.
Soda ash use	Global Trade Information Services; U.S. Geological Survey.
Iron and steel production	Statistics Canada, <i>Primary Iron and Steel</i> , 1990–2004, Monthly, 41-001-XIB.
Iron and steel production; non-energy use of fossil fuels	Statistics Canada, <i>Report on Energy Supply-Demand in Canada</i> , Annual, 57-003-XIB.

HFC emissions from consumption of halocarbons are estimated based on data gathered from surveys conducted by the Chemical Controls Division of Environment Canada in 1996, 1998, 1999, and 2001, and from a study performed in 2005. Process CO₂, PFC and SF₆ emission estimates for aluminium production were obtained directly from the Aluminium Association of Canada. Estimates of N₂O emissions from adipic acid production were also provided by Canada's only adipic acid plant.

5.3 Solvent and other product use

This sector accounts for emissions that are related to the use of N₂O as an anaesthetic and propellant. The emission factors applied were developed based on 1990 population statistics and on nitrous oxide consumption patterns. These factors were multiplied by the population data from Statistics Canada's *Annual Demographic Statistics* (Statistics Canada, 2004a) to estimate emissions for this sector.

5.4 Agriculture

Statistics Canada livestock population data were used in conjunction with IPCC Tier 1 or Tier 2 emission factors to produce estimates of emissions from enteric fermentation and manure management. Livestock categories for which population data are available include cattle (dairy and non-dairy), buffalo, sheep and lambs, goats, horses, swine, and poultry. These data are obtained from Statistics Canada's Census of Agriculture and other annual reports.

Emissions of nitrous oxide from synthetic fertilizers, animal manure applied to soils and crop residue decomposition are calculated using annual fertilizer sales, animal manure and crop production data from Statistics Canada, combined with the country-specific emission factors. To produce emission estimates from manure on pasture, range and paddock, the same data sources as for manure management emissions, and the Tier 1 emission factors are used. The area of cultivated organic soils obtained through consultations with national and regional soil and crop specialists is applied to the IPCC

default emission factor to generate emission estimates for histosols. Other sources of removals of N₂O, such as summer-fallow and conservation tillage practices are also inventoried.

5.5 Waste

The waste sector includes emissions from the treatment and disposal of wastes, including solid waste disposal on land (landfills), wastewater treatment, and waste incineration.

A variety of data sources were used to collect activity data to produce solid waste emission estimates. These sources include Environment Canada (1996), Canadian Council of Ministers of the Environment (1998), Statistics Canada (2004a) and (2000, 2003, 2004b) Natural Resources Canada (1997), and various other unpublished waste inventories.

Provincial-level data, including waste disposal quantities, inputs from the above-mentioned sources and the Scholl Canyon model were used to estimate CH₄ emissions from landfills (Environment Canada, 2006). This model uses a first-order decay equation to relate emission contributions to the waste that has been landfilled in previous years, as opposed to the static default method, which relates emissions to the quantity of waste landfilled in that year only. A multiple linear regression of landfilled waste quantities was performed to fit the Levelton data (1991) with data obtained from Statistics Canada's *Waste Management Industry Survey* (1998, 2003, 2004b) for emission estimates from municipal solid waste (MSW) landfills. New methane generation rate constants (k) and new methane generation potentials were also used for MSW and wood waste landfill emission estimates.

Wastewater handling emission estimates, from municipal and industrial wastewater treatment, were developed using specific emission rates based on the amount of organic matter generated per person in Canada. These emission rates were then multiplied by the amount of wastewater treated anaerobically in each province and then by the population of the respective province (Statistics Canada, 2004a). Emissions from industrial wastewater treatment were estimated from data obtained from Environment Canada reports (1986, 1991, 1996) and from communications with industry associations.

Both MSW and sewage sludge incineration estimates were derived from an Environment Canada (1996) study and extrapolated using Statistics Canada population growth figures. New data on the quantities of sewage sludge being incinerated were used to update the model, where in previous years, due to lack of information, the emissions were assumed to be constant since 1996. This resulted in a recalculation of the CH₄ emissions from 1990 to 2003. This year's inventory also includes N₂O emissions.

6. Statistical analysis

6.1 Quality assurance and quality control

The application of QA/QC procedures is an essential requirement of the GHG inventory development and submission process in order to ensure and improve transparency, consistency, comparability, completeness, and confidence in the national emission and removal estimates for the purpose of meeting Canada's reporting commitments under the UNFCCC.

The data used to compile the NIR are calculated by designated experts within the Greenhouse Gas Division at Environment Canada and are reviewed internally. A draft inventory is then distributed in a formal review process to the Emissions and Projections Working Group (EPWG). The EPWG includes representatives of provincial, territorial, and federal government departments working in the field of air pollution measurement and estimation.

Emission estimates for the various sectors are also reviewed by experts who provided the source data, such as Statistics Canada (energy data, livestock and crop production statistics), Natural Resources Canada (mineral production and forest statistics), Agriculture Canada, and industrial associations. The inventory is then submitted to the UNFCCC in April of each year. Subsequently, the inventory is subject to a formal review by a UN Expert Review Team.

The review of inventories by the UNFCCC is a three-stage process and provides a thorough technical assessment of the inventory. Each stage of the review is finalized with a review report, which is published on the secretariat website (www.unfccc.int). Annual review of individual inventories became mandatory in 2003, ensuring that adequate consideration is given to recalculations and emission trends over time. International teams of sectoral inventory experts examine the data, methods, and procedures used in preparing the inventory.

7. Statistic Canada's Greenhouse Gas Emissions Account

Statistics Canada's Greenhouse Gas Emissions Account is produced following the concepts of the System of National Accounts. It uses many of the same basic data as the greenhouse gas inventory compiled by Environment Canada; however, the information is recast into the commodity and industry framework of the System of National Accounts so that the emissions data can be used for economic modelling. In particular, this linkage permits use of Statistics Canada's national input-output accounts to analyze the interplay between production and consumption of goods and services and the greenhouse gas emissions that result from those activities. Emissions from the production of goods and services are attributed via the input-output model to the final purchaser.

Statistics Canada's Greenhouse Gas Emissions Account provides emissions estimates for 119 industries and 2 categories of household expenditure. In addition to the detailed emissions data produced by sector, several environment-economy "intensity" indicators

are derived from Statistics Canada's Greenhouse Gas Emissions Account, including the greenhouse gas intensity of gross industrial output, the greenhouse gas intensity of household consumption and the greenhouse gas intensity of net exports.

Emissions factors from Environment Canada are applied to Statistics Canada's energy use account data (which are also based on the System of National Accounts industry and commodity frameworks). The energy use data come mainly from Statistics Canada's Industrial Consumption of Energy Survey, transportation surveys, the *Report on Energy Supply-Demand in Canada* and Natural Resources Canada's Census of Mines. Additional estimates of emissions that are not linked to fossil fuel consumption are taken directly from the Environment Canada greenhouse gas inventory and are applied to the appropriate industries in the System of National Accounts.

The final demand categories can be defined as follows:

- **Exports:** receipts from other provinces and territories or from abroad for sales of merchandise or services. The barter, grant, and giving of goods and services as gifts would also constitute exports.
- **Gross fixed capital formation (subdivided into "Construction" and "Machinery and equipment"):** the value of a producer's acquisitions, less disposals, of fixed assets during the accounting period plus certain additions to the value of non-produced assets (such as subsoil assets or major improvements in the quantity, quality, or productivity of land) realized by the productive activity of institutional units.
- **Government net current expenditure:** economic activities of the federal government (including defence), the provincial and territorial governments, local (municipal) governments, universities, colleges, vocational and trade schools, publicly funded hospitals and residential care facilities, and publicly funded schools and school boards.
- **Inventories:** consist of stocks of outputs that are still held by the units that produced them prior to their being further processed, sold or delivered to other units, or used in other ways, and stocks of products acquired from other units that are intended to be used for intermediate consumption or for resale without further processing.
- **Personal expenditure:** represents the purchases of commodities, commodity taxes, wages and salaries, and supplementary labour income of persons employed by the personal sector. Includes individuals, families, and private non-profit organizations.

8. Future improvements

The data and methods used to develop the greenhouse gas emissions indicator described in this document are considered to be the best available at this time (Environment Canada, 2006).

Annex I Parties are required to continuously improve the quality of their national greenhouse gas inventory to further refine and increase the transparency, completeness, accuracy, consistency, and comparability. As new information and data

become available and more accurate methods developed, previous estimates are updated to provide a consistent and comparable trend in emissions. Although more accurate methods are sometimes available, the lack of necessary activity data often limits the use of these methods. Some of the planned initiatives for improving data availability are outlined below.

8.1 Greenhouse Gas (GHG) Emissions Reporting Program

In an effort to improve Canada's ability to monitor, report and verify greenhouse gas emissions, the Government of Canada in March 2004 and in partnership with the provincial and territorial governments, launched a national greenhouse gas reporting system.

The program requires facilities that emit 100 000 tonnes of carbon dioxide equivalent (100 kt CO₂ eq.) or more annually to submit their GHG emission information by June 1 of each year. The program has three main objectives: to enhance the level of detail of the National Greenhouse Gas Inventory; to provide the public with timely GHG emissions information; and to support provincial/territorial GHG emissions information requirements. Portions of the collected data (totals by gas and by facility) are made available to the public.

By providing a more precise picture of the sources and quantities of Canada's GHG emissions, data from the GHG emissions reporting system can be used to improve and confirm emission estimates developed from national and provincial statistics. The extent to which the information from the reporting system can be fully integrated into the inventory is dependent upon the level of detail and type of data available. Environment Canada will continue to use these data as an important component of the overall inventory development process.

8.2 Households and the Environment Survey

In early 2006, Statistics Canada surveyed Canadian households regarding selected environmental practices, such as commuting practices and ownership of household gasoline-powered equipment, to provide additional context for air quality indicators. Initial results of this survey are available, and full results will come out in 2007. The Households and the Environment Survey will be repeated in 2007 and every second year thereafter.

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