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REPORT OF THE INDIVIDUAL REVIEW OF THE GREENHOUSE GAS INVENTORY OF CANADA SUBMITTED IN THE YEAR 2000[1]

(Centralized review)

A. GENERAL OVERVIEW

1. Introduction

1. The Conference of the Parties (COP), at its fifth session, by its decision 6/CP.5, requested the secretariat to conduct, during the trial period, individual reviews of greenhouse gas (GHG) inventories for a limited number of Parties included in Annex I to the Convention (Annex I Parties) on a voluntary basis, according to the UNFCCC guidelines for the technical review of GHG inventories from Parties included in Annex I to the Convention.[2] In doing so, the secretariat was requested to coordinate the technical reviews and to use different approaches for individual reviews, including desk reviews, centralized reviews and in-country reviews.

2. In response to the mandate by the COP, the secretariat coordinated a centralized review of six national GHG inventories (Australia, Canada, Hungary, Japan, the Netherlands and New Zealand) submitted in 2000, which took place from 7 to 11 May 2001. The review was carried out by a team of nominated experts from the roster of experts working at the headquarters of the UNFCCC secretariat in Bonn. The members of the team were: Mr. Ayite-Lo Ajavon (Togo), Mr. Wiley Barbour (United States of America), Mr. Pascal Boeckx (Belgium), Mr. Jose Gonzalez Migues (Brazil), Mr. Tomas Hernandez-Tejeda (Mexico), Mr. Klaus Radunsky (Austria), Mr. Yiannis Sarafidis (Greece), Ms. Sirintornthep Towprayoon (Thailand) and Mr. Hristo Vassilev (Bulgaria). The review was coordinated by Mr. Stylianos Pesmajoglou (UNFCCC secretariat). Mr. Wiley Barbour and Mr. Jose Gonzalez Migues were lead-authors of this report and also served as sector experts.

3. The main overall objective of the centralized review of the GHG inventories was to ensure that the COP had adequate information on the GHG inventories. The review should further assess the progress of the Parties towards fulfilling the requirements outlined in the UNFCCC reporting guidelines on annual inventories (FCCC/CP/1999/7). In this context, the review team

[1] In the symbol of this document, 2000 refers to the year the inventory was submitted, and not to the year of publication. The number (3) indicates that for Canada this is a centralized review report.

[2] Document FCCC/CP/1999/7, in particular the UNFCCC review guidelines (pages 109 to 114), and decision 6/CP.5 (page 121 to 122)

checked the responses of the Parties to questions raised in previous stages of the review process and the consistency of the inventory submission with the UNFCCC reporting guidelines and the *Revised 1996 Intergovernmental Panel on Climate Change Guidelines for National Greenhouse Gas Inventories* (hereinafter referred to as the IPCC guidelines), and identified possible areas for improvement in the inventories of the six Annex I Parties. Each inventory expert reviewed the information submitted for specific IPCC sectors and each IPCC sector was covered by two experts.

4. The review team has also assessed, to a certain degree, whether the reporting fulfils the requirements included in the *IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* (hereinafter referred to as the IPCC good practice guidance), although the IPCC good practice guidance had not been published at the time the inventory was submitted and could not, therefore, have been used in the compilation of the inventory.

5. The UNFCCC secretariat provided the review team with all necessary technical guidance, information and data, such as national inventory data reported according to the common reporting format (CRF) submitted in the year 2000, national inventory report (NIR) for the year 2000, the synthesis and assessment report (S&A report) of GHG inventories prepared by the secretariat, and comments from the Parties on the S&A report.

2. Overall findings

6. Canada's NIR conforms to the current IPCC inventory standards and appears largely consistent with the principles recently developed through the IPCC good practice guidance.

3. Completeness

7. Canada's NIR was found to be generally complete for the years 1990 and 1998. Fugitive emissions from petroleum refining (likely to be a key source category for Canada) and oil transport are not estimated (NE) and trend analysis is hampered by incomplete reporting of data for the years 1991 to 1997 in the CRF tables. Recalculations were provided for the years 1990 to1997, but the full CRF tables were not provided. A quantitative uncertainty analysis was performed for the 1990 inventory.

4. Transparency

8. The NIR for Canada is very well documented and referenced. Methods and emission factors (EFs) are generally described, and models are often discussed in detail, frequently with data on the specific parameter values provided. Use of "Other" categories in the Land-use change and forestry (LUCF) tables hampers detailed analysis. For LUCF and other categories where country-specific methods and practices are used, additional detailed documentation will improve transparency.

5. Data sources used for centralized review

5.1 National greenhouse gas emission inventory report (NIR)

9. An NIR was provided on 14 July 2000 containing information on methodologies, activity data, EFs and uncertainty estimates. Information on uncertainties describes the use of a rounding protocol (NIR, p. 14). The NIR is available in hard copy and electronic format.

10. The NIR describes the process of reviewing and considering inventory data, mainly in the energy section, aimed at improving data collection and data quality. The NIR recognizes that the internal review process is informal in nature and that there is a need for a formalized quality assessment/quality control (QA/QC) protocol. It is planned to develop this in the near future (see the NIR, pp. 97-112).

5.2 Common reporting format

11. The CRF was submitted for the years 1990 and 1998 only, with the exception of recalculation tables which were provided for all years.

12. Except as noted above, the CRF included all requested tables and indicators.

13. Data transcription errors were identified for several energy categories, but otherwise the CRF is consistent with the NIR.

5.3 Synthesis and assessment report (S&A report).

14. Canada provided a response to the S&A report. Canada's comments were taken into account during the centralized review.

15. Time-series consistency for industrial processes was assessed in the S&A report. There were no major deviations in emissions to be found in the trend tables.

B. ENERGY SECTOR

1. General overview

1.1 Completeness

16. The NIR for 1990 and 1998 were found to be largely complete. A more detailed analysis of EFs used, activity data and emissions at category levels than that shown in the trend table was hampered by a lack of data for the years 1991 to 1997.

1.2 Transparency

17. The Canadian NIR provides a clear discussion of methodologies with references to background data.

2. Reference Approach

18. For the sectoral (national) approach, data have been given on a gross calorific value (GCV) basis, while for the reference approach data have been given on a net calorific value (NCV). Energy consumption and CO_2 emissions from the reference approach are 0.7 per cent lower and 10.5 per cent higher respectively compared with the national approach**.** The reason given for the difference (documentation box, table 1.A(c)) is that the national approach does not include fuel-based CO_2 from various industrial processes, such as ammonia and aluminium production. In accordance with the explanations, when these sources are included in the total energy in the national approach, the two match closely with only a 4 per cent difference. However, the difference is not explained and warrants a more detailed review.

19. The NCVs used for liquid fuels (before the per volume conversion) in the reference approach seem to be the default values of the IPCC guidelines, while the NCVs for solid fuels, crude oil, NGL and refinery feedstocks seem to be the 1990 country-specific values in table I-2 in IPCC guidelines, p. I.21.

20. The reference approach energy data for 1998 are 6.2 per cent higher than those reported to the International Energy Agency (IEA). The CRF is 12.0 per cent higher for liquid fuels and 2.4 per cent higher for solid fuels. Natural gas corresponds very closely. Specific differences include:

(a) Production of crude oil and NGLs in the CRF is 505,069 TJ higher than the IEA figures;

(b) Crude oil and residual fuel oil imports are higher in the CRF;

(c) Liquid fuel stock changes are 65,618 TJ different. In fact, the CRF shows a stock build while the IEA shows a stock draw;

(d) Coal imports are 19,597 TJ higher in the CRF;

(e) Coal stock changes are much higher in the IEA figures.

21. Most of the above comments are also applicable to the 1990 data where the CRF data are 5.2 per cent higher than the IEA data. The growth rate of overall apparent consumption between 1990 and 1998 is very similar between the two data sets. The CRF grew by 16 per cent and the IEA by 15 per cent. However, liquid fuels are growing faster in the CRF and solid fuels are growing faster in the IEA data.

3. Feedstocks

22. Feedstocks are reported in the CRF, but no additional information is provided. The fraction of carbon stored and the implied emission factors (IEFs) calculated, are in accordance with the proposed values in IPCC guidelines.

4. Key sources

4.1 Fugitive emissions from oil and natural gas

23. *Emission trends*: Oil and gas fugitive emissions are a key source for Canada, representing over 5 per cent of total reported emissions. Canada reports fugitive CH_4 emissions from oil, increasing from 407 Gg in 1990 to 662.5 Gg in 1998. For natural gas, emissions rose from 816 to 1,083 Gg over this period. CO_2 emissions are also reported.

24. *Methodology*: The Canadian NIR states that a category of "Conventional upstream oil and gas" is used rather than splitting emission estimates between oil and gas. The rationale noted that the industry does not make such distinctions and, in practice, gas is often produced along with oil. However, the CRF table 1.B.2 does provide separate estimates for oil and gas.

25. *Emission factors*: Analysis of IEFs is uniquely difficult for this category because the CRF allows Parties to report in different units. The IPCC defaults are expressed in kg/PJ and Canada uses units of kg/m^3.

26. *Completeness*: Canada does not report fugitive emissions from oil refineries. Table 1.B.2 indicates NE for the subcategory "Refining and storage." This is expected to result in an underestimate of emissions since, as noted in the S&A report, Canada has large refinery throughput. Canada's response to the S&A report did not address this point. Also, no fugitive estimates are provided for oil transport.

4.2 Stationary combustion – CO_2 emissions

27. *Emission trend*: CO_2 emissions from stationary combustion (liquid, solid and gaseous fuels) are key sources for Canada, representing 43 per cent of all reported emissions in 1998 (without LUCF). Canada reports CO_2 emissions from stationary combustion increasing from 269.9 Mt in 1990 to 302.2 Mt in 1998 (12 per cent increase compared to 1990).

28. CO_2 emissions from the stationary combustion of liquid fuels represent 10 per cent of all reported gross emissions in 1998 representing a 5 per cent decrease compared to 1990.

29. CO_2 emissions from the stationary combustion of solid fuels contributed 15 per cent of all reported gross emissions in 1998 representing a 22 per cent decrease since 1990.

30. CO_2 emissions from the stationary combustion of gaseous fuels contributed 18 per cent of gross emissions in 1998 representing a 15 per cent increase compared to 1990.

31. *Methodology*: Estimation of emissions is based on the IPCC tier 1 method (information reported in CRF). A description of the methodologies used is provided in the NIR.

32. *Emission factors*: The EFs used are country-specific and are presented in the NIR. The EFs used differ from those of the IPCC in that they relate emissions to the quantity of fuel used and not the energy content of the fuel. Generally, EFs based on heat content are more accurate.

33. The EFs used for coal vary with the properties of the coal and, therefore, EFs are assigned for different provinces based on the origins of the coal used. The EFs used have remained constant since 1990.

34. The CO_2 IEF from gaseous fuels in all subcategories of stationary combustion (1.A.1, 1.A.2, 1.A.3 and 1.A.4) are the lowest among all reporting Parties.

35. The CO_2 IEF from gaseous fuels used for 1.A.2 "Manufacturing industries and construction" is the lowest among all Parties for the year 1998. This value is very similar to that of New Zealand, which excludes carbon stored in final products (methanol, synthetic petrol, ammonia and urea) in its calculation of the IEF. This may be the reason for this low value but details would improve transparency.

36. *Activity data*: The fossil fuel energy-use data used to estimate combustion emissions are from the Quarterly Report on Energy Supply-Demand (QRESD) compiled by the National Statistics Agency.

37. *Recalculations*: The recalculations reported are attributed to the use of revised energy statistics data for energy industries, manufacturing industries and construction, and other sectors. Recalculations cover the period from 1990 to 1997.

38. *Completeness*: All subsectors are covered, but NO_x, CO, NMVOC and SO_2 emissions are not estimated.

39. *Uncertainty*: A study was completed in 1994 to assess the inherent reliability of the 1990 inventory. The uncertainty estimates of this study are considered as approximations since new sources have been added (NIR, p. 113). The rounding protocol (NIR, p. 114) provides an additional insight into the approximate level of uncertainty for each of the current emission estimates.

4.3 Mobile combustion – CO_2 emissions

40. *Emission trends*: Several mobile source categories (road transportation, other transportation, civil aviation and railways) are key sources for Canada, representing 25 per cent of all reported gross emissions of CO_2 in 1998. Canada reports CO_2 emissions from the above-mentioned sources increasing from 141.1 Mt in 1990 to 169.4 Mt in 1998 (a 20 per cent increase compared with 1990). The "Other transportation" sector comprises off-road vehicles and pipeline transportation.

41. CO_2 emissions from road transportation represent 18 per cent of all reported gross emissions in 1998, an 18 per cent increase compared with 1990.

42. CO_2 emissions from the source category "Other transportation" represent 4 per cent of all reported gross emissions in 1998, a 39 per cent increase compared with 1990.

43. CO_2 emissions from civil aviation represent 2 per cent of all reported gross emissions in 1998, a 21 per cent increase compared with 1990.

44. CO_2 emissions from railways contribute 1 per cent of all reported gross emissions in 1998, a 14 per cent decrease since 1990.

45. *Methodology*: The methodologies applied for the estimation of CO_2 emissions in the transport sector are reported as country-specific in the CRF. The methodologies are presented in the NIR. According to the information provided in the NIR, the applied methodologies are:

(a) IPCC tier 3 method for road transportation. The model M-GEM (NIR, Vol. I, pp. 18-24) is used to calculate emissions of CO_2, CH_4 and N_2O, based on information regarding fuel consumption, vehicle type, vehicle control technology, technology age, age distribution of the fleet, fuel efficiency and average distance travelled per year;

(b) IPCC tier 1 method for other transportation. The model M-GEM generates fuel consumption data for off-road vehicles, while the fuel consumption data for pipeline transportation are provided in the QRESD;

(c) Modified IPCC tier 1 method for civil aviation. Emissions are based on the aircraft fuels consumed and are estimated using the M-GEM model. Apparently the method is considered as "modified" because of the use of country-specific EFs. Clarification would be useful;

(d) Modified IPCC tier 1 method for railways. Estimation of emissions is based on fuel consumption data provided in the QRESD. Apparently the method is considered as "modified" because of the use of country-specific EFs.

46. *Emission factors*: The EFs used are country-specific and are presented in the NIR (Vol. I, table 6, pp. 103-104).

47. *Activity data*: Energy consumption data are provided by the national statistics agency, while vehicle population and distribution data as well as distances travelled per category, are provided from a number of sources cited in the NIR.

48. *Recalculations*: The recalculations reported are attributed to the use of revised energy statistics data for the transport sector. Recalculations cover the period from 1990 to 1997.

49. *Completeness*: All subsectors are covered, but NO_x, CO, NMVOC and SO_2 emissions are not estimated.

50. *Uncertainty*: A study completed in 1994 addresses the uncertainty inherent in the 1990 inventory. The uncertainty estimates of this study are considered as approximations since new sources have been added (NIR, p. 113).

4.4 Mobile Combustion – N_2O emissions

51. *Emission trends*: N_2O emissions from the source category "Mobile combustion - road transportation", represent 1 per cent of all reported gross emissions in 1998. Canada reports N_2O emissions from road transportation sources increasing from 3.7 Mt carbon dioxide equivalent (CO_2-eq) in 1990 to 5.7 Mt CO_2-eq in 1998 (a 54 per cent increase compared with 1990).

5. Bunker fuels

52. International and domestic fuel consumption for navigation and aviation are reported in the CRF, without an explanation of the estimation in the documentation box.

53. This information exists partially in the NIR since different records are kept for fuels that have been sold to foreign-registered marine or aviation carriers. It is also mentioned in the NIR that "it is not clear whether or not all of the fuel sold to foreign-registered carriers in Canada is used for international transport" and "modified statistical procedures may be required to more accurately track bunker fuels". However, it is not clear whether or not all the fuel sold to foreign-registered carriers was used in the calculations.

6. Weather related-adjustments

54. It is presumed that there are no weather-related adjustments of emissions since they are not mentioned in the NIR.

7. Questions and issues from previous review stages

55. Canada provided responses to several issues raised in the draft S&A report. These comments have been taken into account by the central review team.

56. There was no response to the comments concerning:

(a) Low IEF values calculated for gaseous fuels for stationary combustion sources;

(b) The differences between the reference approach energy data and IEA energy data;

(c) The 4 per cent deviation in CO_2 emissions estimated using the reference and sectoral approaches;

(d) The use of GCV and the effect on the IEFs.

C. INDUSTRIAL PROCESSES

1. General overview

1.1 Completeness

57. For CO_2 emissions in A. "Mineral products": 5. "Asphalt roofing", 6. "Road paving with asphalt" and 7. "Glass Production", table 9 of the CRF states: "Unknown activity data".

58. For CH_4 emissions in B. "Chemical industry": 1. "Ammonia production", 4. "Carbide production - silicon carbide and calcium carbide" and 6. "Other" (carbon black, ethylene, dichloroethylene, styrene and methanol); C. "Metal production": 1. "Iron and steel production – coke)", 2. "Ferroalloys production" and 3. "Aluminium production"; and G. "Other and undifferentiated production", table 9 of the CRF states: "Unknown emission rates" (and "Unknown activity data for ferroalloys production").

59. For N_2O emissions in B. "Chemical industry": 1. "Ammonia production", 6. "Other" (ethylene); and G. "Other and undifferentiated production", table 9 of the CRF states: "Unknown emission rates".

1.2 Transparency

60. The Canadian NIR provides brief descriptions of the methodologies used with references to background data.

1.3 Recalculations

61. Canada provided recalculated estimates (table 8(a)) and explanatory information (tables 8(b)) for the years 1990 to 1997. The main reasons for recalculations are the revised figures for activity data, mainly in energy. The effect of the recalculations (as reported in the CRF tables) for 1990 was an increase of 1.8 per cent in total CO_2 equivalent emissions without land-use change and forestry (LUCF). For 1990 to1997, the change for each individual year, compared with previous submissions ranged from 0.8 to 1.8 per cent. In all cases, the new figure was higher than in previous submissions. The average for the eight-years period is 1.12 per cent (without LUCF).

1.4 Methodology

62. IPCC tier 1 and country specific for mineral production and chemical industry. Country specific for metal production and tier 3/country specific for PFCs and SF_6.

1.5 Uncertainty

63. Only quality assessment of the uncertainty of the estimates (high for SF_6, medium for CO_2 and N_2O, NO for CH_4 and low for HFCs and PFCs).

1.6 Cross-cutting issues with the energy sector

64. *Iron and steel industry*: Canada reported as emissions from industrial processes, part of the metallurgical coal carbon content released as CO_2. Other Parties reported such emissions as included elsewhere (IE) (a transparency issue).

65. *Petroleum coking and ammonia production(table 2.G)*: The use of petroleum coke, in anodes for the production of aluminium, is reported by Statistics Canada with all other non-energy uses of petroleum coke. The CO_2 emissions from aluminium must therefore be subtracted from the total non-energy emissions to avoid double counting. Similarly, the natural gas used to produce hydrogen for ammonia production is recorded by Statistics Canada with all other non-energy uses of natural gas. The emissions from ammonia production are also subtracted from total non-energy emissions to avoid double counting (Canadian NIR, p. 60) (see IPCC guidelines, Vol II, p. 2.13).

2. Mineral sector

66. Cement production (2.A.1) is a key source for Canada.

67. Soda ash production was reported as not occurring (NO). Emissions from soda ash consumption were reported.

3. Chemical sector

68. Canada provided estimates for emissions from ammonia, nitric acid and adipic acid production. N_2O emissions from adipic acid production is a key source for Canada.

69. The S&A report states that adipic acid is reported as a point source. No production data are provided. The methodology had changed from the one used for reporting between 1990 and 1997, when an EF was used. In the NIR it is mentioned that emission abatement technology was installed in Canada's only plant. Canada did not provide comments on the S&A report regarding adipic acid production. Notwithstanding that adipic acid is reported as a point source, there is no explanation given in the NIR for not providing information on activity data and IEF for this point source. In actual fact, activity data were reported as NA (not applicable).

70. Emissions from silicon and calcium carbide were reported as IE. Emissions from ethylene and coke were not estimated.

4. Metal Sector

71. Emissions from iron and steel production is a key source in industrial processes for Canada. The NIR mentions that these emissions were estimated by applying a combustion EF for metallurgical coke (included in table 4 of the NIR) to the amount of metallurgical coke in the iron and steel industry.

72. Aluminium production is a key source for Canada (CF_4 and C_2F_6). The S&A report states that no methods were specified in the CRF. According to Canada's answer, methods are outlined in the NIR as follows: "A study of PFC emissions has been conducted to measure actual outputs from a number of plants (Unisearch, 1994). Data were obtained for the four representative types of aluminium smelting technologies used in Canada. Perfluorocarbon emissions can be controlled by computerized alumina feeders. Sensors detect alumina concentration and automatically feed more to the pot when levels become low. In this way, anode events can be controlled. The computers can be programmed to detect the onset of anode effects as well, providing additional

warning for the system to take counteractive measures. 'Point' feeders, as opposed to 'centre-break' types also tend to reduce emissions (Oye, 1990)". (Extract from Canadian NIR).

73. Emissions from ferroalloy production, SF_6 used in aluminium foundries were not estimated. Emissions from SF_6 used in magnesium foundries were estimated as a point source.

5. Production and consumption of HFCs and SF_6

74. Production of HFCs and SF_6 were reported as NO (there is information available from the secretariat of the Montreal Protocol).

75. Potential and actual emissions from consumption of HFCs were estimated. Potential and actual emissions from consumption of SF_6 were not reported.

6. Other

76. The S&A report states that: "2.G "Other industrial processes" are not specified in CRF".

77. Canada provides the following answer: "2.G "Other industrial processes" are not specified in CRF, but are described in the NIR".

7. Key sources

78. CO_2 emissions from industrial processes - other (level assessment of 2 per cent).

79. CO_2 emissions from iron and steel industry (level assessment of 1 per cent).

80. CO_2 emissions from cement production (level assessment of 1 per cent).

81. PFCs emissions from aluminium production (level assessment of 1 per cent).

82. N_2O emissions from adipic acid production (level assessment of 1 per cent).

D. AGRICULTURE

1. General overview

83. The NIR contains data in CRF format for 1990 and 1998 and recalculations for other years. However, no background calculation sheets or workbooks are provided. Both for N_2O and CH_4 emissions there is an increasing emissions trend. For CH_4 emissions this is due to enteric fermentation. For N_2O emissions this is due to agricultural soils.

2. Specific findings

2.1 Enteric fermentation (table 4.A)

84. IPCC tier 1 methodology was used. The IEF for dairy and non-dairy cattle differs considerably from the IPCC guidelines. In the NIR, no specific reasons or references are given. An update is promised in Canada's response to the S&A report.

2.2 Methane emissions from manure management (table 4.B(a))

85. There is consistency between the animal statistics in tables 4.A and 4.B(a). The IEFs correspond to IPCC default values. However, for sheep an unexplained value of 0.32 is given. If the climate allocation is "cool", a factor of 0.19 should be used in accordance with IPCC guidelines. However, sheep does not seem to be a particularly important source category for Canada.

2.3 Nitrous oxide emissions from manure management (table 4.B(b))

86. Goats and horses are not included in the animal statistics in table 4.B(b), although they can be found in table 4.B(a). This is a small inconsistency and could be mentioned under "Other".

87. N excretion values per animal type differ from the IPCC default values for North America. It is not explained in the NIR where the applied N excretion values come from. Moreover, the NIR (p. 66), states that IPCC default EFs are used. The IEF for all animal waste management systems (AWMS) is a factor 10^6 higher than the IPCC default values. This is acknowledged in Canada's response to the S&A report. Table 4.B(b) should be revised. The inconsistency with table 4.D.2 was also acknowledged. As a result, the totals per AWMS are incorrect.

2.4 Agricultural Soils (table 4.D)

88. The source of the activity data is clearly explained in the NIR.

89. *Direct soils emissions*: For synthetic fertilizers, animal wastes applied to soils, N fixing crops and crop residues, the following IEFs were used: 0.006, 0.009, 0.002 and 0.000. These values are much lower than the IPCC default value EF (0.0125). Canada's cooler climate may explain the reduced EFs, but in the NIR no reason for these low IEFs is given. Moreover, it is sometimes mentioned that the IPCC default values were used (e.g., NIR, p. 73, for crop residues). The IPCC good practice guidance is very stringent on the derivation/use of country specific EFs (see box 4.1, p. 4.62 in the IPCC good practice guidance). The IEF for histosols is the default value.

90. *Animal production*: For reasons mentioned in table 4.B(b), the calculation of N excretion on "pasture range and paddock" is not transparent. See also other parameters (FRACgraz) below.

91. *Indirect emissions*: The IEF for N leaching and run-off is higher than the IPCC default value. No reason is given in the NIR. The correct value is obviously 0.0274 (Canada's response to the S&A report), which is close to the default EF.

92. *Other parameters*: In the additional information box, all parameters except $FRAC_{NCR0}$ are IPCC default values. However, the NIR (pp. 73) mentions that for $FRAC_{NCR0}$ the default value was used. For FRACgraz a value of 0.0 is reported. FRACgraz is calculated as the ratio of N excretion on "pasture, range and paddock" to the total animal N excretion. The latter should be calculated using data from table 4.B(b). FRACgraz is a parameter needed to calculate the amount of animal wastes applied to soils. More attention should be given to a better calculation of manure N produced in the different AWMS (table 4.B(b)). The latter also appears in the S&A report.

2.5 QA/QC

93. The NIR describes an informal internal review process for the GHG inventory. However, an updated system is planned.

2.6 Uncertainty

94. A quantitative uncertainty analysis was performed for the 1990 inventory. The NIR mentions that this should provide "guidance" on the precision of the more recent inventory. The NIR contains qualitative information on uncertainty (table 4.1).

E. LAND-USE CHANGE AND FORESTRY (LUCF)

1. General overview

95. Total sequestration due to LUCF was estimated to be 20,089 Gg of CO_2-e (this corresponds to 3 per cent of the total GHG emissions in 1998) during 1998, which is smaller than the 1990 removals (36,676 Gg of CO_2-e), as presented in summary table 2 of the CRF.

2. Specific findings

2.1 Changes in forest and other woody biomass stocks (table 5.A)

96. *Completeness*: Data have been provided for subsector 5.A.5 "Other" only, the categories being harvested wood, firewood, slash and Canadian wood production forest. This makes it impossible to assess CO_2 emissions for the two types of relevant forest (temperate and boreal forests).

97. Estimated emissions for the sum of harvested wood, firewood and slash shows a small increase from 244,949 Gg CO_2 to 256,424 Gg CO_2 between 1990 and 1998. The net CO_2 emissions/removals have decreased from -45,224 to 33,030 Gg CO_2 during the same period. These findings are reasonably consistent. Most of the CO_2 emissions come from harvested wood and slash.

98. Category 5.A.1 "Tropical forests" has been classified as NO which is reasonable in Canada's case. Categories, 5.A.2 "Temperate forests" and 5.A.3 "Boreal forests" have been classified as being NA for emissions, and have been included under "Canadian wood production forest" for removals. Category 5.A.4 "Grassland/tundra" has been classified as NE. Rationales for why the categories temperate and boreal forests would not be applicable to Canada are not provided.

99. *Consistency*: According to the data provided, the LUCF data are mutually consistent over a period of nine years. Similar methods were used for calculations throughout the period of assessment. The data show a small decrease in CO_2 net emissions throughout the years assessed, especially during the last three years. The data also show reasonable fluctuations in such emissions. However, no detailed information corresponding to the CRF has been provided for the intervening years 1991 to 1997.

100. *Recalculations*: Recalculations have been indicated in table 11 of the CRF. The 1996 centralized review of greenhouse gas inventories (CGHGI) was the first attempt to report on sector 5 emissions and removals (see CGHGI, p.76, parag. 5). All figures reported in 2000 are drawn from a study (Sellers, P. and Wellisch, M.) prepared in July 1998.

101. No information has been provided describing the quantitative effects of the recalculations according to the latter study.

102. *Transparency*: Transparency has been achieved by providing calculations in table 5.A in the CRF, as well as in the NIR. However, figures have only been provided for the category "Canadian wood production forest", but any details about type of forest or species have not been included. It is also noted that background tables have only been provided for 1990 and 1998.

103. *Comparability*: Country-specific methods and EFs have been used in conjunction with IPCC default approaches for all subsectors. Owing to a lack of information, the country-specific EFs could not be compared with those of other countries. Because of the use of country-specific methods and EFs, it is difficult to assess comparability for the time being; however, by increasing transparency and completeness, comparability should be achievable.

104. *Methodology*: For estimation, country-specific and default methods were used in sections 5.A, 5.B and 5.D. According to the NIR (p. 79), the current IPCC method has been used. The NIR points out that "it is likely that some double-counting occurs between the estimates in the Changes in forest and other woody biomass stocks sector and those reported in the Energy and waste sector". No attempt has been made to resolve the problem, as, according to the NIR, it must be addressed in the methodology.

105. *Emission and conversion factors*: Country-specific EFs have always been used for CO_2, CH_4 and N_2O. The following information has been taken from sectoral background table 5.A for wood production forests:

(a) Average annual growth rate (t dm/ha): 1.26;

(b) Implied carbon uptake factor (t C/ha): 0.63;

(c) Carbon fraction of dry matter (carbon EF: t C/t dm): 0.50;

(d) The same EFs have been used in 1990 and 1998. No information was provided for the years 1991 to 1997;

(e) In addition to the above indicators, a more detailed description of the figures, e.g., differentiation into forest type and species, would be helpful.

106. *Activity data*: Activity data and EFs come from different governmental agencies: NRCan, Agriculture Canada, Industry Canada, Transport Canada and Statistics Canada, as well as from stakeholders. Activity data for area of forest/biomass stocks and commercial harvest have been provided for 1990 and 1998 in sectoral background table 5.A. A reference for the origin of the data has been included, namely, the Canadian Forest Inventory, 1991 (Revision 1994). However, a short description of the methodology used to estimate them would be welcome.

Category	**Area of forest/ biomass stocks (kha)**	**Commercial harvest (kt dm)**	**Fuelwood consumed (kt dm)**
Canadian Wood Production Forest	122,842 (1990 to 1998)	82,200 (1998) 79,778 (1990)	17,984 (1998) 16,070 (1990)

107. It is noted that throughout the period 1990 to 1998 there have only been changes in commercial harvest and fuelwood consumption but not in area of forest/biomass stocks.

2.2 Forest and grassland conversion (table 5.B)

108. *Completeness*: Data have been provided for category 5.B.5 for emissions of CO_2 only, because of insufficient data available to allocate the change in biomass density to different routes (on-site burning, off-site burning and decay). CO_2 emissions were reported for the categories "Temperate forests", "Boreal forests", "Grassland/tundra" and "Other" (agriculture and unknown). The data address changes in above-ground carbon only; soil data have been included under sector 5.D.

109. According to summary table 2, in 1998 sector 5.B contributed 3,924 Gg carbon dioxide equivalent (Gg CO_2-e). This value was 1,419 in 1990. It is noted that data have been provided for CO_2 emissions for boreal and temperate forests in sector 5.B whereas in sector 5.A those emissions have been qualified as not applicable.

110. *Consistency*: See comments for table 5.A above.

111. *Transparency*: Transparency was largely achieved as the sectoral data and the CRF were reported for sections 5.B.2, 5.B.3, 5,B.4 and 5.B.5. It is noted that background tables have only been provided for 1990 and 1998.

112. *Comparability*: See comments for table 5.A above.

113. *Methodology*: Country-specific and default methods have been used. Worksheets were provided in appendix 2 of the 1990 and 1998 CRF submissions. Only changes in above-ground biomass were addressed. Changes in soil carbon levels have been included under category 5.D. The NIR points out that reliable data on rates of land-use change are lacking because they are not tracked or reported. Data have been based on net increases in agricultural and urban areas.

114. *Emission and conversion factors*: The following information has been taken from sectoral background table 5.B and the NIR:

Category	**Biomass before conversion (t dm/ha)**	**Biomass after conversion (t dm/ha)**	**Implied emission factor for off site burning t CO_2/ha)**
Temperate: mixed broadleaf/coniferous	Canadian Forest service	IPCC default data	187.42 - 187.64
Grasslands	?	?	1.04 - 1.68
Boreal: mixed broadleaf/coniferous	Canadian Forest service	IPCC default data	73.16 - 73.30
Agriculture to urban	?	?	18.33 - 18.39
Unknown to urban	?	?	3.67 - 3.75

115. The above table indicates that a more detailed description of the figures would be helpful. It has been assumed that all above-ground carbon is released off site.

116. *Activity data*: Activity data for the area converted annually have been provided for forest and grassland conversion in table 5.B for 1990 and 1998.

Category	Area converted annually (kha)
Temperate: mixed broadleaf/coniferous	3.10 (1990) - 14.90 (1998)
Grasslands	58.70 (1990) - 65.30 (1998)
Boreal: mixed broadleaf/coniferous	8.80 (1990) - 10.70 (1998)
Agriculture to urban	6.20 (1990) - 11.00 (1998)
Unknown to urban	4.80 (1990) - 9.00 (1998)

117. No data have been provided for the years 1991 to 1997.

118. It would help verification if larger areas (e.g., larger than 100 ha) of land use and land-use change were identified with the help of a map.

2.3 Abandonment of managed lands (table 5.C)

119. *Completeness*: Data have been provided on CO_2 removals for categories 5.C.2 "Temperate forests" and 5.C.3 "Boreal forests" addressing accumulation of above-ground carbon on abandoned, formerly managed agricultural lands.

120. According to summary table 2, in 1998 sector 5.C contributed -4,008 Gg carbon dioxide equivalent (Gg CO_2-e). This value was -3,245 in the year 1990.

121. *Transparency*: Transparency has been achieved by providing calculations in table 5.C in the CRF as well as in the NIR. It is noted that background tables have only been provided for 1990 and 1998.

122. *Methodology*: According to table 3 of the CRF (summary report for methods), IPCC default methods for removals and emissions of CO_2, CH_4 and N_2O have been used. The total area of abandoned agricultural land was compiled from reductions in total agricultural land in those provinces where such decreases were observed. Owing to a lack of specific data, it was assumed that half of the abandoned areas had been converted to urban land and the remainder had re-grown to its natural state in estimated proportions (NIR, p. 84).

123. *Emission and conversion factors*: The following information has been taken from sectoral background table 5.C and the NIR:

Category	Annual rate of aboveground biomass growth (t dm/ha)	Carbon fraction of aboveground biomass	Rate of aboveground biomass carbon uptake (t C/ha/yr)
Temperate: mixed broadleaf/coniferous	0.95	0.50	0.48
Grasslands	-	-	-
Boreal: mixed broadleaf/coniferous	0.21	0.50	0.11

124. The same factors have been used for 1998 and 1990. No information was provided for 1991 to 1997.

125. It has been assumed that abandoned agricultural land reverting to grassland does not accumulate significantly more above-ground biomass.

126. *Activity data*: Activity data for the area converted annually have been provided for abandonment of managed land in table 5.C for 1990 and 1998.

Category	**Total area abandoned and regrowing First 20 years (kha)**	**Total area abandoned and regrowing > 20 years (kha)**
Temperate: mixed broadleaf/coniferous	869 (1998) - 884 (1990)	913 (1990) – 1,352 (1998)
Grasslands	296 (1998) - 301 (1990)	330 (1990) - 482 (1998)
Boreal: mixed broadleaf/coniferous	131 (1990) - 132 (1998)	163 (1990) - 231 (1998)

127. No data have been provided for the years 1991 to 1997. It would help verification if larger areas (e.g., larger than 100 ha) of land use and land-use change were identified with the help of a map.

2.4 CO_2 emissions and removals from soil (table 5.D)

128. *Completeness*: Data have been provided on CO_2 emissions and removals for the category 5.D ("Other", specified as land conversion and abandonment of managed areas). IPCC methodology allows the reporting of net CO_2 fluxes from agricultural soils in the agriculture sector or LUCF.

129. Emissions and removals have increased during the period assessed, as well as net emissions of CO_2.

130. *Transparency*: The background table 5.D does not include any relevant information because the categories "Cultivation of mineral soils" and "Cultivation of organic soils", as well as "Liming of agricultural soils" were included under sector 4 "Agriculture". Using the qualifier NE for "Cultivation of organic soils" seems to be inconsistent with using the qualifier IE for subcategories "Upland crops" and "Pasture/Forest".

131. The NIR describes the methodology used for calculating CO_2 emissions and removals under sector 5.D "Other", but there is a lack of transparency owing to a lack of data on land area, although some information might be included in tables 5.B and 5.C. The actual calculation sheets used would provide better transparency.

132. *Methodology*: Country-specific methods (and EFs) have been used. Emissions of CO_2 from land conversion were included in this section, as well as CO_2 removal from the abandonment of managed lands. It remains unclear how the various types of forest and grassland converted were treated, as well as the various types of managed land abandoned.

133. *Emission and conversion factors*: Although CO_2 emissions and removals have been reported under section 5.D, no specific information regarding EFs has been included in sectoral background table 5.D or the NIR. It is possible some additional information is included in the literature cited, but that was not available for the review.

134. *Activity data*: Although CO_2 emissions from land conversion and abandonment of managed lands have been calculated, no specific activity data have been provided for sector 5.D, "Land conversion and abandonment of managed lands". Such data would be welcome in addition to those provided for sectors B and C as indicated above.

2.5 Other (table 5.E)

135. Emissions data have been provided on CO_2 emissions for category 5.E ("Other", specified as anthropogenic fires in the forests) but no calculation sheets have been provided. Also, data are provided for emissions of CH_4 and N_2O by category 5.E ("Other", specified as prescribed burning and anthropogenic fires in the wood production forests) that are not included in the IPCC guidelines. It is noted that the data do not relate to the soil types as specified in the IPCC guidelines but to the category "Other".

136. The "Other" category was specified as land conversion and abandonment of managed lands. For land conversion, CO_2 emissions have been reported, whereas for abandonment of managed land, CO_2 removals have been calculated. An explanation of the qualification "Not applicable" referring to the cultivation of soils, and "Not estimated" referring to forest soils, would be helpful. According to the NIR, wildfires have been calculated, but such a category has not been included in the CRF.

137. According to summary table, 2 in 1998 sector 5.D contributed 5,261 Gg carbon dioxide equivalent (Gg CO_2-e). This value was 3,526 in the year 1990.

138. *Transparency*: Country-specific methods and EFs for CO_2, CH_4 and N_2O were applied. No specific activity data information regarding activities has been included in the NIR. The NIR provides some information on the methodology used and includes literature references. However, actual calculation sheets used would improve transparency. No specific information on factors has been included in the NIR. Some additional information may be included in the literature cited, but that was not available for the review.

3. Uncertainty

139. According to the NIR (p. 78), estimates in sector 5 have to be treated as first approximations that reflect the direction (i.e., source or sink) and magnitude of emissions and removals. They are characterized by a high degree of uncertainty (over 100 per cent in almost every case). Estimates of emissions reflect "higher or maximum emissions" while the estimates of removals reflect "lower or minimum removals".

4. Reporting

140. The NIR includes a lot of very relevant information for the review process and helps to clarify the methodology used. However, in the case of emission/conversion factors or activity data, it frequently refers to background literature which was not available for the review.

5. Feed back on in-depth review

141. In its second national communication, Canada did not provide information on sector 5 and it was requested to do so. This information has now been supplied.

6. Areas for improvement

142. Canada's country-specific methods should be explained in more detail. It is recommended that the missing data should be supplied, together with additional information, as identified.

F. WASTE

1. General overview

143. The NIR presents a summary and description of the methods used, as well as references to data sources, but it could be improved by the addition of selected data tables and complete reporting in the CRF tables.

2. Specific findings

2.1 Completeness

Key sources*: *Solid waste disposal on land

159. The activity data were reported as NA in the CRF. The NIR explains use of a per capita rate to establish waste in place.

Non-key sources*: *Wastewater handling

160. Activity data are not reported in the CRF. Emissions from industrial wastewater handling are not reported owing to a lack of data on industrial practices.

Non-key sources*: *Waste incineration

161. As indicated in table 9s1, CH_4 and N_2O emissions are assumed to be negligible.

2.2 Methodology

Key sources*: *Solid waste disposal on land

162. A country-specific method was used based on the Scholl Canyon model of gas generation. It is noted in the additional information box in table 6A in the CRF, that the waste generation rate of 1.98 kg/capita/day is high compared to the IPCC guidelines.

Non-key sources*: *Wastewater handling

163. The activity data in table 6.B and the additional information box were reported as NA. However, the emission of methane was shown only from domestic and commercial wastewater handling. In addition, the N_2O from human sewage was taken into account despite the incompleteness indicated in table 9s1.

Non-key sources*: *Waste incineration

164. It is recommended that details of MSW combustion and CO_2 emissions from incineration should be elaborated.

2.3 Emission Factors

Key sources*: *Solid waste disposal on land

165. The IEF cannot be calculated owing to a lack of activity data in the CRF. The use of a model restricts analysis, but estimates appear to be based on standard assumptions.

Non-key sources*: *Wastewater handling

166. The IEF cannot be calculated owing to a lack of activity data in the CRF.

2.4 Activity data

167. The activity data were reported as NA in both key source and non-key source categories in the CRF. Provincial population data from Statistics Canada were used with per capita generation rates.

2.5 Recalculation

168. No recalculation data were found.

2.6 Result from previous review

169. Incompleteness was found in the non-key sources.

2.7 Trends

170. Emission trends in CO_2 CH_4 and N_2O gradually increased between 1990 and1998.

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