Canada's Emissions Outlook: An Update

National Climate Change Process
Analysis and Modelling Group

Processus national sur la changement climatique
Le Groupe de l'analyse et de la modélisation

Canada

CANADA'S EMISSIONS OUTLOOK: AN UPDATE

ANALYSIS AND MODELLING GROUP

NATIONAL CLIMATE CHANGE PROCESS

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Preface

This report provides an updated outlook for greenhouse gas emissions in Canada over the next twenty years. It is built upon, but replaces, the forecast developed by Natural Resources Canada in *Canada's Energy Outlook: 1996-2020*, published in April 1997. The primary objective of the update is to provide a revised reference scenario to frame the Climate Change National Implementation Strategy.

In commissioning the Analysis and Modelling Group (AMG) to undertake the update, the National Air Issues Coordinating Committee and the National Climate Change Secretariat were concerned that the development not unduly burden the analytical resources of the Issue Tables which, at the time, were deeply involved in developing their options. Given this concern, the AMG is most appreciative of the time and expertise which the Tables generously provided to its many inquiries. With apologies to anyone inadvertently not mentioned, we would particularly like to thank the following individuals for their assistance in this endeavour:

- from the Industry Table: John Dillon, Gary Webster, David Shearing, Jean Van Loon
- from the Enhanced Voluntary Action Table: Bob Redhead and François Bregha
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A work of the scope of the update is by its nature an ensemble performance. The members of the Natural Resources Canada team - Réjean Casaubon, Hertsel Labib, Nick Macaluso, David McNabb, Nancy Roberts, Joycelyn Exeter, Michel Berubé, Hy-Hiên Tran, Jai Persaud, Wally Geekie, Catherine Roberts, JoAn Halliday, Co Tran and Lifang Cui - deserve special praise for the professionalism and dedication with which they carried out this project.

We are most interested in what you, the reader, think of the report. If you have comments or questions, or require additional information, please contact me at the address below.

Best Regards

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Chapter 1

"Are these the shadows of the things that will be,
or are they only the shadows of things that may be"

Ebenezer Scrooge
A Christmas Carol
Charles Dickens, 1843

Introduction

This report has been prepared by Natural Resources Canada (NRCan) for the Analysis and Modelling Group (AMG). It responds to a request to the AMG, by the National Air Issues Coordinating Committee and the National Climate Change Secretariat, to develop a revised outlook for greenhouse gas emissions (GHG) in Canada to frame the Climate Change National Implementation Strategy. The results contained in this document should be viewed as an update to the projections published by NRCan in *Canada's Energy Outlook: 1996-2020* rather than a completely new forecast.

Several considerations led the AMG to adopt an update approach. First, a completely new forecast could not be developed within the time lines of the National Implementation Strategy. Second, the projection in the April 1997 edition of *Canada's Energy Outlook* (CEO97) was considered to be reasonably sound in terms of its fundamental trends. Third, the Issue Tables were already heavily engaged in the development of options, the analysis of which was based on the CEO97 projections of GHG emissions and the estimates of energy trends which underpin them. At the same time, the existence of the Issue Tables offered a unique opportunity to solicit the views of stakeholders on the aspects of the CEO97 projections requiring change.

The updated outlook is, thus, the projections contained in CEO97, modified by the implications of events and changes of views which have occurred since 1997 and corrected for new methodologies and for data revisions. The rationale for almost every change documented in the report has been developed in consultation with the Issue Tables.

Before describing the organization of the report, one point needs to be emphasized. The updated outlook, like its predecessor, is a "policy as usual" projection. This means both that all current federal and provincial energy, environment and related policies are held constant over the projection period and that no new policies are introduced. A policy initiative, to be included in the "policy as usual" projection, must have some tangible legislative, regulatory or program expression. A statement of intent is not sufficient grounds for inclusion in the "policy as usual" projection.

Most obviously, "policy as usual" means that Canada's Kyoto commitment - six percent below 1990 levels by the 2008 to 2012 period - is not incorporated in the projections, as the means to achieve this objective are currently being articulated through the National Implementation Strategy process. In fact, the "policy as usual" projection provides a reference against which to assess the nature and scope of the policy initiatives to achieve the Kyoto objective.

The report is organized as follows:

- Chapter 2 examines the framework assumptions used in the development of the Update;

- Chapter 3 details the emissions consequences of the changes that were recommended by the Issue Tables;

- Chapter 4 provides an overview of the updated greenhouse gas emissions projections from various perspectives including the size of the Kyoto "gap", the distribution of emissions growth across sectors and provinces, the sensitivity of the projections to changes in pricing and macroeconomic assumptions, and the outlook in the context of historical emissions trends;

- Chapter 5 outlines the conclusions drawn from the document;

- A statistical appendix provides detailed results, at the Canada level, for the Update scenario. Other annexes provide a revised listing of emissions factors and energy and emissions projections for the territories.

Full reference case results, at the national and provincial levels, are available on the Government of Canada's Global Climate Change website (www.climatechange.gc.ca), the National Climate Change Secretariat website (www.nccp.ca) and the Natural Resources Canada site (www.NRCan.gc.ca).

Chapter 2

Framework Assumptions

Canadian energy supply and demand and, thus, greenhouse gas emissions, are strongly influenced by “external” factors such as macroeconomic and demographic trends, international energy prices and the characterization of current policy. This chapter summarizes the changes made (and not made) to the assumptions for these framework variables between the CEO97 and the Update.

2.1. Changes to Macroeconomic and Demographic Assumptions

The energy and emissions projections presented in CEO97 were predicated on expected economic conditions from the perspective of late 1994. Unforeseen events such as the Asian crisis, stronger economic growth in the United States, and better-than-anticipated fiscal conditions have altered this economic growth profile significantly over the short and medium-terms. A comparison of key national and provincial macroeconomic variables for the CEO97 and Updated projections is provided below.

As highlighted in Chart 2.1, the economic projections underlying the Update are, over the medium-term, more bullish than those assumed in the CEO97. The revised Informetrica forecast calls for more robust growth in the United States through to 2000. Given the strong trade links between the two countries, the better U.S. economic performance translates into higher Canadian growth over the period to 2000 in the Update (2.9 percent annually versus 2.2 percent in the CEO97). It is noteworthy that in the Update, the improved short-term economic performance is more evenly spread between industry and services relative to CEO97. This stems from the more relaxed fiscal situation which is expected to lead to greater spending on health and education (which collectively account for one-half of the service sector). In the Update, the industrial sector is, by contrast, relatively smaller in 2000, owing to a slightly lower rate of economic growth.

Chart 2.1 also shows that while the short-term economic performance of the Canadian economy has changed in the Update, the long-term growth pattern (i.e., from 2000 to 2010) is much the same. This reflects the view of the macroeconomic forecasting community, including Informetrica, which argues that long-term growth is largely determined by future employment and productivity trends. There is no strong consensus that these trends have altered based on the evidence from the past few years. As noted below, however, this does not imply that the long-term prospects for provincial economies and specific industries have remained static.

Chart 2.1
Macroeconomic & Demographic Assumptions
(Average Annual Growth Rates %)

	1995/2000		2000/2010	
	CEO97	**Update**	**CEO97**	**Update**
US GDP	2.3	2.8	2.0	2.2
Canada GDP [1]	2.2	2.9	2.2	2.3
Industry	3.1	2.8	2.0	2.0
Services	1.7	2.8	2.3	2.3
	In Millions			
	2000		**2010**	
	CEO97	**Update**	**CEO97**	**Update**
Population	31.0	31.2	33.8	34.0
Households	11.2	12.0	12.7	13.8
Light Vehicles	16.2	16.3	18.4	19.3
Disp. Inc./HH	51,506	49,620	54,779	55,194

[1] Total GDP includes other industries such as agriculture, transportation, utilities, etc., not included in industry and services GDP.

Finally, although the economic outlook used for this update features higher GDP growth, real disposable income per household, to 2000, is lower than in the CEO97. This is partly explained by the fact that Statistics Canada has changed its definition for households with the result that the number of households is now greater both historically and in the projection. Based on the old household definition, real disposable income per household would be roughly 3.0 percent higher by 2000 in the Update relative to the CEO97.

As outlined in Chart 2.2, the Update suggests slightly lower overall industrial output growth up to 2000 relative to the CEO97. However, the performance varies widely

Chart 2.2
Industrial Output Growth Assumptions
(Average Annual Growth Rates %)

	1995/2000		2000/2010	
	CEO97	Update	CEO97	Update
Pulp & Paper	1.2	0.7	2	2
Chemicals	2.7	3	2.7	2.7
Iron & Steel	1.3	3.1	1.1	0.9
Smelting & Refining	1.5	2.6	2.4	2.5
Cement	1.5	1.3	1.6	1.5
Petroleum Refining	0.5	1.9	1	0.9
Other Manufacturing	4.7	3.7	2.5	2.3
Mining	1.2	4.6	1.1	1.1
Construction	3.2	1.8	2.2	1.9
Forestry	0.5	-2.3	1.7	1.5
Total Industrial	3.1	2.8	2	2

on an industry-by-industry basis. Export-oriented industries tied to Asian markets, such as pulp and paper, are likely to experience slower growth over the medium-term. By contrast, industries more dependent on U.S. exports, for example iron and steel and smelting and refining, are expected to experience higher growth over the medium-term relative to the CEO97 because of the stronger growth of the U.S. economy.

At the provincial level (see Chart 2.3), all provinces except British Columbia are expected to experience stronger growth over the short-term (i.e., to the year 2000) relative to the CEO97. In the case of the Atlantic provinces, the higher growth is led by the resource-based sector, notably from the Hibernia and Sable Island projects. The stronger economic performances for Québec and Ontario reflect higher personal disposable income (higher GDP and lower income taxes) and higher U.S. export growth. The provinces of Manitoba, Saskatchewan and Alberta are expected to experience GDP performance above the national average over the 1995/2000 period. This performance is partly driven by higher growth for the consumer and service sectors, higher export growth, and, for Alberta, the recently announced oil sands developments. British Columbia is expected to show the lowest GDP growth of all provinces, largely the result of stagnant Asian demand for B.C. products. Interestingly, however, growth in the high technology and services industries, located largely in the lower mainland, is expected to offset the declines in the resource industries.

Chart 2.3

Provincial Economic Growth Assumptions

(Average Annual Growth Rate %)

	1995/2000		2000/2010		% Change in Size of Economy in 2010
	CEO97	Update	CEO97	Update	Update vs CEO97
Atlantic Provinces	1.7	2.8	1.8	2	8%
Quebec	2.4	2.8	2.3	2.1	0%
Ontario	2.5	3.1	2.3	2.5	5%
Manitoba	1.6	3.5	1.9	2.3	14%
Saskatchewan	1.6	3.4	1.6	2.3	17%
Alberta	1.9	3.3	1.9	2.2	10%
British Columbia	2	2	2.2	2.3	1%
Canada	2.2	2.9	2.2	2.3	5%

The changed economic assumptions have consequences for emissions growth. The generally stronger economic growth in the short-term, coupled with the unchanged prospects post-2000, means that by 2010 the economy is 5 percent

Chart 2.4

Impact of Changed Economic Assumptions on GHG Emissions in 2010, by Sector

Sector	Increase (+)/ Decrease(-) Mt CO_2 Equivalent
Residential	0.4
Commercial	2.0
Industrial	1.0
Transportation	8.3
Agriculture	0.0
Electricity Generation	19.0
Fossil Fuel Production	0.0
Waste/Other	0.0
Total	30.7

larger in the Update. A larger economy implies, in turn, higher energy demand and emission levels. The emissions impacts in 2010, by sector, resulting from the changed economic assumptions alone are summarized in Chart 2.4. Overall, the improved economic performance underlying the Update adds about 30 Mt to the 2010 GHG estimates in CEO97. The increases are particularly large in transportation and electricity generation, the latter due to the more robust economic performance of the coal-dependent provinces of Alberta and Saskatchewan.

2.2. Energy Prices

The Update retains the energy pricing assumptions underlying the CEO97. In reviewing the energy price information, consideration was given to lowering world oil prices to reflect the drastic fall in 1998, but the balance of evidence was in favour of retaining our original assumptions. First, world oil prices currently exceed $US 22/bbl. This is in part due to the OPEC's May 1999 decision to adjust quotas, as well as the partial restoration of the Asian economies. Second, as shown in Chart 2.5, recent projections from national and international organizations call for oil prices to average $18.35/bbl in 2010 to $23/bbl in 2020. The Update assumption of $20.60/bbl is only marginally above these averages and is well within the range of forecasts.

Chart 2.5
Crude Oil Projections: WTI at Cushing
US$ 1997/Barrel

	2000	2005	2010	2020
IEA	19.50	19.50	19.50	28.70
US/DOE – Reference Case	13.95	19.25	21.30	22.75
ARC-Baseline Scenario	16.05	18.75	17.00	N/A
WEFA	18.25	19.05	19.75	21.30
GRI	17.15	16.85	16.80	N/A
DRI	15.55	16.94	19.05	24.15
PEL	15.55	14.20	13.35	N/A
PIRA	20.35	19.25	20.10	N/A
Dobson Resources (Average Consultants View)	15.50	18.65	18.65	N/A
NEB	18.00	18.00	18.00	18.00
AVERAGE	16.98	18.04	18.35	22.98
NRCan	20.60	20.60	20.60	20.60

Sources:
IEA, International Energy Agency, World Energy Outlook 1998, December 1998.
US DOE/EIA, Annual Energy Outlook 1999 with Projections to 2020 December 1998.
ARC, Advisory Research Capital, Energy Update March 1999.
PIRA Energy Group, Retainer Client Seminar, October 1999.
NEB, Canadian Energy Supply and Demand to 2025, July 1999.
PEL, GRI WEFA, were taken from US DOE/EIA International Energy Outlook 1999 with Projections to 2020
NRCan, Canada's Energy Outlook April 1997.

Consultations with the Oil and Natural Gas Sub Table, however, highlighted the importance of "risking" projects. This is to say that the industry, when deciding on investments, analyses a project's financial viability under varying energy price assumptions. In Chapter 4, the report examines the issue of price sensitivity and its implications for the greenhouse gas emissions projection.

Natural gas price assumptions are the same as in the CEO97, increasing to $2.10/Mcf in 2010 and remaining at this level until 2020. The Oil and Natural Gas Sub Table largely agreed with this projection. Its view is that increased competition, improved pipeline accessibility, the commoditization of natural gas, the greater use of storage capacity, technological advances and the sheer size of the resource base are expected to put pressure on prices from increasing substantially above this level. The average of forecasts from various organisations, in Chart 2.6, calls for prices to increase from $2.21/Mcf in 2000 to $2.25/Mcf in 2010 to $2.50 in 2020.

Chart 2.6
North American Natural Gas Prices Projections at Henry Hub
US$ 1997/Mcf

	2000	2010	2015	2020
US/DOE – Reference Case	2.20	2.60	2.70	2.80
ARC-Baseline Scenario	2.15	1.95	N/A	N/A
GRI	2.05	2.10	2.30	2.30
AGA	2.22	2.45	2.50	N/A
PIRA	2.90	2.55	N/A	N/A
Dobson Resources (Average Consultants View)	2.10	2.20	N/A	N/A
NEB (Case 1)	1.85	1.90	2.10	2.40
AVERAGE	2.21	2.25	2.40	2.50
NRCan	1.95	2.10	2.10	2.10

Sources:
US DOE/EIA, Annual Energy Outlook 1999 with Projections to 2020 December 1998.
ARC, Advisory Research Capital, Energy Update March 1999.
GRI, 1999 Baseline Projections.
AGA, 1999 Outlook.
PIRA Energy Group, Retainer Client Seminar, October 1999.
Dobson Resource Management Ltd., July 1999 Survey.
NEB, Canadian Energy Supply and Demand to 2025, July 1999. Henry Hub Prices are estimated on the basis of the NEB's Case 1 projections. Case 2 prices are about U.S.$ .90 cents per Mcf higher by 2020.
NRCan, Canada's Energy Outlook April 1997.

Electricity and coal prices are also unchanged from the CEO97. Electricity prices will continue to be determined largely at the provincial level. Coal prices are projected to remain constant in real terms over the projection period. These assumptions may understate the downward pressure on prices from increasing international competition.

2.3. The Policy Setting

The Updated outlook, like its predecessor (CEO97) is a "policy as usual" projection. This means that the outlook for greenhouse gases is predicated on the maintenance of current federal and provincial energy and related policy over the projection period. The policy framework in effect during the preparation of the CEO97 remains in place.

A critical element of current policy incorporated in the projections is the effect of existing federal, provincial and municipal energy efficiency and alternative energy initiatives resulting from the National Action Program on Climate Change (NAPCC) and the Voluntary Challenge and Registry (VCR) Program. The CEO97 undertook an extensive review of the some 272 initiatives and 235 VCR submissions. For this Updated Outlook, there has been no full-scale review of either government initiatives or of more recent VCR submissions. Therefore, recent views on the impact of initiatives may not be fully reflected. If, however, during the course of our consultations, the Issue Tables suggested changes to the assumed effectiveness of specific initiatives or to the commitments under the VCR, these changes were reflected in the Updated outlook projections.

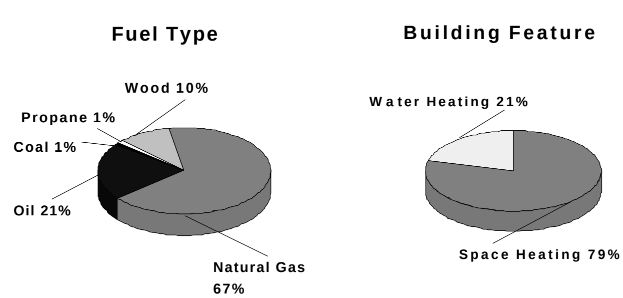
Chapter 3

Emissions Update - Detailed Changes by Sector

This chapter details the revisions to the emissions projections by sector resulting either from methodological changes or discussions with the Issues Tables. The focus is on the results in 2010, the mid-year of the Kyoto commitment period (2008-2012) and on the base year (1990). Changes in the latter are almost exclusively related to changes to methodologies for calculating emissions mandated by the United Nations Intergovernmental Panel on Climate Change (IPCC) or to data revisions. The discussion for each sub-sector begins with a review of emission sources in 1997. In these reviews, it is important to recognize that the estimates reflect direct emissions by the sector. Emissions associated with the production of oil, natural gas and coal are assigned to the Fossil Fuel Production Sector, while those related to electricity generation are assigned to the Electricity Sector.

3.1. Residential Sector

Chart 3.1
Residential GHG Emissions
Canada, 1997



53 Megatonnes

In 1997, direct GHG emissions from the residential sector (including agriculture space heating) were estimated at 53 megatonnes of CO_2 equivalent. The use of natural gas accounted for two-thirds of the emissions in this sector (Chart 3.1). A large percentage of the emissions in the sector are also attributable to the burning of refined petroleum products (RPPs), mainly heating oil. Approximately 10 percent of the total is associated with methane emissions resulting from the incomplete combustion of wood.

In the residential sector, the use of fossil fuels and wood for space heating accounts for the largest proportion of emissions (almost 80%), followed by water heating. The contribution of fuels used in cooking, lighting and refrigeration is small.

Changes in events and assumptions from CEO97 for fuel use and efficiency in the residential sector, which affected emissions, include: higher energy demand, higher wood emission factors, home energy code adoption, energy efficiencies of equipment and appliances and new thermal archetypes for housing stock. After considering these changes, emissions in the sector increased for both the baseline (1990) and the forecast years.

Revisions to Historical Energy Demand

Historical energy demand data have been revised since CEO97. Energy supply and demand information is provided primarily by Statistics Canada in the "Quarterly Report on Energy Supply and Demand". The revision to energy consumption data increased the 1990 emissions for the sector by 0.7 Mt.

Increased Economic Growth

Compared to CEO97, the Update incorporates personal disposable income per capita which is 8 percent higher. The impact of this higher income, which influences, in part, housing starts and their related energy requirements (space and water heating), is to increase emissions in 2010 by 0.4 Mt.

Methane Emissions from Combustion of Wood Products

IPCC proposed revisions to the methods and background data for calculating GHG emissions from residential wood combustion.[1] Using the new methodology and data, the methane and nitrous oxide emissions[2] from residential wood combustion have increased almost seven-fold over previous estimates. Compared to the emissions reported in

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[1] See Environment Canada, *Canada's GHG Inventory 1997 Emissions and Removals with Trends*. Air Pollution Prevention Directorate. December 1999.

[2] Carbon dioxide emissions from biomass combustion are not included in the inventory. Incomplete combustion, however, gives rise to methane (CH_4) and nitrous oxide (N_2O) emissions.

CEO97, the impact of this revision is to increase residential GHG emissions by 5.0 Mt for 1990 and by 6.0 Mt for 2010.

Change to Energy Codes for New Homes

The CEO97 assumed that the provinces would adopt the federal Model National Energy Code For Houses (MNECH) for new homes that was proposed at the time. Despite the fact that, with the exception of Quebec, no province has as yet adopted the code, the Buildings Issue Table indicated that building practices have evolved towards levels equivalent to the proposed energy codes for new houses. Based on the Table's advice, it is now assumed that building practices will be 5 percent above the proposed Model National Energy Code for Houses by 2010.

The previous forecast also assumed that future codes would move toward R-2000 levels such that, by 2010, almost all new construction would have been at R-2000 level or better. It was assumed that R-2000 homes would become the standard and that provinces would enact legislation adopting this standard. This improvement is now judged to have been too ambitious. Thus, on the advice of the Buildings Issue Table, the anticipated market take-up of R-2000 homes has been lowered and is now expected to account for only 3 percent of new construction by 2010. This closely reflects the historical penetration rates of R-2000 homes.

The net impact of these two changes increases the 2010 forecast for the residential sector by 0.6 Mt from CEO97 estimates.

Energy Efficiency of Space Heating Equipment (and Electrical Appliances)

The CEO97 postulated a "ratcheting-up" of certain regulations related to furnaces, water heaters and appliances to coincide with the regulatory cycle in the United States. It now seems likely that the U.S. will delay the application of more stringent regulations. Therefore, following the advice of the Buildings Issue Table, application of these regulations in Canada has been delayed by between two and four years. The implication of these delays, chiefly as they apply to water heating and furnaces, is to increase 2010 emissions in the residential sector by 2.2 Mt compared to CEO97.

New Thermal Archetypes for Housing Stock

New archetypes for homes were developed in order to take into account more recent survey data. Using new information from Statistics Canada and the Canadian Mortgage and Housing Corporation, older houses were found to be more efficient than was originally thought while the new houses are somewhat less efficient than anticipated. The use of these new archetypes increases residential emissions in 2010 by 0.4 Mt .

Emissions Update

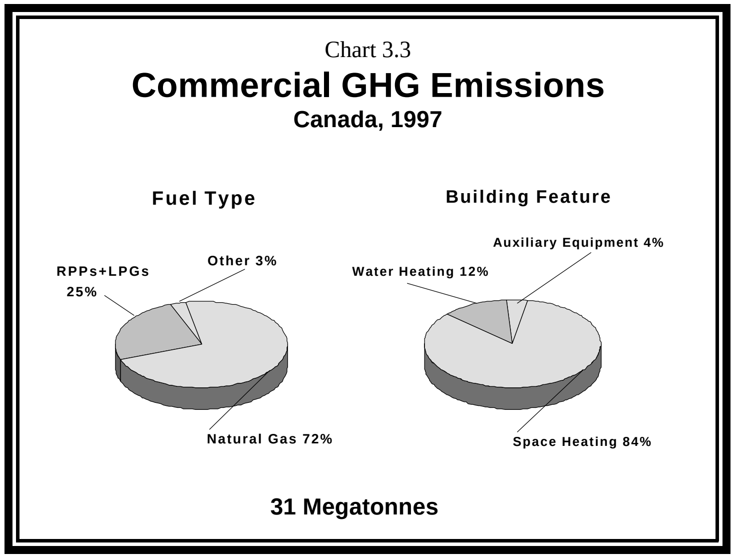
Overall, both 1990 and 2010 residential sector emission levels have risen as a result of the changes discussed above (Chart 3.2). Emissions increased by 6 Mt to 49 Mt for 1990 and by 10 Mt to 48 Mt for 2010; the difference between the 1990 and 2010 emissions level increased by 5 Mt. In CEO97 it was expected that residential sector emissions would be 6 Mt below the 1990 level in 2010. In the Update, the new estimate is 1 Mt below 1990.

Chart 3.2
Residential Sector Emissions Update

	1990 Emissions Mt	2010 Projected Emissions Mt	Difference 2010 vs 1990 Mt
CEO97	**44**	**38**	**-6.0**
Changes:			
1. Revisions to Historical Energy	0.7		
2. Increased Economic Growth		0.4	
3. Higher CH_4 and N_2O wood emissions	5.0	6.0	
4. Change to energy codes for new homes		0.6	
5. Delays in regulation for equipment/appliances		2.2	
6. New thermal archetypes for housing		0.4	
Update	**49**	**48**	**-1.0**

3.2. Commercial Sector

The commercial sector encompasses commercial and institutional buildings such as offices, retail establishments, schools and hospitals. Almost three quarters of the 31 Mt of GHG emissions in 1997 (Chart 3.3) resulted from the use of natural gas, while emissions from the use of refined petroleum products (RPPs) and liquified petroleum gases (LPGs) accounted for most of the remainder.



The space heating of buildings accounts for almost 85 percent of fuel use and associated emissions in the commercial sector. Other activities which emit GHG include water heating and the use of auxiliary equipment.

The changes outlined in the following text alter slightly the emissions estimates from those in CEO97. Although 1990 emissions for the sector remain the same, 2010 emissions increase marginally.

Increased Economic Growth

The revised short-term economic assumptions increased commercial real domestic product (RDP) in 2010, by about 6 percent as compared to CEO97. This higher RDP translates into an increase of 2 Mt of direct GHG emissions for the sector.

Non-Adoption of the "Model National Energy Code for Buildings"

In CEO97 it was assumed that the Model National Energy Code for Buildings (MNECB) would be adopted in spirit by all provinces and that provincial and municipal regulations would be harmonized. Given that nationwide adoption of the MNECB has not occurred, the Buildings Table recommended that this assumption be removed from the "policy as usual" scenario in the Update. The effect of this change is to increase commercial sector emissions by 1 Mt in 2010.

New Efficiency Programs

Although the MNECB is assumed not to be formally adopted by the provinces, it is understood that current construction practices in all provinces are equivalent to the code in place or better. In fact, new construction was 4 percent above code in 1998 and is expected to be 10 percent above in 2010. According to the Buildings Table, this further efficiency improvement is attributable to the Commercial Building Incentive and Energy Innovators Plus Programs introduced in 1998. The introduction of these programs offsets the non-adoption of the MNECB by reducing 2010 emissions by 1 Mt.

Accelerated Building Retrofits

Building retrofit activities improved energy intensity for federal building initiatives relative to the expectations in CEO97. For federal buildings, CEO97 expected a 15 to 20 percent reduction in building energy intensity affecting 70 percent of federal buildings by 2005. As energy-cost savings are about 20 percent, the Buildings Issue Table recommended that the Update adopt a more ambitious target of 100 percent of the federal buildings retrofitted by 2010.

Similarly, on the advice of the Buildings Table, the new target for municipal buildings is more ambitious given there is already significant penetration of efficiency initiatives. The CEO97 expected a 15 to 20 percent improvement in building energy efficiency, affecting 30 percent of buildings by 2005 and 90 percent by 2020. The energy intensity reductions are now expected to affect 60 percent of the municipal buildings by 2005, and the 90 percent target will be reached by 2010 instead of 2020.

Overall, the retrofit assumptions for this update improve building energy intensity targets for federal and municipal buildings over those of CEO97. However, the Update incorporates reduced retrofit activity targets for office, health, education, retail and accommodation buildings. Energy intensity reductions changed from 15 to 20 percent in CEO97 to 10 to 20 percent in the Update and are expected to affect 45 percent of the buildings by 2020 instead of 90 percent in CEO97.

The combined impact of all building retrofit activities reduces emissions by 1.2 Mt for 2010.

Updated Emissions

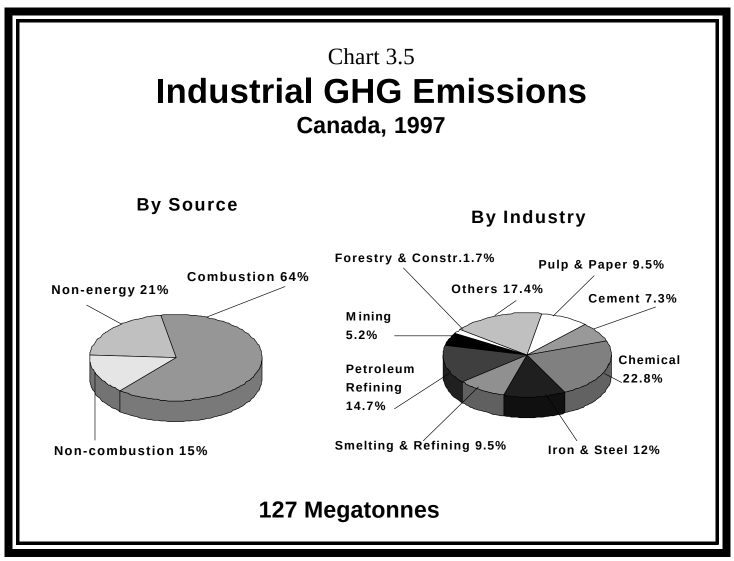
The net impact of the above changes is that commercial sector emissions are forecast to be 34 Mt in 2010, compared to 33 Mt in CEO97 (Chart 3.4). The difference with respect to the 1990 levels also increased by 1 Mt as the 1990 emissions number remained unchanged from CEO97.

Chart 3.4
Commercial Sector Emissions Update

	1990 Emissions Mt	2010 Projected Emissions Mt	Difference 2010 vs 1990 Mt
CEO97	**26**	**33**	**7**
Changes:			
1. Increased Economic Growth		2.0	
2. Non-adoption of Model National Energy Code		1.0	
3. New Efficiency Programs		-1.0	
4. Accelerated Building Retrofit		-1.2	
Update	**26**	**34**	**8**

3.3. Industrial Sector

The industrial sector is the largest energy-using sector and includes all manufacturing industries, forestry, construction and mining (but excludes the oil and gas sector)[3]. In 1997, the industrial sector produced 127 Mt of direct GHG emissions. Two-thirds of these emissions were from the consumption of energy and the remaining third from various industrial processes such as CO_2 release from cement production, anode production in aluminum



3 Emissions from non-combustion uses of energy (feedstocks, asphalt, etc.) and from fuel use in petroleum refining are included in the industrial sector. Emissions from oil and gas production in the mining sector are excluded from the industrial sector and included in the fossil fuel production category.

smelting, adipic acid in chemicals and sulphur hexafluoride use in magnesium smelting (Chart 3.5). The six energy-intensive industries (chemicals, petroleum refining, iron and steel, smelting and refining, pulp and paper and cement) account for over 80 percent of the emissions.

Based largely on discussions with the various Industry Sub-Tables and with the Forest Sector Table, a number of modifications to emissions estimates for the industrial sector have been made. A description and explanation of each change by industry follows:

Revision to Data

The revision to historical energy demand stems from an oversight in accounting for industrial processes in the CEO97. 1990 emissions in CEO97 were 564 Mt, compared to the official historical emissions prepared by Environment Canada of 567 Mt. Emissions in the Update have been increased by 3 Mt, and now coincide with Environment Canada estimates.

Changes in Macroeconomic Assumptions

As noted earlier, the revised short-term economic growth assumptions resulted in about 2 percent lower industrial output in the Update. This reduced growth is distributed across a number of industries. Of the six most energy-intensive industries, only pulp and paper is experiencing a lower growth rate than in CEO97. Therefore, from an energy requirement basis, the other five industries (i.e., chemicals, iron and steel, smelting, cement and petroleum refining) are experiencing an increase in emissions that was not entirely counter-balanced by the reduced economic activity for pulp and paper and the other less energy-intensive industries. The net effect of the changes in macroeconomic assumptions is to increase emissions by about 1 Mt in 2010.

Iron and Steel Industry

At the request of the Mineral and Metals Sub Table, the results for the iron and steel industry were reviewed with the Canadian Steel Producers Association (CSPA). This review prompted three changes to the outlook for this industry, the net effect of which is to raise GHG emissions in 2010 from iron and steel production by 1 Mt.

- ***Higher Output Growth:*** CEO97 assumed output growth in the iron and steel industry at 0.7 percent per year over the period to 2010. Because of recent increases to the steel intensity of the North American economy, CSPA argued that overall shipments would grow, from a combination of incremental increases and possibly new capacity (all from electric arc furnace production), by about 1.3

percent per year. Incorporating the CSPA growth assumption increases the emissions by some 1.2 Mt above the CEO97 level.

- ***Reduced Energy Intensity:*** CSPA does not foresee any major technological change that would decrease energy intensity substantially and, therefore suggested that energy intensity be improved at a rate of 0.8 percent per year. The CSPA assumption for energy intensity improvement is lower than that assumed in CEO97 (0.9 percent). The impact of this change is to increase emissions by 0.5 Mt in 2010.

- ***Fuel Mix - Electric arc furnace penetration:*** CSPA also indicated that the penetration of electric arc furnaces is greater than that expected in CEO97, resulting in a 0.7 Mt decrease in direct emissions in 2010.

Mining, Smelting and Refining Industry[4]

Based on discussions with representatives of the Mineral and Metals Sub Table, the Update has incorporated two changes to the emissions forecast from CEO97. Collectively, these reduce mining and smelting emissions by 1.0 Mt in 2010 from CEO97.

- ***Reduction of the Use of SF_6 in the Smelting of Magnesium:*** Sulphur hexafluoride (SF_6) is a particularly powerful greenhouse gas (one gram of SF_6 has a global warming potential of 23,900 CO_2 equivalent). It is used primarily in the smelting of magnesium, other applications being gas insulated switches and circuit breakers, fire suppression and explosion protection, sound proofing windows, leak detectors, gas-air tracers and for various electrical applications.

  Magnola Metallurgy Inc., a subsidiary of Noranda Inc., and Norsk Hydro have recently made commitments to le Ministère de l'Environnement du Québec to reduce and gradually eliminate the use of SF_6 in their magnesium casting facilities[5]. In the case of Magnola Metallurgy Inc., sulphur dioxide will gradually replace SF_6

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4 This section reports the aggregate impact for the mining and metal smelting and refining industries. This aggregation is in response to concerns from industry representatives that it is extremely difficult to disaggregate the energy use, and hence emissions, for these respective sub-sectors. Many of the companies which are involved in these sub-sectors are integrated (i.e., they are involved in both mining and smelting and refining). If Statistics Canada reports a company's energy consumption as smelting and refining, and if the company is also involved in mining activities, it is not possible to separate its energy use in mining operations from that in its smelting and refining activities. Industry representatives have suggested that this issue be further investigated.

5 Noranda, 1998 Environment, Safety and Health Report.

as the casting protective cover gas (unless another commercially viable alternative is found). The use of SF_6 will be reduced and eliminated by the year 2005. Norsk Hydro has reduced the use of SF_6 from 5.11 kg per tonne of magnesium in 1990 to 0.64kg in 1997. Further, it has made commitments to reduce SF_6 emissions to 0.15 kg per tonne of magnesium by 2000 and to completely eliminate SF_6 emissions by the end of 2003[6].

Compared to CEO97, the above commitments reduce the forecast of SF_6 emissions by 1.5 Mt of CO_2 equivalent in 2010. Overall, therefore, SF_6 emissions fall from 2.9 Mt in 1990 to 0.5 Mt in 2010.

- ***Reduction of the Use of Natural Gas in the Smelting and Refining Industry:*** In CEO97, NRCan assumed a high penetration of natural gas in the Quebec-based smelting and refining industry, implicitly suggesting natural gas availability for north shore smelters. Industry noted that the extension of a pipeline to Quebec north shore smelters does not appear plausible at this time. NRCan has revised the forecast to reflect this modification, which results in an additional 0.5 MT, as natural gas is replaced by heavy fuel oil.

Cement Industry

The Cement Issue sub-Table representatives from the Canadian Portland Cement Association and Environment Canada suggested two changes for the cement industry, resulting in an increase of 1.7 Mt in 2010.

- ***Fuel Mix to Include Waste Fuels:*** In CEO97, waste fuels were not included in the industry's fuel mix. The industry indicated a trend in the cement industry towards waste fuel use, largely replacing natural gas. The industry foundation paper[7] indicates that by 2010 waste fuels will constitute 15 percent of the fuel mix. As waste fuels are more carbon intensive than natural gas, this change increased the 2010 estimate by approximately 0.1 Mt.

- ***Growth Rates for Process Emissions:*** The chemical process to produce cement accounts for about two-thirds of emissions from the industry. One of the main processes involves the combination of heat and limestone ($CaCO_3$), producing carbon dioxide (CO_2) and quicklime (CaO). Based on discussions with Sub-Issue

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[6] Press Release, Le ministère de l'Environnement et de la Faune et le ministère des Ressources naturelle se réjouissent de l'adhésion de Norsk Hydro au programme EcoGESte., November, 1998.

[7] *Metals and Minerals Foundation Paper*, Chapter 6.

Table members and with Environment Canada, it appears that process emissions for the cement industry were underestimated in CEO97. The updating of process emissions to correspond with the industries projected growth increased process emission by 1.6 Mt for 2010.

Pulp and Paper Industry

The pulp and paper industry's emissions have been changed to reflect new information regarding the use of wood waste and natural gas. In the CEO97 projection, NRCan assumed that there would be an available, sufficient and stable economic supply of wood residues over the forecast period. Analysis by the Forest Sector Table[8], however, suggests that the economic availability of wood residue significantly constrains its use as a fuel source. Based on this analysis, the Update projection has lowered the use of wood waste, while increasing the use of natural gas (electricity in Quebec). These changes result in an increase in CO_2-equivalent emissions of roughly 0.6 Mt in 2010.

Petroleum Refining

The Update has incorporated two changes to the emissions forecast from CEO97: the first results from a modification in the methodology for establishing energy demand for the fossil fuel industries, and the second from the impact of new regulations for the petroleum refining industry.

- **Incorrect Assignment of Producer Consumption**: In CEO97, producer consumption associated with the petroleum refining industry was incorrectly assigned to the fossil fuel production sector rather than to the industrial sector. The Update corrects this, resulting in an increase in industrial emissions of about 3 Mt in 1990. The correction does not, however, affect forecast emissions from this source as the methodology for developing future producer consumption estimates is not based on historical data.

- **Lower Sulfur Levels in Motor Gasoline**: Environment Canada recently announced new regulations to restrict the sulphur levels in motor gasoline sold in Canada.[9] New regulations set a limit of 30 parts-per-million of sulphur content in gasoline starting January 1st, 2005. These new regulations will be phased-in. In

[8] Forest Sector Table, *Options Report: Options for the Forest Sector to Contribute to Canada's National Implementation Strategy for the Kyoto Protocol*, page 23, July 21, 1999.

[9] Environment Canada, *Lower levels of sulphur in gasoline will result in cleaner air for all Canadians*, Press Release, June 7, 1999.

2002, sulphur levels in gasoline produced or imported into Canada must meet an average of 150 ppm.

These regulations will necessitate large capital investments in existing refineries to allow them to meet the new standards. As well, given existing technology, it is estimated that meeting the new regulations will require up to 10 percent more "own-use" refined petroleum product use per unit of output. Less energy-intensive technologies are being developed, but will not be commercially available by 2002.

The Canadian Petroleum Products Institute (CPPI), acting on behalf of the Industry Sub-Issue Table on Petroleum Refining, provided the following tentative assessment of the consequences of the introduction of the new regulations for the petroleum refining industry:

- three small refineries will likely shut down (one each in the Atlantic region, Ontario, and British Columbia), and the lost output from the shut down refineries will be replaced by imports.

- refineries with current sulphur levels in gasoline less than 300 ppm will be able to take advantage of the averaging period in the regulations and wait to implement the less energy-intensive technologies; these will experience a 3% increase in RPP-related CO_2 emissions. All other refineries will likely experience a 10% increase in RPP emissions.

Based on these assumptions, the estimated impact of the de-sulphurization requirements is a decrease of 0.5 Mt over the CEO97 in 2010.

Other Industry Concerns Regarding Emissions Data

It should be noted that the emissions numbers identified in this section are estimates based on the best current available information provided, in large part, by Issue Table representatives. During the course of updating the emissions numbers, issues arose which could not be resolved within the framework of this report. Their resolution in the future will no doubt affect some sectoral emissions estimates. For example, the Mining and Smelting and the Chemicals industries both have concerns about the energy supply and demand data provided by Statistics Canada. For Mining and Smelting, there is a concern over data dissagregation and categorization (see footnote 4). For the Chemical industry there is a concern with the methodology used to estimate emissions. In particular, as emissions related to chemical processes are very site-specific, they cannot be estimated accurately using the present methodology and data.

Updated Emissions

The net impact of the above changes is to increase the 1990 and 2010 emissions estimates by 6 Mt and 3 Mt respectively for the industrial sector (Chart 3.6). The difference between the 2010 and 1990 levels consequently decreased by 3 Mt relative to CEO97. The changes which have the largest impact on increasing emissions are the more robust economic assumptions for cement (1.6 Mt) and iron and steel (1.2 Mt). The change most responsible for reducing emissions is the reduction in the use of SF_6 (1.5 Mt) in smelting and refining.

Chart 3.6
Industrial Sector Emissions Update*

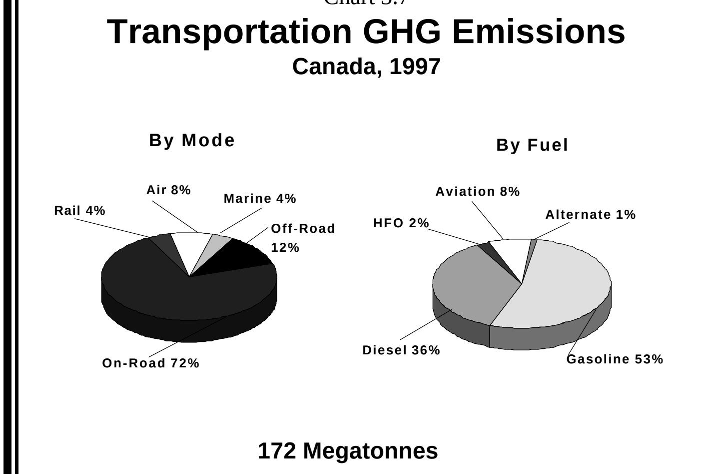
	1990 Emissions Mt	2010 Projected Emissions Mt	Difference 2010 vs 1990 Mt
CEO97	**119**	**135**	**16**
Changes:			
1. Revisions to Historical Emissions	3.0		
2. Changes to Macroeconomic Assumptions		1.0	
By Industry			
Iron and Steel			
1. Higher Output Growth		1.2	
2. Reduce Energy Intensity		0.5	
3. Increased Penetration of Electric Arc Furnaces		-0.7	
Mining and Smelting			
1. Reduction in the use of SF_6		-1.5	
2. Reduction in the use of Natural Gas		0.5	
Cement			
1. Change in Fuel Mix to Include Waste Fuels		0.1	
2. Change in Growth Rates for Process		1.6	
Pulp and Paper			
1. Substitution of Natural Gas for Wood Waste		0.6	
Petroleum Refining			
1. Reassignment of Producer Consumption	3.0		
2. Regulations Removing Sulfur From Gasoline		-0.5	
Update	**125**	**138**	**13**

*** Industrial process emissions (e.g., N_20 from adipic acid in chemicals, SF_6 in mining and smelting and CO_2 from the limestone process in cement) are included with the relevant industries**

3.4. Transportation Sector

Emissions in the transportation sector are primarily the result of gasoline (53%) and diesel fuel (36%) combustion (Chart 3.7). On-road vehicles are the largest consumer of fuels and consequently the largest contributor - over 70 percent - to emissions. Off-road is a small contributor today, but as it includes, among other things, oil sands mining activities, it grows appreciably in the future. Of the remaining modes, air is the largest at 8 percent.

Chart 3.7



Changes to assumptions about economic growth, diesel fuel demand, catalytic converter effectiveness, fuel efficiencies and the use of alternate fuels contributed to altering CEO97 estimates. These changes are detailed below.

Increased Economic Growth

Transportation is very sensitive to higher economic growth, particularly if the growth is export-led. As well, relatively low energy prices, coupled with increasing personal disposal income, contribute to increased travel. As a result of higher economic growth in the Update relative to CEO97, transportation energy demand and emissions are expected to be about 4 percent higher in 2010 relative to the CEO97 case. This translates into an 8 Mt increase in emissions in 2010 for this sector.

Increased "Off-Road" Diesel Fuel Demand

The increase in off-road diesel fuel demand is attributed to the mining sector and its associated transportation requirements. In particular, this demand increased because of the increased off-road activities related to the oil and gas industry. The overall impact is to increase 2010 emissions by 6.8 Mt.

According to the Transportation Table, only 3 Mt of the increase from diesel fuel off-road should be allocated to transportation, while the remaining 3.8 Mt is from stationary sources and should be allocated to industry. However, following the IPCC guidelines, also used by Environment Canada, all emissions from off-road diesel fuel consumption are allocated to transportation.

Lower N_2O Factor for Catalytic Converters

Catalytic converters reduce the principal causes of urban smog (hydrocarbons, carbon monoxide and nitrogen oxide (NOx) emissions) from automobile exhaust. They can, however, also produce nitrous oxide (N_2O), a powerful greenhouse gas, if their performance deteriorates with age.

Advanced 3-way catalytic units first appeared in the early 1980s, and after 1987 nearly all gasoline automobiles sold in Canada incorporated this technology. N_2O is emitted directly from catalytic converters as a result of several chemical formations (e.g., $2NO+CO= N_2O+ CO_2$). N_2O formation is dependent on the temperature of the catalysts and the age of the catalytic converter. Information available from testing a limited number of vehicles in the early 1990s suggested that the amount of N_2O emitted increases considerably as convertors age. The CEO97 used this assumption for its forecast.

Additional testing and analysis by the United States Environmental Protection Agency, and a recent review by Delucchi and Lipman[10] have resulted in revisions to emission factors for early 3-way catalytic converters. The new estimates do not indicate significant degradation with catalyst age. Estimates of N_2O emissions for vehicles after 2004 are not available in the literature, but indications from the types of technology being developed suggest that further reductions are very likely - a conservative 25% reduction has been assumed. Some of the reasons underlying this expectation are the lower sulphur content of gasoline and the use of electrically-heated or “closed-coupled catalysts”. These catalysts, which will likely be used to meet the proposed new emission standards, will reduce significantly the catalyst warm up period, during which most of the N_2O emissions are generated.

Based on the revised N_2O emission factors provided by Environment Canada, the 1990 GHG emissions from this sector has been reduced by 2 Mt compared to the CEO97. Based on the information provided by the Transportation Issue Table, the Update assumes that the gasoline N_2O emissions factor for automobiles and light duty trucks, per unit of fuel, will decline during the forecast period. The reduction in the N_2O factor decreases the 2010 emissions for the transportation sector by 8.3 Mt of CO_2 equivalent.

Improved Fuel Efficiency - Rail/ Marine Transportation

[10] Timothy E. Lipman and Mark A. Delucchi, *Emissions of Methane and Nitrous Oxides from Energy Systems*. September 1998.

In CEO97, it was assumed that fuel efficiency (i.e., kilometre-tonnes per litre) in the rail transport would increase by 0.25 percent per year, while the efficiency in marine transport would remain virtually unchanged. Modal studies prepared for the Transportation Issues Table identified several potential advancements in fuel efficiency technology in the rail and marine sectors. For example, recent orders by Canadian Pacific for new AC traction locomotives are expected to decrease fuel consumption by 20 percent. On the basis of these studies, [11,12] the Table recommended increasing the baseline assumptions on fuel efficiency improvements to 0.3 percent per year for marine and 1.0 percent per year for rail. As a result of these changes, CO_2 emissions in 2010 decline by 0.7 Mt in the rail sector and 0.3 Mt in the marine sector.

Reduced Fuel Efficiency - Air Transportaion

Based on consultations with the Air Transportation Association of Canada (ATAC), the Transportation Table recommended an improvement in aircraft fuel efficiency at one percent per year, rather than the two percent rate that was assumed in CEO97. This change results in an increase of CO_2 emissions of about 2 Mt in 2010.

Alternative Transportation Fuels

Natural Gas and Propane: A review of the Statistics Canada's estimates of natural gas and propane consumption, reported in CEO97, indicated an overstatement of the actual volumes used on the road. Accordingly, the historical estimates of natural gas and propane use were revised to agree with the estimates by the Canadian Natural Gas Vehicle Alliance (CNGVA) and the Propane Gas Association of Canada (PGAC). Recent evidence also indicates reduced activity and lower sales of new alternative-fuelled vehicles. The higher average usage associated with alternative-fuelled vehicles also means that their retirement rate is higher than that of other vehicles. The combination of there factors results in a diminishing stock of propane vehicles and a slightly lower number of natural gas vehicles in the update, compared to CEO97.

The above factors led the Transportation Table to propose a lower use of these alternate fuels on the road relative to the CEO97 case. Since gasoline will replace these fuels, emissions increase by 1 Mt in 2010. It should be noted that the forecasts are under policy as usual conditions which include another 3 years of MDIP incentives for natural gas

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[11] Bronson Consulting Group/CPCS Transcom Ltd., *Assessment of Opportunities to Reduce GHG Emissions in the Marine Transportation Industry*, April 1999.

[12] Delcan Corp, *Assessment of Freight Forecasts and GHG Emissions*, Final Report, March 1999.

vehicle manufacturers and no federal incentives for propane.

Ethanol: The Transportation Table recommended an increase in the levels of ethanol use projected in CEO97 on the basis of increased domestic supply. Initiatives, such as the IOGEN-PetroCanada venture to lower the cost of producing ethanol from waste biomass and the continuation of current excise tax and provincial motor fuel tax exemptions, support this recommendation. Construction of two ethanol plants is expected by 2010, with a further three cellulosic ethanol plants between 2010 and 2020. The ethanol produced is assumed to be used in blends of 5 to 10 percent by volume in gasoline. As a result of this assumption, emissions decline by 0.3 Mt in 2010.

The combined impact of the changes to natural gas, propane and ethanol consumption increases the 2010 projection by 0.7 Mt of CO_2-equivalent.

Update Emissions

As shown in chart 3.8, the net effect of the above changes is to decrease 1990 emissions in the transportation sector by 2 Mt, but to increase 2010 emissions by 9 Mt. Consequently, the difference between the 2010 and 1990 level in this sector rises from 39 Mt to 50 Mt, an increase of 11 Mt. It should be noted that about 3 Mt of this is accounted for by activities related to oil (e.g., oil sands mining and production) and natural gas exploration and extraction.

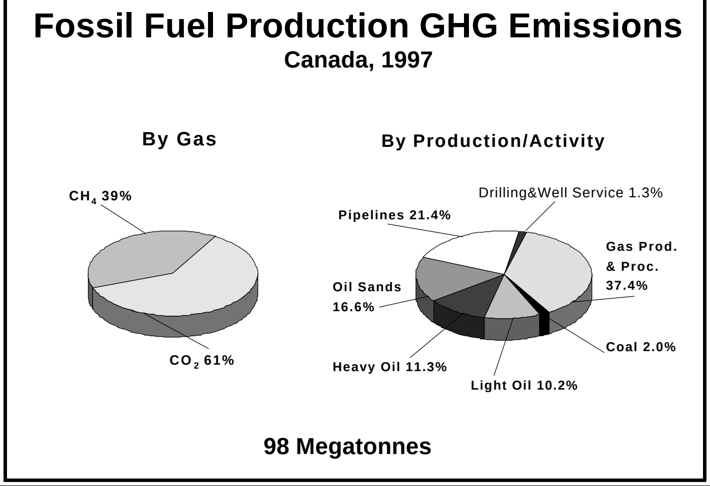
Chart 3.8
Transportation Sector Emissions Update

	1990 Emissions Mt	2010 Projected Emissions Mt	Difference 2010 vs 1990 Mt
CEO97	**149**	**188**	**39**
Changes:			
1. Revised Economic Growth		8.3	
2. Increased Off-Road Diesel Fuel Demand		6.8	
3. Lower N_2O Factor for Catalytic Convertors	-2.0	-8.3	
4. Improved Fuel Efficiency For Rail		-0.7	
5. Improved Fuel Efficiency For Marine		-0.3	
6. Reduction in Fuel Efficiency For Air		2.0	
7. Alternative Fuel Penetration		0.7	
Update	**147**	**197**	**50**

3.5. Fossil Fuel Production

In 1997, the fossil fuel producing industry (i.e., oil, natural gas and coal extraction and production) accounted for 98 Mt of GHG emissions (Chart 3.9). Almost 40 percent of the emissions came from the production and processing of natural gas, while conventional oil production (light and heavy) and oil sands contributed 22 percent and 16 percent respectively.

Chart 3.9



Since the publication of CEO97, there have been several significant developments in the oil and gas industry. New pipelines and pipeline expansions have been reviewed and approved by the National Energy Board (NEB), major oil sands developments were announced late in 1997 and oil prices have fluctuated significantly during the last two years. These events and several methodological changes (such as revised GHG emissions factors and new oil and gas production profiles) influence the GHG emissions projection for the sector.

The changes to the assumptions underlying this update have been discussed with the Canadian Association of Petroleum Producers (CAPP) and the Canadian Energy Pipeline Association (CEPA), which were designated by the Oil and Natural Gas Sub-Industry Issue Table to speak on its behalf. The changes to emissions are as follows.

Revised Data/Definition

In CEO97, NRCan made a first attempt to identify the emissions associated with fossil fuel production (i.e., oil, natural gas, and coal producers). In the process, the producer consumption associated with the petroleum refining industry was incorrectly transferred to the fossil fuel industries sector. The Update correctly assigns the producer consumption to the refining industry. The impact of this change is to decrease emissions, in 1990, by 3 Mt.

Revised Emissions Rates

Chart 3.10
CO_2 and CH_4 Emissions Rates - 1995
(CO_2 Equivalent)

	CO_2		CH_4	
	CEO97	**Update**	**CEO97**	**Update**
Bitumen (Kg/bbl)	38	69.8	1.8	4
Synthetic (Kg/bbl)	115.7	117.8	1.8	6.7
Gas Production (Kg/Mcf)	3.2	2.2	1.1	1.4
Gas Processing (Kg/Mcf)	2.7	1.2	1.1	1.1
Conventional Light Oil (Kg/bbl)	12.5	23.2	6.3	7.7
Conventional Heavy Oil (Kg/bbl)	23	10.2	38.9	58.7

To estimate CO_2 and CH_4 emissions, CEO97 relied on the emission rates contained in a 1992 study by Clearstone Engineering Ltd. This study, prepared for CAPP and Environment Canada, developed a detailed inventory of organic and common-pollutant emissions for the Canadian upstream oil and natural gas industry. This Update relies on a more recent study, also prepared for CAPP and Environment Canada, by Clearstone Engineering Ltd. in 1997[13] (Chart 3.10). Applying these new rates, the 1990 emissions are reduced by 5 Mt.

With respect to the emissions rates used for future emissions, the Clearstone study suggests that the factors used in CEO97 underestimated the emissions generated from the upstream oil and gas industry. Applying the new rates to the production levels forecast in CEO97 increases emissions in 2010 by about 4 Mt.

Revised Efficiency Improvements (VCR)

The CEO97 estimates of energy efficiency and process improvements in the oil and gas sector were based on the 1995 and 1996 VCR submissions of CAPP and of several large companies in the industry. CAPP now considers the rate of efficiency and process improvement assumed in CEO97 to be higher than what is currently believed achievable. As well, the Canadian Energy Pipeline Association (CEPA) suggested a revision to the factors assumed in CEO97 and suggested rates that more reasonably represent its expectations related to pipeline capital expenditures and the contribution of more efficient technologies. The efficiency improvements used in the Update have been reduced to reflect the above views of the industry. The lower efficiency gains over time further increase the emissions for 2010 by about 5 Mt. A complete set of emission rates adjusted for efficiency over time can be found in Appendix B.

13 Clearstone Engineering Limited, *CH4 and VOC Emissions From The Canadian Upstream Oil and Gas Industry*: Volumes 1 through 4. 1997.

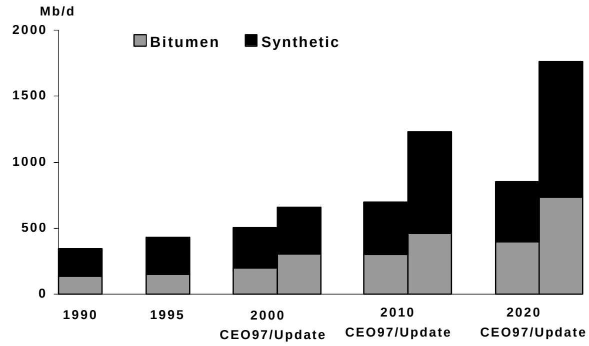
Greater Oil Sands Production

The largest change in the updated outlook relates to expected oil sands production. Although such production was anticipated to increase in CEO97, all observers were surprised by the number and size of the developments announced following the improved fiscal and regulatory terms enacted by the Alberta and federal governments in 1996 and 1997. To date, there have been announcements of investments totalling about $20 billion to develop projects generating up to 1.2 million barrels per day.

Chart 3.11

Bitumen and Synthetic Production

(Thousands of Barrel Per Day)



It seems unlikely, however, that all of the proposed developments will take place by 2010. Based on discussions with the Oil and Gas Sub Issue Table, these developments have been effectively phased-in over a twenty-year period. This scenario is similar to that proposed by the National Energy Board in its recent Supply and Demand report.[14]

Under the phased-in scenario, oil sands production is projected to increase from 525 thousands barrels per day (mb/d) in 1997 to 1230 mb/d in 2010. This will further increase to 1765 mb/d in 2020 as a result of expansions to existing facilities and development of new projects. Synthetic oil production is projected to increase from 290 mb/d in 1997 to 770 mb/d in 2010 and 1030 mb/d in 2020. Bitumen supply is expected to increase to 460 mb/d in 2010 and 735 mb/d in 2020. The direct GHG emissions associated with the additional production of synthetic crude oil and bitumen, using the new factors, are estimated at 11 Mt and 4 Mt, respectively.

Greater East Coast Oil Supply

In CEO97, crude oil supply from Canada's East Coast was projected to level off at 200 mb/d sometime between 2000 and 2005. Owing to higher reserve estimates and a revised project design, production from Hibernia is now anticipated to increase from 135 mb/d to

[14] The National Energy Board, *Canadian Energy Supply and Demand to 2025*. July 1999.

180 mb/d. The anticipated level of East Coast oil production has been adjusted accordingly to 250 mb/d. This level of production is assumed to remain unchanged until the end of the forecast period. An increase of 50 mb/d corresponds to about 0.2 Mt of additional GHG emissions.

Higher Natural Gas Supply

Chart 3.12
Marketable Natural Gas Supply and Demand
(Trillions of Cubic Feet Per Year)

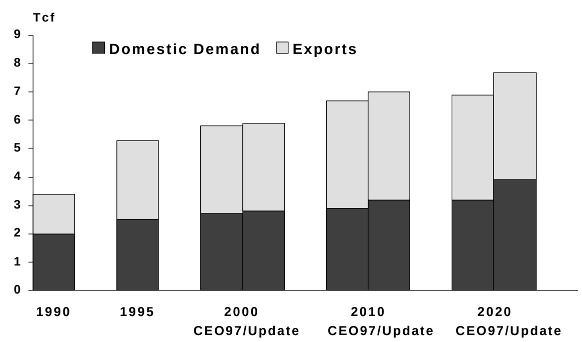


Chart 3.12 shows marketable natural gas production and exports for the CEO97 and for the Update. In the latter, natural gas production is expected to increase from 5.5 Tcf in 1997 to 7.0 Tcf in 2010 and to 7.7 Tcf in 2020 reflecting both growth in domestic demand and exports. Domestic demand is projected to increase to about 3.2 Tcf in 2010 to 3.9 Tcf in 2020. The growth in domestic demand is stronger than anticipated in CEO97, reflecting greater natural gas use in the residential sector as well as for electricity generation. Natural gas exports are projected to increase from 2.9 Tcf in 1997 to 3.8 Tcf in 2010 and remain at this level until the end of the forecast period. The CEO97, by contrast, called for lower levels at 3.5 Tcf in 2010 and 3.7 Tcf in 2020. Pipeline expansions (including the Foothills, TransCanda Pipelines, and Alliance) are assumed sufficient to meet the increased export levels. Using the revised emission factors, the production increase in 2010 translates into an additional 2 Mt in emissions.

Updated Emissions

The net effect of the changes outlined for this sector is to widen significantly the difference in emission levels between 1990 and 2010. As a result of changes to emissions factors and correction for the misallocation of refinery producer consumption, emissions for 1990 decreased by 8 Mt compared to the CEO97 (Chart 3.13). Conversely, the suggested changes increase projected emissions, for 2010, by 26 Mt. These factors contribute to a widening the difference between 2010 and 1990 from 14 Mt in CEO97 to about 48 Mt for this Update.

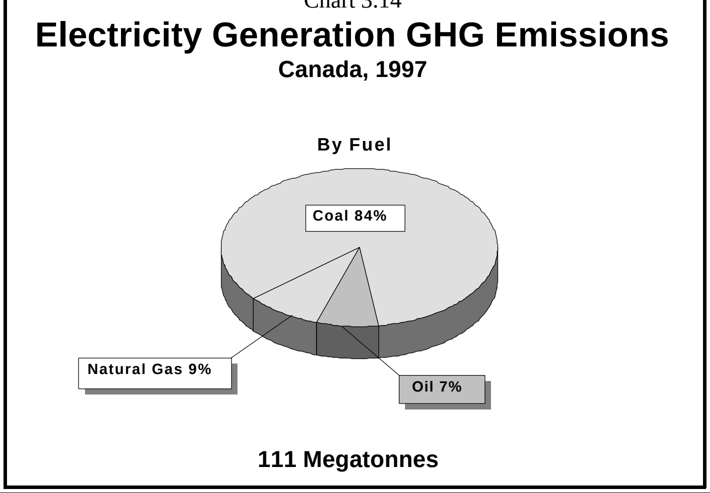
Chart 3.13
Fossil Fuel Production Emissions Update

	1990 Emissions Mt	2010 Projected Emissions Mt	Difference 2010 vs 1990 Mt
CEO97	**83**	**97**	**14**
Changes:			
1. Transfer of Producer Consumption	-3.0		
2. Revised Emissions Factors	-5.0	4.0	
3. Revision to Efficiency Improvements (VCR)		5.0	
4. Crude Oil Production			
- Higher Oil Sands Production		15.0	
- Greater Crude Oil Supply From East Coast		0.2	
5. Higher Natural Gas Supply		2.0	
Update	**75**	**123**	**48**

3.6. Electricity Generation

Emissions from electricity generation in 1997 were 111 Mt. The overwhelming proportion - 84 percent - was from the use of coal. Natural gas and oil accounted for 9 and 7 percent respectively (Chart 3.14).

Chart 3.14



The restructuring of the electricity market in Canada is fundamentally altering the electricity supply industry. The basic trends include unbundling of major utility functions into generation, transmission and distribution. Restructuring should allow open access to transmission networks, thereby creating a more competitive generation market.

The degree and pace of change taking place in the electric utility industry varies significantly from province to province. Alberta, with the establishment of the Alberta Power Pool in 1995, was the first province to implement a competitive framework with customer choice expected to be in-place by 2001. With the implementation of *The Energy Competition Act*, Ontario is also moving toward a competitive market. In 1999, Ontario Hydro was restructured into three components - an independent market operator, a generating company and a service company. Wholesale and retail competition is expected by 2000. British Columbia, Alberta, Manitoba and Québec have opened their transmission system to competitors and as a result have gained access to the U.S. market.

As the electricity market is expected to change considerably during the period covered by this projection, it is recognized that the modelling of electricity supply is becoming more difficult and complex. In a dynamic market place, the electricity demand in a specific province or region will not necessarily be met by electrical energy generated in the same region. In the context of this update of CEO97, however, the provinces and territories are still considered as distinct markets in terms of supply and demand, after consideration for specific or anticipated amounts of energy transfers.

The assumptions incorporated in CEO97 were discussed with representatives of the Electricity Issues Table and the resulting proposed changes were incorporated in this revised outlook. The changes, examined below, result in a higher emissions forecast for 2010.

Increased Economic Activity

Compared to CEO97, the Update's electricity demand projections for 2010 increased by about 45 TWh (or about 7%). The more robust macroeconomic assumptions, described in Chapter 2, combined with revisions to the fuel mix for different industries (mainly iron and steel) increased demand for electricity in the end-use sectors by about 33 TWh. Revisions in our assessment of electricity requirements for the oil and natural gas industry accounted for the remaining 12 TWh. Assuming the same generation mix as in CEO97 (i.e. hydro where available and a 50-50 mixture of coal, and natural gas-fired plants in the other provinces), the net effect on emissions would have been an increase of about 11 Mt for the change attributable to macroeconomic assumptions and about 8 Mt for additional electricity requirements of the oil and natural gas industry. This large increase (19 Mt) was computed using the fuel mix assumed in CEO97. The real net impact for this update is, however, much lower. The revised assumptions on new capacity additions are discussed in the following item.

Capacity Additions and Retirement Assumptions

Another important assumption for this Update is the choice of technologies for new generating facilities. In CEO97, we had assumed an economic life for thermal plants of about 50 years and, as noted above, a specific generation mix (i.e., hydro where available and a 50-50 mixture of coal and natural gas-fired plants in the other provinces). The Electricity Table recommended that all existing thermal plants be assumed to operate at their current level of efficiency during their economic life (estimated at about 40 years). As new or replacement units are required to firm up dependable generation, they will be constructed in small capacity increments mostly through high efficiency combined cycle gas turbines (CCGT), or through hydro developments in the provinces where it is possible.

Coal-fired generation, however, is expected to remain competitive in Alberta and Saskatchewan, as a result to improvements in combustion technology. Coal-fired generating capacity is, thus, assumed to remain relatively constant over the projection period. Consequently, any retiring coal-fired plants in these provinces will simply be replaced with much more efficient units. Several CCGTs will also be added to meet increasing electrical energy demand.

Overall, the changes in assumptions for new capacity additions and retirements reduce emissions by about 12 Mt in 2010 compared to CEO97. Changing the economic life assumption from 50 years to 40 years, and replacing these retiring units, mainly in Ontario, with natural gas reduces emissions by about 3 Mt. The reduction associated with changing the 50% coal/50% natural gas assumption to natural gas (or clean coal) is about 9 Mt in 2010.

Lower Churchill Hydroelectric Project

The Lower Churchill hydroelectric development, located in Labrador, was not included in CEO97. In March 1998, the Premiers of Newfoundland and Labrador and of Quebec announced the beginning of formal negotiations between Newfoundland and Labrador Hydro and Hydro Québec, with a view of arriving at an agreement for the completion of the hydroelectric development of the Churchill River in Labrador and of the related projects in Québec[15]. The Memorandum of Understanding currently being negotiated proposes the building of a new 2264 MW generating station at Gull Island on the lower Churchill River, with possibly another 824 MW station at Muskrat Falls, and a new 1000 MW facility at the existing Churchill Falls site.

[15] Press Releases from the Office of the Premier of Quebec and the Office of the Premier of Newfoundland and Labrador, March 9, 1998.

For purposes of this Update, it is assumed that the Lower Churchill development comes on stream in 2008 with annual production of about 17 TWh. It is further assumed that this power will either be exported to the United States, via a transmission line through Quebec, or serve to meet electricity demand in Quebec. The use of Lower Churchill power in Quebec substitutes for the development of hydro sites in that province. The consequence of these assumptions is that the Lower Churchill development does not lead to any direct emissions reductions in Canada[16].

Natural Gas Use in the Atlantic Region

In CEO97, it was assumed that all natural gas from the Sable Island project would be exported to the United States. It is increasingly apparent, however, that a portion of the gas will be used in the Maritime provinces. As natural gas from the Scotian Shelf becomes available, many facilities currently in operation are expected to be retrofitted to burn natural gas (as well as to retain the capability to burn oil). In 2000, it is anticipated that the Nova Scotia Power's Tuft's Cove facilities and one of the units of New Brunswick Power's Courtnay Bay facility will be retrofitted in this way. A second unit at the Courtney Bay facility will also be repowered in late 2001, and by 2003, the Tractebel 350 MW CCGT will in service. The impact of these retrofits is estimated to reduce emissions in 2010 by 2 Mt.

Bruce Not Restored

As part of its nuclear recovery plan, Ontario Hydro announced, in August 1997, that the A units of the Pickering and Bruce nuclear generating stations would be laid-up for an indefinite period.[17] The units to be shut down were the four units at the Pickering station, each of about 500 megawatts capacity, and the three at the Bruce station, rated at about 800 megawatts each.

While there is considerable uncertainty associated with the status of these nuclear units, the Electricity Issue Table has indicated that of the seven nuclear units, the four at Pickering are more likely candidates for return to operation than the Bruce units. The basic argument is that a policy as usual scenario does not appear to provide the

16 It is worth noting, however, that the proposed Québec-Newfoundland Agreement provides for an assignment of greenhouse gas emissions credits, if such a credit system is created in Canada, between the two provinces. Newfoundland would receive all the credits from Gull Island and 50 percent of those from Muskrat Falls and the new facility at the existing site.

17 Ontario Hydro News Release, *Ontario Hydro Moving Ahead on Major Overhaul of Its Production Facilities,* August 13, 1997.

appropriate economic conditions for the refurbishment of the Bruce units.

Consequently, in the Update, the Bruce A units are assumed not to be restored to service. Such a change from the original assumptions should eliminate the majority of the interruptible exports that were anticipated in CEO97 and will support power purchases from Québec and Manitoba (or from U.S. based generators). An annual amount of 5 TWh (1.4 TWh from Manitoba and 3.6 TWh from Quebec) is assumed, although with no firm purchase agreements contemplated in an open market.

The remaining required energy to be generated within the province in the absence of the Bruce A units is about 8 TWh. On the assumption that this is accomplished by a combination of existing coal and new gas-fired facilities, emissions in 2010 would increase by about 4 Mt over CEO97 projection.

It should be emphasized, however, that future market forces, price signals and cost structures could heavily influence the outcome for some of the above assumptions. The Bruce A units could be returned to service, providing enough energy to influence both the need for new generating facilities as well as the level of electricity transfer either into or from the province.

Updated Emissions

The net effect of the above changes is to increase electricity generation emissions in 2010 from 110 to 119 Mt (chart 3.15). The resulting difference between the 2010 and 1990 levels for this sector therefore rises by 9 Mt (i.e., from 15 Mt to 24 Mt). The new demand for electricity is responsible for the bulk of the change followed by the assumption that the Bruce A units are not returned to service.

Chart 3.15
Electricity Sector Emissions Update

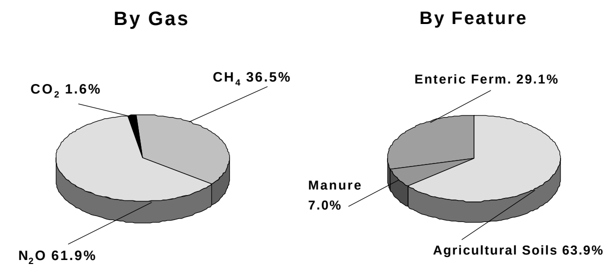
	1990 Emissions Mt	2010 Projected Emissions Mt	Difference 2010 vs 1990 Mt
CEO97	**95**	**110**	**15**
Changes:			
1. Increased Economic Growth		19.0	
2. Capacity Additions and Retirements		-12.0	
3. Lower Churchill Hydroelectric Project		0.0	
4. Natural Gas in Atlantic Region		-2.0	
5. Bruce Not Restored		4.0	
Update	**95**	**119**	**24**

3.7. Agriculture

Chart 3.16

Agricultural GHG Emissions

Canada, 1997



63 Megatonnes

GHG emissions in the agricultural sector are largely non-energy related. As shown in Chart 3.16, the largest proportion of emissions in the agricultural sector comes from the release of N_2O attributed to agricultural soil management and crop practices (i.e., soil nitrification and denitrification processes). Manure storage and handling and enteric fermentation from livestock produce methane which also contributes significantly to the GHG emissions for the sector while CO_2 release from soil cultivation is relatively marginal in its emissions contribution.

Changing methodologies for estimating various types of GHG emissions is the most significant change to the sector. This Update increases the emissions for the agricultural sector significantly from CEO97 for both 1990 and 2010. In 1990 the emissions increase from 30 Mt to 61 Mt while in 2010 it changes from 38 Mt to 72 Mt.

New IPCC Methodologies for Emissions From Agricultural Practices

In CEO97, agricultural emissions were quite small (30 Mt). After the release of the Outlook, the Intergovernmental Panel on Climate Change (IPCC) recommended a new methodology for estimating emissions, chiefly nitrous oxide, from agricultural practices. The effect of this new methodology is to increase emissions in 1990 by some 31 Mt of CO_2 equivalent so that 1990 emissions from this sector are now 61 Mt.

Agriculture and Agri-Food Canada, using its modelling structure and the new methodologies, has projected that non-energy agriculture emissions, in 2010, will be some 34 Mt higher than previously reported in the Outlook. In this projection, nitrous oxide emissions from fertilizer use increase while carbon dioxide emissions from soil tillage and methane emissions from manure are reduced.

Emissions Update

The new methodologies and the subsequent new forecast have practically doubled agricultural emissions for both 1990 and 2010 (Chart 3.17). The changes to this sector have resulted in an widening of the differences between 2010 and 1990 from 8 Mt to 11 Mt.

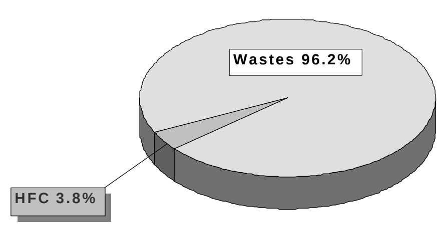
Chart 3.17
Agriculture Sector Emissions Update

	1990 Emissions Mt	2010 Projected Emissions Mt	Difference 2010 vs 1990 Mt
CEO97	**30**	**38**	**8**
Changes:			
1. New IPCC Methodologies for:			
- Land Use (CO_2)		-5.0	
- Manure (CH_4)		-4.0	
- Soil (N_2O)	31.0	44.0	
Update	**61**	**72**	**11**

3.8. Non-Sector Specific Emissions

While the Update has attempted to allocate emissions to the sector responsible for their generation, there were instances where such an allocation was not possible. For example, it was not possible to assign emissions related to the consumption of hydrofluorocarbons (HFC) to a particular sector. In addition to landfill wastes, this category includes emissions associated with the production and use of

Chart 3.18
Non-Sector Specific Emissions
Canada, 1997



26 Megatonnes

anaesthetics and propellants and from wastewater handling and waste incineration.

Emissions from waste (i.e. wastewater handling and waste incineration) are not directly measured, but are estimated from data collected by Environment Canada. A change in methodology, recommended by Environment Canada, has resulted in an increase of 4 Mt in 1990 and by 3 Mt in 2010 compared to the estimates used in CEO97.

Chart 3.19
Non-Sector Specific Emissions Update

	1990 Emissions Mt	**2010 Projected Emissions Mt**	**Difference 2010 vs 1990 Mt**
CEO97	**19**	**31**	**12**
Changes:			
1. Revised Data	4.0	3.0	
Update	**23**	**34**	**11**

3.9. CEO97 vs Update: A Summary of Sectors

This Chapter has identified several changes to the 1990 emissions levels and examined the impact of a large number of changes suggested by the various Issue and Industry Sub-Issue Tables on forecasted emissions. The impact of all these changes is summarized by sector in Chart 3.20 which provides the following important comparisons between CEO97 and the Update:

- comparison of the changes to the 1990 baseline.
- comparison of the changes to emissions in 2010.
- the difference between 2010 and 1990.
- the change in the difference.

The changes identified in this Update increase 2010 emissions by 95 Mt (i,e, from 669 Mt reported in the CEO97 to 764 Mt). Other, primarily methodological changes have increased 1990 emissions by 37 Mt. As a consequence of these revisions, the change in emissions between 1990 and 2010 has increased by 58 Mt. Also, as the Kyoto commitment is measured against the 1990 level, the changes noted above increase the emission target from 531 Mt to 565 Mt (see chart 3.21).

Chart 3.20
Update for GHG Emissions by Sector
Comparison of CEO97 to the Update

Sectors	**1990 Mt**		**2010 Mt**		**Difference 2010-1990**		**Change in Difference Mt**
	CEO97	**Update**	**CEO97**	**Update**	**CEO97**	**Update**	
Residential	44	49	38	48	-6	-1	5
Commercial	26	26	33	34	7	8	1
Industrial	119	125	135	138	16	13	-3
Transportation	149	147	188	197	39	50	11
Fossil Fuel Production	83	75	97	123	14	48	34
Electricity	95	95	110	119	15	24	9
Agriculture*	30	61	38	72	8	11	3
Others (e.g., wastes, HFC, anaesthetics and propellants)	19	23	31	34	12	11	-1
Total	**564**	**601**	**669**	**764**	**105**	**163**	**58**

* Non-energy related agriculture emissions. Energy related emissions included in residential

Overall, the Update forecasts that Canada's greenhouse gas emissions are 199 Mt greater than the Kyoto target in 2010 (see Chart 3.21).   This represents an increase of about 61 Mt from CEO97 and is due to the changing sectoral circumstances described in the preceding text. The fossil fuels sector is the greatest contributor to this widening emissions gap. It accounts for about 60 percent (34 Mt) of the increase in the Kyoto gap. Transportation (11 Mt) and Electricity Generation (9 Mt) are the next largest contributors. All sectors, except for industrial and others, have a larger emissions gap with the Kyoto target than was indicated in CEO97.

Chart 3.21
The Kyoto Gap
Comparison of CEO97 to Update

Mt	**1990 Emissions**	**Kyoto Target**	**2010 Projected Emissions**	**Kyoto Gap in 2010**
CEO97	564	531	669	138
Update	601	565	764	199
Change	37	34	95	61

Under the Update, the relative size of the Kyoto gap has also increased. In CEO97, the percentage change in the gap (i.e., projected 2010 emissions relative to the Kyoto target) was 21 percent. In the Update the overall gap has increased to 26 percent.

Chapter 4

The Updated Emissions Outlook

This section explores the updated GHG emissions outlook, constructed in the previous chapters, from several perspectives. These perspectives include:

- the magnitude of the "gap" - the difference, in 2010, between the Kyoto target and the policy-as-usual projection.
- the impact of current government initiatives in reducing emissions.
- the distribution of the GHG projections by gas, by fuel, by sector, and by province.
- the sensitivity of the estimate of the "gap" to changes in underlying variables such as world oil prices and economic growth.
- a comparison, over the historical and projection periods , of the proximate factors underlying the trends in emissions.

4.1. The Gap

Figure 4.1 provides the overall projected trend in Canada's greenhouse gases from 1990 to the second decade of the next century. It also offers an estimate of the magnitude of the Kyoto challenge expressed as the "gap" between the policy-as-usual outlook and Canada's target under the Protocol (six percent below 1990 levels, on average, over the

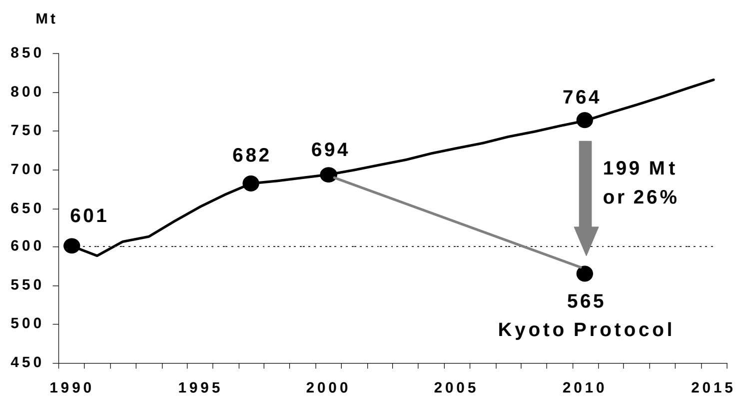
2008-2012 period).[18]

In 1990, Canada's greenhouse gas emissions were 601 Mt of CO_2 equivalent. By 1997, the latest year for which data are available, they had risen to 682 Mt, a growth of 13 percent. The updated forecast suggests that, by 2010, Canada's GHG emissions will increase to 764 Mt and, by 2020, to 845 Mt. By 2010, therefore, GHG emissions would be some 27 percent above the 1990 level. By 2020, in the absence of policy changes, they would be 41 percent above the 1990 level (i.e., 845 Mt vs 601 Mt).

Canada's Kyoto target for the 2008-2012 commitment period is 565 Mt. To achieve that target, emissions, in 2010, must be reduced by 199 Mt. This represents a gap of some 26 percent between the Updated forecast projection and the Kyoto target[19]. This compares to a gap of 21 percent in CEO97.

Chart 4.1

Canada's Policy as Usual Emissions Projection and the Kyoto Protocol



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18 The Kyoto Protocol covers six greenhouse gases - carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6). The aggregate target is established using the carbon dioxide equivalent of each of the greenhouse gases. For the three synthetic greenhouse gases - HFCs, PFCs, and SF_6 - a country can use either a 1990 or a 1995 base, whichever is most advantageous. Based on the data for those emissions, Canada will use a 1990 base.

19 The Kyoto target is specified over the average of the five years of the commitment period 2008-2012. On this basis, the gap in 2008 is 24 percent rising to 28 percent by 2012.

4.2. Contribution of Initiatives to Emissions Reductions

The Update, like its predecessor, incorporates estimates of the impact of federal, provincial and municipal initiatives - including the Voluntary Challenge and Registry (VCR) program - resulting from the 1993 National Action Program on Climate Change (NAPCC). Although, as noted earlier, we did not undertake a wholesale review of these initiatives for the Update, there have been some specific changes resulting from consultations with the Issue Tables. The most important of these are: the non-adoption of the Model National Energy Code for Housing; the delays in regulations for equipment and appliances; the Innovators Programs introduced in 1998; the reduced VCR potential in the oil and gas industry; and the commitments of magnesium producers to eliminate SF_6.

Chart 4.2
Impact of Initiatives

	2000	2010	2020
	Mt of CO_2 Equivalent		
Emissions level Pre-Initiatives	729	824	942
Impacts of Initiatives			
• **End-use**	12.0	26.0	61.0
• **Electricity Generation**	3.0	3.0	3.0
• **Fossil Fuel Production**	10.0	19.0	20.0
• **Non-Energy**	10.0	19.0	20.0
Total Impact of Initiatives	35.0	60.0	97.0
Emissions level Post-Initiatives	694.0	764.0	845.0
Initiatives as Percentage of Pre-Initiative level	4.8	7.3	10.3
Initiative as percentage of Kyoto Gap	-	30.6	-

Chart 4.2 provides estimates of the emissions impact of the NAPCC initiatives for 2000, 2010 and 2020. The first line shows the emissions level which would have been projected in the absence of the initiatives. The following panel details the emissions impact of the initiatives by sector. Among the various initiatives, those from non-energy - the N_2O reduction from adipic acid and the SF_6 elimination by magnesium producers - have a large immediate impact. By contrast, the impact of the initiatives in fossil fuel production and the end-use sectors, since they depend on capital stock turnover, grow appreciably over time.

Overall, the NAPCC initiatives are estimated to reduce emissions by 35 Mt in 2000, 60 Mt in 2010, and almost 100 Mt in 2020. Had it not been for these initiatives, emissions would have been almost 8 percent higher in 2010 and 11 percent higher in 2020. More pointedly, in the absence of the initiatives, the Kyoto gap would have been about 30 percent larger.

Chart 4.3
GHG Emissions By Gas
Mt of CO_2 Equivalent

	1990	1997	2000	2010	2020
Carbon Dioxide (CO_2)	461	520	537	596	662
Methane (CH_4)	75	90	90	92	97
Nitrous Oxide (N_2O)	57	64	57	62	65
Sulfur Hexafluoride (SF_6)	3	1	1	1	1
Perfluorocarbons (PFC)	6	6	6	6	6
Hydrofluorocarbons (HFC)	0	1	2	7	14
Total	601	682	694	764	845

Total may not add due to rounding.

4.3. Estimates by Gas and Fuel

Chart 4.3 provides a view of the long-term trend in GHG emissions by gas. By 2010, CO_2 emissions are 135 Mt (29 percent) higher than in 1990. By 2020, they are 201 Mt (44 percent) higher. Given the dominance of CO_2 in the overall total of GHG emissions, its growth accounts for slightly more than 80 percent of the emissions increases between 1990 and 2010.

Methane emissions generally follow the overall upward trend. Nitrous oxide emissions decline after 1997 and remain below the 1997 levels until after 2010. This pattern is the result of two offsetting developments. First, Dupont installed an emission control technology, in 1997, at its Maitland, Ontario adipic acid facility that will soon eliminate about 10 Mt (of CO_2 equivalent) of N_2O emissions. Second, and operating in the opposite direction, the use of nitrogen fertilizers in agriculture continues to increase over time.

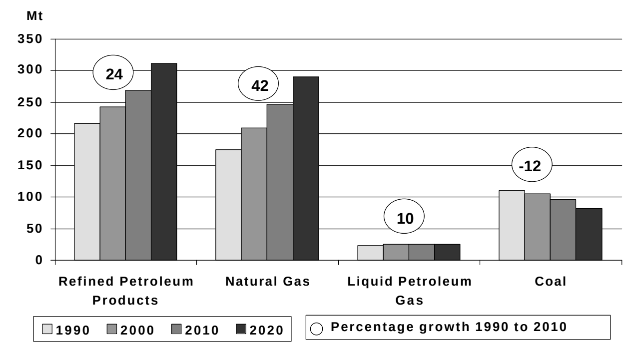
Other sources include the CFC substitutes (i.e., HFCs), PFCs and sulfur hexafluoride (SF_6). As noted in the previous chapter, the use of SF_6 in magnesium casting will be gradually reduced and eliminated by the year 2005. The remaining SF_6 emissions (about 0.5 Mt) are from the other applications of this gas. HFCs, which did not exist in 1990, are expected to grow appreciably from a small base, while PFC emissions, largely a by-product of aluminium smelting, are expected to remain constant throughout the period.

As illustrated in Chart 4.4, emissions from refined petroleum products (RPPs), the largest energy-related source, increase by some 24 percent between 1990 and 2010. This largely reflects the growth in transportation fuels which account for over 80 percent of emissions from RPPs.

Natural gas is the second leading source of energy related emissions. The large increase in emissions to 2000 is mainly a consequence of the rapid growth of natural gas exports during the 1990s. The post-2000 growth is related primarily to the increased use of natural gas as a fuel for electricity generation. This latter phenomena also explains the decline in coal-related emissions.

Chart 4.4

Energy-Related GHG Emissions By Fuel



4.4. Emissions By Sector

This section explores the trends in GHG emissions by sector with special focus on the large contributors - transportation, industry, fossil fuel production and electricity generation. It also provides a view of sector emissions if emissions associated with electricity generation are assigned to the sectors consuming the electricity.

Chart 4.5

GHG Emissions By Sector

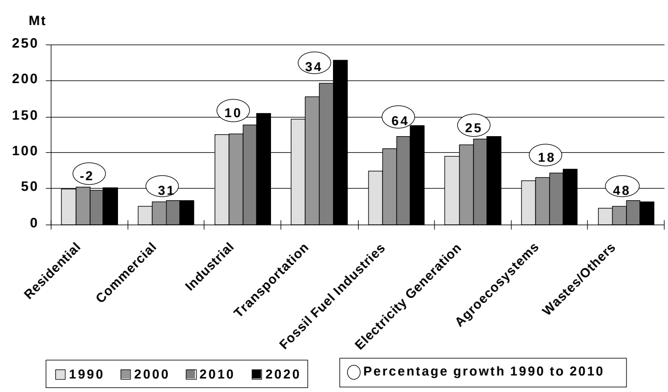


Chart 4.5 provides an overview of direct emissions by sector. The Fossil Fuel Industry - the largest

contributor to emissions growth - increases by some 64 percent between 1990 and 2010. This largely reflects the increase in oil sands production anticipated to occur during this period. In terms of absolute increase, transportation accounts for the largest contribution (50 Mt) . The emission growth in the transportation sector - some 34% between 1990 and 2010 - is closely related to the growth in travel and freight services, but the “off-road” component related to the oil, natural gas and coal mining activity also plays a role. The increase in emissions from the industrial sector is also significant but the pace is somewhat slower owing primarily to greater energy efficiency improvements and reductions in certain process emissions (N_2O from adipic acid and SF_6 from magnesium smelting). The residential sector generates a slight decrease, while the commercial sector experiences a fairly modest increase in emissions. These latter results are closely linked to the impact of energy-efficiency regulations on buildings, heating systems, and other energy using equipment.

For electricity generation, emissions grow rapidly from 1990 to 2015. After 2015, however, growth declines sharply as existing coal-fired plants, reaching the end of their service life are retired and replaced by natural gas or highly efficient coal-fired plants. In the fossil fuel production sector, emissions grow rapidly from 1990 to 2000. From 2000 onward, emissions continue to increase but at a lower rate of growth. This trend is related to the increasing effectiveness of initiatives to constrain CO_2 emissions and methane leakage by the oil and gas industry which takes place against a backdrop of significantly increased production.

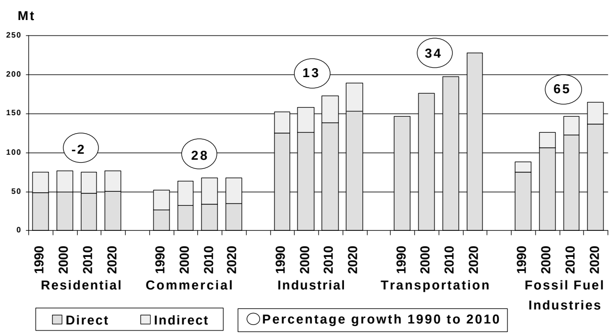
Emissions related to agroecosystems exhibit a steady growth over the projection period, increasing by some 18 percent between 1990 and 2010. Likewise, emissions from waste and CFC substitutes are expected to increase by some 48 percent. The major driver of this growth is the increasing use of hydrofluorocarbon substitutes for CFCs.

In the preceding discussion, emissions are assigned to the emitting sector (i.e, the sector which is directly responsible for combusting fossil fuels). Sectors such as electricity generation, however, produce emissions because they are responding to a demand for energy services emanating from the consuming sectors.

Chart 4.6 is an experiment in which the "indirect" emissions from electricity generation are distributed to the end-use sectors - chiefly residential, commercial, industrial, and fossil fuel production - which consume the electricity[20]. As expected, the re-allocation of these indirect emissions increases emissions in the end-use sector. The re-allocation, however, does not fundamentally change the growth trends for the end-use sectors.

Chart 4.6

Direct and Indirect GHG Emissions By Sector



As noted earlier, emissions from the transportation sector are expected to increase by some 34 percent between 1990 and 2010. Chart 4.7 provides some insights into the sources of this growth. Road transport dominates the sector. Thus, the growth in emissions for road transport is close to that for the sector as a whole. Emissions from heavy

Chart 4.7
GHG Emissions From the Transportation Sector
Mt of CO_2 Equivalent

	1990	2000	2010	2020	% Change 1990-2010
Road					
Light & Medium Vehicles[1]	84.8	97.4	107.8	124.4	27.2
Heavy Trucks[2]	18.1	26.5	28.6	32.9	58.4
Others	0.7	0.6	0.9	1.1	18.2
Total On-Road	103.6	124.5	137.3	158.4	32.5
Farm Gasoline	3.9	2.9	2.7	2.9	-30.8
Air	10.6	14.4	17.6	21.1	66.0
Rail	7.1	6.9	7.1	7.4	0.0
Marine	6.1	6.7	7.0	7.4	14.7
Off-Road Gasoline	4.0	4.9	5.6	6.4	40.0
Off-Road Diesel	12.2	16.5	20.1	24.2	64.7
Total	147	177	197	228	34.0

1. Includes cars, minivans, light-duty trucks, vehicles used by the public administration and manufacturing sectors and alternative fuelled vehicles.

2. Includes trucks above 15 tonnes.

20 While the exercise is instructive, there are certain drawbacks. First, as industrial demand is typically considered base load - base load is met by mainly hydro, nuclear and coal in provinces where there is no hydro or nuclear - the bulk of the remaining electricity-related emissions should be assigned to the residential and commercial sectors. Second, the argument can be made that transportation emissions should be assigned to the residential, commercial, industrial and fossil fuel production sectors because the demands generated within these sectors are responsible for the emissions.

trucks, however, grow at more than twice the rate of emissions for light and medium vehicles reflecting the strong link between trucking services and economic growth.

Among the other modes, emissions growth from marine and rail activity is very modest reflecting both the limited expansion of such activity and more energy-efficient rolling stock. Emissions from air transport, however, grow by more than 66 percent between 1990 and 2010. This large increase is due mainly to economic growth and growth in leisure travel. Off-road emissions also grow rapidly over the period. About one-half the increase is related to increased oil and natural gas activity, in particular, the oil sands developments.

The industrial sector is extraordinarily complex and heterogeneous. By definition, it includes all manufacturing, as well as metal mining, and construction activities. Within manufacturing, industries range from those that transform raw materials into more refined forms (e.g., the primary metals and petroleum refining industries) to those that produce highly finished products (e.g., pharmaceuticals, and electronic industries). The most significant determinant of industrial emissions is demand for final outputs.

Chart 4.8 shows the emissions anticipated for the industrial sector and the various industries and groupings.[21] Over the 2000 to 2020 period, total industrial emissions are projected to grow from 125 Mt to 152 Mt. This slow growth - almost one percent a year - is due to a shift to less energy-intensive industries and efficiency gains. The reductions in N_20 from adipic acid production and SF_6 from magnesium smelting also contribute to the slow growth in emissions.

Chart 4.8
GHG Emissions by Industry
Mt of CO_2 Equivalent

	1990	2000	2010	2020	% Change 1990-2010
Pulp and Paper	12.6	11.3	13.3	13.7	5.6
Chemicals	26.8	20.2	23.0	26.9	-14.2
Iron and Steel	14.1	16.0	16.2	17.5	14.9
Smelting and Refining	14.1	12.8	12.6	13.2	-10.6
Petroleum Refining	17.8	21.4	23.3	26.9	30.9
Other Manufacturing	24.3	24.6	27.2	29.3	11.9
Metal Mining	4.7	6.9	7.7	8.5	63.8
Construction	0.7	1.3	1.2	1.2	71.4
Cement	9.7	10.0	12.0	14.7	23.7
Forestry	1.0	0.7	0.7	0.7	-30.0
Total	**125**	**125**	**138**	**152**	**10.4**

May not add-up due to rounding

21 Emissions from industrial processes and petrochemical feedstocks have been assigned to the respective industrial sectors.

While the emissions increase for the sector is some 10 percent, not all the industrial sub-sectors are experiencing increases. Among the industry sub-sectors, the largest increases compared to the 1990 emissions levels are projected for construction (71 percent), metal mining (64 percent)[22], petroleum refining (31 percent), cement (24 percent), with iron and steel (15 percent)[23] the fifth highest. The largest declines in emissions are anticipated for forestry (30 percent), smelting and refining (11 percent), and for chemicals (14 percent).

GHG emissions from fossil fuel production are derived from two principal sources:

- from fossil fuel used in the exploration, development, production and transport of crude oil, natural gas and coal; and,

- from fugitive emissions (mainly CO_2 and CH_4) from the production and transport of these raw materials (i.e. venting, pipeline leakage).

The trends in both emission sources are closely related to the volume of oil, natural gas and coal production. They can, however, be modified by improved monitoring and the application of technology.

The CO_2 and methane emissions associated with fossil fuel exploration, extraction, production and transport are presented in Chart 4.9.[24] As expected, the increase in oil and natural gas production volumes generates significant increases in emission levels. CO_2 emissions, largely related to oil sands and natural gas production, grow from 46 Mt in 1990 to 84 Mt in 2010 and to 98 Mt in 2020. Methane emissions, which are driven by increased gas production, increase 35 percent between 1990 and 1997, increase further by

[22] As noted earlier (see footnote number 4) the integrated nature of the mineral industry makes it difficult to segment mining from smelting and refining activities.

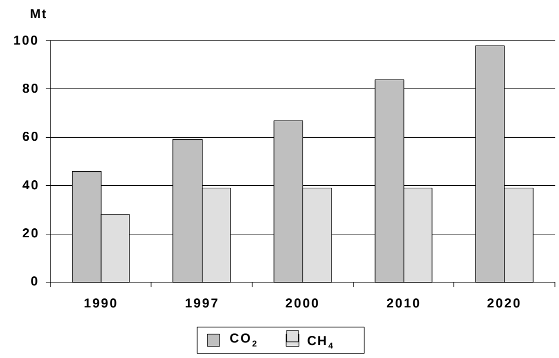
[23] The selection of 1990 as the base year for establishing the Kyoto Commitment raises an important concern for the Iron and Steel industry. In 1990, employees at three integrated steel mills were on strike for six months, and consequently, steel production was lower than it would have been under normal conditions. If 1990 were a normal year, emissions from steel production would have totaled 17.4 Mt rather than the 14.1 Mt actually recorded.

[24] As previously reported, diesel used in fossil fuel production is reported in the transportation sector.

2000 before plateauing at about 39 Mt after 2010. This levelling off in methane emissions is due to the voluntary actions undertaken by this industry to reduce venting and pipeline leakages.

Chart 4.9

Emissions From Fossil Fuel Production



Electricity use is currently the third largest source of GHG emissions. Although the consumption of electricity produces no emissions at the point of use, its generation currently accounts for 15 percent of total emissions, and that share is expected to increase to 16 percent in 2010. By 2020, as many of the existing coal plants reach their in-service life and are retired, emissions from the sector could account for some 12 percent of total emissions.

Chart 4.10 provides the projections for emissions from electricity generation by fuel type. As noted earlier, emissions from this sector are expected to increase by some 25 percent between 1990 and 2010. The Chart provides several insights into the source of this growth. Emissions from natural gas-fired generation increase significantly by some 650 percent. This reflects the increasing importance of natural-gas fired capacity. Emissions from coal-fired generation increase by 5 percent between 1990 and 2010, while those from oil-fired generation are declining significantly by 55 percent.

The more dramatic changes occur post-2010. Over the 2010-2020 period, the coal-fired related emissions decline from 84 Mt in 2010 to some 49 Mt in 2020. Offsetting this decline is a more

Chart 4.10

GHG Emissions From Electricity Generation

(Megatonnes)

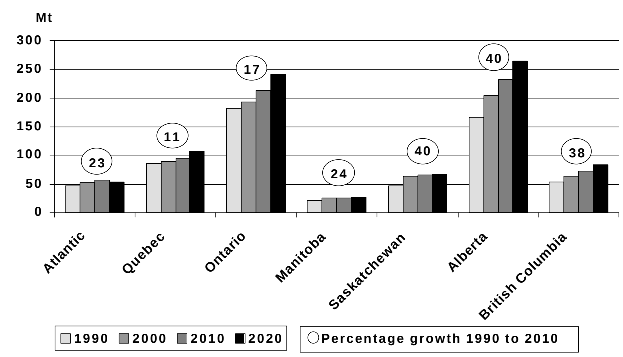
	1990	2000	2010	2020	% Change 1990-2010
Coal	80	90	84	49	5.0
Natural Gas	4	18	30	69	650.0
Oil	11	3	5	5	-54.5
Total	**95**	**111**	**119**	**123**	**25.3**

than doubling of emissions related to natural-gas fired generation. Natural-gas fired emissions increase from their 2010 level of 30 Mt to some 70 Mt in 2020. Oil-fired generation remains, except in Newfoundland and in certain isolated communities, a marginal fuel used for peaking. It should be noted that over the projection period the majority (i.e. over 75 percent) of Canada's electricity production is generated by non-emitting GHG sources: principally hydro and nuclear power.

4.5. Emissions By Province and Territory

Charts 4.11, 4.12 and 4.13 portray long-term emissions growth on a provincial and territorial basis. The pattern of emissions growth varies across provinces, largely reflecting the distribution of energy reserves and production, manufacturing activities and population densities.

Chart 4.11
GHG Emissions By Province



The major highlights of emissions growth in the provinces and territories are:

- Between 1990 and 2010, the provinces of British Columbia,[25] Alberta and Saskatchewan are expected to experience the largest increases. Emissions for British Columbia are expected to increase by some 38 percent, while those for Alberta and Saskatchewan increase by 40 percent; by contrast, emissions in Québec are expected to increase by only 11 percent.

- The growth in emissions from 1990 to 2010 in Ontario and Québec is about one-half that in Saskatchewan and Alberta.

- In absolute terms, Alberta and Ontario are expected to experience the largest increase in emissions. Between 1990 and 2010, emissions in Alberta, which is the leading oil and natural gas producer, are expected to increase by 67 Mt, while

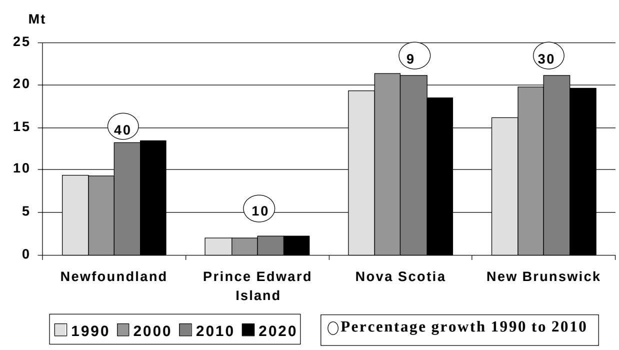
[25] British Columbia includes the emissions projections for the Territories.

emissions in Ontario - Canada's industrial heartland and most populated province - are expected to increase 31 Mt.

- Up to 2000, Alberta (1.6 percent) and Saskatchewan (1.2 percent) will experience the highest annual growth in emissions. These increases are associated with the resource boom in the west (e.g., in particular greatly increased natural gas production largely for export to the United States).

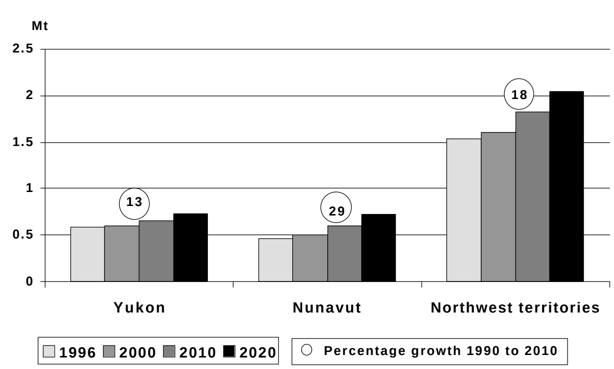
- In the longer-term (2000-2010 period), however, Ontario and Alberta are anticipated to have above average increases. For the former, the chief reasons for the increase are the closure of some of the nuclear plants and the increasing use of natural gas and coal for electricity generation.

Chart 4.12
GHG Emissions - Atlantic Provinces



Between 1990 and 2010, emissions in the Atlantic region are expected to increase by 23 percent. Newfoundland experiences the largest increase at 40 percent (see Chart 4.12). The higher emissions are due to increased economic activities resulting from projects such as Hibernia, Terra Nova and Voisey's Bay.

Chart 4.13
GHG Emissions - Territories



Despite anticipated economic growth in Nova Scotia and New Brunswick, emissions will decline after 2010. The reduction in emissions is primarily due to fuel switching from oil and coal to natural gas from the Sable Island project.

Between 1996 and 2010, emissions in the territories are expected to increase by 13 percent for the Yukon, by 29 percent for Nunavut, and by 18 percent for the Northwest Territories (Chart 4.13). It should be noted that 1996 is the first year for which historical emissions data are available. An energy and emissions projection for the Territories can be found in Annex A of this report.

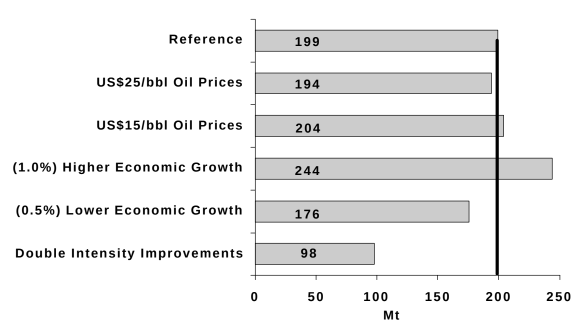
4.6. Sensitivity Analysis

The reference case projection is only one among many possible views of the future. Changes in any of the key assumptions will result in a different outcome for energy demand and supply and greenhouse gas emissions (GHG). This section reviews the implications, for the Kyoto gap, of changing world oil prices, of increased and decreased economic growth prospects and of greater declines in the rate of carbon intensity. In doing so, the sensitivities also help establish some confidence bounds around the reference case projection. It is important to emphasize, however, that these sensitivities are not <u>alternative scenarios</u> but rather cases in which one assumption is changed while everything else is held constant. Chart 4.14 summarizes the impact of changing key assumptions on the gap.

<u>Lower Oil Prices</u>

This simulation assesses the impact of lower world oil prices on the gap. Specifically, the world oil price is assumed to fall to US $15 per barrel in 2000 and remain $5.00 (US 1999$) below the reference projection over the entire forecast horizon.

Chart 4.14
Sensitivity Analysis: Projected Changes in the "GAP"



A sustained reduction in world oil prices would have a significant impact on energy demand and supply. On the one hand, lower oil prices increase the demand for petroleum products. On the other, lower oil prices diminish the economics of crude oil production. These demand and supply changes have opposite effects on GHG emissions.

As a result of lower prices, gasoline, diesel and heavy fuel prices are about 5 ¢/litre (1999$) below reference case levels. The higher energy use resulting from these lower prices lead to a 20 Mt increase in GHG emissions by 2010. The increase stems from purchases of less efficient vehicles (e.g., sport utility vehicles) and greater distances travelled in the transportation sector and a switch to less expensive heavy fuel oil in the industrial sector.

On the supply side, however, a drop of oil prices to $US 15/bbl negatively impacts project economics and industry cashflow and consequently, oil production. In particular, at $15/bbl, new synthetic grass roots projects are likely to become uneconomic given the high capital and operating costs associated with these projects. A significant number of the announced bitumen projects also would not proceed given the low netbacks to producers with prices at $15/bbl. Conventional oil production does not decline substantially due to the relatively lower replacement and operating costs. The overall impact of lower oil prices is a 15 Mt decline in upstream GHG emissions. Given the higher emission factors, and greater decline in supply, oil sands accounts for most of the drop in GHG emissions.

On balance, the net outcome of lower oil prices is a 5 Mt increase in the gap. It should be stressed, however, that this analysis is based on several speculative assumptions such as natural gas prices being unaffected by lower oil prices and the capacity of industry to switch from natural gas to heavy fuel. Environmental considerations may also limit the switching potential.

Higher World Oil Prices

In this case, world oil prices are assumed to rise to US $ 25/bbl in 2000 and remain at US $ 5/bbl above the reference level throughout the forecast period. As in the case of lower prices, the price change has opposite effects on energy demand and supply. Petroleum product demand is reduced by higher prices while crude oil production is positively affected.

Because of higher prices, lower energy use reduces GHG emissions by 20 Mt in 2010 relative to reference case levels. The lower and higher oil price cases display symmetric demand-side results for similar reasons.

On the supply side, the increase in oil prices to US $25/bbl leads to higher production and consequently, greater GHG emissions. Higher oil prices, we believe, will advance the start-up of synthetic oil sands projects in comparison to the reference scenario. It is not expected, however, that more than the announced projects will come on stream by 2010 given the long lead times associated with planning and execution of these projects. Similarly, higher prices will result in increased bitumen production but it is expected that market constraints and various bottlenecks within the system will restrain a more aggressive development pattern prior to 2010. Improved economics and industry cashflow are also expected to result in increased conventional production. The higher level of oil production results in a 15 Mt increase which is parallel to those in the lower world price case (see Chart 4.14). Further, as in the lower price sensitivity case, most of the change in GHG emissions results from changing synthetic and bitumen supply.

The net effect of higher oil prices, is therefore, a 5 Mt decrease in the gap. As in the lower price case, the analysis for higher world oil prices hinges upon speculative assumptions such as unchanged natural gas prices and the presumption that construction of all announced oil sands projects can be undertaken within the next decade. If the latter is not possible, then the reduced demand effect would dominate.

Lower Economic Growth

The reference case assumes a growth rate of 2.3 percent per year over the 2000-2010 period. For the lower economic growth case, we assume a generalized growth of 1.8 percent per annum[26] or 0.5 percentage points below the reference. As a consequence, the economy is approximately 5.5 percent smaller by 2010. This represents a pessimistic view of economic growth given the range of forecasts for this period.

Overall, energy demand is about 4 percent lower in 2010 relative to the reference case because of lower economic output. The non-proportionality between economic growth and energy demand is due to the fact that demographic trends do not change and hence, demand in the residential and personal transportation sectors is not as negatively affected as other sectors directly tied to economic performance. The lower energy demand

[26] In order to accommodate this lower growth, labour productivity is assumed to grow by 0.5 percent less per year. The latter is reflected by a corresponding decrease in real personal disposable income because of the decline in the real wage rate to compensate for lower productivity gains. A significantly lower economic growth assumption, e.g., 1 percent less per year, would necessitate changes to assumptions concerning demographic trends, labour markets, structural shifts in economic production, etc.

translates into a 23 Mt reduction in GHG emissions by 2010 relative to reference case levels. In terms of the gap, this amounts to a 12 percent reduction. The decrease in GHG emissions is less than the decrease in energy demand because of the impact of lower growth on the electricity intensive industrial sector. This reduced electricity demand would have been generated primarily from non-emitting sources such as hydro.

Higher Economic Growth

This case examines the implications of generalized higher economic growth on the gap. GDP is assumed to grow by 3.3 percent, on average, per year over the 2000-2010 period instead of 2.3 percent in the reference case forecast. This higher growth profile is similar to the growth experienced since 1993. The improved performance results in economic output that is approximately 11.5 percent higher in 2010 relative to reference case levels.

As a result of higher economic growth, emissions in 2010 are 45 Mt higher, an increase of approximately 25 percent in the gap relative to reference case levels. The lower percentage increase in emissions relative to economic output reflects the smaller impact on demand in sectors driven chiefly by demographic variables (e.g., residential and personal transportation). It should be noted, however, that the impact of higher economic growth on the gap may be somewhat overstated. Higher growth implies greater investment in buildings, equipment and machinery and these investments are typically more energy-efficient. The methodology does not fully capture the impact of this new investment on the average efficiency of the capital stock.

Doubling the Decline in Carbon Intensity

Carbon intensity, defined as GHG emissions divided by Gross Domestic Product, is a key aspect of emissions trends. In the reference case, the carbon intensity decreases at an annual rate of 1.4 percent between 2000 and 2010.

For illustrative purposes, we have assumed for this scenario, an arbitrary doubling of the carbon intensity decline across the economy. The simulation, therefore, assumes that the carbon intensity of the economy decreases by 2.8 percent per year over the 10-year period. Carbon intensity is thus about 25 percent lower in 2010 relative to the year 2000 instead of a 12 percent reduction in the reference case.

As a result of this increased reduction in the carbon intensity, the gap narrows significantly to 98 Mt or roughly half way to the Kyoto target by 2010. It should be noted that this is by no means a policy scenario and it is solely intended for illustrative purposes. Further, we do not speculate on how it would occur nor do we project the capital stock and low carbon technologies that would be required to achieve this scenario.

4.7. The Proximate Causes of GHG Trends

An examination of GHG emissions trend raises several issues, three of which are:

- What are the underlying causes of the trend in GHG emissions?
- Are the forecast results consistent with historical trends or, at least deviate from the latter in explicable ways?
- Can we identify those variables which policy can influence to achieve Kyoto and the magnitude of the required change?

This section explores these questions by means of a simple mathematical device known as the Kaya identity. This approach, also known as "factorization", directly relates the growth in historical and projected GHG emissions to its proximate causes: changes in the carbon intensity of the economy, growth in output and population increases.

The simple "mathematics" of the approach are developed below. In any year t, the level of greenhouse gases (GHG_t) in Canada can be expressed as:

1) $$GHG_t = (GHG_t / GDP_t) * (GDP_t / POP_t) * (POP_t)$$

where GDP_t and POP_t are, respectively, the level of gross domestic product and the size of the population.

Expression (1) can be differentiated between any two years as:

2) $$\%\triangle GHG = \%\triangle(GHG / GDP) + \%\triangle (GDP / POP) + \%\triangle (POP)$$

Expression (2) indicates that the annual rate of change in greenhouse gas emissions ($\%\triangle GHG$) is equal to the sum of three terms:[27]

$\%\triangle (GHG / GDP)$ is the annual per cent change in the greenhouse gas intensity of the economy (i.e., the rate at which GHG emissions are generated for

[27] The right-hand side of (2) is not precisely equal to the $\%\triangle GHG$ as there is typically a small residual summarizing the interaction of each of the three variables with the other two.

changes in the country's economic output). This variable can change as a result of improvements in energy intensity, by fuel switching to/from more carbon intensive from/to less carbon intensive fuels or by reductions in non-energy process-related emissions.

$\% \triangle (GDP / POP)$ is the annual per cent change in the ratio of GDP and population. This term can be viewed as a proxy for the growth of income per capita and is related roughly to the growth of labour productivity.

$\% \triangle (POP)$ is the annual per cent change in population.

Two of the three components which influence the growth in emissions (i.e, the GDP growth per population and the percentage change in population) are unlikely to be the subject of energy or environment policy, programmes or initiatives. This implies that the only component which can be targetted by such policies or programmes is the economy's emissions intensity.

Chart 4.15 portrays the components of GHG emissions growth from a historical and forecast perspective for each decade from the 1970s to 2000-2010. The movement of the components for the 1970s is examined to illustrate how the various components influenced the growth of GHG emissions in that decade. For the 1970-1980 period, emissions grew by 2.1 percent per year. Two of the determinants of this growth (the GDP growth per population and the percentage change in population) grew annually by 2.7 percent and 1.4 percent respectively. To achieve the emissions growth of 2.1 percent, the economy's emissions intensity declined by 2.0 percent per year.

In the 1980s, emissions growth declined to 0.9 percent per year. In part, this reduction in growth was achieved by a halving of the growth in output per capita (related largely to the recession in the early part of the decade). The other factor was the continued reduction in the carbon intensity of the economy occasioned in larger measure by the introduction of the National Energy Program (1980-1985) with its high oil prices, natural gas price regulation and large energy conservation and "off-oil" programs.

Chart 4.15
The Components of GHG Emissions Growth
Average Annual Growth Rates
1970-2010

	%△GHG	=	%△GHG/GDP	+	%△GDP/POP	+	%△POP
1970-80	2.1		-2.0		2.7		1.4
1980-90	0.9		-1.8		1.5		1.2
1990-2000	1.4		-0.9		1.1		1.2
2000-2010 (Update)	0.9		-1.4		1.4		0.9
To Achieve the Kyoto Target:							
2000-2010	-2.0		-4.3		1.4		0.9

By the 1990s much of the impetus for energy conservation had dissipated with the result that the rate of carbon intensity of the economy declined to 0.9 percent annually. Although per capita output remained weak, population continued to grow by 1.2 percent per annum. In combination, these factors led to an increase in the rate of growth in emissions, to 1.4 percent, relative to the previous decade.

For the 2000-2010 period, the policy as usual forecast calls for emissions growth of only 0.9 percent per annum. This result reflects a 1.4 percent decline in carbon intensity (a considerable improvement over the 1990s) offset by a growth in output per capita and population of, respectively, 1.4 and 0.9 percent

To achieve the Kyoto target (565 Mt), assuming policy actions commence in 2000, requires a rate of reduction in GHG emissions of 2 percent annually (the required rate accounts both for reductions from the 1990 level and for the fact that, by 2000, Canada's emissions level will be already 15 percent above the 1990 level). It is reasonable to assume that neither GDP per capita nor population would be altered by government policy in pursuit of the climate change objective. Therefore, for Canada to achieve the Kyoto target, by domestic actions alone, would require a reduction in the carbon intensity of the economy of 4.3 percent annually. This is, by historical standards, a large reduction[28]

[28] To be fair, during the only historical period of emissions intensity reduction (the Oil Crises and National Energy Program era of the late 1970s and early 1980s) the objectives of policy were not related to emissions reductions but rather to energy

which to be achieved would require a combination of significant energy or process intensity improvements and fuel switching.

security.

Chapter 5

Conclusions

This report, prepared in response to a request from the National Air Issues Coordinating Committee and the National Climate Change Secretariat, provides a revised outlook for GHG emissions in Canada. The results should be viewed as an update to the projections published in CEO97 incorporating the implications of events and changes of view which have occurred since 1997 and corrected for new methodologies. In developing the Update, we have relied extensively on the advice of the Issue Tables and we would again wish to express our appreciation to the members of the tables and their staffs for their assistance.

The Update suggests that greenhouse gas emissions in 2010 will be some 95 Mt higher than estimated in CEO97. Largely for methodological reasons, however, the 1990 level has also increased by 35 Mt relative to that reported in CEO97. Together, these changes mean that the gap in 2010 - the difference between the policy as usual projection and the Kyoto target - increases from 138 Mt to 199 Mt or by 61 Mt. In percentage terms, this suggests a widening of the gap from 21 to 26 percent.

Higher emissions from fossil fuel production, chiefly related to oil sands developments and revised emission factors, account for more than half (34 Mt) of the increase in the Kyoto gap. Emissions from transportation (11 Mt) and electricity (9 Mt) are the next largest contributors.

The report also examines the growth in emissions from several perspectives. The main conclusion is that achieving the Kyoto target represents a significant challenge. A 26 percent reduction in emissions implies a commensurate reduction in fossil fuel use. The gap is roughly equivalent to all of the emissions in 2010 from transportation activities.

Furthermore, the analysis of the proximate causes of GHG emissions suggests that to accomplish this task, by domestic action alone, requires a large reduction in carbon intensity.

The results also indicate fairly pronounced regional and sectoral variations emissions growth. From the provincial perspective, the growth in emissions from 1990 to 2010 in Ontario and Québec is about one-half that in Saskatchewan and Alberta. By sector, fossil fuel production and transportation exhibit rates of growth considerably in excess of those of the industrial and electricity generation sectors.

The above results do not imply that achieving the Kyoto target is an impossible undertaking. Rather, the Update's message is that achieving the Kyoto target requires a unique blend of creative policies. One ingredient in the blend will be the international flexibility mechanisms which Canada worked to have included in the Kyoto Protocol. These mechanisms will assist in discharging Canada's obligation under the Protocol. Domestically, the challenge is to design and implement a set of focussed and regionally balanced options. This is the purpose of the National Implementation Strategy (NIS) process.

Annex A

Energy and Emissions Projections for the Territories

Introduction

As part of its commitment to the Analysis and Modelling Group, Natural Resources Canada (NRCan) undertook to prepare the first energy and GHG emissions projections for the Northwest Territories (NWT), Nunavut and the Yukon[29] [30]. The projections in this annex have been developed in close collaboration with officials from the Territorial governments and lay the foundation for future discussions related to climate change and other energy-environmental issues.

Because of data limitations, it was not possible to build an econometric model for the territories. However, a judgmental projection was developed in consultation with the NWT and Yukon governments. The remainder of the Annex reviews the economic and demographic assumptions and the energy demand/supply and emissions projections.

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[29] The projections for the territories were developed by Michel Bérubé, Wallace Geekie and Jai Persaud of the Analysis Modelling Division, Natural Resources Canada.

[30] The new territory of Nunavut, encompassing essentially the eastern half of the Northwest Territories, was created on April, 1, 1999. The projections in this annex reflect the new boundaries of Nunavut and the Northwest Territories.

1. Framework Assumptions

In developing the framework assumptions (see Chapter 2 for oil and gas prices and other assumptions) for the territorial economies, NRCan relied upon different sources of projections. In the case of demographics, NRCan used population projections prepared by the NWT, Nunavut and Yukon governments. Based on these projections, NRCan established a historical relationship between population and household formation and assumed that this trend would persist over the longer term. The population and household projections represent key determinants for forecasting residential and commercial (e.g., services related to education and health services, etc.) energy use and associated GHG emissions. In terms of the economic assumptions, NRCan reviewed several sources of information such as economic projections produced by Informetrica Ltd., the Conference Board of Canada and specific mining project employment and production estimates provided by the Territorial governments. These economic projections were then used to forecast energy demand in the industrial and transportation (along with demographic projections for passenger road transport) sectors and associated GHG emissions. The demographic and economic assumptions are summarized in Table Annex A-1.

Table Annex A-1
Framework Assumptions: NWT, Nunavut and Yukon
(Average Annual Growth Rates)

	1996/2010	2010/2020
Population		
NWT	1.4	1.4
Nunavut	2.4	2.4
Yukon	1.7	1.7
Households		
NWT	1.6	1.6
Nunavut	2.6	2.6
Yukon	2.0	2.0
Industry Employment		
NWT	2.2	1.2
Nunavut	N/A	N/A
Yukon	1.3	1.2
Service Employment		
NWT	2.6	2.0
Nunavut	N/A	N/A
Yukon	1.3	1.2

1.a Demographic Assumptions

Unlike larger provincial economies, population is highly mobile in the territories. Some studies have suggested that population decreases by approximately three to four persons for each job loss in the mining industry. With this in mind, the population projections are highly dependent on mining activity and hence, are subject to a relatively high degree of uncertainty.

The Update used the population projection developed by the NWT Bureau of Statistics in

June 1999. This projection calls for population in the NWT to increase by about 1.4 percent per annum over the 1996/2020 period or by about 15000 persons over the 24 year period. Historically, the number of persons per household has been declining gradually in the NWT following the general trend in the overall Canadian economy. For the purposes of this projection, this declining trend is expected to continue such that household formation in the NWT is projected to increase by 1.6 percent per year over the 1996/2020 period.

According to the latest population projection developed by the government of Nunavut, population is expected to grow at a rate of 2.4 percent per year or by about 16000 persons over the 1996/2020 period. NRCan assumed that household formation would increase at an annual rate of about 2.6 percent per year.

For the Yukon, the Update projection relied upon the Yukon government's high growth population projection published in July 1999. This population projection assumes that fertility rates increase by 10 percent, mortality rates fall by 10 percent and net migration averages 300 persons per year over the next ten years. NRCan assumed that these demographic assumptions would persist up to 2020 such that the Yukon population would grow at annual rate of about 1.7 percent between 1996 and 2020 resulting an increase of approximately 16,000 persons in 2020 relative to 1996. NRCan assumed that household formation would increase at an annual rate of 2.0 percent over the forecast period.

Both the NWT and Yukon projections show declining population within the 45 year and below age group and an increasing population within the 45-year and above age group. NRCan incorporated this age-group structural change in developing its energy demand projection, i.e., less requirements for education facilities and more requirements for health services.

1.b Economic Assumptions

The territorial economies are highly dependent on three major sectors: government for employment and stability, mining for income generation, and tourism for employment and income generation. For these reasons, NRCan focused its attention on future prospects in the mining and service industries.

The medium-term outlook underlying the NWT economic outlook is based essentially on the production and employment prospects for the Diavik Diamond Mines, BHP

Diamonds'Ekati Mine at Lac de Gras and the Fort Liard natural gas projects[31]. In consultation with Informetrica Ltd. and the NWT government, NRCan developed an economic projection that calls for mining employment to expand by about 2.2 percent per year up to year 2003 and by 1.2 percent per year over the remainder of the forecast period. NRCan assumed that other industries, because they are dependent on mining and oil and gas development, would follow a similar trend.

Based on the demographic and economic assumptions, NRCan assumed that employment in the service sector for the NWT would increase by about 2.5 percent per year over the forecast period . The growth prospects for the NWT service industry are similar to those of most Canadian provinces.

No major mining projects were assumed for Nunavut. In other words, current mining activity is assumed to remain constant over the forecast period.

For the Yukon, NRCan used the latest Conference Board of Canada report on the Yukon economy. According to this report and the Yukon government's high population projection, annual overall GDP growth is expected to average about 2.3 percent and employment 1.3 percent over the 2000/2010 period .

2. Energy & Emissions Projection

2.a End-Use Demand

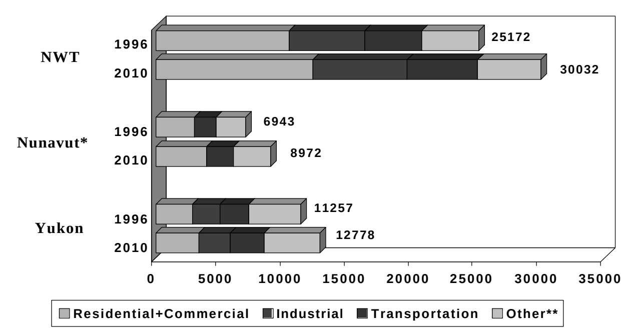
End-use demand comprises energy consumption in the residential, commercial, industrial and transportation sectors.

Assuming the sectoral national average annual energy intensity declines and the territory-specific demographic projections, the end-use

Chart Annex A-2

Primary Energy Demand By Sector

(Terajoules)



* Note that diesel demand for mining is included in conversion requirements for electricity (i.e., other).

** Includes producer consumption, conversion requirements and non-combustion.

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31 Employment was chosen as an economic driver for developing energy use in the NWT because diamond mining is a new industry in Canada and as such it is difficult to value the output of such mines.

energy demand is forecast to increase at an annual rate of 1.1 percent over the 1996-2010 period for the Yukon, 1.4 percent for NWT and 1.9 percent for Nunavut. In other words, end-use demand is approximately 16 percent higher in 2010 relative to 1995 in the Yukon, 21 percent in the NWT and 30 percent in Nunavut. The higher demand in Nunavut relative to the two other Territories is attributed to higher population growth (see Chart Annex A-2).

2.b Oil and Gas Production

As in Canada's Energy Outlook, the 1999 Update does not incorporate any major development for the Mackenzie Delta-Beaufort Region. The major constraint on oil development is the insufficient economic reserves at current oil prices to warrant field and pipeline development for the Mackenzie Delta-Beaufort Region. There will, however, be some oil development of the upper Mackenzie that could be linked to the Norman Wells - Zama pipeline.

In the case of natural gas, the price and supply scenario developed in the 1999 Update suggest that opportunities in the western basin would be more attractive than major development of Mackenzie Delta reserves. It is worth noting, however, that natural gas supply from the NWT could increase several fold if prices were to escalate substantially and/or options to implement the Kyoto Protocol involve measures to increase significantly natural gas consumption in North America. The recent gas discovery by Chevron also provides some optimism for gas development in the North. It should be noted that the 1999 Update is based on a Policy as Usual Scenario which is neutral with respect to the implementation of the Kyoto Protocol.

The territorial supply projection is summarized below:

- Oil production from the NWT declines slightly from 30 thousand barrels per day (mb/d) in 1997 to 23 mb/d in 2020. The share of NWT's total Canadian production is expected to decline from 1.4 percent to less than 1 percent in 2020. The expectation is that continued infill drilling at Norman Wells, improvement in technology and new developments such as Atkinson, Mayogiak and others would prevent a much more rapid decline of northern production.

- Northern oil production is also sensitive to oil prices. The NEB's recent outlook which is based on an oil price forecast of US $18/bbl calls for Norman Wells production to decline to 15 mb/d by 2020 under its Case 1 and Case 2 projections. In a $22/bbl price sensitivity scenario, production from the Mackenzie Delta-Beaufort region could reach 250 mb/d by the 2010-2012 period.

- Natural gas production from the NWT increases from 17 Bcf in 1997 to 70 Bcf in 2020. The increase in production reflects the recent promising discoveries in the Fort Liard area which are slated to come on stream post-2000. These developments cause the share of northern gas production in total Canadian production to increase slightly but to remain below 1 percent over the forecast period.

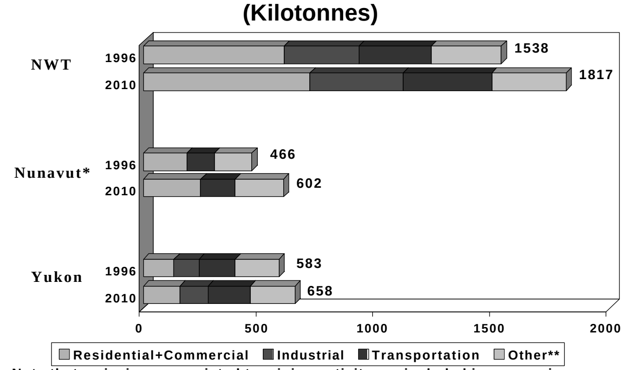
- Based on consultations with government officials of the NWT, it is recognized that supplies could be greater in an environment of higher prices, particularly given the significant resource potential in the region. The NEB's Case 2 projections which involve significantly higher gas prices than NRCan's 1999 Update call for non conventional gas production to increase substantially over the long term. By 2017, gas from the Mackenzie Delta region reaches 1.5 Bcf/day.

2.c Emissions Projection

Chart Annex A-3

Greenhouse Gas Emissions By Sector

(Kilotonnes)



* Note that emissions associated to mining activity are included in conversion requirements for electricity (i.e., other).

** Includes producer consumption, conversion requirements and non-combustion.

For the purposes of this projection, NRCan defined emissions sources according to the sectoral definitions contained in the Statistics Energy Demand/Supply Quarterly data in order to facilitate the comparison of energy demand/supply and emissions projections. Statistics Canada does not provide energy data for the NWT and Nunavut. For the purpose of this analysis, the split for the two new territories is based on a study entitled <u>Greenhouse Gas Emissions in 1996 for the Northwest Territories and Nunavut</u> prepared by Ferguson Simek Clark Engineers and Architects for the Government of the Northwest Territories[32]. No data are available prior to 1996 and hence, 1996 was used as the baseline year.

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32 Available on website http://www.ssimicro.com.

Northwest Territories

For the NWT, the projection shows emissions increasing by about 278 kt or 18 percent between 1996 and 2010. The residential and commercial sectors are responsible for 38 percent of the increase over the 14 year period, industrial 29 percent and transportation 25 percent. As highlighted in Figure A-3, the increases in emissions from the energy end-use sectors more than offset the declines emissions from oil and gas production.

Nunavut

Emissions for Nunavut are for the most part driven by population growth. On this basis, emissions are projected to increase by 135 kt or by about 29 percent between 1996 and 2010 (see Chart Annex A-3).

Yukon[33]

The Update projection calls for overall energy related greenhouse gas emissions to increase by about 77 kt or by 14 percent between 1996 and 2010. On a sectoral basis, residential and transportation account for the lion's share of the increase - 32 percent and 40 percent respectively - between 1996 and 2010. The industrial sector accounts for roughly 17 percent of the increase.

On the supply side, emissions are expected to remain at current levels because no major expansion of the Kotaneelee gas field is expected over the forecast period.

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33 The emissions for the Yukon presented here are lower than those in the publication Greenhouse Gas Inventory for The Yukon prepared by Jennifer Jones and Sue Moodie of the Yukon Conservation Society. The difference is largely explained by how gross gasoline and diesel fuel sales are measured. In 1996, the gross motor gasoline sales collected by the Yukon Finance Department were 30 percent higher than those reported by Statistics Canada. Thus, the emissions shown in Figure A-3 would be higher if NRCan were to use the Yukon Finance Department data.

Annex B

Conversion Tables

Conversion Tables

Metric Units to Imperial Units Table 1

Metric Units		Imperial Equivalent Units
1 cubic metre of oil at: (15˚C and 922 kg/m^3) (15˚C and 855 kg/m)	 = =	 6.29226 barrels (60˚C) 6.29258 barrels (60˚C)
cubic metre of natural gas	=	35.30101 cubic feet
1 tonne	=	1.102311 short tons
1 kilojoule	=	0.9482133 Btu
1 gigajoule (GJ)	=	approximately 0.95 million Btu
1 petajoule (PJ)	=	approximately 0.95 billion cubic feet of natural gas
1 litre (L)	=	approximately 0.22 Imperial gallon
1 kilogram (kg)	=	approximately 2.2 pounds
1 metre (m)	=	approximately 3.28 feet

Abbreviations of Terms Table 2

Abbreviation	Prefix	Multiple
k	kilo-	10^3
M	mega-	10^6
G	giga-	10^9
T	tera-	10^{12}
P	peta-	10^{15}
E	exa-	10^{18}

Abbreviation	Definition	Abbreviation	Definition
GJ	gigajoule = 10^9 Joules(J)	m^3	cubic metre
TJ	terajoule = 10^{12}J	L	litre
PJ	petajoule = 10^{15}J	kg/m^3	kilograms per cubic metre
EJ	exajoule = 10^{18}J	t	tonne
kW	kilowatt = 10^3 Watts	Mt	megatonne
kW.h	kilowatt hour = 10^3W.h	Btu	British thermal unit
MW	megawatt = 10^3kW	Mcf	thousand cubic feet
MW.h	megawatt hour = 10^3kW.h	Bcf	billion cubic feet
GW	gigawatt = 10^6kW	Tcf	trillion cubic feet
GW.h	gigawatt hour = 10^6kW.h	bbl	barrel
TW	terawatt = 10^9kW	mmb/d	million barrels per day
TW.h	terawatt hour = 10^9kW.h	mb/d	thousand barrels per day
		C$ or $	Canadian dollars
		US$	United States dollars

Gross Energy Content Factors Table 3

Fuel Source	Energy Content		
Natural Gas	37.23 MJ/m^3 [(1)]		
Ethane (liquid)	18.36 GJ/m^3		
Propane (liquid)	25-53 GJ/m^3		
Butanes (liquid)	28.62 GJ/M^3		
Crude Oil			
- Light	$1m^3$	=	38.51 GJ
- Heavy	$1m^3$	=	40.90 GJ
- Pentanes Plus	$1m^3$	=	35.17 GJ
Coal			
- Anthracite	1 tonne	=	27.70 GJ
- Bituminous	1 tonne	=	27.70 GJ
- Subbituminous	1 tonne	=	18.80 GJ
- Lignite	1 tonne	=	14.40 GJ
- Average domestic use	1 tonne	=	22.20 GJ
Petroleum Products			
- Aviation Gasoline	$1m^3$	=	33.62 GJ
- Motor Gasoline	$1m^3$	=	34.66 GJ
- Petrochemical Feedstocks	$1m^3$	=	35.17 GJ
- Naphtha Specialties	$1m^3$	=	35.17 GJ
- Aviation Turbo Fuel	$1m^3$	=	35.93 GJ
- Kerosene	$1m^3$	=	37.68 GJ
- Diesel	$1m^3$	=	38.68 GJ
- Light Fuel Oil	$1m^3$	=	38.68 GJ
- Lubes and Greases	$1m^3$	=	39.16 GJ
- Heavy Fuel Oil	$1m^3$	=	41.73 GJ
- Still Gas	$1m^3$	=	41.73 GJ
- Asphalt	$1m^3$	=	44.46 GJ
- Petroleum Coke	$1m^3$	=	42.38 GJ
- Other Products	$1m^3$	=	39.82 GJ
Electricity			
- Hydro	1kW.h	=	3.6 MJ
- Nuclear [(2)]	1kW.h	=	11.6 M

(1) Assumes 15˚C, 101.325kPa and free of water vapour. The energy content of 37.23 MJ/m^3 approximately the equivalent of 1 000 Btu per cubic foot in the imperial system. The actual energy content will vary depending on the amount of natural gas liquids (mostly ethane) contained in the gas.

(2) Typical value. Actual values at nuclear generating plants depend on specific plant efficiencies.

Emission Conversion Factors Table 4

	CO_2		CH_4		N_2O	
COMBUSTION SOURCES						
Gaseous Fuels	(t/ML)[b]	(t/TJ)	(kg/ML)	(kg/TJ)	(kg/ML)	(kg/TJ)
Natural Gas	1.88	48.77	(4.3-4.8)	(111.5 to 124.5)	0.02	0.52
Coke Oven Gas	1.6	86	-	-	-	-
Liquid Fuels	(t/kL)	(t/TJ)	(kg/kL)	(kg/TJ)	(kg/KL)	(kg/TJ)
Motor Gasoline	2.36	68.09	(0.25 to1.3)	(7.21 to 37.51)	(0.046 to 0.58)	(1.33 to 16.73)
Kerosene	2.55	67.68	(0.006 to 0.26	(0.16 to 5.68	0.07	1.86
Aviation Gas	2.33	69.51	2.19	65.33	0.23	6.86
LPGs	(1.11 to 1.76)	(59.84 to 61.38)	0.03	1.18	-	-
Diesel Oil	2.73	70.58	(0.05 to 0.15)	(1.29 to 3.88)	(0.1 to 1.1)	(2.59 to 38.44)
Light Oil	2.83	73.11	(0.01 to 0.3)	(0.16 to 7.76)	(0.013 to 0.07)	(0.34 to 1.81)
Heavy Oil	3.09	74	(0.03 to 0.3)	(0.72 to 7.19)	(0.013 to 0.40)	(0.31 to 9.59)
Still Gas*	2	47.93	-	-	0.02	0.62
Aviation Jet Fuel	2.55	70.97	0.08	2.23	0.25	6.95
Petroleum Coke	4.2	100.05	0.12	2.83	-	-
Solid Fuels	(t/t)	(t/TJ)	(g/kg)	(kg/TJ)	(g/kg)	(kg/TJ)
Anthracite	2.39	86.8	0.015	varies	(0.05 to 2.11)	varies
U.S. Bituminous	(2.46 to 2.50)	(80.4 to 85.4)	0.015	varies	(0.05 to 2.11)	varies
Cdn. Bituminous	(1.70 to 2.52)	(55.8 to 87.8)	0.015	varies	(0.05 to 2.11)	varies
Sub-Bituminous	1.74	(95 to 137.9)	0.015	varies	(0.05 to 2.11)	varies
Lignite	(1.34 to 1.52)	(89.5 to 101.5)	0.015	varies	(0.05 to 2.11)	varies
Coke	2.48	86	-	-	-	-
Fuel Wood	1.5	83.3	(0.15 to 15)	(8.3 to 83.3)	0.16	8.89
Slash Burning	1.47	81.47	5	0.01		
Incineration						
Municipal Solid Waste	0.91	85.85	0.23	0.02		
Spent Pulping Liquor	1.5	107.1	-	-		

[a] Note: Where ranges are given for emission factors, please consult the report cited below for details.
[b] The SI abbreviations M for mega (x 10^6); G for giga (x 10^9); and T for tera (x 10^{12}).
* HFO equivalent
Source: Canada's Greenhouse Gas Inventory, 1997 Emissions and Removals with Trends, Environment Canada

Emission Conversion Factors Table 5

INDUSTRIAL PROCESS SOURCES

Source	*Description*	CO_2 *g / kg feed*	CF_4	C_2F_6
Mineral Use				
Limestone Use	**In Iron & Steel, Glass, Non-Ferrous Metal Prod.**	**440**	**-**	**-**
Soda Ash Use	**In Glass Manufacture**	**415**	**-**	**-**
		g / kg product	*g / kg product*	*g / kg product*
Mineral Products				
Cement Production	**Limestone Calcination**	**500**	**-**	**-**
Lime Production	**Limestone Calcination**	**790**	**-**	**-**
Chemical Industry				
Ammonia Production	**From Natural Gas**	**1,600**	**-**	**-**
Metal Manufacture				
Primary Aluminum	**Electrolysis Process**	**(1.54-1.83)**	**(0.3-1.1)**	**(0.02-0.1)**

Source: Canada's Greenhouse Gas Inventory, 1997 Emissions and Removals with Trends, Environment Canada

HYDROCARBON NON ENERGY PRODUCTS

Description	CO_2 *g / L*
Ethane Use	222
Butane Use	352
Propane Use	306
Petrochemical Distillate Use for Feedstocks	500
Naptha Used for Various Products	625
Petroleums Used for Lubricants	1410
Petroleums Used for Other Products	1450
	t / m^3
Natural Gas Use for Chemical Products	1260

Source: Canada's Greenhouse Gas Inventory, 1997 Emissions and Removals with Trends, Environment Canada

GHG Emission Rates For Oil and Natural Gas Production

CO2		1990	1995	2000	2005	2010	2015	2020
Oil Sand - Bitumen	**Kg/ bbl**	72.8	69.8	69.8	69.8	69.8	69.8	69.8
Oil Sand - Synthetic	**Kg/ bbl**	137.4	117.8	96.0	82.5	82.5	82.5	82.5
Nat. Gas Production	**Kg/mcf**	2.4	2.2	2.2	2.1	2.1	2.1	2.1
Nat. Gas Processing	**Kg/mcf**	1.3	1.2	1.2	1.1	1.1	1.1	1.1
Flaring	**Kg/ bbl**	12.0	13.6	13.6	13.6	13.6	13.6	13.6
Conventional Oil	**Kg/ bbl**	17.4	23.2	23.2	23.2	23.2	23.2	23.2
Heavy Crude Oil	**Kg/ bbl**	11.4	10.2	10.0	10.0	9.7	9.7	9.7
Drilling	**Gr./GJ**	208.5	392.8	392.8	392.8	392.8	392.8	392.8
Well Services	**Gr./GJ**	75.2	93.4	93.4	93.4	93.4	93.4	93.4

CH4 (CO2 E)		1990	1995	2000	2005	2010	2015	2020
Bitumen	**Kg/ bbl**	4.2	4.0	3.8	3.6	3.5	3.4	3.3
Oil sand	**Kg/ bbl**	1.2	6.8	6.4	6.1	6.0	5.8	5.7
Gas Prod.	**Kg/mcf**	2.4	1.4	1.3	1.2	1.1	1.1	1.0
Natural gas processing	**Kg/mcf**	0.4	1.2	1.1	1.0	1.0	0.9	0.9
Flaring	**Kg/bbl**	0.0	1.3	1.3	1.3	1.3	1.3	1.3
Conv. Oil	**Kg/ bbl**	7.1	7.7	6.9	6.4	6.1	5.9	5.7
Heavy Oil	**Kg/ bbl**	57.2	58.7	53.0	49.7	48.4	47.2	46.1
Drilling	**Gr./GJ**	25.3	31.0	28.0	25.8	24.6	23.4	22.2
Well Serv	**Gr./GJ**	64.4	86.1	77.8	72.2	68.6	65.3	62.1
Gas Pipelines	**Kg/mcf**	1.3	1.0	1.0	0.9	0.9	0.9	0.9
Gas Dist	**Gr./mcf**	0.8	0.6	0.5	0.5	0.5	0.5	0.5

N2O (CO2 E)		1990	1995	2000	2005	2010	2015	2020
Bitumen	**Kg/ bbl**	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Oil sand	**Kg/ bbl**	1.7	1.4	1.4	1.4	1.4	1.4	1.4
Gas Prod.	**Kg/mcf**	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Conv. Oil	**Kg/ bbl**	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Heavy Oil	**Kg/ bbl**	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Gas Pipelines	**Gr/mcf**	0.03	0.04	0.04	0.04	0.04	0.04	0.04

Source: Base on Clearstone Engineering Limited, *CH4 and VOC Emissions From The Canadian Upstream Oil and Gas Industry*: Volumes 1 through 4. 1997.

Annex C

Projection Results - Canada Tables