

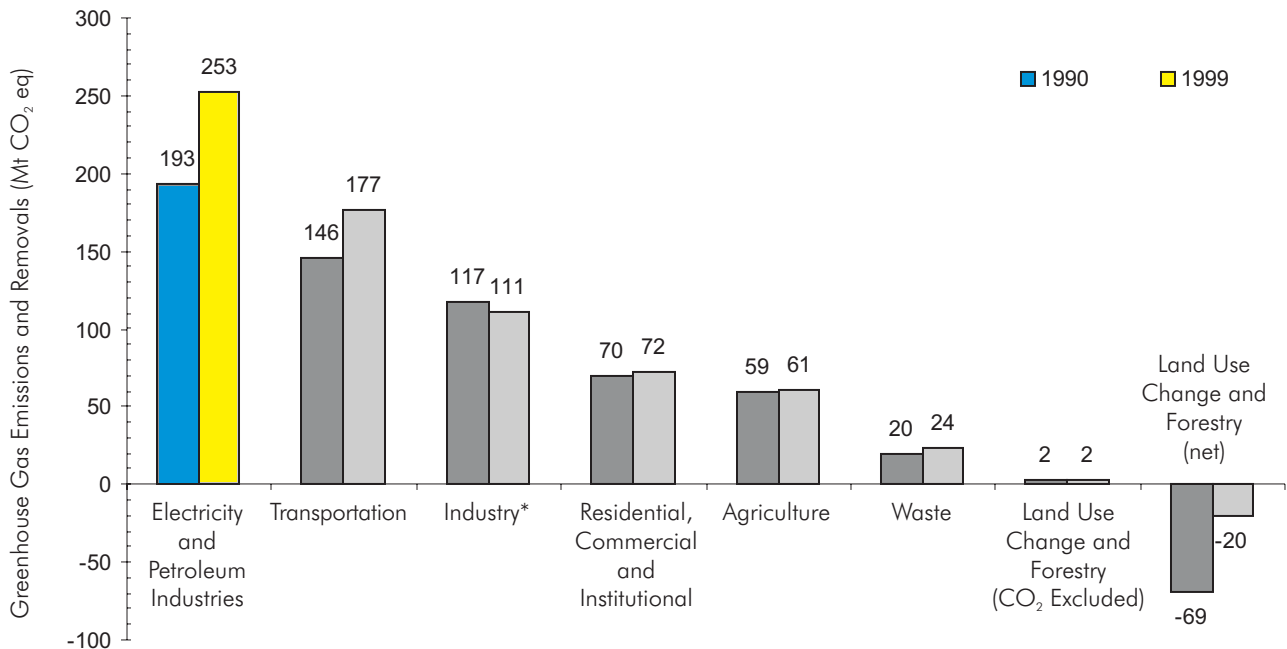
Electricity and Petroleum Industries: 1990-1999

The Electricity and Petroleum Industries Fact Sheet is comprised of two sectors: the Electricity Generation sector and the Petroleum Industry sector. The Petroleum sector includes both upstream (oil and gas exploration, production and transport) and downstream (refining of oil products and distribution of natural gas) petroleum emissions. The Electricity Generation sector consists of combustion emissions associated with electricity generation and steam production for commercial or public use.

- *In 1999*, Electricity and Petroleum Industries contributed 36% or 253 megatonnes of carbon dioxide equivalent* (Mt CO₂ eq) of Canada's total greenhouse gas emissions of 699 Mt. Both petroleum and electricity production contributed almost equally to emissions (134 Mt and 119 Mt, respectively). On a sub-sector basis, upstream petroleum emissions accounted for the majority of the Petroleum Industry sector emissions (113 Mt, or 85% of the sector total), while downstream petroleum contributed 21 Mt in 1999.
- *Between 1990 and 1999*, emissions within the Electricity and Petroleum Industries grew by almost 33%, from 193 Mt to 253 Mt, surpassing the growth rate of total national emissions of 15%. On a sector basis, although electricity generation increased 19%, emissions in this sector grew 24%, due to an increased proportion of fossil fuel-generated electricity in the latter part of the decade. Although the Petroleum Industry sector emissions increased 38% over the period, on a sub-sector level upstream emissions rose 52% while downstream emissions decreased 9%. Upstream Industry emissions rose primarily as a result of increased production of oil and gas for export, whereas increased production efficiency in the refining of oil products contributed to the emissions decline in the Downstream Industry.

*Unless otherwise indicated, all emissions are reported in Mt CO₂ eq. For brevity, this has been shortened to Mt. This concept provides a relative measure of the impacts of different greenhouse gases on global warming, with the effect of carbon dioxide being equal to one.

Figure 1 - Canadian Greenhouse Gas Emissions and Removals 1990 and 1999



* Value illustrated includes emissions due to Solvent and Other Product Use.

Table 1. Greenhouse Gas Emission Trends in the Electricity and Petroleum Industries Sector by Subcategory, 1990 to 1999

Sector	NAICS Code	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
<u>(A) Electricity Generation¹</u>		95.3	96.7	103	93.8	96	101	99.7	111	124	119
<u>(B) Upstream Petroleum Industry</u>		<u>74.1</u>	<u>75.4</u>	<u>82.9</u>	<u>86.3</u>	<u>90.9</u>	<u>97.4</u>	<u>100</u>	<u>97.1</u>	<u>103</u>	<u>113</u>
Upstream Oil and Gas ²	211113, 211114	62.9	63.4	68.3	71.2	75.1	80.2	82.3	79.3	85.2	95.1
Natural Gas Transmission	486, 2212	11.2	12.1	14.6	15.2	15.8	17.1	17.7	17.8	17.8	17.9
<u>(C) Downstream Petroleum Industry</u>		<u>23.4</u>	<u>22.3</u>	<u>22.6</u>	<u>22.9</u>	<u>21.9</u>	<u>21.9</u>	<u>23.2</u>	<u>21.9</u>	<u>22</u>	<u>21.3</u>
Petroleum Refining ³	324	20.7	19.5	19.7	20.1	19	18.9	20.2	18.8	18.8	18.1
Natural Gas Distribution	2212	2.75	2.84	2.91	2.84	2.95	2.96	3.01	3.07	3.17	3.24
(B+C) Total Petroleum Industry		97.5	97.8	106	109	113	119	123	119	125	134

¹ Includes both utility and industrial generation and commercial steam generation.

² Includes combustion, process and fugitive emissions associated with conventional and unconventional production of oil and gas.

³ Includes combustion and process emissions associated with the refining of crude oil.

Canada's Electricity and Petroleum Industries Sector

The Electricity and Petroleum Industries are comprised of two important energy sectors -the Electricity Generation sector and Petroleum Industries sector. The Petroleum

Industries sector can be further subdivided into two categories: the Upstream Petroleum Industry and the Downstream Petroleum Industry.

Emissions from the Upstream Industry are those associated with oil and natural gas exploration, production and transmission, and include:

- *fugitive* emissions (see box) during exploration, production and transport. Responsible in 1999 for 43% of Upstream Industry emissions;
- *process* emissions from the extraction of hydrogen from natural gas (used in heavy oil upgrading). Responsible in 1999 for only 2% of Upstream Industry emissions; and
- *combustion* emissions from producer generated fuel for the exploration and extraction of oil and gas, the upgrading of oilsands, as well as the transport and distribution of natural gas (including compressor station fuel consumption). Responsible in 1999 for 55% of Upstream Industry emissions.

The Downstream Petroleum category includes the refining of oil products and the distribution of natural gas. Emission sources consist of:

- *fugitive* natural gas emissions from gas distribution. Responsible in 1999 for 15% of downstream emissions;
- *process* emissions from the extraction of hydrogen from natural gas used in upgrading processes. Responsible in 1999 for only 5% of Downstream Industry emissions; and
- *combustion* emissions during refining of the industry's produced petroleum products (such as

The Canadian Greenhouse Gas Inventory (CGHGI)

The Canadian Greenhouse Gas Inventory is developed, compiled, and reported annually by the Greenhouse Gas Division of Environment Canada, and utilizes methods and models developed in-house by engineering and scientific staff, as well as published data, data developed by industry, or methods developed by the Intergovernmental Panel on Climate Change (IPCC, 1997).

The greenhouse gases that have been estimated in the national inventory are carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), sulphur hexafluoride (SF₆), perfluorocarbons (PFCs), and hydro fluorocarbons (HFCs).

The inventory uses an internationally agreed to reporting format that groups emissions and removals into the following six sectors: Energy, Industrial Processes, Solvent and Other Product Use, Agriculture, Land-Use Change and Forestry, and Waste. The 1999 Trends Fact Sheet Series, while presenting the latest information on Canadian greenhouse gas emissions and removals derived from the latest national inventory, use a modified sector approach to facilitate the use of information by the public.

natural gas, diesel, and natural gas liquids) and purchased natural gas. Responsible in 1999 for 80% of downstream emissions.

The Electricity Generation sector includes greenhouse gas emissions from thermal generation in Canada, whether from a utility or from industry. Only a portion of Canada's generation is responsible for greenhouse gas emissions. In 1999, about 26% of the total 558 TWh generated were from greenhouse gas emitting thermal generation sources (coal, oil, natural gas and petroleum coke). The remainder was from non-emitting sources such as hydro and nuclear, with a minor portion from biomass and wind (Figure 2).

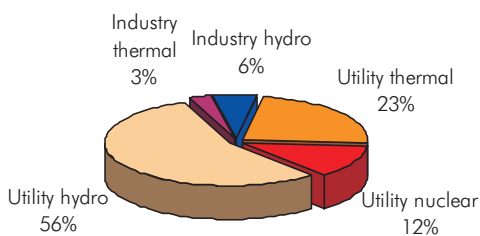
Electricity and Petroleum Industries Emission Trends: 1990 to 1999

Emissions within the Electricity and Petroleum Industries have grown significantly in the 1990 to 1999 period. While total Canadian emissions grew by 15%, the Electricity and Petroleum Industries sector grew by almost 31%, from 193 Mt to 253 Mt. Emission growth occurred mainly in the Upstream Petroleum Industry sub-sector and the Electricity Generation sector (Table 1).

Several factors can influence the growth or decline of emissions:

- changes in the demand for production of Canadian energy (e.g. emission increases due to increased exports of natural gas and crude oil);
- Changes in the emission or energy efficiency by which energy is produced, refined or transported (e.g. emission reductions due to reduction in fugitive natural gas emissions from pipelines);
- changes in the carbon intensity of the primary fuel used to generate, mine or transport the finished energy product (e.g. emission reductions due to

Figure 2. 1999 Electricity Generation Sources in Canada



increased electricity generation with hydroelectricity).

The Petroleum Industries Sector

Emissions from the Upstream Industry have experienced high growth over the period. Since 1990, upstream petroleum emissions increased by over 50%; nearly 80% of these emissions are created in the extraction and product conditioning of crude oil, heavy oil sands and natural gas, through either combustion for mining/extraction or fugitive emissions at the source of production.

The growth of greenhouse gas emissions can therefore be directly attributed to increased production of oil and gas. Growth in oil and gas exports, primarily to the United States, contributed significantly to emissions growth between 1990 and 1999 (Figure 3). In this period, net oil exports grew by 296% to 955 PJ, while net exports of gas increased 137% to 3590 PJ (Table 2). As natural gas exports increased, so too did transmission networks, such that emissions increased by nearly 80% from pipeline compressors and other equipment, as well as fugitive emissions from leaks. The proportion of emissions from all oil and gas production and processing activities that is attributable to exports increased from 22 Mt in 1990 to 45 Mt in 1999. Overall, total energy exported increased 159% between 1990 and 1999, while emissions

Figure 3. Upstream Oil and Gas Indexed: Production, Exports and Greenhouse Gas Trends

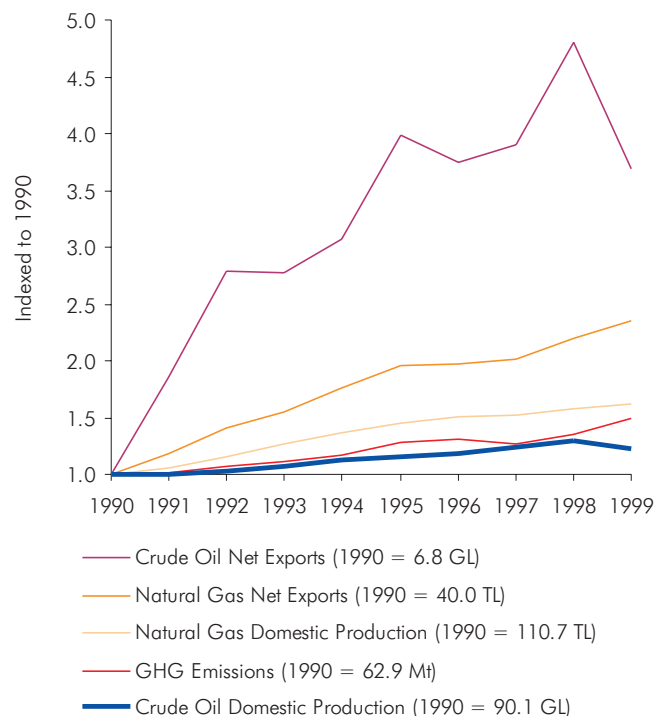


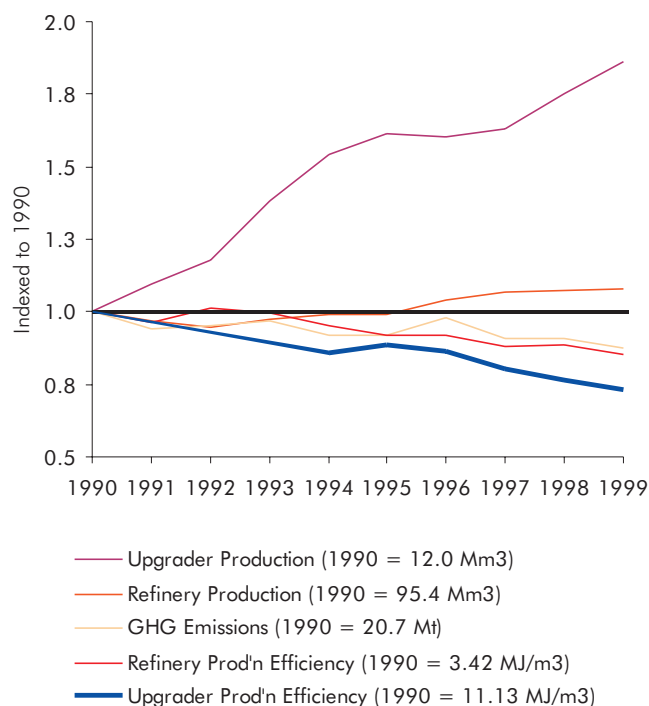
Table 2. Crude Oil and Natural Gas - Net Exports and Greenhouse Gas Emissions Trends, 1990 to 1999

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	
Net Export	PJ										
	Crude Oil	241	473	726	719	797	1,045	977	1,013	1,260	955
	Natural Gas	1,513	1,792	2,130	2,364	2,713	2,985	3,006	3,070	3,356	3,590
Emissions Associated with Exports	Mt CO ₂ eq										
	Crude Oil	8.8	10.8	13.1	11.2	14.3	17.8	16.0	16.3	19.1	15.7
	Natural Gas	12.7	14.9	17.3	19.1	22.1	25.1	24.7	25.2	27.8	29.8
Total Upstream Petroleum Industry Emissions	74.1	75.4	82.9	86.3	90.9	97.4	100	97.1	103	113	

associated with exports increased 111%.

As production increases, efficiency improvements are contributing to emissions reduction in the Upstream Industry. By 1997, oil sands produced 45% less emissions per unit production over 1990. On the other hand, offsetting efficiency improvements is a growing requirement for more energy per unit production, particularly for conventional crude, in Canada's ageing reserves. This is likely due to increased pumping for deeper deposits and disposing of increasing amounts of water (Athabasca, 2000). Unfortunately, data are not readily available to support detailed analysis of efficiency changes in the sub-sector.

Figure 4. Oil and Gas Refinery Indexes: Production, Efficiency and Greenhouse Gas Trends

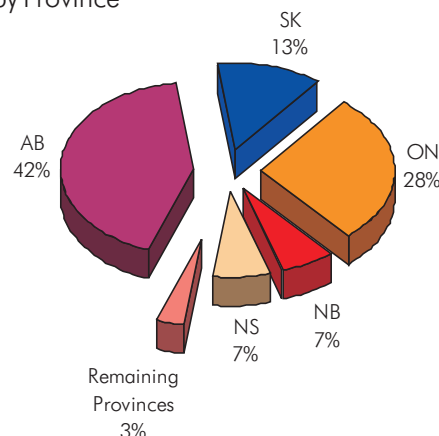


Emissions from the Downstream Industry show an opposite trend to that of emissions in the Upstream sector, having decreased 12% since 1990. These emission reductions occurred even though the sub-sector experienced increases in production. The majority of emissions in the sub-sector, about 85%, are due to the refining of crude to finished products while fugitive emissions from gas distribution contribute the remainder. Refinery production has increased by 7% over 1990 levels. The overall reduction in emissions can be attributed to the increasing production efficiency in refining. The energy requirements per unit of output dropped dramatically (25%) over the 1990 to 1999 period (CIEEDAC, 2000) (Figure 4).

Electricity Generation Sector

Regionally in Canada, five provinces (Alberta, Ontario, Saskatchewan, New Brunswick and Nova Scotia) together contribute nearly all of the electricity generation emissions, largely because of their reliance on coal or other fossil fuels (Figure 5). Of these, Ontario and Alberta contributed 70% in 1999. On the other hand, Ontario only generated 27% and Alberta 10% of total Canadian electricity in that year.

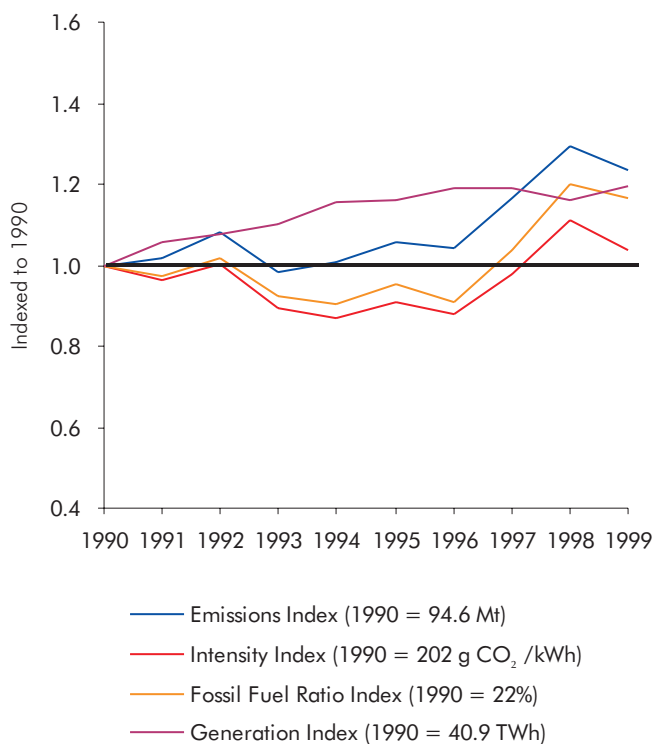
Figure 5. 1999 Electricity Generation Greenhouse Gas Emissions by Province



Emission trends for electricity generation have been generally upward since 1990. The growth of emissions is influenced by the growth in electricity demand and hence generation. By 1999, electricity generation from all sources had grown 19%. At the same time greenhouse gas emissions were 24% higher. The widening gap between growth in emissions and generation may be explained by the growing “emission intensity” of Canadian generation sources. This intensity, or the mass of CO₂ eq./kWh generated, is dependant on the proportion of fossil fuel-generated electricity in the overall total mix. As fossil fuels play a proportionally larger role in generating power, greenhouse gas emissions tend to rise proportionally, as well. For example, in 1999 fossil fuels contributed about 16% more to the total generation mix than they did in 1990. As a result, the greenhouse gas intensity was about 4% higher. Over the period changes in total emissions, in emission intensity and in the proportion of fossil fuel generation to the total (or the fossil fuel ratio) tend to mirror each other (Figure 6).

As discussed earlier two provinces, Alberta and Ontario, contributed the majority of emissions (70%) in 1999 because of their relatively large generation capacities and high proportions of fossil fuel generation. Because of their influence on Canada-wide emission intensity trends, it is instructive to take a detailed look at these provinces.

Figure 6. Indices of Canadian Electricity Generation Trends: Generation, Greenhouse Gas Emissions and Intensity, 1990 to 1999



Ontario

Ontario's utility generation capacity is made up of hydroelectric, nuclear, coal, oil and gas. In 1990 non-greenhouse gas emitting generation contributed 78% of the electric energy. Until 1996 this portion grew larger as nuclear and hydro contributed a greater share. In the mid 1990s, nuclear facilities suffered reduced capacity for maintenance purposes; as a result, these losses were made up for by unused fossil-fuel thermal capacity.

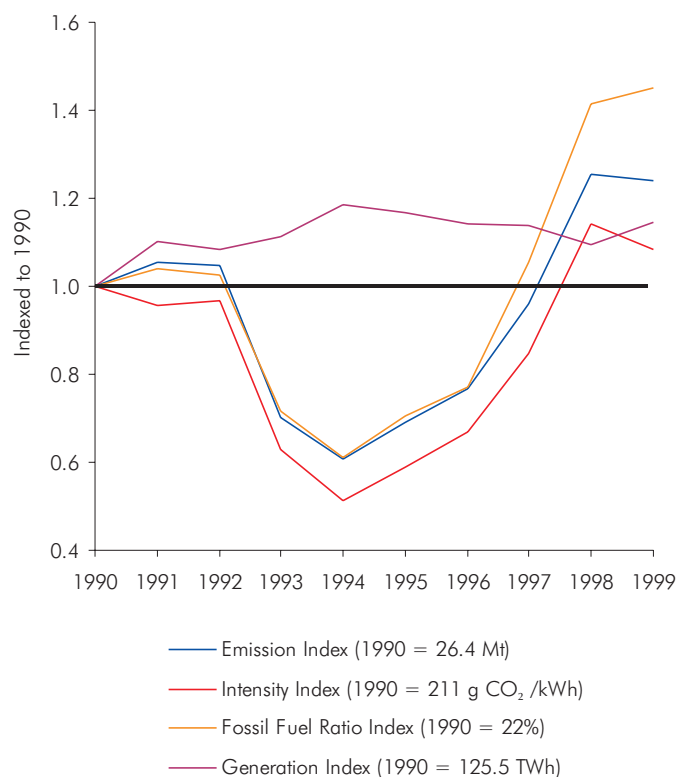
The trend over this period is clear. Generation output grew to the middle 1990s and then leveled off with recession. Changes to emissions and emission intensity followed closely the proportion of fossil fuel generation (Figure 7).

Alberta

Alberta's utility generation capacity is comprised of primarily fossil fuel generation: coal and natural gas. Together these fuels produced about 95% of all electricity in the province over the last decade. From 1994 natural gas began replacing coal, such that this fuel's share of generation was reduced from 88% to 83%.

There are clear trends over the 1990 to 1999 period. Total

Figure 7. Ontario Electricity Trends: Generation, Greenhouse Gas Emissions and Intensity, 1990 to 1999



generation increased by about 25% and, because of the dependence on fossil fuel generation, total emissions followed in parallel. As natural gas replaced a portion of coal, emission intensities were lowered in the latter part of the decade (Figure 8).

References

Athabasca Oil Sands Developers, *Progress in Canada's Oil Sands*, p.12, 2000; as reported in VCR, *Annual Report 2000*, Canada's Climate Change Voluntary Challenge and Registry Inc., Ottawa.

CIEEDAC, *A Review of Energy Consumption in Canadian Refineries and Upgraders: 1990, 1994 to 1999*, Simon Fraser University, October 2000.

Environment Canada, *Canada's Greenhouse Gas Inventory 1990 - 1999: Emission and Removal Estimation Practices and Methods*, April 2001.

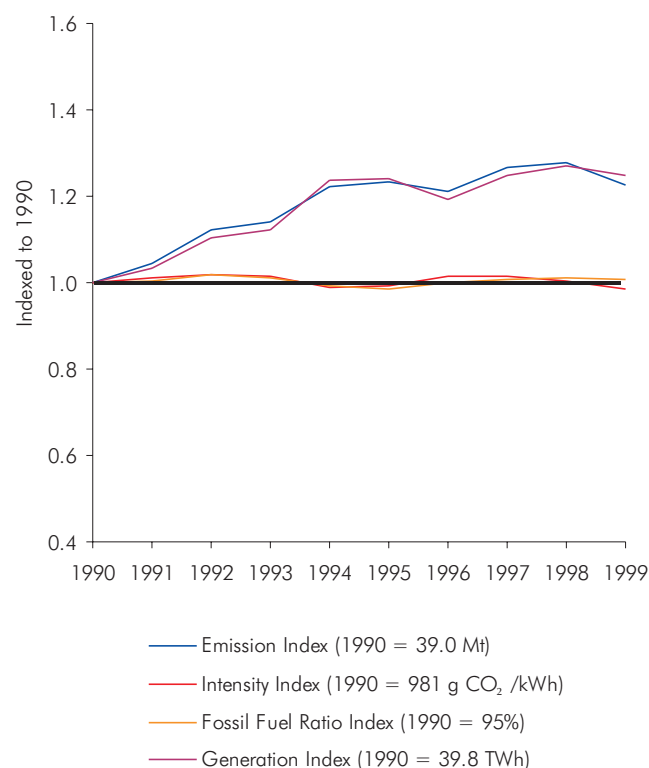
Intergovernmental Panel on Climate Change (IPCC), *Greenhouse Gas Inventory Reporting Instructions*, Vol. 1;

and *Greenhouse Gas Inventory Reference Manual*, Vol. 3, Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories, 1997.

Statistics Canada, *Crude Petroleum and Natural Gas Production, 1990-1999*, Catalogue #26-006.

Statistics Canada, *Quarterly Report on Energy-Supply Demand in Canada (QRES)*, Catalogue #57-003.

Figure 8. Alberta Electricity Trends: Generation, Emissions and Intensities, 1990 to 1999



Fugitive Emissions

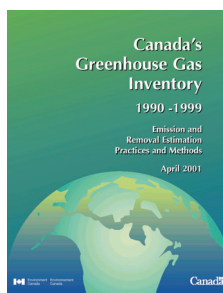
Fugitive emissions from upstream Oil and Gas Industries are generally methane (except for the stripping of carbon dioxide in the processing of natural gas) and occur from the following sources:

- natural gas production and processing (including raw CO₂ releases, surface casing vent blows and gas migration);
- natural gas transmission;
- conventional oil production;
- heavy oil production;
- natural gas flaring; and
- other fugitive sources (including oil sands activity, crude bitumen production, liquid product transport, heavy oil upgrading, oil and gas well drilling and servicing, accidents and equipment failures).

Also available in this series:

Overview * Residential, Commercial & Institutional Transportation * Electricity and Petroleum Industries Land Use Change and Forestry * Agriculture Industry * Waste

Also available in French



Contact:

Art Jaques, P. Eng
 Chief - GHG Division, Environment Canada
 351 St. Joseph Boulevard, Hull, QC, K1A 0H3
 (819) 994-3098, (819) 953-3006 (fax)
 ghg@ec.gc.ca

