

CANADA'S GREENHOUSE GAS INVENTORY

GHG Trends Information from Environment Canada's Greenhouse Gas Division

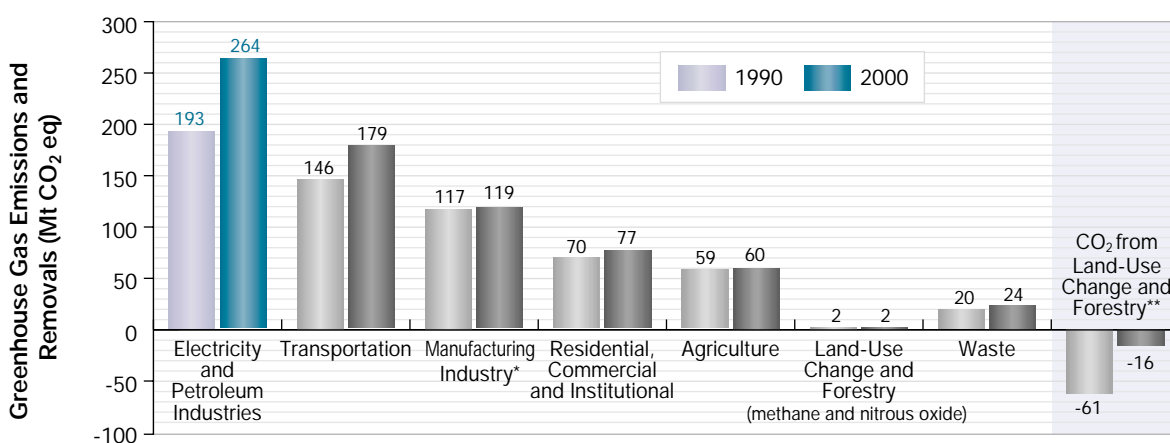
Electricity and Petroleum Industries: 1990-2000

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 emissions from both the upstream and downstream petroleum industries. The Electricity Generation sector consists of combustion emissions associated with electricity generation and steam production for mainly residential, commercial and manufacturing use.

- In 2000*, Electricity and Petroleum Industries contributed 36% or 264 megatonnes of carbon dioxide equivalent* (Mt CO₂ eq) of Canada's total greenhouse gas emissions of 726 Mt. Both the petroleum and electricity production contributed 136 Mt and 128 Mt of emissions, 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.
- Between 1990 and 2000*, emissions within the Electricity and Petroleum Industries grew by almost 37%, from 193 Mt to 264 Mt, surpassing the growth rate of total national emissions of 20%. On a sector basis, although electricity generation increased 25%, emissions in this sector grew 35%, due to an increased proportion of fossil fuel-generated electricity in the latter part of the decade. Although the Petroleum Industry sector emissions increased 39% over the period, on a sub-sector level upstream emissions rose 54% while downstream emissions decreased 5.5%. 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 2000



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

**Carbon dioxide emissions from the Land-Use Change and Forestry sector are not included in the national inventory totals.



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Canada's Electricity and Petroleum Industries Sector

The Electricity and Petroleum Industries are comprised of two important energy sectors - the Electricity Generation and Petroleum Industries sectors. The Petroleum Industries sector can be further subdivided into two categories: the Upstream Petroleum Industry and the Downstream Petroleum Industry.

Emissions from the Upstream Petroleum Industry are those associated with oil and natural gas

exploration, production and transmission, and include (Table 1):

- *fugitive* emissions (such as flaring, raw CO₂ releases, vent blows, gas migrations etc.) during exploration, production and transport; responsible in 2000 for 44% of Upstream Industry emissions;
- *process* emissions from the extraction of hydrogen from natural gas (used in heavy oil upgrading); responsible in 2000 for only 2.1% of Upstream Industry emissions; and
- *combustion* emissions from the exploration and extraction of oil and gas, the upgrading of oilsands, as well as the transmission of natural gas; responsible in 2000 for 54% of Upstream Industry emissions.

The Downstream Petroleum Industry includes the refining of crude oil and the distribution of natural gas. Emission sources consist of (Table 1):

- *fugitive* natural gas emissions from gas distribution; responsible in 2000 for 15% of downstream emissions;
- *process* emissions from the extraction of hydrogen from natural gas used in refining processes; responsible in 2000 for 4.6% of downstream emissions; and
- *combustion* emissions during refining of the industry's produced petroleum products (such as motor gasoline, diesel, and aviation fuel); responsible in 2000 for 80% of downstream emissions.

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 hydrofluorocarbons (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 2000 Trends Fact Sheet Series, while presenting the latest information on Canadian greenhouse gas emissions and removals derived from the latest national inventory, uses a modified sector approach to facilitate the use of information by the public.

Table 1 Electricity and Petroleum Industries' Greenhouse Gas Emissions, 2000, Mt CO₂ eq

Sector	Fuel Combustion	Industrial Process	Fugitive
Electricity Generation¹	128		
Petroleum Industry	79.5	3.4	53.1
Upstream Petroleum Industry⁴	61.7	2.3	49.8
Upstream Oil and Gas ²	50.4	2.3	44.2
Natural Gas Transmission	11.3		5.6
Downstream Petroleum Industry	17.8	1.0	3.3
Petroleum Refining ³	17.8	1.0	
Natural Gas Distribution			3.3

Notes: Due to rounding, individual values may not add up to totals.

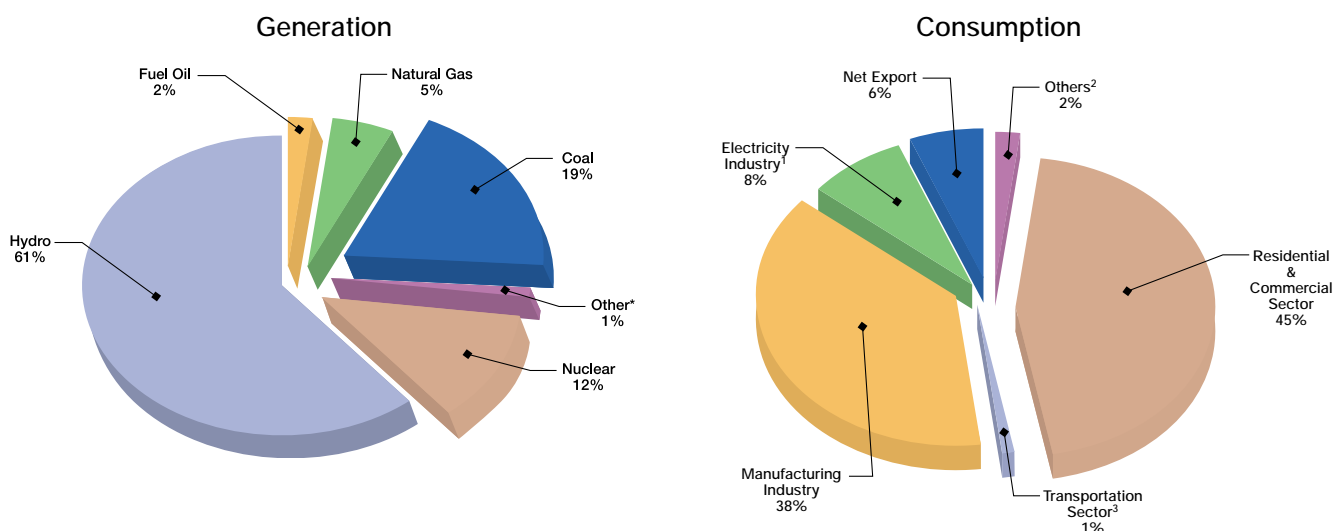
¹ Includes both utility & industrial generation and commercial steam generation.

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.

⁴ A small proportion of emissions from the Upstream Petroleum Industry is accounted for in the Mining sector due to data limitations.

Figure 2 2000 Electricity Generation and Consumption Sources in Canada



*Includes - Use of wood waste, spent pulping liquor and other fuels

¹ Includes - Electricity industry's own consumption and transmission losses

² Includes - Agricultural sector's electricity consumption

³ Includes - Pipelines, urban transit and street lighting

Data Source: Statistics Canada, Electric Power Generation, Transmission and Distribution, Catalogue 57-202, 2000

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 2000, about 28% of the total 586 TWh generated electricity was from greenhouse gas emitting thermal generation sources (fossil fuels). The remainder was from non-emitting sources such as hydro and nuclear, with a minor portion from biomass and wind (Figure 2). The manufacturing, residential and commercial sector together consumed nearly 83% of available electricity in 2000. Main uses of electricity in the residential and commercial sectors are for lighting, appliances, electronic devices, water heating and space heating and cooling. The Smelting, Refining and the Pulp and Paper industries are also some of the large primary electricity consumers within the manufacturing industries.

Electricity and Petroleum Industries Emission Trends: 1990 to 2000

Emissions within the Electricity and Petroleum Industries have grown significantly in the 1990 to 2000 period. While total Canadian emissions grew by almost 20%, those from the Electricity and Petroleum Industries sector grew by almost 37%, from 193 Mt to 264 Mt. Emission growth occurred mainly in the Upstream Petroleum Industry and the Electricity Generation sector by 54% and 35%, respectively. (Table 2).

Several factors can influence the growth or decline of emissions:

- Energy Demand (domestic and foreign demands)
- Energy Production Efficiency Improvements
- Fuel Switching

Table 2

Greenhouse Gas Emission Trends in the Electricity and Petroleum Industries, 1990 to 2000, Mt CO₂ eq

Sector	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
ELECTRICITY GENERATION¹	95.3	96.7	103	93.8	96.0	101	100	111	124	121	128
PETROLEUM INDUSTRY	97.5	97.8	106	109	113	119	123	119	125	135	136
Upstream Petroleum Industry⁴	74.1	75.4	82.9	86.3	90.9	97.4	100	97.1	103	113	114
Upstream Oil and Gas ²	62.9	63.4	68.3	71.2	75.1	80.2	82.3	79.3	85.2	95.5	97.0
Natural Gas Transmission	11.2	12.1	14.6	15.2	15.8	17.1	17.7	17.8	17.8	17.9	16.8
Downstream Petroleum Industry	23.4	22.3	22.6	22.9	21.9	21.9	23.2	21.9	22.0	21.3	22.1
Petroleum Refining ³	20.7	19.5	19.7	20.1	19.0	18.9	20.2	18.8	18.8	18.1	18.8
Natural Gas Distribution	2.8	2.8	2.9	2.8	3.0	3.0	3.0	3.1	3.2	3.2	3.3

Notes: Due to rounding, individual values may not add up to totals.

¹ Includes both utility & 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.

⁴ A small proportion of emissions from the Upstream Petroleum Industry is accounted for in the Mining sector due to data limitations.

The Petroleum Industries Sector

Emissions from the Upstream Petroleum Industry have experienced high growth over the period 1990-2000. Since 1990, upstream petroleum emissions have increased by 54%. In 2000 nearly 85% of these emissions were created in the extraction and product conditioning of crude oil, 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 2000 (Figure 3). In this period, net oil exports grew by 328% to 1037 PJ, while net exports of gas increased 150% to 3785 PJ. As natural gas exports increased, so 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

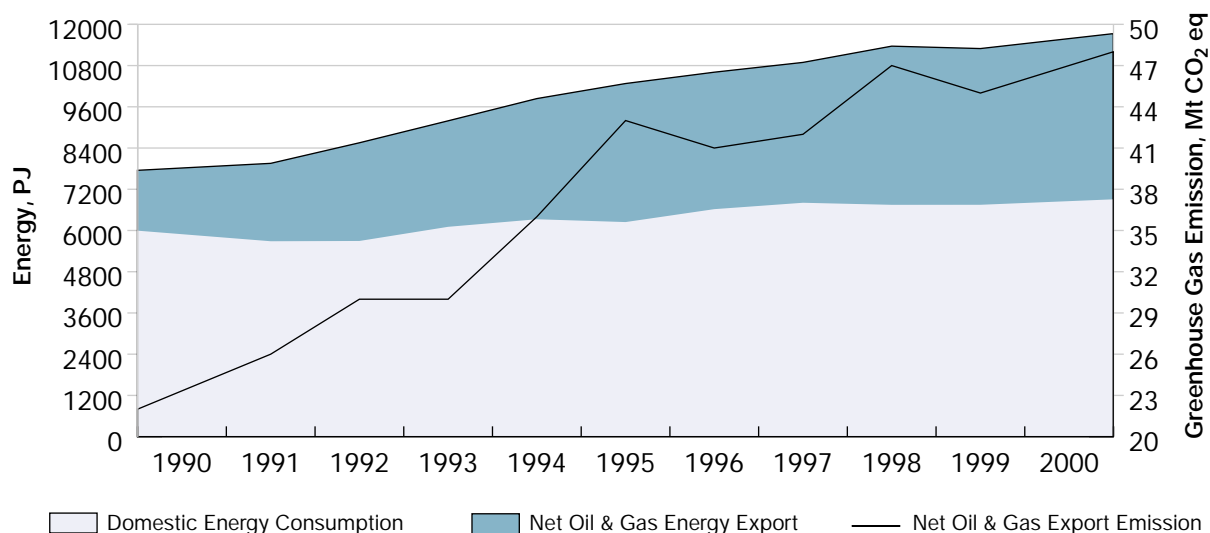
increased from 22 Mt in 1990 to 48 Mt in 2000. Overall, total oil and gas energy exported increased 175% between 1990 and 2000, while emissions associated with oil and gas exports increased 121%.

As production increases, efficiency improvements are contributing to emission reductions in the Upstream Petroleum Industry. By 1997, oil sands produced 45% less emissions per unit production over 1990. On the other hand, ageing conventional crude reserves are offsetting the upstream petroleum industries' efficiency improvements, due to increased pumping for 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.

Emissions from the Downstream Petroleum Industry show an opposite trend to that of emissions in the Upstream sector, having decreased 5.5% since 1990. These emission reductions occurred even though the sub-sector experienced increases in production. 85% of downstream emissions, are due to the refining of crude oil while fugitive emissions from gas distribution contribute the remainder. Refinery

Figure 3

1990 to 2000 Domestic Energy Consumption, Net Energy Export and Emission Trends



production has increased by 11% 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 (9%) over the 1990 to 2000 period (CIEEDAC, 2001).

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 to generate electricity (Figure 4). Of these, Ontario and Alberta contributed over 71% in 2000. On the other hand, Ontario only generated 26% and Alberta 10% of total Canadian electricity in that year.

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 2000, electricity generation from all sources had grown 25%. At the same time greenhouse gas emissions were 35% 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 mix. As fossil fuels play a proportionally larger role in generating power, greenhouse gas emissions tend to rise proportionally, as well. For example, in 2000 fossil fuels contributed about 28% more to the total generation mix than they did in 1990. As a result, the greenhouse gas intensity was about 7.5% higher. Although changes in the overall emission intensity and in the proportion of fossil fuel generation to the total tend to mirror each other (Table 3), the increased use of natural gas combined with the decreased use of highly carbon intensive fuels such as coal and fuel oil has resulted in a 13% decrease in fossil fuel generated emission intensity.

As discussed earlier, Alberta and Ontario, contributed the majority of emissions in 2000 because of their relatively large generation capacities and high proportions of fossil fuel generation (Figure 4). Because of their influence on Canada-wide emission intensity trends, it is instructive to take a detailed look at these provinces.

Figure 4 Electricity Generation and Greenhouse Gas Emissions by Province, 2000

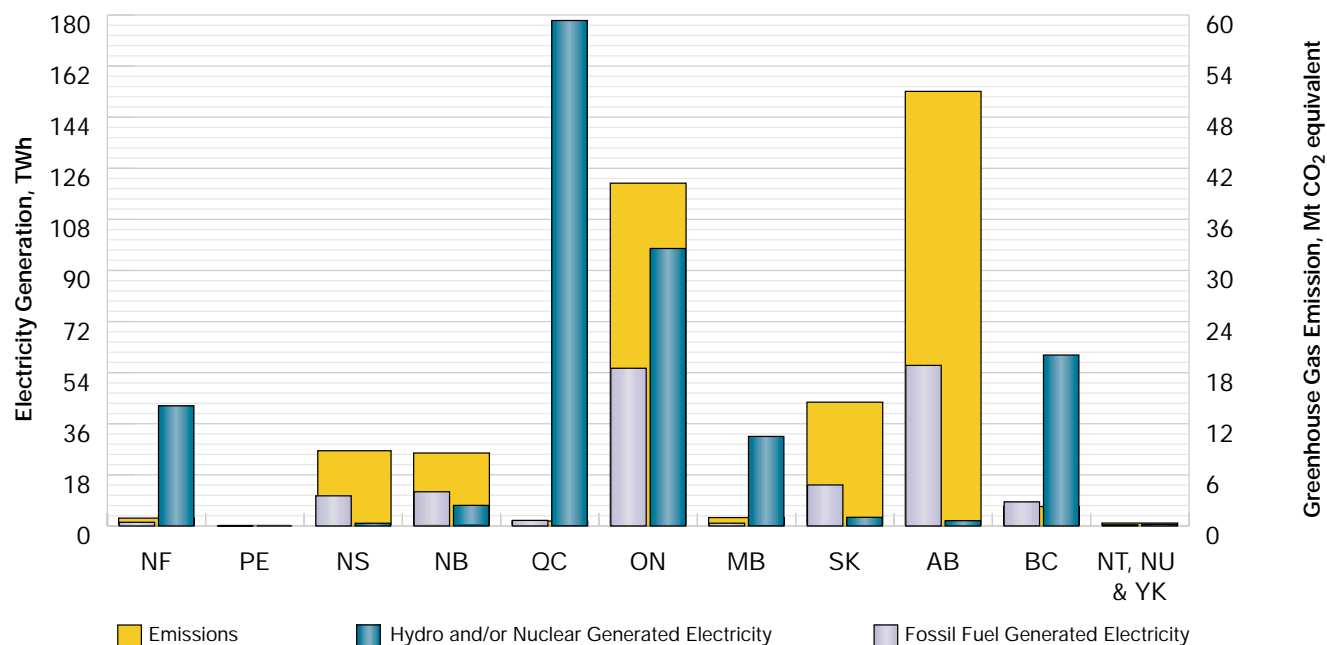
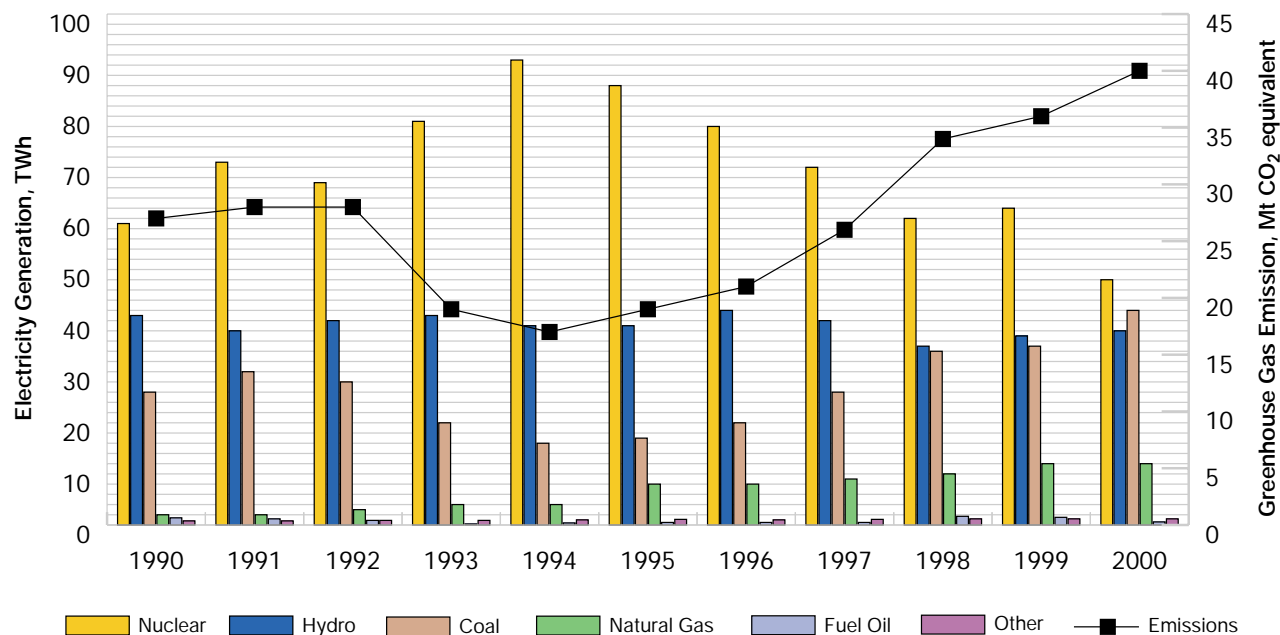


Table 3 Trends in Electricity Emissions and Energy Used, 1990 to 2000

	Overall Emission Intensity	Overall Electricity Generation by Sources			Fossil Fuel Generated	Fossil Fuel Generated Electricity				
		Fossil Fuel	Hydro	Nuclear		Emission Intensity	Total	Percent Contribution		
	Coal				Natural Gas			Fuel Oil	Other ¹	
										kt CO ₂ equivalent/ TWh
1990	204	22	63	15	909	105	73	9	14	4
1991	196	22	62	16	899	108	77	7	11	4
1992	204	23	62	15	894	115	73	11	12	5
1993	182	21	62	17	877	107	72	13	9	5
1994	178	21	61	19	864	111	73	14	7	6
1995	186	22	61	17	858	118	69	17	8	6
1996	179	21	63	16	859	116	72	15	7	6
1997	200	24	62	14	851	131	71	15	9	5
1998	227	27	60	12	837	148	68	17	11	5
1999	217	27	61	12	818	148	68	17	9	6
2000	219	28	61	12	791	162	68	19	8	5

¹ Includes wood & spent pulping liquor, manufactured gases, other petroleum products, other fuels and station service
Statistics Canada, Quarterly Report on Energy Supply-Demand in Canada, Catalogue 57-003-XPB

Figure 5 Ontario Electricity Trends: Generation by Sources and Greenhouse Gas Emissions, 1990 to 2000



Other: Includes wood waste, spent pulping liquor and other fuel use to generate electricity

Statistics Canada, Quarterly Report on Energy Supply-Demand in Canada, Catalogue 57-003-XPB

Ontario

Ontario's 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 1994 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 (Figure 5).

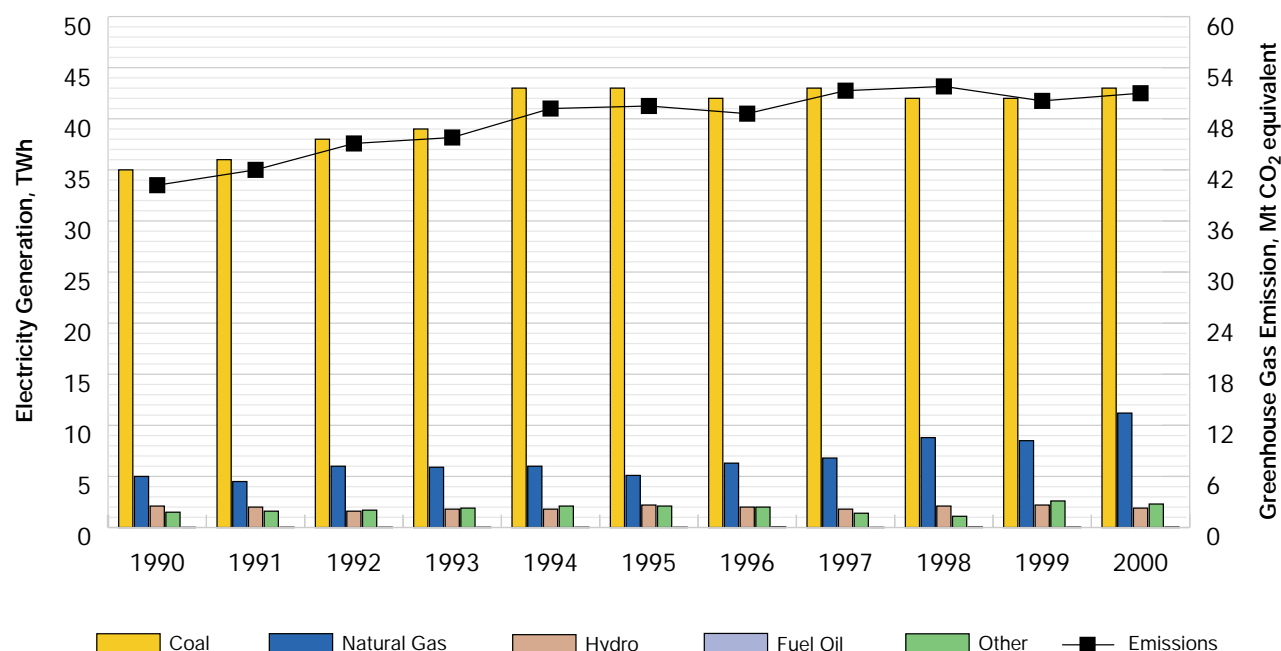
The trend over this period is clear. Generation output grew to the middle 1990s and then levelled off with the recession. Changes to emissions followed closely to the proportion of fossil fuel generation sources, such as coal and natural gas.

Alberta

Alberta's generation capacity is comprised primarily of fossil fuel generation: coal and natural gas. Together these fuels produced about 95% of all electricity in the province over the last decade. In the mid 90's natural gas began replacing coal, such that this fuel's share of generation was reduced from 82% to 74%.

There are clear trends over the 1990 to 2000 period. Total generation increased by about 35% and, because of the dependence on fossil fuel generation, total emissions also increased by 27%. As natural gas replaced a portion of coal, emission intensities were lowered in the latter part of the decade. Emission intensity decreased by 6% in 2000 (Figure 6).

Figure 6 Alberta Electricity Trends: Generation by Sources and Emissions, 1990 to 2000



Other: Includes wood waste, spent pulping liquor and other fuel use to generate electricity
 Statistics Canada, Quarterly Report on Energy Supply-Demand in Canada, Catalogue 57-003-XPB

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