Canadian Energy Research Institute

Energy and Climate Change Initiative Foundation Paper

Douglas Bruchet
Senior Vice President, Environmental-Energy Modelling
Telephone: (403) 220-2393
Facsimile: (403) 284-4181
Email: dbruchet@ceri.ca
Web: www.ceri.ca

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Relevant • Independent • Objective

Energy and Climate Change Initiative Foundation Paper

Canadian Energy Research Institute
#150, 3512 –33rd Street N.W.
Calgary, Alberta
Canada T2L 2A6

Tel: (403) 282-1231
Fax: (403) 284-4181
Web: www.ceri.ca

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1. Introduction

The objective of this project is to explore the linkages between energy, climate change and the economy from a Canadian, as well as a continental perspective. To achieve this objective the following report describes the interactions and interdependencies of Canada's energy system and identifies the major supply challenges. The primary focus of this report is on fossil fuels.

1.1 The Energy System

The energy system is complex, both in terms of its linkages within its various components as well as its relation to the external environment. Within the energy system (the lower portion of figure 1 shade in grey), primary energy resources such as crude oil, coal, and natural gas in their raw form are processed into consumable energy forms through energy conversion technologies. The final products in the form of refined petroleum products, piped natural gas, and electricity are used as final energy in various energy demand sectors of the economy, these products are deemed to be secondary.

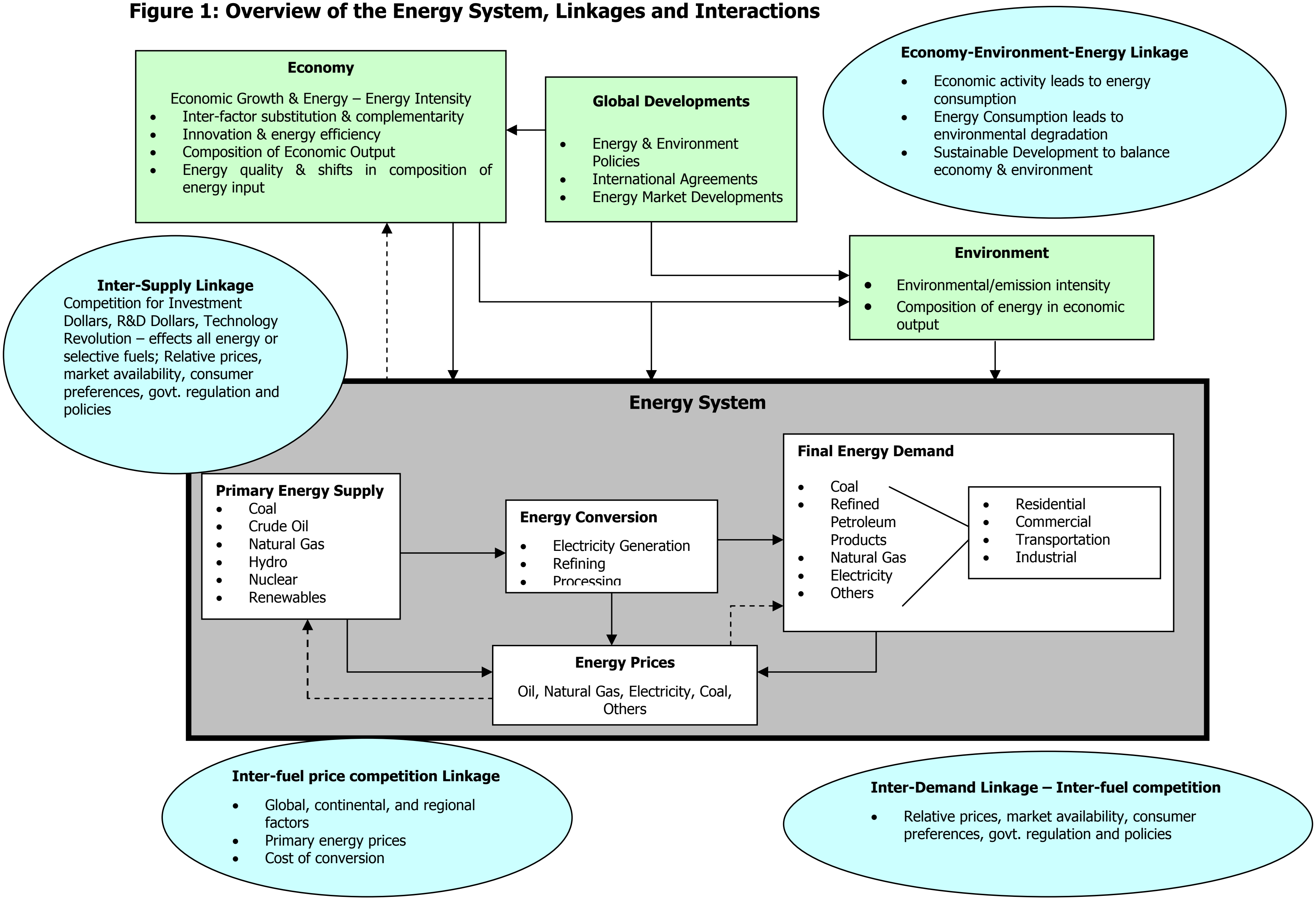
This complex relationship is illustrated simply in Figure 1. Within this energy system, energy is consumed to provide energy service in several demand sectors, which can broadly be categorized as residential, commercial, industrial and transportation. Like any other commodity, the supply and demand for various fuels interact to determine energy prices. Although some energy prices such as coal and electricity are determined primarily via local and regional energy demand and supply factors, others such as oil are determined within a global market.

The energy system within a jurisdiction interacts with external determinants including the rest of the economy, environment, and the global energy and environment systems. Overall, an increase in economic activity increases the demand for energy. The supply response to increased demand creates higher air emissions from the energy sector. These increased emissions from stem both consumption and production of energy.

Developments in the global energy and environment arena also affect the energy system within any country, not only through globally determined pricing but also through energy trade and environmental agreements.

Feedback effects between the various components of the energy system are also prominent in the energy system. While overall economic activity determines the demand for energy, the production of energy also contributes to the economy. In some economies, such as North America, the energy production is a significant contributor to the gross domestic product (GDP). The impact of the energy sector to GDP is discussed in section 1.2.

Figure 1: Overview of the Energy System, Linkages and Interactions



Source: CERI

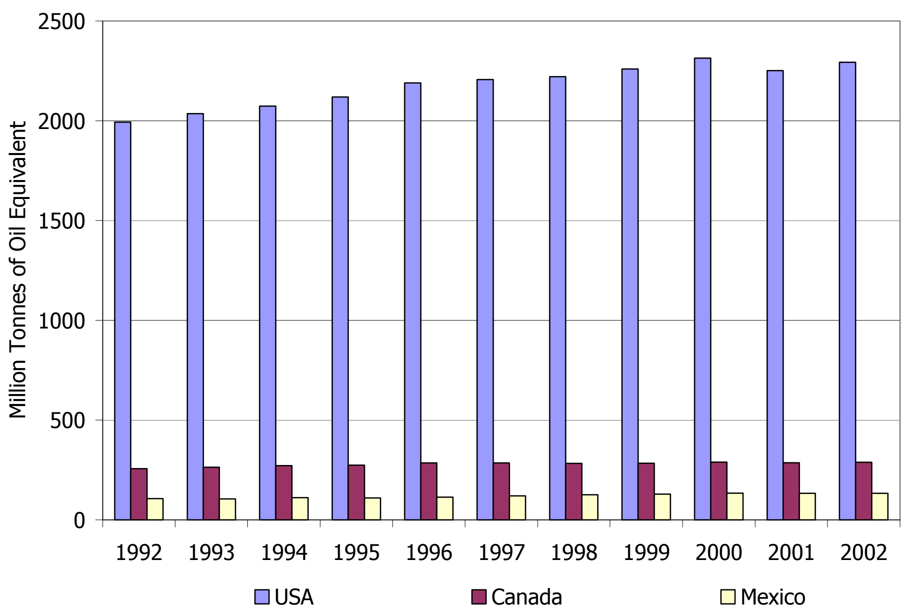
1.1.1 Energy Overview

As mentioned previously, North America is an important region for energy producing about one-fourth of global energy supply and consuming about 30 percent of the world's commercial energy. Canada is the fifth largest energy producer in the world[1] (third largest producer of natural gas and ninth largest producer of crude oil).

North American primary energy consumption[2] increased by an average of 1 percent per annum from 1992-2002.[3] As clearly shown in Figure 2, the United States is the major contributor to energy demand in North America.

North America has a strong reliance on fossil fuels as demonstrated by Figure 3. In Canada, hydro power plays a more important role with 27 percent of Canada's energy requirements met by hydroelectric power. Despite having abundant coal reserves (reserves/production ratio of 97 years),[4] coal contributes only 11 percent of Canada's total energy consumption, less than half that of the U.S. Natural gas represents about 25 percent of Canada's overall energy mix. Canada relies on fossil-based fuels for approximately 67 percent of its total energy needs.

Figure 2: North American Primary Energy Consumption (1992-2002)



Source: BP Statistical Review of World Energy 2003.

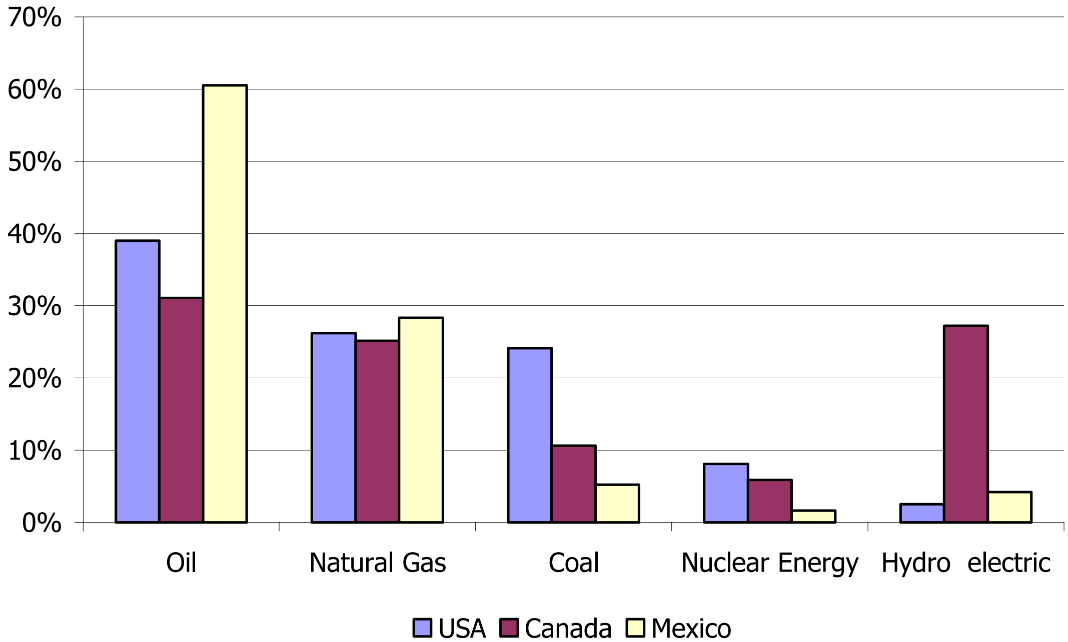
[1] US EIA Country brief: www.eia.doe.gov/emeu/cabs/canada

[2] Refers to sum of domestic production and net export adjusted with stock change. In other word, total energy consumption by both final demand sectors (e.g., residential, commercial) and transformation sectors (e.g., electricity generation).

[3] Primary energy consumption includes oil, natural gas, hydroelectricity, nuclear and coal.

[4] Source: BP Statistical Review of World Energy 2003.

Figure 3: Primary Energy Consumption by Fuel – 2002



Source: BP Statistical Review of World Energy 2003.

The three main determinants for energy demand are population, economic activity and technological change, which affects the efficiency of energy using processes. North America's annual population growth is expected to be 0.76 percent to 2010, and GDP annual growth rate projections between 2000 and 2010 are: Canada (2.5 percent), Mexico (4.0 percent), and the United States (2.9 percent)[5]. The forecast increase in population and economic growth is projected to cause an annual energy consumption increase of 1.7 percent for North America as a whole.[6] The impact of GDP and energy intensity on the energy sector is discussed in the report sections 1.2 and 1.3 respectively.

Table 1: Energy Use Per Capita– 2002

	Energy use Mtoe	**Energy use per capita** Mtoe
U.S.	2,293	8.0
Canada	289	9.2
Mexico	134	1.6
North America	**2,716**	**6.5**

Source: World Bank.

[5] North American energy Working Group, The Energy Picture; June 2002.
[6] IEA Outlook 2003.

1.2 Role of Energy in Canada's Economy

1.2.1 Energy Sector Contribution in GDP

The energy sector has played an important role in both federal and provincial economies in Canada and is expected to continue in the future. Table 2 presents the contribution of the energy sector in the total economy for the 1990-2001 period in Canada. The energy sector contributed between $44 billion and $56 billion to the total national GDP during the 1990-2001 period. This constitutes about 6 to 7 percent of the total national GDP. A strong correlation appears between the growth of the energy sector and the national economy. While the national GDP has increased at an average rate of 2.7 percent per year during the 1990-2001 period, the energy sector GDP has increased at a slightly smaller rate (2.3 percent).

Table 2: Contribution of the Energy Sector in Total National GDP (1990-2001)

Year	Total GDP	Energy Sector GDP	Energy Sector Share in Total GDP
	1997 Million Dollar		%
1990	707,147	44,392	6.28
1991	697,443	46,603	6.68
1992	702,705	48,100	6.84
1993	720,235	50,170	6.97
1994	752,890	52,017	6.91
1995	772,889	53,677	6.94
1996	783,834	54,072	6.90
1997	816,808	54,627	6.69
1998	848,964	55,003	6.48
1999	893,564	55,315	6.19
2000	935,426	57,115	6.11
2001	948,109	56,731	5.98

Source: CERI E2020 Database.

The role of the energy sector is important in some provinces and territories particularly, Alberta, Saskatchewan, and the Northwest Territories, accounting for an average of between 11 and 15 percent of the total GDP in these provinces (see Table 3). While the shares are fairly stable in most of the provinces, in Newfoundland and Labrador these shares have significantly increased implying an increasing role of the energy sector.

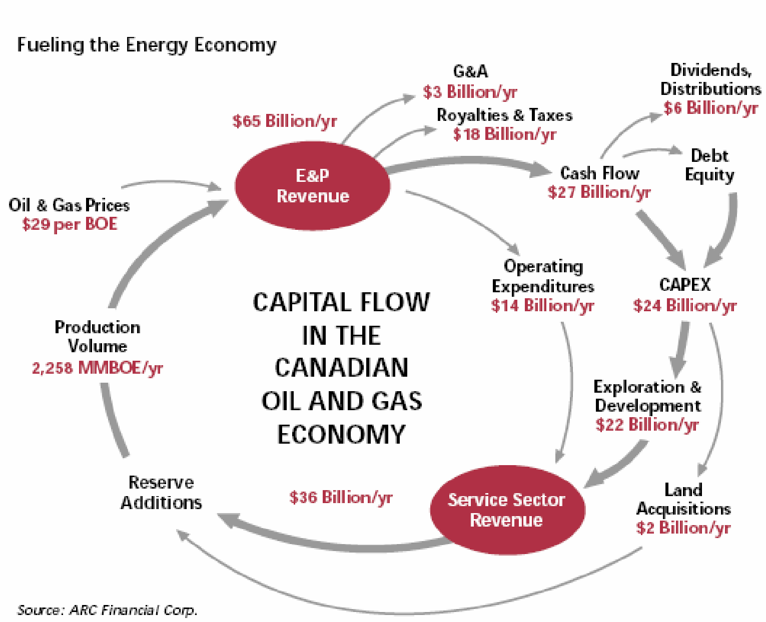
Table 3: Energy Sector's Share in total GDP in Canadian Provinces and Territories

Province	Energy Sector Share in GDP (%)		
	1990	1995	2001
Nova Scotia	3.5	3.6	3.7
Prience Edward Island	1.2	1.2	1.2
New Brunswick	4.7	4.8	5.0
Newfoundland & Labrador	5.2	5.5	12.5
Qubec	4.6	4.8	4.0
Ontario	3.4	3.5	2.9
Manitoba	4.7	5.1	4.6
Saskatchewan	12.0	14.2	13.5
Alberta	19.5	22.7	18.6
British Columbia	4.2	4.7	4.4
Territories	7.1	8.8	7.5

Source: CERI E2020 Database.

The contribution discussed above represents only energy production activities. Besides production from the energy sector, investment (particularly exploration and development), also contributes to the economy. The upstream petroleum industry is the country's largest private sector investor[7]. Figure 4 illustrates that the oil and gas sector is expected to invest, on average, 22 billion per year over the 2002-2005 period in conventional oil and gas, oil sands and frontier oil exploration and development.

Figure 4: Capital flow in the Canadian oil & gas economy



[7] Laurent, 2004.

1.2.2 Energy Sector Contribution in International Trade

Canada is one of the four OECD countries, which are net energy exporters. The other three are Australia, Mexico and the United Kingdom. Canadian exports primarily to refineries in the central and western U.S. amounted to roughly 694 million barrels per year of crude oil and about 3.8 trillion cubic feet per year of natural gas in 2002. Table 4 presents the dollar value of Canadian energy exports and energy commodities' share in total exports of goods and services during the 1990-2003 period. The share of energy commodities in the total exports of goods and services varies between 7 to 13 percent in the last 14 years. The share has almost doubled in 2003 (13 percent) from that in 1998 (7 percent).

In 2003, energy exports amounted to 61 billion dollars (13 percent) out of the 460 billion dollars of total exports of goods and services from Canada. Of the total energy exports, oil accounted for 51 percent, natural gas accounted for 43 percent, electricity and coal each accounted for 3 percent[8]. Higher oil and gas prices were the primary drivers for the large value of energy exports in 2003. Note that all energy commodities are exported to the U.S. with the exception of coal, which is also exported to Japan, Europe and various Asian countries.

Table 4: Energy Sector's Share in Total Exports of Goods and Services in Canada (1990-2003)

Year	Total Goods & Service Exports	Energy Export	Share of Energy in Total Export
	Billion Canadian Dollars		%
1990	174	15	9
1991	171	16	9
1992	189	17	9
1993	218	19	9
1994	261	21	8
1995	301	23	8
1996	320	28	9
1997	347	30	9
1998	377	26	7
1999	423	30	7
2000	489	54	11
2001	481	57	12
2002	478	49	10
2003	460	61	13

Source: Department of Foreign Affairs and International Trade

8 Export Development Canada, Global Export Forecast, Spring 2004.

Energy commodities are the main exports for some provinces, especially, Alberta, New Brunswick, Newfoundland & Labrador and Saskatchewan. Oil and gas exports accounted for 70 percent of the total merchandise exports and 62 percent of the total goods and service exports for Alberta in 2003. In New Brunswick, energy accounts for more than 40 percent of total exports of goods and services. Table 5 presents the share of energy commodities in the total exports of goods and services in Canadian provinces and territories in 2003.

Table 5: Energy Sector's Share in Total Exports in Canadian Provinces and Territories (2003)

Province/ Territories	Total Goods & Service Exports	Energy Export	Share of Energy in Total Exports
	Million Canadian Dollar		%
Nova Scotia	7,549	1,302	17
Prince Edward Islanc	1,119	n.a.	n.a.
New Brunswick	9,641	4,020	42
Newfoundland	7,451	2,527	34
Quebec	219,209	n.a.	n.a.
Ontario	84,830	n.a.	n.a.
Manitoba	10,877	935	9
Saskatchewan	13,752	3,263	24
Alberta	64,557	40,234	62
British Columbia	38,707	4,980	13
Territories	1,866	n.a.	n.a.

Source: Department of Foreign Affairs and International Trade and Export Development Canada.

1.2.3 Energy Sector: a Key Employment Generator in Canada

The energy sector also makes an important contribution to overall employment. According to a recent study conducted by the Petroleum Human Resources Council of Canada[9] (see Table 6), the upstream petroleum industry provided 120,040 jobs in the country in 2001. The Canadian Association of Petroleum Producers (CAPP) estimates the total (direct and indirect) employment impact from the industry in Canada to be more than 500,000 jobs. The oil and gas industry is among the largest employers of First Nations people in the country[10].

[9] Strategic Human Resources Study of the Upstream Petroleum Industry: The Decade Ahead, Petroleum Human Resources Council of Canada, 2004.

[10] Policy Direction for Canada's Oil and Gas Industry, Report Submitted by the Canadian Association of Petroleum Producers (CAPP) to the Council of Energy Ministers, September 2003.

Table 6: Employment in Upstream Oil and Gas Sector (2001)

Region	Oil & Gas Extraction	Activities Supporting Extraction	Crude Oil Pipeline	Natural Gas Pipeline	Total
Canada	**49,800**	**65,165**	**2,415**	**2,660**	**120,040**
WCSB	39,575	54,080	1,725	2,115	97,495
Oil Sands	6,620	905	n/a	n/a	7,525
North	150	440	20	n/a	610
East Coast	1,550	2,295	40	25	3,910
Central Canada	1,245	5,960*	550	400	8,155
Other:	660	1,485	80	120	2,345

*For Central Canada, this number also includes mining occupations. Due to the nature of the occupational codes used by Statistics Canada, this employment figure could not be further differentiated to reflect only the upstream petroleum industry.

Source: Strategic Human Resources Study of the Upstream Petroleum Industry: The Decade Ahead, Petroleum Human Resources Council of Canada, 2004.

According to the Canadian Electricity Association (CEA), the electric utility sector (including electric power generation, transmission and distribution) provided about 87,000 direct jobs in 2001 and 88,000 jobs in 2002. Similarly, coal mining accounted for 6,030 direct jobs[11]. According to the Coal Association of Canada, if indirect employment is also considered, the coal industry would have provided over 56,000 jobs in the country in 2001.

1.3 Linkages between Various Elements of the Energy System

The energy system as described in section 1.1 identifies four key linkages: the inter-energy demand linkage and inter-fuel price emerge from the substitutability of energy fuels; the inter-energy supply linkage results from the capital and resource constraints that lead to competition for investment dollars. The economy-environment-energy linkage indicates the overall inter-dependence of these components. The following sections provide further discussion on these linkages.

1.3.1 Energy, Economy & Environment Linkage

Energy, together with capital and labour, is input into the production of goods and services that an economy produces. The quantity of energy consumed in the production of goods and services is dependent on the technical nature of energy-using capital equipment. Whether and to what degree is energy a substitute or a complement has been the subject of considerable empirical work[12]. Overall, there is greater substitution between the various forms of energy, than between energy and others factors of production. As a broad generalization, it appears that

[11] Statistics Canada, CANSIM II.

[12] Kaufman, R.K., Azary-Lee, L.G. (1991), A biophysical analysis of substitution: Does substitution save energy in the U.S. forest products industry? Proc. Ecol Econ: Implications Forest Manage Practice, 1991

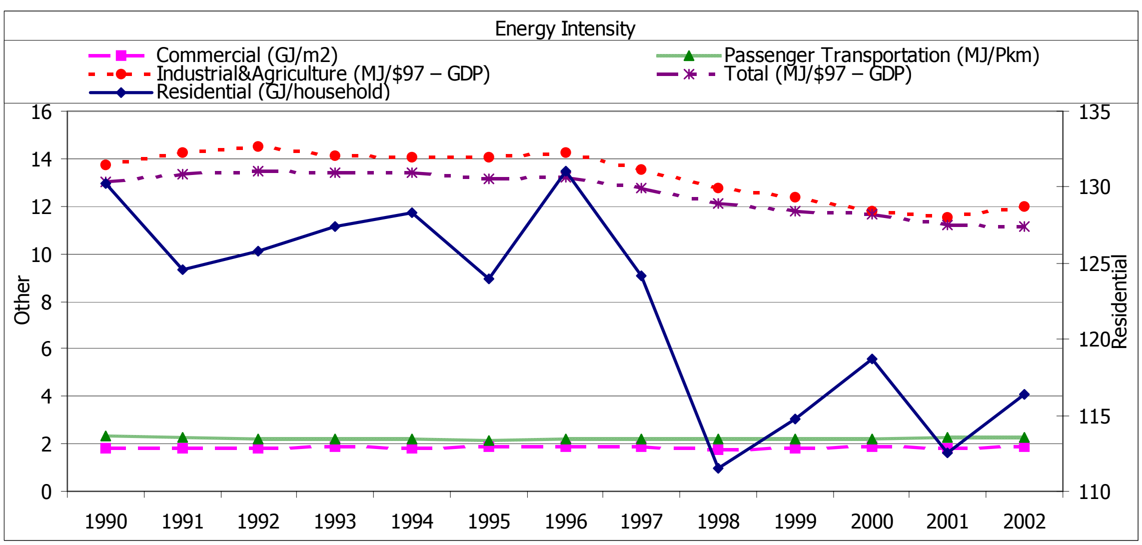
there often has been a strong relationship between energy consumption and gross domestic product (GDP). This relationship is measured by the ratio of energy consumption to GDP known as the energy intensity ratio.

Energy intensity of the economy changes over time. In Canada, there has been a significant decrease in energy intensity over the last decade. The change in energy intensity is driven by several factors including[13]:

- innovation and energy efficiency, resulting in per unit production of economic output with lower amounts of energy;
- inter-factor substitution away from energy into non-energy factors of production;
- energy quality and shifts in composition of energy input leading to changes in the heat unit of fuel; and
- structural change resulting in shifts in the composition of output, which lead to changes in consumption of energy.

Figure 5 indicates that with the exception of the commercial sector, energy intensity has decreased in residential, industrial and transportation categories. Between 1990 and 2002, the residential demand per household decreased at a rate of 0.9 percent per year. This trend compares with a decrease of 1.25 percent per year in energy consumed per dollar of GDP in the industrial sector and a decline of 0.1 percent in energy consumed per passenger mile traveled. The overall consumption of energy per dollar of GDP decreased by 1.3 percent per year over this period.

Figure 5: Energy Intensity



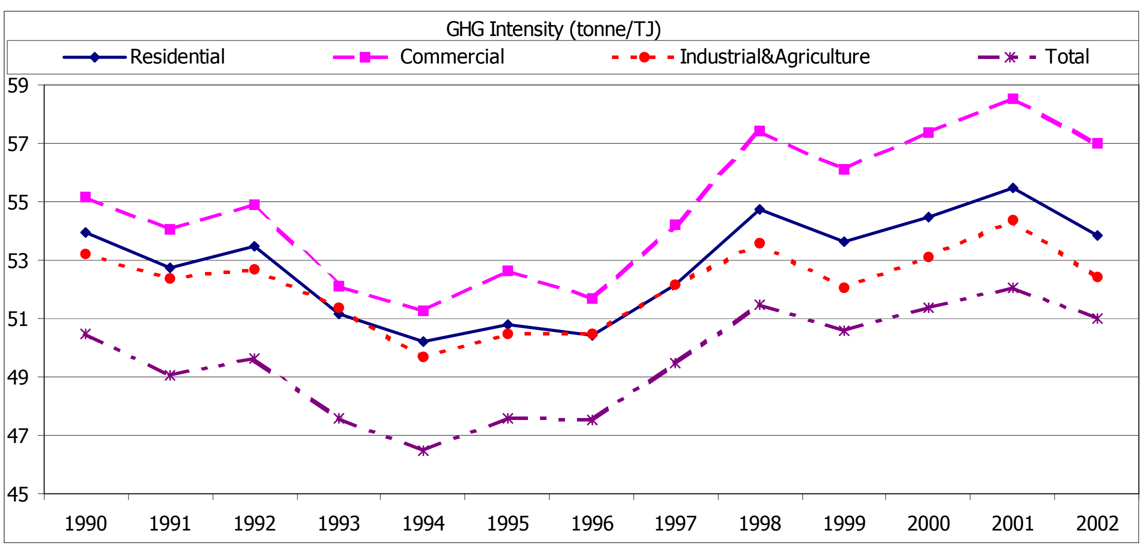
Source: NRCan Comprehensive Energy Use Database

[13] David L. Stern, (2004), Economic Growth and Energy in Encyclopedia of Energy, 2004

Although economic activity leads to energy consumption, the reverse linkage also needs to be noted. The production of energy is an economic activity, and an increase in the production of energy leads to an increase in economic output. For a country like Canada, where energy resources are abundant, the energy production sector contributes significantly to the economy (see section 1.2). The contribution of the energy-producing sector to trade is also noteworthy.

Energy extraction, processing and consumption involves some form of environmental impact, including both geomorphological and ecological disruption as well as environmental pollution[14]. The environmental impact of energy production and use may change over time due to factors such as technological innovation and a shift to higher quality energy sources, and others. Thus, shifts from coal consumption to natural gas will reduce environmental emissions. In the context of climate change, emissions intensity measures the emissions released per unit of energy consumed. Emissions intensity could also be defined per dollar of output. In Canada, there has not been much of a shift in emission intensity per unit of energy consumed (Figure 6). The residential, industrial and transportation have fairly constant emission intensity between 1990 and 2002. There are some year-to-year changes, but the changes are small. The most noticeable change is in the commercial sector intensity, which clearly appears to be on an upward trend. These results imply that overall there is no clear movement towards cleaner energy fuels. However, emissions per dollar of output have decreased during this time period at a rate of 1.2 percent per year (Figure 7). Thus the composition of economic activity in Canada is becoming less emission intensive; this perhaps follows from the decreasing energy intensity of the Canadian economy.

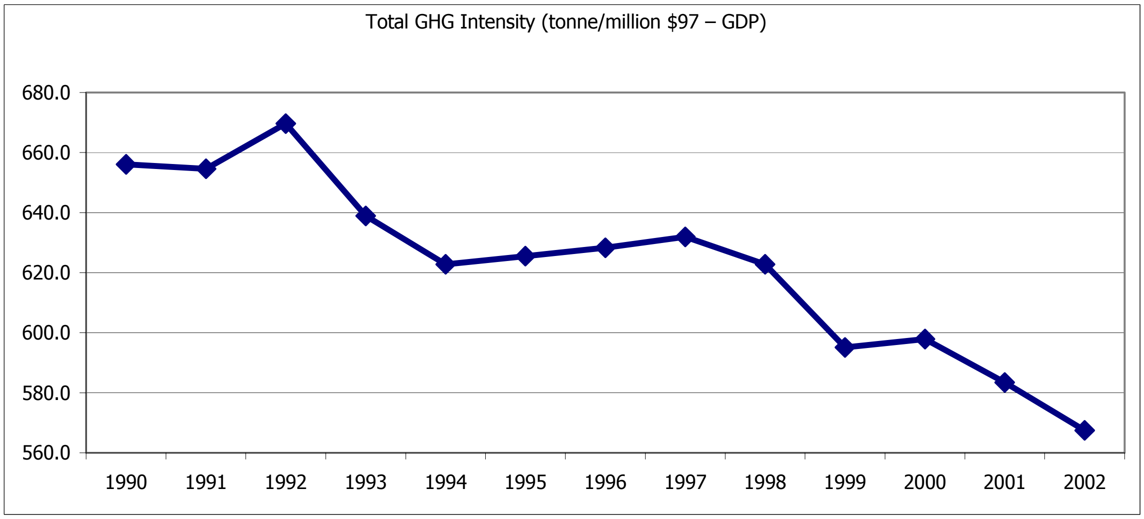
Figure 6: Emissions Intensity



Source: NRCan Comprehensive Energy Use Database

[14] David L. Stern, (2004), Economic Growth and Energy in Encyclopedia of Energy, 2004

Figure 7: Emissions Intensity



Source: NRCan Comprehensive Energy Use Database

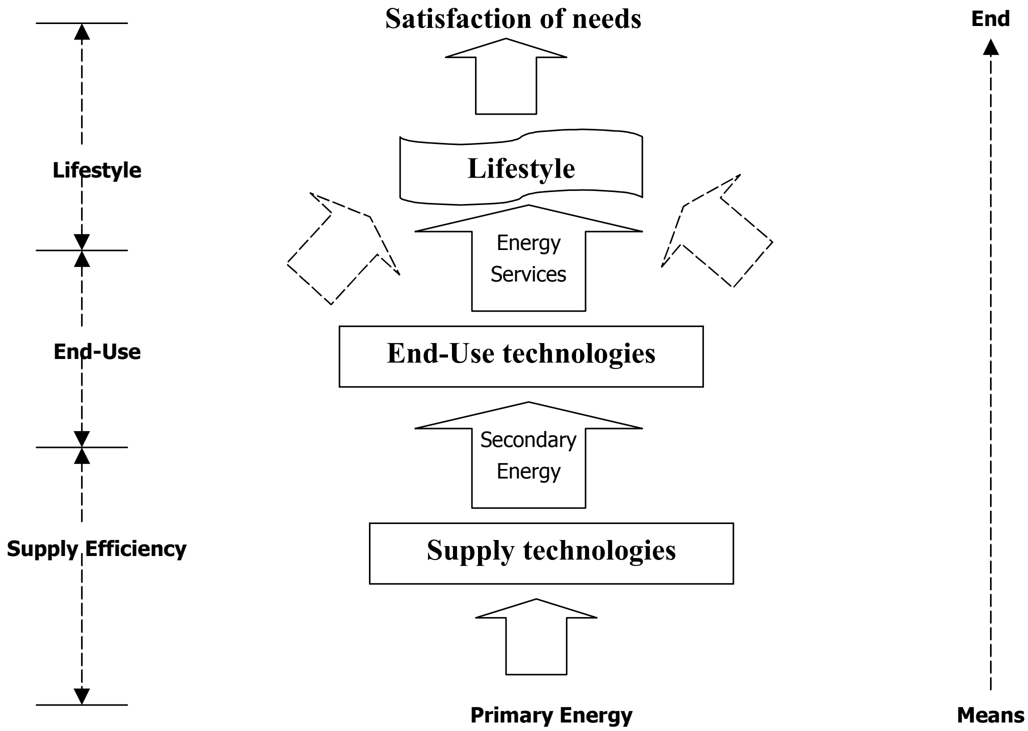
1.3.2 Inter-Demand Linkage (inter-fuel competition)

Demand for energy is a derived demand in that energy fuels are consumed to provide an energy service. It is the energy service such as heat, light, motive power, chemical conversion and such that is needed rather than the energy fuels. Energy, therefore, is a means to an end; this is illustrated clearly in Figure 8.[15]. All energy fuels compete (i.e., inter-fuel competition) to provide the "end" i.e., the energy service. The consumer choice for one energy fuel vis-à-vis the other is determined by such factors as relative fuel prices, market availability, consumer tastes and preferences, technology costs, government policies and regulations.

Relative price of energy is an important determinant in the choice of energy fuel. And, the choice of fuel in turn has important implications for energy prices, economy and trade, and environment. Thus, energy prices influence energy choices, which further effect energy supply and trade. This interdependence is reflected back in further changes to energy prices.

[15] John Peet, (2004) Economic Systems and Energy, Conceptual Overview, in Encyclopedia of Energy Volume 2, pg. 103-115.

Figure 8: Conversion of Primary Energy to Energy Services



Source: J.S Norgard, Encyclopedia of Energy [16]

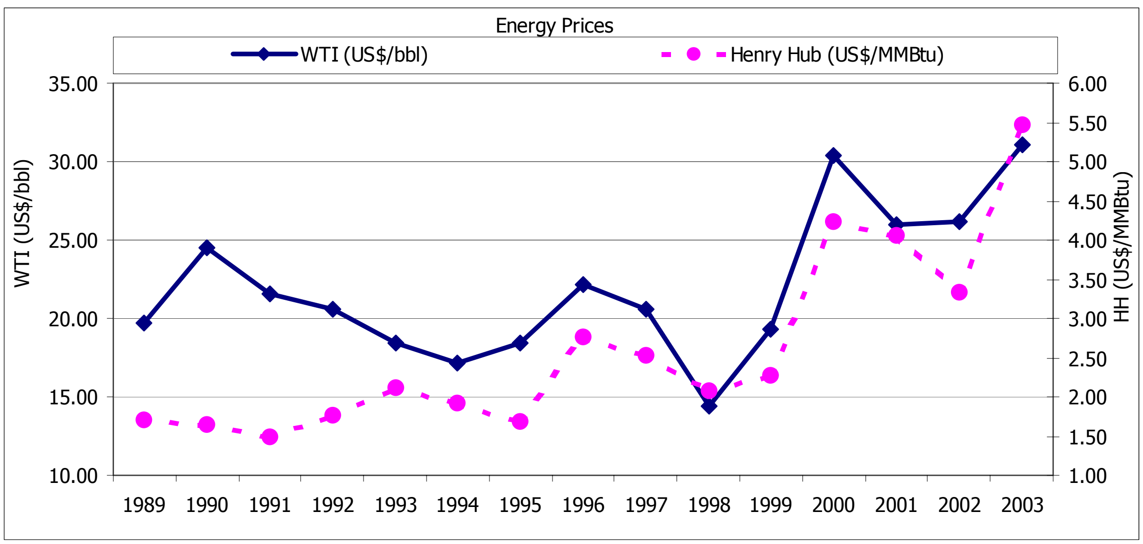
The effect on energy prices of local, regional or national demand and supply factors depends upon whether the price is determined locally, regionally or globally. The price of oil is determined at a global level, and therefore, changes to Canadian demand for oil, which is small (2 percent) will have minimal effect on world oil prices. Changes to the Canadian supply of oil also do not influence the price of oil as long as the Organization of Petroleum Exporting Countries (OPEC) remains the price setter, and the share of Canadian oil supply in total world supply is small (approximately 3 percent). The price of natural gas is determined in the North American market, and although the Canadian demand may not have a significant effect on the price, the Canadian natural gas supply will effect North American prices as Canadian production available for export flattens. However, as natural gas becomes a globally traded commodity, through the increased penetration of liquefied natural gas (LNG), the effect on North American natural gas prices from changes in natural gas demand and supply in Canada will decrease. Electricity prices are determined at a more regional level. The choice of energy fuels plays an important role in determining the cost of generating electricity and therefore electricity prices.

[16] John Peet, (2004) Economic Systems and Energy, Conceptual Overview, in Encyclopedia of Energy Volume 2, pg. 103-115.

1.3.3 Inter-fuel Price Competition

Energy is not a homogenous resource, and the prices of the various energy fuels do not necessarily track each other. In examining the relationship between the three key traded energy fuels, oil, natural gas and coal, little evidence has been found to indicate that coal prices move together with oil prices[17]. Unlike oil, there is no world price of thermal coal, and the price of coal in various locations does not move together. The price of natural gas, however illustrates a relation with the price of oil over certain time periods. The oil and natural gas prices are illustrated in Figure 9. Between 1993 and 2003, the two prices appear to move together in terms of peaks and direction of change. The monthly data for 2004 indicates that there may not be a continuation of this trend in this year. The prices may de-couple, with each driven by its own demand, supply and geopolitical factors.

Figure 9: Wholesale Prices (WTI versus Henry Hub)



Source: WTI – US EIA; Henry Hub - CAPP[18]

In Canada, a significant part of electricity is generated from fossil fuels (primarily, natural gas and coal), and as such the price of coal and natural gas are important determinants of electricity prices. In many jurisdictions across Canada, natural gas is the marginal fuel for electric generation and the price of natural gas determines electric power rates.

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[17] Beck, Peter & Roberts, Michael J, 2004, Prices of Energy, in Encyclopedia of Energy. Volume 5 pg. 135-143.

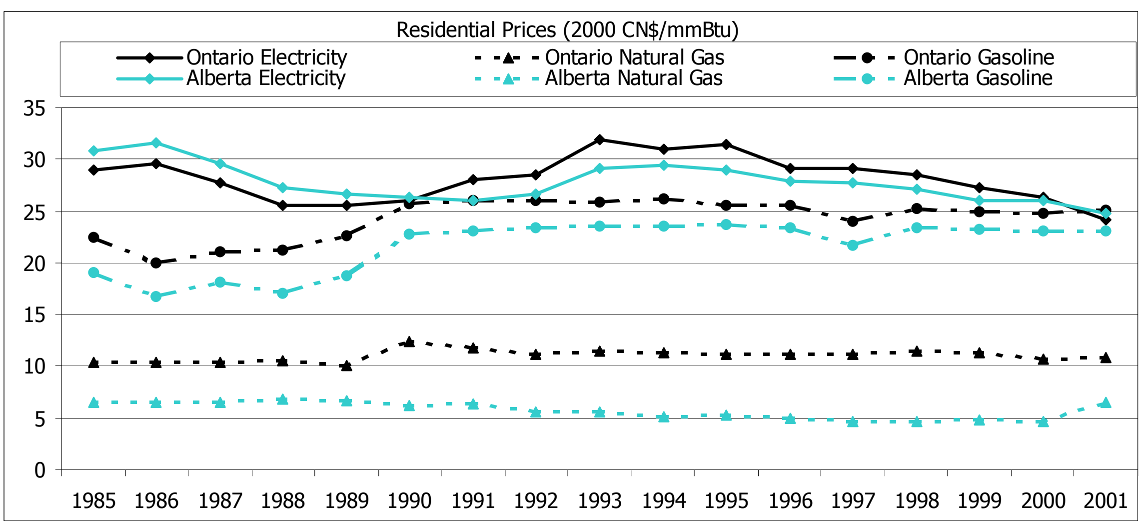
[18] WTI (West Texas Intermediate) is a grade of crude oil that has its main delivery point in Cushing, OK. The spot price for WTI delivered Cushing is the ultimate settlement price for the NYMEX (q.v.) oil futures contract. The Henry Hub is the largest centralized point for natural gas spot and futures trading in the United States. The New York Mercantile Exchange (NYMEX) uses the Henry Hub as the point of delivery for its natural gas futures contract.

Although there is an international market for many the energy fuels, the end-use prices to the consumer vary dramatically between jurisdictions. This is largely due to the wide variation in national and provincial taxes on energy. Since much of the fuel competition occurs at the end-use level, and it is the final end-use prices that determine the fuel shares, it is useful to review the trends and relation between the end-use prices. Figure 10 provides the end-use gasoline, natural gas and electricity prices for the residential sector in Alberta and Ontario. Overall the trends in the natural gas and gasoline prices are similar. The electric prices follow a somewhat different trend.

1.3.4 Competing for Investment Dollars

On the energy supply side, there is continuous competition for investment dollars in supply capacity, research and technology development. For the investor in the energy sector, the choice needs to be made between investing in various energy fuels. Even within the same energy fuel, there is competition between the various technologies. The investor in Canada's oil and gas industry needs to choose between investing in oil, natural gas, or even between conventional oil or non-conventional oil such as oil sands or between onshore and offshore resources. These investment decisions effect supply capacity both in the short and long term; the decisions also effect supply and trade.

Figure 10: End-Use Prices ($/mmbtu)
(Residential Natural Gas, Electricity and Gasoline, Ontario and Alberta)



Source: CERI E2020 Database

1.3.5 Demand – Supply linkages

Energy demand and energy supply are inter-linked through the price of energy. This dynamic relationship is constantly effected by feedback and rebound effects[19]. A higher energy demand for natural gas results in a higher natural gas price, which signals an increased supply of natural gas, and a reduced demand. Since energy is also an input to the production of energy, relative price of energy commodities may also effect capacity decisions for one or more forms of energy. The case of higher natural gas prices is a pertinent example. Higher natural gas prices due to increased demand pressures in the North American market have generated increased investment in natural gas productive capacity. However, those higher prices have also led to consideration of other energy investments in oil from oil sands and generation of electricity from other sources, such as coal.

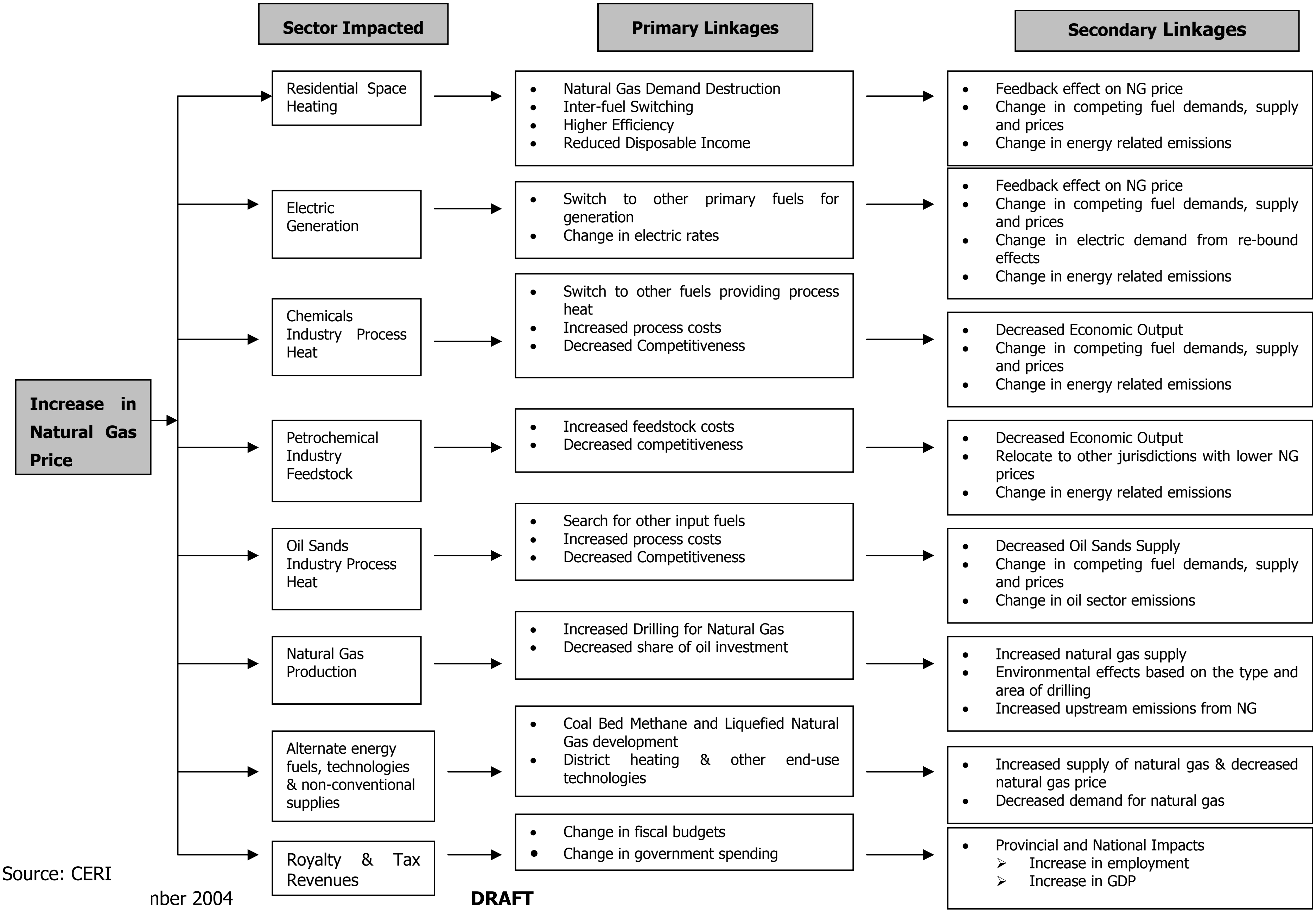
1.3.6 Energy Inter-Linkages in Action: A Case Study in Natural Gas

The above discussion on linkages is summarized in Figure 11, which provides illustrative impact of higher natural gas prices on the energy system. Eight direct impact points (sectors impacted) are traced through their primary and secondary effects. There is only a fine line between the primary and secondary effects; the distinction only reflects the sequence of impact, and the time frame over which the impact materializes. The impacts illustrated in this figure can be grouped into:

- Energy conservation due to increased efficiency and decreased natural gas demand;
- Increased demand for competing fuels;
- Energy price changes for competing fuels as well as where natural gas is an input (i.e., electricity);
- Decreased economic competitiveness and economic output for industries using natural gas including oil sands;
- Industry relocation due to competitiveness impacts;
- Increased natural gas supply;
- Increased development and penetration of alternative energy fuels, technologies and supplies;
- Change in air emissions from changes in energy demand fuel mix and composition of energy supply;
- Changes in royalty and tax revenues.

[19] Rebound effects in this context refer to change in consumption or production that often occurs contrary to the first set of effects. In the case of energy demand, this effect implies the increased consumption that occurs when efficiency improvements reduce user costs of energy service.

Figure 11: Energy Inter-Linkages in Action: A Case Study in Natural Gas



Source: CERI

1.4 Linkages between GHG Emissions and Other Pollutants

There is a close relationship between greenhouse gas (GHG) emissions (particularly, CO_2) and other air pollutants such as SO_x, NO_x, VOC, particulate matters. This is because the source of both types of emissions is the combustion of fossil fuels. Coal emits higher level CO_2, SO_x, NO_x and VOC as compared to other fossil fuels to produce the same amount of heat although on a per tonne basis that may not be so. Moreover, the emissions from coal also depend on its quality (anthracite, bituminous, sub-bituminous, lignite) and type of technology where it is burned (e.g., boiler type and firing configuration).

Table 7 shows the level of CO_2, SO_x and NO_x emissions for each of the main fossil fuel types used in Canada. Obviously, the combustion of all fossil fuels emits larger amount of CO_2, as compared to other pollutants such as SO_x and NO_x. Although, emitted in smaller amounts, the latter pollutants are more harmful than CO_2 and directly impact the environment nearer to the source of emissions. These pollutants are the main factors causing acid rain problems in the Great Lakes area.[20]

Table 7: Reductions in GHG and other pollutants (in kg) due to reductions in burning of various fossil fuels (in tons) in Canada

Fuel	GHG	Other Pollutants	
	CO_2	SO_x	NO_x
Anthracite[a]	2390	15.4	4.1 - 8.2
Bituminous[b]	1852 - 2432	9.9 - 12.1	10.0 - 14.1
Sub-bituminous[c]	1733 - 1765	9.9 - 11.1	4.0 - 10.9
Lignite[d]	1424 - 1476	5.5	2.6 - 5.9
Heavy Fuel Oil	3135	13.7 - 21.6	3.9 - 6.7
Light Fuel Oil	3371	0.6 - 2.5	2.9 - 4.5
Diesel	3252	0.05 - 0.5	-
Gasoline	3167	0.002 – 0.073	-

[a] Used in Quebec, Ontario and Alberta.
[b] Used in all provinces except Saskatchewan, Newfoundland & Labrador, Prince Edward Island and Territories.
[c] Used in Ontario, Manitoba and Alberta.
[d] Used in Ontario, Manitoba and Saskatchewan.

Source: Environment Canada, Greenhouse Gas Emissions 1990-2000, Appendix D and US Environmental Protection Agency.

To date the reduction in fuel consumption is the best option available to control CO_2 emissions from fossil fuel combustion. Since, fossil fuels are the common source of other pollutants (e.g., SO_x and NO_x), cuts in fuel consumption also generally reduce emissions of other pollutants. A

[20] US Environmental Protection Agency website. http://es.epa.gov/ncer/publications/topical/nox.html

policy of reducing 10 percent of CO_2 emissions from the business as usual case could also reduce about the same level of SO_x and NO_x emissions under the two situations. First, no SO_x and NO_x control equipment are planned to be installed, secondly the CO_2 reduction policy does not results into a significant fuel switching to natural gas from coal and oil. This implies that a CO_2 emission reduction policy not only reduces CO_2 emissions, but also results in the reduction of other pollutants. Thus, these types of ancillary benefits have an important role to play in assessing an overall GHG mitigation policy.

2. Key Challenges

2.1 The Supply Challenge

Despite its vast reserves of energy, North America is an energy-importing region. As a result of political instability in countries that export to North America (especially in the Middle East and Venezuela), there is concern in North America (particularly in the U.S.) over the dependence on unstable supply sources and possible supply disruptions. A significant proportion of U.S. energy consumption is currently met by imports, approximately 26 percent of the total and this is expected to increase to 36 percent by 2025.[21]

North American energy markets are becoming increasingly integrated. Both Mexico and Canada are net exporters of energy to the U.S. Most of Mexico's oil exports go to the U.S; Canada exports about half of its natural gas and crude oil production to the U.S., as well as significant amounts of electric power.[22] The U.S. also exports coal to Canada and smaller quantities of gas and refined petroleum products to Mexico. With growing world energy demand, North America also faces challenges in securing supplies outside of North America.

2.1.1 <u>Resource Base and Supply Issues</u>

2.1.1.1 <u>Conventional Crude Oil</u>

Conventional crude oil reserves in Canada's Western Canada Sedimentary Basin (WCSB) are in decline. At the end of 2002, proven reserves of Canada amounted to 6.9 billion barrels as of the end of 2002, representing 9 years of production at current rates.[23] In the near term, conventional oil output is expected to increase by more than 200 thousand barrels per day. The main source of this increase will be from Hibernia that could produce more than 155 thousand barrels per day at its peak sometime in the next several years. Thereafter, conventional oil is expected to resume its historical decline.

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[21] The U.S. Energy Information Administration: Annual Energy Outlook 2004 with Projections to 2025.

[22] U.S. and Canadian electric systems are increasingly integrated with flows of power moving from country to country depending on time of day and the capacity of the hydro system.

[23] Source: BP Statistical Review of World Energy 2003.

2.1.1.2 Canadian Oil Sands

Canada's bitumen resources from oil sands represent one of the world's largest hydrocarbon deposits. The Alberta Energy and Utilities Board (EUB) estimates remaining established reserves of crude bitumen in Alberta to be 174.4 billion barrels as of end-2002.

The oil sands industry faces a number of development issues and potential constraints. Oil sands operations require significant energy inputs, in particular natural gas for steam generation and hydrogen production. Assuming that all of the oil sands projects currently proposed move forward, it is estimated that demand for gas by the oil sands industry could reach 1 billion cubic feet per day as early as 2005.

The oil sands industry is actively seeking ways to improve energy efficiencies. However, if alternate energy sources are not found to replace natural gas, incremental gas consumption by the industry could have a significant impact on the balance of natural gas/supply and demand resulting in upward pressure on natural gas prices.

Oil sands development has considerable environmental impact, whether in situ, surface mining/extraction or, to a somewhat lesser extent, upgrading. Surface disturbance is extensive; water consumption is significant; air and water emissions are substantial. Current technologies result in large greenhouse gas emissions. The industry is working hard to mitigate these impacts but concern about environmental impact remains.

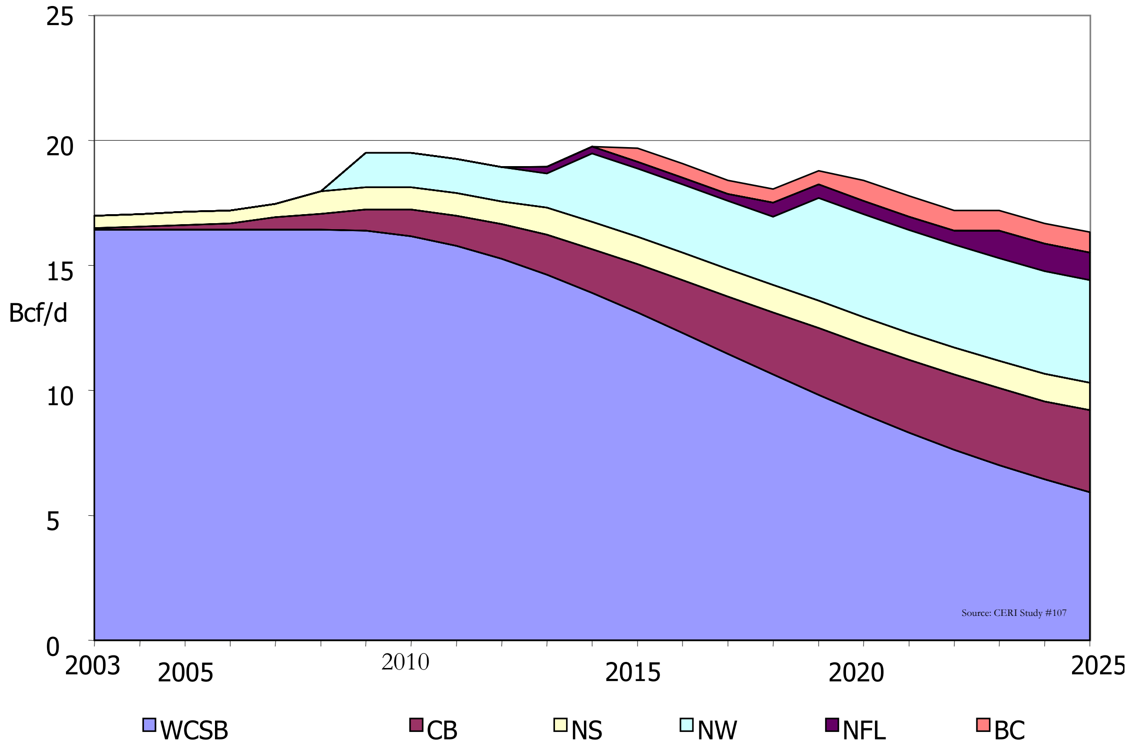
2.1.1.3 Natural Gas

The Energy Information Administration (EIA) forecasts U.S. production to grow, but the anticipation is that it will not keep pace with domestic consumption. Consequently, imports from Canada are expected to increase supplemented by LNG shipments. Conventional production in Canada is declining while other sources of gas in Canada include production from Canada's offshore East Coast, the north and coalbed methane (CBM). Supply from CBM, the East Coast offshore and Mackenzie Delta will make up for some of the decline in WCSB conventional gas (see figure 12).

Gas production from the Mackenzie Delta and other northern frontier areas is dependent upon whether infrastructure to take gas out of the region proceeds. Additional gas supply could be available from CBM deposits in Western Canada. CBM deposits exist mainly in Alberta, with some in British Columbia. CBM development is still in its infancy in Alberta, but preliminary estimates suggest that the size of the resource is between 70 and 215 trillion cubic feet (Tcf), or between 2 and 6 trillion m^3.[24] However, even with all of these expected additional sources, gas supply in Canada is expected to flatten by 2009 and begin declining by 2016.

[24] Paul Mortensen, Matthew Foss, Brian Bowers and Peter Miles, *Potential Supply and Costs of Natural Gas in Canada*, CERI Study No. 107 (Calgary, Alberta: Canadian Energy Research Institute, June 2003).

Figure 12: Canadian Natural Gas Supply, 2003 – 2026



Source: CERI Study No. 107, Potential Supply and Costs of Natural Gas in Canada, June 2003.

2.1.2 Petroleum Trade Issues

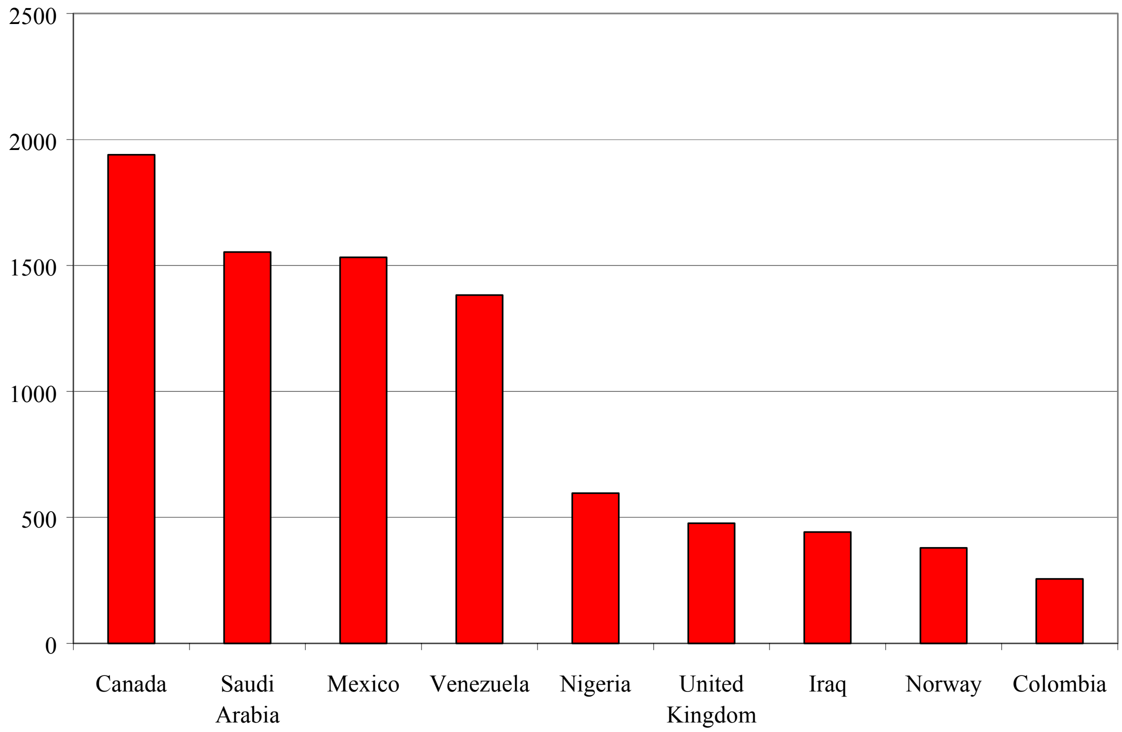
2.1.2.1 Oil

In 2002, net oil imports by the U.S. represented approximately 58 percent of its domestic oil consumption. Canada's exports amounted to 1.9 million barrels per day, the largest of any country exporting to the U.S. In Figure 13 major imports into the U.S. are listed by country of origin.

In its 2003 energy outlook,[25] the EIA projects that by 2025, net petroleum imports by the U.S. will increase to 68 percent of consumption. Volumes from the Persian Gulf nations are expected to more than double highlighting the country's dependence on a politically volatile region for much of its oil supplies.

[25] United States, Energy Information Administration, *International Energy Outlook 2003*, May 2003.

Figure 13: Major U.S. Oil Imports by Country of Origin (million barrels per day)[26]



Source: Energy Information Administration (EIA), Historical Data, Table 5.4, *Petroleum Imports by Country of Origin, 1960-2001*.
Note: The shows the nine countries, which account for 8.6 out of a total of 11.4 million barrels per day of oil imported into the U.S.

2.1.2.2 Natural Gas

In the U.S., growing natural gas production is not expected to keep pace with rising consumption. Consequently, imports are expected to increase. In 2002, the U.S. imported 4.1 trillion cubic feet of gas (3.9 and 0.2 by pipeline and through LNG shipments, respectively) to satisfy 18 percent of its domestic consumption of 23.6 trillion cubic feet. It is significant to note that in its latest forecast [27] of U.S. gas imports, the EIA dramatically reduced pipeline shipments from Canada citing the following reasons:[28]

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[26] We show the nine major countries exporting oil to the U.S. These countries account for 8.6 out of a total of 11.4 million barrels per day of oil imported into the U.S.

[27] United States, Energy Information Administration, *Annual Energy Outlook 2004*, January 2003.

[28] The EIA's report also noted that the decline in Canadian imports could be mitigated by the construction of a pipeline to move MacKenzie Delta gas into Alberta. However, it concluded that "such a dramatic increase [consumption by the oil sands industry] could divert significant amounts of gas from the U.S. import market".

- Lower forecasts of Canadian gas production by the National Energy Board;
- Increasing gas use by Alberta's oil sands industry;
- Higher projections of domestic Canadian gas demand; and
- Recent disappointments in Canadian drilling results, including smaller discoveries with lower initial production rates and faster decline rates.

Total net imports by the U.S. are projected to increase from 4.1 trillion cubic feet in 2002 to 7.2 trillion cubic feet by 2025. Nearly all of the increase in net imports is expected to consist of Liquefied Natural Gas (LNG), from various African, Asian, and South American sources. Imports are expected to increase from 228 billion cubic feet in 2002 to 2.2 trillion cubic feet in 2010, and 4.8 trillion cubic feet (or 66 percent of net imports) by 2025.[29]

2.1.2.3 Electricity

The North American electric power sector is facing major changes in its operating environment resulting from pending or actual deregulation of electricity pricing, privatization of government-owned utilities, and interregional competition. A shift in ownership is occurring from regulated utilities to competitive suppliers. This highly integrated systems represent an infrastructure of more than $1 trillion in asset value, more than 320,000 kilometers of transmission lines, and 950,000 megawatts of generating capacity.[30] Major questions exist about the systems ability to continue providing citizens and businesses with relatively clean, reliable, and affordable energy services.

Reliability of supply is a major concern for each country in North America and has important implications for future development of infrastructure. System reliability can be dependent on many factors including regional generating capacity, transmission constraints, and enforceable reliability standards. North America has major electric power grids but does not have an overall, comprehensive grid. Transmission constraints limit power flows resulting in higher electricity prices influencing investment in infrastructure. Capital investment is required in the next several years in new generation, transmission, and distribution facilities to prevent service degradation and costs increases. System reliability issues came to the forefront with several blackouts, in August 2003 in Ontario and in the states of Ohio, Michigan, Pennsylvania, New York, Vermont, Massachusetts, Connecticut, and New Jersey affecting approximately 50 million people.[31]

One option to address the supply challenge is to diversify the fuel mix used to meet demand. However, there are significant obstacles to changing the fuel mix; energy use patterns will change slowly and North America will continue to satisfy the majority of its energy needs from

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[29] United States, Energy Information Administration, *Annual Energy Outlook 2004*, January 2003.

[30] U.S.-Canada Power System Outage Task Force. Interim Report: Causes of the August 14th Blackout in the United States and Canada. November 2003.

[31] U.S.-Canada Power System Outage Task Force. Interim Report: Causes of the August 14th Blackout in the United States and Canada. November 2003.

fossil fuels until 2025 according to the EIA world energy outlook. Some of the issues regarding diversifying energy sources are described below.

a) ***Hydro***

Hydropower accounts for most of the renewable energy in North America. Canada is the world's largest producer of hydroelectricity accounting for over 58 percent of its electricity generation mix. Hydroelectric power is attractive because of its high efficiency, long life, low operating costs, and low emissions. Although potential sites for hydroelectricity have already been developed in the U.S., Canada is expected to expand its mid- to large -scale hydroelectric capacity. The high initial costs and environmental impacts are issues that need to be addressed for large-scale hydro developments.

b) ***Coal***

Coal is constrained by environmental considerations. Coal-fired generation currently accounts for about 52 percent of electricity production in the U.S. and about 18 percent in Canada.[32] The use of coal raises environmental concerns, particularly with regard to atmospheric emissions of SOx, NOx, particulates and CO_2. The ability of coal to increase in North America's fuel mix will depend on the ability of the industry to adapt to emission standards and other regulatory requirements.

Although forecasts generally predict that natural gas will be favoured over coal in the development of new power generation, coal's competitive price makes it attractive. In addition, limited natural gas supplies and volatile natural gas prices also increase coal's appeal. Coal-fried generation is expected to remain an important part of electricity generation in the U.S. and Canada, and Mexico is also looking at developing new coal-fired generation.

c) ***Nuclear***

Nuclear power capacity is expected to increase in Canada and United States. The EIA outlook forecast an increase in Canada's nuclear capacity of over 5000 megawatts by 2020[33]. Environmental policy, such as Ontario's mandate to eliminate coal-fired generation, as well as public attitudes towards building new nuclear capacity will be a key factor for influencing nuclear power development.

[32] NEB, Supply and Demand Outlook, 2003.

[33] EIA International Outlook, April 2004.

d) ***Renewables***

Renewable energy sources are not expected to be economically competitive with fossil fuels in the mid-term without subsidies from government. Renewable technologies are generally characterized by relatively high capital costs and low operation and maintenance costs. These characteristics make them attractive in the long run, but less so in a competitive setting where the premium is on near-term cost minimization. Renewable generating technologies continue to make advances, thereby increasing their efficiency and lowering cost; however, outside of some niche market applications, they still are not economically competitive with conventional sources of power. As renewables' costs come down and technologies advance, they will become more important. But at this point, their impact is small. Wind and solar together provide less than 1 percent of North Americas total energy.

2.2 Technology Challenge

Greenhouse gases (GHG's) are derived from a variety of energy resources and processes, and no single technology will be sufficient to stabilize atmospheric GHG concentrations. Rather, a portfolio of technologies that improve energy efficiency, and increase use of clean carbon fuels/processes will be required to reduce GHG emissions and other environment impacts. Technology has played a major role in reducing GHG emissions and new technologies hold considerable promise for increasing Canada's supply of energy more efficiently and more cleanly.[34]

Because Western Canada comprises the majority of Canada's fossil fuel production, and this trend is expected to continue in the future, this report deals specifically only with technology options for Western Canada. Moreover, as other parts of this report deal with demand-side technology issues, the information presented below focuses on the supply-side and includes new technology developments that are likely to produce a smaller emissions footprint per given level of energy output. [35] While much is known about past technological change, much less is known about future technological change. Uncertainties exist regarding:

- where inventions will come from;
- what inventions will become successful;
- what any given dollar of R&D will return;
- how much learning will occur;
- how quickly a particular product or process will diffuse or penetrate into wider use. 36

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[34] The Cleaner Hydrocarbon Technology Futures (CHTF) Group. Technology Challenges and Opportunities for the Western Canadian Hydrocarbon Energy Sector. February 2003, p. 2.

[35] The information presented below summarizes a broad-ranging report by the Cleaner Hydrocarbon Technology Futures (CHTF) Group, a working body, consisting of representatives from the three Western Provinces and the Federal government, that was formed in February 2002 to provide an understanding and strategic direction for future hydrocarbon research. This recent report well summarizes the work that has been done to date across Canada dealing with the prospects for fossil fuel technology development.

[36] The Cleaner Hydrocarbon Technology Futures Group. Technology Challenges and Opportunities for the Western Canadian Hydrocarbon Energy Sector. February 2003, p.15.

Notwithstanding the uncertainties of research investment and its associated impact on emissions reduction, the Cleaner Hydrocarbon Technology Futures (CHTF) Group report presents estimated GHG reductions. These are based on historical emissions levels without technology development based on data from Canada's Energy Outlook until 2020 versus the potential impact of rapid deployment of new technologies. The results of this assessment are presented in the table below. While these results are only for Alberta, the CHTF Group report notes that similar reductions are possible for Saskatchewan and British Colombia.

Table 8: Alberta GHG Emission Estimates With/ Without Technology Development

Energy Sector	**Alberta GHG Emissions (CO2 E Mega tonnes)**						**Performance Targets and Co-Benefits**
	Without Additional Technology Development				**With CHTF Recommended Technology Development**		
	1990	**1997**	**2010***	**2020***	**2010***	**2020***	
Power	40	48	49	54	46	28	• Near zero emissions of sulphur, nitrogen oxides, particulates, mercury, trace elements and organics. • 40-50 percent reduction in CO_2 emissions by efficiency improvements, near 100 percent reduction with carbon management and storage. • Minimal/Zero water contamination and removal from the natural cycles. • Maximized solid waste usage. • Full and effective site remediation & reclamation. • Low thermal signatures.
Bitumen	3.7	6.1	12.3	19.6	10.4	9.8	
Oil Sands	9.5	11.7	24.8	33.1	21.1	16.6	
Natural Gas	18	25.7	30.6	32.8	28	16	
Convent. Oil	6.3	6.9	6 5	3	5	4	
Heavy Oil	4	6.7	5.2	4.2	5	3	
Pipelines	2.2	4.2	3.8	4	3.5	2	
Totals:	**83.7**	**109.3**	**131.7**	**153**	**119**	**79.4**	

SOURCE: The Cleaner Hydrocarbon Technology Futures Group. Technology Challenges and Opportunities for the Western Canadian Hydrocarbon Energy Sector. February 2003, p.16.

This table indicates that technologies put in place now will have modest impacts to 2010 where CO2 emissions are reduced from 131.7 to 119 MTs versus significant reduction possibilities for 2020 when GHG emissions are expected to fall to 79.4 MTs from 153 MTs. In effect, the CHTF recommended technology development would see a GHG emissions reduction of 10 percent by 2010 but a significant reduction of 48 percent by 2020.[37]

2.3 Other Challenges

Current energy issues facing North America include energy resources, technologies, infrastructure, trade and investment, the environment, and energy security. In addition many of the economic, social, technological, and environmental issues facing the energy sector require cross border communication and cooperation. The North American Free Trade Agreement (NAFTA) has played an important role in trying to achieve an integrated energy market.[38] NAFTA provides energy exporters with increased access to the market while attempting to maintain energy security for consumers. Although NAFTA has worked towards an integrated market, difficulties still remain when dealing with more than one jurisdiction or regulatory body. Harmonization of regulation and legislation is an important topic facing the energy sector.

In Canada, jurisdiction over energy is divided among the federal, provincial, and territorial governments.[39] Provincial governments have responsibilities over the exploration, development, conservation and management of non-renewable natural resources, as well as over sites and facilities for the generation and production of electrical energy within their borders. Federal jurisdiction in energy is primarily associated with regulation of interprovincial and international trade and commerce, and the conservation and management of non-renewable resources on federal lands. There is an increasingly difficult process for opening up new areas (Northern/ Offshore) for energy development. The ownership of offshore resources in Canada is more complicated, with the distinction between provincial and federal being the subject of legal rulings and interpretations.[40] Many exclusive provincial responsibilities are increasingly intertwined with a large federal regulatory process. Regulatory reform and streamlining has become a prominent issue for the oil and gas industry in recent years.

Environmental authority is shared in some areas, exclusive to the provinces in others. Northern development may be more complex because some environmental authority has been allocated to a number of groups as well as to the National Energy Board.[41] The sharing of authority may

[37] The Cleaner Hydrocarbon Technology Futures (CHTF) Group. Technology Challenges and Opportunities for the Western Canadian Hydrocarbon Energy Sector. February 2003, p. 16.

[38] North American energy Working Group, *The Energy Picture*, June 2002. Pg.

[39] Center of Constitutional studies website: http://www.law.ualberta.ca/ccskeywords/charlottetown.html

[40] For example, in British Columbia a Supreme Court ruling found resources between Vancouver Island and the mainland where the jurisdiction of the province. However, while the province has claimed so right to an 'Inland Marine Zone' the legal status of ownership of resources along much of the coastline remains unclear.

[41] Ginsler and Associate website: Environmental Policy in Canada. http://www.ginsler.com/html/partv_b.htp

lead to inefficiencies from the point of view of applicants and thereby give rise to some potential for increasing efficiency through common practices or other arrangements that facilitate co-operative assessment. Within provinces, resource development authority is sometimes separate from environmental authority. This adds a need for facilitating processes within provinces as well as between provinces and the Federal government. It is the perception of some energy developers that the regulatory and permitting processes have become so cumbersome and confusing that it is deterring new development rather than guiding and controlling it as was originally intended. The lack of clear process lines to follow and the conflicting nature of permit stipulations from one agency to the next can be costly and lengthy which can lead to a delay in development. Regulation necessarily slows development to some extent, presumably offering offsetting benefits through meeting the objectives of the regulation. However, when regulatory practice impedes development more than necessary to meet its stated objectives, there may be a case for reform.

While a complete review of the regulatory interactions and potential for enhancement is not possible here, the following issues have been identified as warranting further discussion.

2.3.1 Frontier Development

Natural gas market conditions in North America have undergone a fundamental change in the last few years, resulting in a renewed interest in major pipeline proposals to deliver Mackenzie Delta and Alaska North Slope and gas to southern markets.[42]

The industry responds to market supply and demand, particularly natural gas. Areas such as the Mackenzie Valley, the Beaufort area or offshore of Alaska are in competition to fill that demand. Developing in frontier poses a range of economic, environmental, technical challenges but in addition there are several distinct approval agencies that have to be co-ordinated including[43]:

- The Inuvialat Game Council;
- the Mackenzie Valley Environmental Impact Review Board;
- The Mackenzie Valley Land and Water Board;
- The NWT Water Board;
- The Canadian Environmental Assessment Agency; and,
- The National Energy Board.

Under the Final Agreements and Self-Government Agreements, First Nations have power to enact laws over a wide range of areas, including the use, management and protection of Settlement Land, and the use, management and protection of natural resources under First Nation jurisdiction[44]. Since oil and gas deposits may be found under both First Nation Settlement Land and Yukon land, there is a potential for having different rules apply to different lands.

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[42] CERI. A Comparison of Natural Gas Pipeline Options for the North.
[43] Department of Justice Canada website: http://laws.justice.gc.ca/en/M-0.2/
[44] Gwich'in Land Planning Board. Gwich'in Land Use Plan. August 2003.

One of the biggest challenges industry faces when developing in the North is an understanding of the regulatory regime and the relationship between the aboriginal land claim agreements, federal responsibilities, and Inuvialuit and Yukon responsibilities and how they interact. Dealing with First Nations treaty and land claim issues adds to expense and length of the development projects.

2.3.2 West Coast Offshore

In 1972, the Government of Canada imposed a moratorium on crude oil tanker traffic through Dixon Entrance, Hecate Strait, and Queen Charlotte Sound due to concerns over potential environmental impacts. A later federal order prohibited oil and gas drilling activities for an indefinite period. British Columbia extended the moratorium in 1982 with its own ban that included the Strait of Georgia between Vancouver Island and the mainland and Juan de Fuca Strait between the southern tip of Vancouver Island and the U.S. mainland.

In July 2003, Natural Resources Canada (NRCan) announced the panel to review the moratorium.[45] The Federal Government is looking to complete the overall review process in 2004. Lifting the federal and provincial moratoriums would open the potentially prolific Queen Charlotte Basin to offshore oil and gas exploration and development.

The First Nations issues have been particularly difficult, resulting in both physical and legal confrontations. There has been a concerted three-way effort by government, industry and aboriginal leaders to establish a clearer regulatory process that gives industry greater certainty over land access and the First Nations a share of the economic benefits without undermining their treaty rights.

In April 2002, the provincial government created the Economic Measures Fund to promote Native participation in northeastern British Columbia's oil and gas industry as part of the process to foster partnerships between the Treaty 8 First Nations and industry. A further boost to the process is a Canadian Association of Petroleum Producers-Treaty 8 forum to facilitate discussions involving First Nations, industry and government.

Earlier this year, a federally-appointed panel of scientists released a comprehensive scientific report giving its blessing to offshore petroleum exploration provided there are environmental safeguards.[46] Since then, the BC Government has formed the BC Offshore Oil and Gas Team to devise policies for oil and gas drilling near the Queen Charlotte Islands in anticipation of the lifting of the federal moratorium. Industry observers report that while the drilling bans could be removed as early as 2005 but it could be several years of seismic testing and studies before drilling resumes in the Queen Charlotte Basin.

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[45] Natural Resources Canada News release. Dhaliwal Makes Appointments for B.C. Offshore Moratorium Review. July 30, 2003.

[46] Government of B.C. Ministry of Offshore Development website: http://www.offshoreoilandgas.gov.bc.ca/reports/Scientific-review-panel/

2.3.3 Coalbed Methane

CBM is an unconventional form of natural gas bound to coal and can only be released by changing the pressure in the underground coal seam. Although CBM production is in a relative stage of infancy in Canada, CBM production has been occurring in the Unites States since the 1980's. CBM production accounts for approximately 10 percent of the gas produced in the United States compared to 0.4 per cent of Canada's total natural gas production.[47]

CBM development in Canada has been under scrutiny in the last few months as Montana Governor Judy Martz requested a joint international assessment of the proposed CBM development in B.C.'s Elk Valley. Governor Martz was concerned that B.C. did not have the necessary regulatory framework in place to ensure accurate environmental protection. Geologists suggest that there are more than 20 trillion cubic feet (tcf) of natural gas trapped in the coal seams in Elk Valley, Crownsest and the Flathead coalfields.

Earlier in the year, the B.C. government announced a auction would grant a five-year exploration permit to successful bidders, who will also have the right to development permits once they propose formal plans for methane fields. Gov. Judy Martz wanted a detailed environmental review prior to the auction. Although a review was not conducted, the profile given to the land may have deterred potential bidders and raised questions regarding regulatory jurisdiction of CBM development.

[47] Ebner, Dave. B.C. finds no bidders for coal-bed gas rights. Friday, August 27, 2004, Globe and Mail.

3. Planning for the Long-term

Cleaner hydrocarbon technologies are among the tools and techniques that will be used to implement sustainable energy development. Clean hydrocarbon technologies embrace a zero emissions concept, and a shift away from methods in which "wastes" are the norm, to integrated systems with "no waste". The introduction of such a philosophy is a key issue related to hydrocarbon fuels production in the 21st century, transforming energy use by:

- Providing affordable, clean energy to meet expanding energy demand.
- Solving critical environmental problems (reduce GHG's and criteria air emissions, effective water resource and land management).
- Addressing energy security by supporting the use of diverse fossil fuels and encouraging greater use of alternative energy sources.[48]

The CHTF Group focused on five key technology areas related to Canada's potential contribution to a cleaner hydrocarbon future. These include:

- Coal
- Oil Sands/Heavy Oil
- Conventional/ Unconventional Oil and Natural Gas
- Carbon Capture, Use & Storage
- Hydrocarbon to Hydrogen Bridging Technologies.[49]

Based on extensive consultation, draft plans for investment in basic and applied research, development and demonstration over a twenty-year timeframe were developed. An abridged overview of these CHTF Group research conclusions is presented below for these five technology categories.

3.1 Clean Coal

Significant RD&D investment is required to assure that sustainable technologies are developed such that Canada's abundant coal reserves are used to produce cleaner electricity, hydrogen, nitrogen and chemical feedstock. Environmental issues that must be accounted for in developing and demonstrating these technologies include carbon dioxide emissions and other criteria pollutants (NOx, SOx, mercury, particulate matter) that impact the global and local environments.

RD&D initiatives that will enable the achievement of reach the goals cited above include: strengthening RD&D linkages with other countries; adapting innovate clean coal technologies for Canada and focusing RD&D in the following areas: 1) adapt and develop advanced conversion

[48] The Cleaner Hydrocarbon Technology Futures (CHTF) Group. Technology Challenges and Opportunities for the Western Canadian Hydrocarbon Energy Sector. February 2003, p. 3.

[49] Ibid., p. 18.

systems that produce a CO_2 stream suitable for efficient capture; integrate the capture of other pollutants and offer product flexibility; 2) develop and deploy coal cleaning processes; and 3) improve coal conversion waste management and land reclamation.

If RD&D is successful, coal will be acknowledged as an important energy resource and clean coal energy will play an essential role in the North American supply system and energy security. To accomplish this will require that an investment of $1.2 Billion in research and a similar amount in demonstration projects over the next 20 years.

3.2 Oil Sands/Heavy Oil

Oil sands are poised to be Canada's dominant oil resource and it is the only resource vast enough to provide long-term North American energy security. However, major plans for expansion of oil sands development over the next two decades must account for concerns pertaining to sustainable development of operations. Competitiveness is also an issue that must be accounted for in complying with GHG targets because lack of GHG targets for other oil producing countries could reduce competitiveness of oil sands leading to underdeveloped resources.

RD&D initiatives that are required include: a focus on RD&D to improve Steam Assisted Gravity Drainage (SAGD) processes; a focus on hydrogen production processes; increases in efficiencies; and reductions in all emissions. This will require that RD&D focus on lower energy intensity separation methods that reduce costs, and produce higher concentration CO_2 streams for storage.

To accomplish this over the next 20 years will require an investment of $1.7 billion in research and a similar amount in demonstration projects. This RD&D will result in major improvements in efficiency and emissions reductions; a reduction in land disturbance; an increase in the total recoverable reserves of the Athabasca Basin; and development of new technologies which can be exported.

3.2 Conventional Oil and Conventional/Unconventional Gas

Canada has a huge potential in coal bed methane and tight gas. In addition, offshore B.C. and the Northern Canadian basin offer future potential in oil, gas and hydrates development. However, only 20-30 percent of oil-in-place is currently recoverable and about 75-90 percent of natural gas is recoverable meaning that new technologies must be developed to enhance existing productivity rates and reduce environmental impacts.

This will require demonstration of good engineering practices in heat and energy management that can result in significant GHG reductions. Use of CO_2 and other chemicals has the potential to increase recovery of original oil-in-place. Moreover, to reduce environmental impacts RD&D must also focus on water management for coal bed methane (CBM); and demonstration of gas collection systems that use gas, which is presently flared and vented, to produce heat, electricity and liquids.

These objectives will require an investment of $1.2 Billion in research and a similar amount in demonstration projects over the next 20 years which will result in improved conventional oil and natural gas recovery and unconventional natural gas becoming a mainstream energy supply option.

3.4 Carbon Capture, Use & Storage

There is potential to use CO_2 to recover hydrocarbon resources such as oil and methane from coalfields. However, the economic potential for injecting CO_2 into selected oil fields for enhanced oil recovery must be assessed and the public acceptance of this must also be resolved.

This will require CO_2 demonstration projects; efforts to reduce cost of CO2 capture that make it commercial for enhanced oil recovery operations; monitoring CO_2 use and storage projects and verification of the fate of the CO_2 to ensure it is being stored in geological formations; as well as public consultation and awareness programs.

Over the next 20 years all this implies an investment of $700 million in research and a similar amount in demonstration projects resulting in a total value of resources recovered in oil and coal bed methane in the range of $50 billion to hundreds of billions of dollars. Additional value will be generated from CO2 stored, if a market is developed as a result of environmental considerations, and additional co-benefits include reduction of air pollution, and possible substitution of CO_2 for water in flooding for recovery. Moreover, this RD&D would result in developing expertise and technology that could be exported to other countries with a significant potential for long-term atmospheric stabilization of GHG.

3.5 Hydrocarbon-To-Hydrogen Bridging Technologies

There is a potential for hydrogen to have a significant mitigating impact on GHG emissions but barriers include costly infrastructure, lack of storage facilities, and codes and standards. Hydrogen production from fossil fuels can produce significant high purity CO2 stream and thus carbon capture and storage may have to be integrated into hydrogen production to make significant GHG reductions possible. This will require collaboration/consortia to identify lead processes to efficiently produce hydrogen from hydrocarbons at low cost; a RD&D focus on materials and processes for hydrogen production; and a focus on process integration and efficiencies.

To make the above feesible, an investment of $530 million in research and a similar amount in demonstration projects. These investments would create a suite of new technologies that would begin to sever the relationship between GHG emissions and hydrocarbon energy production and large point source use.

About CERI

The Canadian Energy Research Institute (CERI) is a co-operative research organization established through an initiative of government, academia, and industry in 1975. The Institute's mission is to provide relevant, independent, objective economic research and education in energy and related environmental issues Related objectives include reviewing emerging energy issues and policies as well as developing expertise in the analysis of questions related to energy and the environment.

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