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Research Memorandum

Canada: Estimates of Future Energy/GNP Relationships

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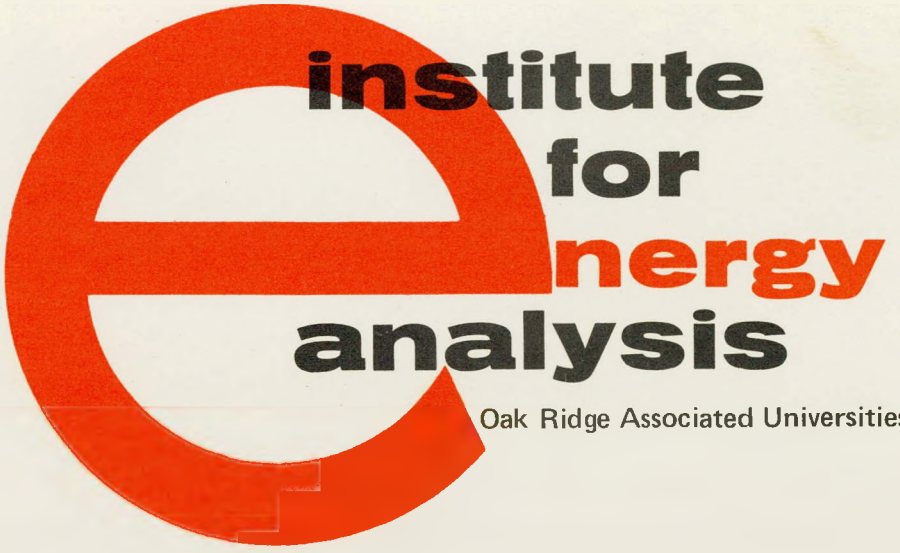

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MASTER

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December 1979

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Abstract

Canada

The Canadian economy has been expanding at an annual rate of 4.6 percent in the 1970s (GNP growth), second only to the remarkable record of Japan. Economic development has been bolstered by supportive government policies, a high rate of domestic savings, and a continuing inflow of investment capital. The average annual increase in nonresidential fixed investment has been 6.5 percent, which is higher than in any other major industrialized nation. As a consequence, productivity, or output per worker, has not experienced the decline in growth which has been so striking in the United States.

In the future, Canadian economic development is expected to fall below past rates of achievement primarily because of declining numbers of new entrants in the labor force. This trend will be only partially offset by higher female participation rates. However, other factors affecting growth remain favorable. Canada, in particular, is virtually self-sufficient in energy. Government policy is to carry out a vigorous program of conservation, and to parallel this effort with domestic energy price increases which will move up to world levels over the next few years.

As to economic growth, we anticipate that GNP expansion will remain well above 3 percent a year for the balance of this century. Energy consumption is expected to grow from 7.51 Btu x 10^{15} (quads) in 1976 to 13.3 quads by 2000. This means that energy growth, as a consequence

of determined conservation in households, commercial establishments, industry and transportation, is expected to be about half as rapid to the year 1990 as economic growth.

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Canada: Estimates of Future Energy/GNP Relationships

Summary

In the 1970s, Canadian economic growth and energy consumption increased rapidly compared with the performance of other leading industrial nations. Gross national product (GNP) growth averaged 4.6 percent a year, 1970-77, and historically growth in energy consumption has roughly paralleled GNP growth. Past economic growth has been bolstered by a high rate of private savings and a continued inflow of investment capital from abroad. The average annual increase of nonresidential fixed investment, measured in constant prices, has been 6.5 percent since 1970, higher than in any other industrial nation.

As a consequence of the flow of capital into the economy, and more moderate environmental regulations, Canada has not experienced a decline in productivity such as the United States has undergone since 1970.

Fertility in Canada has fallen to about 1.8 (average number of children per woman), a level below that required to sustain the population in the long run. Past economic growth has been buoyant not only because of a high rate of investment, but also because of the rapid increase in the size of the labor force. Declining numbers of new entrants in the future labor force will be only partially offset by higher female participation rates, which have been growing very rapidly, and must slow down over the next decade.

Our estimates of future real annual GNP growth in percent are: 1977-80, 5.31; 1980-85, 3.72; 1985-90, 3.65; 1990-95, 3.23; and 2000, 3.33.

The Canadian government has prepared an elaborate program of energy conservation, covering all major sectors of the economy. Its Energy Strategy Scenario calculates an annual primary energy consumption growth rate of 3.7 percent between 1975 and 1990, assuming no explicit actions to encourage energy conservation beyond energy price increases. Government policy is to raise Canadian energy prices to world levels in the next few years. The Energy Conservation Scenario calculates that annual primary energy growth will fall to 2 percent with the successful execution of its conservation program. This performance would be aided by insulation of existing homes and commercial establishments, by new building codes requiring the installation of energy-saving materials and equipment, by mandated improvements in passenger automobile performance and technological gains in trucking and air transport. The two scenarios do not differ significantly in the assumed levels of industrial demand; both industrial estimates build in some tax incentives to quicken the pace of industrial conservation.

We find the official projected level of population and economic growth to be higher than the Institute for Energy Analysis (IEA) calculates to 1990, under either scenario.

IEA believes that the Canadian programs already announced will result in significant savings and will lower the E/GNP ratio by 1990. The Institute's total energy demand estimates are for an increase from 7.51 quads in 1976 to about 10 quads in 1990 and 13.3 quads in 2000. Our rough estimate is that between 1976 and 1990, GNP growth could be

about twice as rapid as increases in energy consumption as the more easily achieved energy savings are realized. However, after 1990, the savings potential is expected to be much smaller, because housing and commercial facilities will have been made energy efficient, and the path of further effiency gains in transport and industry will be a more difficult one.

Energy intensities are analyzed in Chapter 4. Below are two tables extracted from that chapter which summarize the expected activity levels by sector and show the anticipated E/GNP ratios to the year 2000.

Canada: Energy Demand Projections, 1976-2000

(quadrillion Btu)

Year	Household	Commercial	Industrial	Transport	Total
1976	1.67[a]	1.49	2.80	1.55	7.51
1990	1.67	1.65	4.31	2.25	9.88
2000	1.82	2.17	6.15	3.14	13.28

[a] Percent is given in parentheses.

Canada: E/GNP Ratios by Sector, 1976-2000

(Btus per 1977 $)

Year	Household	Commercial	Industrial	Transport	Total
1976	8.25[a]	7.36	13.82	7.65	37.08
1990	4.79	4.74	12.37	6.46	28.36
2000	3.78	4.51	12.78	6.53	27.60

[a] Percent of 1976 sector ratio is given in parentheses.

Chapter 1

Canada: The Path of Economic Growth

Introduction

Canada has relied primarily on inexpensive and abundant domestic sources of energy to fuel her economy, and on a per capita basis ranks with the United States as an energy-intensive nation. The historical growth of energy consumption has been rapid, averaging 4.7 percent annually in the 1960-76 period. The ratio of annual percentage change in energy to the annual percentage change in GNP was approximately one over the same years. In other words, energy consumption grew about as rapidly as the output of the economy.

Because of its favorable energy endowment, Canada has developed several large energy-intensive industries, based primarily on hydro power. The increasing costs of energy are expected to slow the historical rate of energy growth in the future.[1] While Canada's remaining energy sources are extensive, many of them lie in remote frontier areas where climatic conditions are harsh and transportation distances are long, a combination that raises delivered costs.

A relatively demanding climate and low population densities result in both high household fuel consumption and primary dependence on the personal automobile for transportation. By 1974, Canadian ownership of passenger automobiles per 1,000 persons was equal to 77 percent that of the United States, and was greater than the relative standing of any other country.

The official national energy strategy is one of self-reliance, a policy which is short of self-sufficiency but entails major

exploitation of domestic sources. Canadian federal and provincial policy is to encourage the development of domestic energy supplies through fiscal (tax) and pricing incentives. This policy is currently resulting in the commercial exploitation of reserves of tar sands and heavy oil.

Historical Population Growth

The analysis of future Canadian economic growth begins with the consideration of demographic trends. Population growth determines the size and age composition of the labor force. Canada's population growth, like that of the United States, has been heavily influenced by immigration. In 1871, there were 3.7 million persons; by 1971 the total had risen to 21.6 million. This rapid increase, roughly six times in 100 years, was made possible not only by continuing immigration, but also by high fertility among married Canadian women.

Immigration now is running about 100,000 persons a year. It continues to make a significant contribution to population growth. Canada, like most industrial nations, underwent a domestic "baby boom" following World War II. By 1977, the birth rate had fallen about 50 percent from the postwar peak, and is expected to continue at the current rate for at least several years (see Table 1).

Table 1. Canada: Population, 1950-77

Year	Thousands of Persons	Annual Growth Rate
1950	13,712	2.0
1960	17,870	2.2
1965	19,644	1.8
1970	21,297	1.4
1975	22,679	1.5
1977	23,291	1.3

Source: Department of Finance, Economic Review, Ottawa, April 1978, p. 120.

Future Population Projections

The projected size of the labor force is a key input to economic growth. The continued expansion of gross national product (GNP) depends upon the expansion of the labor force and the growth of output per worker, or worker productivity. As in most countries that are becoming increasingly industrialized, one of the consequences of a decline in the relative size of the agricultural sector is a concomitant decline in fertility. The total fertility rate (a weighted average of births per woman over all female cohorts) in Canada is now below the rate needed to sustain the population at a constant level in the long run (see Table 2).

The Canadian government has projected Canada's population to the year 2000 using varying assumptions of fertility rates and net immigration. We favor a projection which continues the fertility rate at 1.8 and annual net immigration of 60,000.[2] Under this assumption, the population of Canada will reach more than 28 million by the year 2000, as shown in Table 3. Should the fertility rate increase to the average that prevailed during the first half of the current decade--about 2.2--total population would exceed 30 million in 2000.

Table 2. Canada: Total Fertility Rates, 1926-74

Year	Fertility Rate
Average 1926-30	3.3
Average 1931-35	2.9
Average 1936-40	2.7
1950	3.5
1960	3.9
1965	3.1
1970	2.3
1974	1.8

Source: Statistics Canada, Vital Statistics Preliminary Annual 1974, Series 84-201, Ottawa, p. 12.

Labor Force and Participation Rates

The labor force consists of all persons 15 years of age and older who are actually employed or actively seeking employment. The rate of expansion of the labor force has been decelerating since 1974 as the proportion of working age population entering the job market has been falling. In 1974, the labor force increased 4.2 percent; by 1977 the rate was 2.6 percent. Trends since 1960 are shown in Table 4. While the participation rate will be moving up slowly, the annual decline in numbers of teenagers reaching labor force age will dominate trends in the 1980s and early 1990s.

Table 3. Canada: Estimated Future Population, 1980-2000

(thousands)

	0-14 Years		15 Years and Over		Total 15	Total
Year	Male	Female	Male	Female	and Over	Population
1980	2,791	2,658	9,049	9,279	18,329	23,777
1985	2,834	2,695	9,636	9,954	19,590	25,119
1990	2,954	2,811	10,096	10,507	20,603	26,368
1995	2,979	2,832	10,547	11,039	21,586	27,397
2000	2,872	2,733	11,037	11,584	22,621	28,226

Note: Population growth based on a fertility rate of 1.8 and net immigration of 60,000 annually.

Source: Statistics Canada, Population Projections for Canada and the Provinces, 1972-2001, Census Field, Ottawa, June 1974.

Table 4. Canada: Population and Labor Force, 1960-77

Year	Total Population 15 and over (10^3)	Labor Force Participation Rate, Percent	Males 15 and over (10^3)	Male Participation Rate, Percent	Females 15 and over (10^3)	Female Participation Rate, Percent
1960	11,831[a]	54.2	4,754	80.8	1,653	28.0
1965	13,128[a]	54.4	5,066	77.9	2,076	31.3
1970	14,528	57.8	5,571	77.8	2,824	38.3
1975	16,470	61.1	6,363	78.4	3,697	44.2
1977	17,250	61.3	6,549	77.7	4,022	45.9

[a] 14 and over.

Source: 1960 and 1965 data from Bank of Canada, Statistical Summary, 1967 supplement, pp. 138-139. 1970, 1975 and 1977 data from Bank of Canada Review, June 1978 supplement, pp. 104-105.

The rapidly increasing proportion of women entering the labor market is resulting in an increase in the total participation rate. The male participation rate has been declining slowly, probably as a consequence of earlier retirement. We project the female participation rate to grow to 52 percent by 2000, compared with about 46 percent in 1977. We have considered a female participation rate as high as 55 percent, but believe that while this is possible it is unlikely since it would push female participation in the prime age brackets (18 to 62) to over 70 percent. Our projections of labor force are shown in Table 5.

Table 5. Canada: Projected Labor Force Growth, 1977-2000

(thousands)

Year	Population 15 and over	Participation Rate	Labor Force
1977	17,250	61.3	10,571
1980	18,329	62.0	11,363
1985	19,590	62.5	12,244
1990	20,603	63.0	12,980
1995	21,586	63.0	13,599
2000	22,621	63.5	14,364

Unemployment

In order to calculate the contribution of the employed labor force to GNP, it is necessary to estimate a probable rate of future unemployment. Unemployment has been relatively high in recent years, as shown in Table 6.

Table 6. Canada: Unemployment as a Percent of Labor Force

Year	Percent
1960	7.0
1965	3.9
1970	5.7
1975	6.9
1976	7.1
1977	8.1
1978 (midyear)	8.5

Source: 1960 and 1965, Bank of Canada, Statistical Summary, 1967 supplement, p. 138. For 1970 and subsequent years, Department of Finance, Economic Review, April 1978, p. 159. Mid-year 1978, Canadian Embassy report, Washington, D.C.

Unemployment rates are highest among teenagers of both sexes. They are lower for the 20-24 year group and drop slightly after age 25. In 1977, the unemployment rate for males over 25 years of age was 4.9 percent; for about half the years between 1966 and 1977, it was less than 4 percent. The 1977 female unemployment rate for the age group 25 and over was 7.4 percent, reflecting the very rapid growth of female participation in the labor force. Until 1971, the female unemployment rate was under 5 percent. As the number of teenagers entering the labor market decreases, a trend which has already begun, unemployment should fall. Also, the phenomenal growth of the female participation rate, from 28 percent in 1960 to 45 percent in 1976, will almost certainly slow down in the future. Therefore, a lower growth rate of the labor force in the 1980s and 1990s is virtually assured, in the absence of an unprecedented new wave of immigration. We project unemployment to fall from the present 8.5 percent to an average of 6 percent in the 1980s and to 5 percent in the 1990s.

Hours Worked

Apart from the impact of unemployment in decreasing the potential contribution of labor force growth to economic growth, a second important subtraction is the continuing reduction in hours worked.

The average Canadian workweek has fallen steadily since World War II, from 46.1 hours in 1946 to 36.9 hours in 1976. This is an average annual decline of -0.74 percent (1946-76) (see Table 7). At the same time this trend is moderating, from a 7.6 percent decline in 1946-56 to 7.3 in 1956-66 and further to 6.6 percent in 1966-76.

The moderating decline has influenced the following projections (base year = 1977):

$$H_t = H_o(1+r_t)^t$$

where $r_t = r_o + t\ 0.15 \times 10^{-3}$, 1977-1985

$r_t = r_{1985} + t\ 0.075 \times 10^{-3}$, 1985-1995

$r_t = r_{1995}$ 1995-2000

and H_t is the average hours per week in a given year, H_o is the average hours per week in the base year (1977), r_o is the historical rate of decline, r_{1985} and r_{1995} are the rates of decline in 1985 and 1995, t is the number of years beyond 1977, and 0.00015 and 0.000075 taper the trend to 2000. For example, in 1980

$$H_t = 36.7\ (1-0.0068 + 0.00015\ (3))^3 = 36.0$$

Table 7. Canada: Man-hours, Persons Employed, and Average Workweek, 1946-76

Year	Man-hours (10^6)	Persons Employed (10^3)	Average Workweek
1946	9,812	4,093	46.1
1956	10,569	4,771	42.6
1966	11,459	5,579	39.5
1976	13,121	6,838	36.9

Source: Statistics Canada, Aggregate Productivity Measures, 1946-76, Cat. 14-201, pp. 22 and 47. Average work-week= man-hours ÷ persons employed ÷ 52.

Our GNP projections incorporate estimated total hours worked per year. This is a product of average hours per week times 52 times the number employed. For example, in 1980, total hours are (36.0) (52) (10,681) (10^3) = 19995 (10^6). See Table 8 for values for selected years 1977-2000.

Table 8. Canada: Average Workweek, Persons Employed, and Man-hours, 1977-2000

Year	Average Workweek	Persons Employed	Man-hours (10)
1977	36.7	9,715	18,540
1980	36.0	10,681	19,995
1985	35.1	11,509	21,006
1990	34.3	12,331	21,994
1995	33.6	12,919	22,572
2000	32.8	13,646	23,275

Aggregate Productivity

During the postwar period, aggregate productivity in Canada increased at an average annual rate of 2.7 percent, from $5.42 output/man-hour in 1952 to $10.24 in 1976. This aggregate measure covers all sectors of the economy, including government and agriculture. It has

been prepared by the Institute for Energy Analysis from the following data series: (1) annual GNP in 1971 dollars, (2) employment, and (3) average workweek for each year.[3] The formula was:

$$\frac{\text{GNP/yr.}}{\text{man-hour/yr.}} = \frac{\text{GNP/yr.}}{\text{man-hours/worker/wk. x 52 x employment}}$$

These values were then converted to 1977 constant dollars (see Table 9). Annual rates of productivity change are computed from this series. These rates are quite variable, ranging from a decline of 1.8 percent for 1974-75 to an increase of 7.7 percent in 1954-55. Generally, the productivity cycles are in line with the overall business cycles. For example, during the 1974-75 recession the growth rate fell to 0.0 percent (1974) and decline 1.8 percent (1975) (see Table 9 and Figure 1).

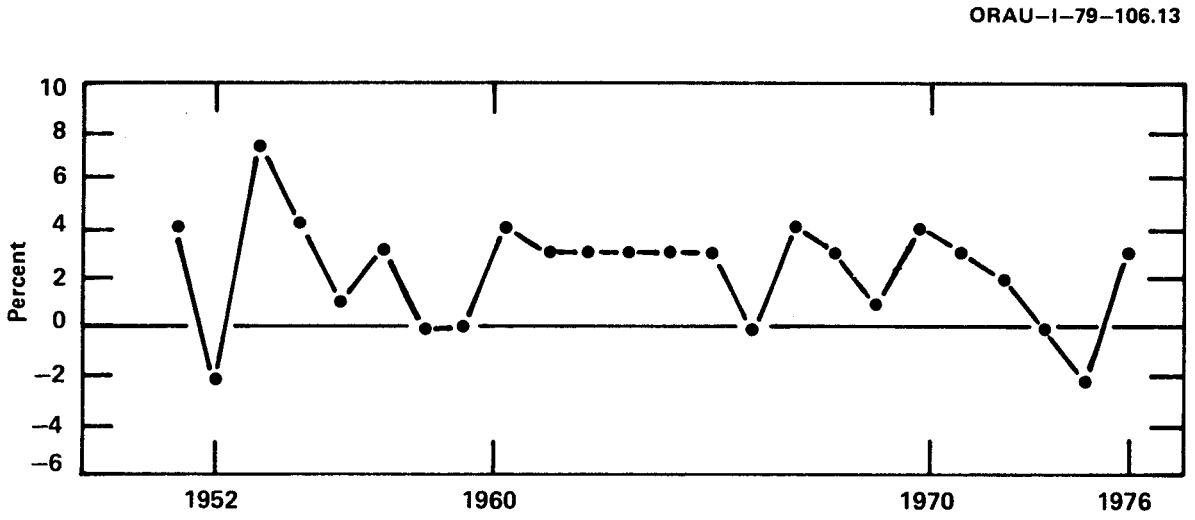
Annual rates of productivity change do not show any long-term trend. The average annual growth has been about 2.7 percent. There is concern in the Economic Council of Canada that productivity is headed for a persistent decline. The Council cites the following:[4]

1. There is the general employment shift from goods production, where productivity growth is normally high, to service industries where it is normally low.

2. The long-term exodus of workers from agriculture, where productivity is quite low, to other sectors of the economy has largely been completed.

3. Productivity increases during the 1980s will hinge on a substantial increase in savings and investment, because much of the savings and investment will be directed toward such capital-intensive activities as resource extraction and transportation, including oil

Figure 1. Rate of Productivity Increase, 1952-1976.



and gas pipelines. It is estimated that capital needs for 1975 to 1985 will range between $800 billion and $860 billion, measured in current dollars.

Table 9. Canada: Productivity and Rate of Productivity Change, 1952-76

Year	Output/Man-hour ($1977 constant)	Percentage Change from Previous Year
1952	5.42	-
1953	5.64	4.1
1954	5.59	-0.9
1955	6.02	7.7
1956	6.29	4.5
1957	6.34	0.8
1958	6.57	3.6
1959	6.63	0.9
1960	6.63	0.0
1961	6.94	4.7
1962	7.22	4.0
1963	7.46	3.3
1964	7.73	3.6
1965	8.00	3.5
1966	8.31	3.9
1967	8.34	0.4
1968	8.72	4.6
1969	8.99	3.1
1970	9.08	1.0
1971	9.49	4.5
1972	9.85	3.8
1973	10.12	2.7
1974	10.12	0.0
1975	9.94	-1.8
1976	10.24	3.0

4. The government sector has risen from about 20 percent of GNP in 1950 to over 40 percent in 1975. Transfer programs shift resources from savers to nonsavers, and public financing competes with private financing.

These concerns are not supported by recent trends. Gross private saving as a ratio of GNP has not declined over the period 1961-76. It has ranged between 16 and 20 percent of GNP. Also, gross investment as a ratio of GNP has increased slightly over the same period, growing from just under 22 percent in 1961-65 to over 23 percent in 1976 (see Table 10). In addition, the other developments that concern the Economic Council of Canada may not carry the weight that is given them. The employment shift to the service sector has been underway for several decades and probably will slow down. Second, the agricultural sector in Canada has been relatively small in recent decades. Finally, the impact of the rising government sector on total savings and investment is not clear. Consequently, we project annual productivity growth to continue at 2.7 percent over the medium to long term. This implies an output of $15.84 per man-hour in 1990 and $20.67 in 2000, measured in 1971 dollars, based on a 1977 value of $11.20.

There is a striking difference between productivity growth in Canada and the United States. In the United States from 1945 to 1965 productivity grew at 2.2 percent per year and from 1965 to 1975 at 0.9 percent per year. The much higher Canadian record is in part due to higher savings and investment rates and to the continued influx of investment capital. The U.S. gross private savings rate has run at 15-17 percent of GNP from 1960 to 1977, while the Canadian rate

has run at 17-20 percent. The U.S. gross investment rate declined from 18 percent in 1961-65 to 16 percent in 1976, while the Canadian rate rose from 22 percent to over 23 percent in the same period.

Table 10. Canada: Gross Private Saving and Gross Investment as a Proportion of GNP, 1961-75

Period	Gross Private Savings	Gross Investment
1961-65	18.1	21.9
1966-70	17.7	22.4
1971-75	18.6	22.8
1976	19.8	23.3

Source: Gross private savings are based on data from Statistics Canada, and gross investment is based on data from the International Monetary Fund, International Financial Statistics, as reported in Economic Council of Canada, Fourteenth Annual Review, Into the 1980's, Minister of Supply and Services, Canada, 1977.

Gross National Product Projections

We now have all of the elements that factor into our GNP projections: (1) population 15 and over; (2) participation rates; (3) labor force numbers; (4) persons employed; (5) average workweek; (6) total hours worked; and (7) a productivity rate. The derivation of these factors has been explained above. Briefly, (1) population growth is based on a fertility rate of 1.8 and net immigration of 60,000 persons per year. (2) The participation rate is assumed to grow from 61.3 percent in 1977 to 63.5 percent in 2000. (3) Unemployment is assumed to decrease from 8.1 percent in 1977 to 5.0 percent of the labor force in 2000. (4) The average workweek is assumed to decline from 36.7 hours in 1977 to 32.8 hours in 2000. (5) Output per man-hour is projected to increase at an annual rate of 2.7 percent.

GNP for a given year is as follows:

$$GNP = (P_w \times R)\ (1-u)\ (WW \times 52)\ (OM)$$

where P_w is population of working age, R is participation rate, u is unemployment rate, WW is average workweek, and OM is output per man-hour. For example, for 1990

$$GNP = 20{,}603 \times 10^3\ (0.063)\ (0.95)\ (34.3)\ (52)\ (\$15.84)$$

$$= \$348{,}375 \times 10^6$$

See Table 11 for GNP projections for selected years from 1977 to 2000. Our projection for the year 1990 is $348 billion and for year 2000, $481 billion.

These projections generate the following GNP growth measured in percent per year: 1977-1980, 5.31; 1980-1985, 3.72; 1985-1990, 3.65; 1990-1995, 3.23; and 1995-2000, 3.33.
(Note that the 1977-80 growth rate is comparatively high, at 5.3 percent. This is because we assumed that unemployment will fall from 8.1 to 6.0 percent over this period.)

Table 11. Canada: Population, Labor Force, and Gross National Product, 1977-2000

Year	Population 15 and over (10^3)	Labor Force (10^3)	Employed Labor Force (10^3)
1977	17,250	10,571	9,715
1980	18,329	11,363	10,681
1985	19,590	12,244	11,509
1990	20,603	12,980	12,331
1995	21,586	13,599	12,919
2000	22,621	14,364	13,646

Year	Hours Worked (10^6)	GNP per Hour ($1977)	GNP ($1977($10^6$))
1977	18,540	11.20	207,714
1980	19,995	12.13	242,563
1985	21,006	13.86	291,149
1990	21,994	15.84	348,375
1995	22,572	18.09	408,336
2000	23,275	20.67	481,091

Notes:

1. Population 15 and over based on fertility rate of 1.8 and net annual immigration of 60,000.
2. Labor force based on a participation rate increasing from 61.3 percent in 1977 to 63.5 percent in 2000.
3. Employed labor force based on an unemployment rate of 6.0 percent from 1980 to 1985 and 5.0 percent from 1990 to 2000.
4. Hours worked based on a workweek declining from 36.7 hours in 1977 to 32.8 hours in 2000.
5. GNP per hour is based on a projected annual productivity growth of 2.7 percent from 1977 to 2000.

Chapter 2

Canada: The Intermediate Factors

Households

There is more housing available to Canadians now than at any time in the recent past. The number of households rose by almost three-fifths during 1961-76 and the average number of persons per household declined rather steadily from 3.9 to 3.1. This decline resulted mainly from a continuing fall in the birthrate and rising affluence. More young single individuals and elderly people are maintaining separate households rather than living with their families. Fragmentation of families coupled with an increasing divorce rate and a reduction in the marriage rate for women under 20 years of age has resulted in the rapid growth in the proportion of nonfamily households, which are largely single-person units. Table 12 shows that during the decade 1966-76, the number of nonfamily households increased 90 percent and their share of total households rose from 16 percent to 21 percent.

Net immigration also plays an important role in household formation in Canada. Between 1969 and 1973, net immigration was responsible for about 17 percent of net additional household formation. The impact was strongest in Toronto, Montreal, and Vancouver where about half of the recent immigrants are concentrated.

Projections of the number of households, as shown in Table 13, are based on assumptions about population growth, net immigration, and the trend of young single individuals and elderly people to live separately. As noted earlier, we assume the fertility rate will remain at the current 1.8 and that net immigration will amount to

60,000 persons annually through the year 2000. One result of the continuation of a low fertility rate and an expected increase in longevity will be a population shift toward the older age brackets. By the year 2000 more than 3.3 million Canadians, or 12 percent of the total estimated population, will be in the 65 and over category compared with 9 percent at present.

Table 12. Canada: Number of Households, 1966-76

(thousands)

	1966	1971	1976
Total households	5,180	6,031	7,166
of which:			
Family	4,377	4,925	5,634
Nonfamily[a]	804	1,105	1,532

Sources: Statistics Canada, 1976 Census of Canada, Dwellings and Households. Ottawa (1978). Statistics Canada, 1971 Census of Canada, Housing. Ottawa (1975).

[a] The term "nonfamily household" refers to one person living alone in a housing unit or a group of persons who are not related by blood or marriage occupying such a unit.

Table 13. Canada: Estimated Numbers of Households, 1976-2000

(millions)

Year	Total	Family	Nonfamily
1976	7.2	5.6	1.5
1980	7.7	6.1	1.7
1985	8.9	7.0	1.9
1990	9.6	7.6	2.0
1995	10.1	8.0	2.1
2000	10.6	8.3	2.3

The trend to smaller families and more nonfamily households probably will continue throughout most of this century and suggests a ratio shift from single-family dwellings to multifamily units. Multifamily units and single detached units each have accounted for roughly half of residential dwelling completions in recent years. Because multifamily units contain fewer square feet of living space per unit than new single detached homes, the changes in household composition noted above should tend to decrease energy requirements for space heating and cooling, especially if, as anticipated, there will be fewer people home during the day (i.e., more women employed) in these smaller households. A partial offset in energy demand is the growing size of single-family homes, reflecting higher incomes. Because the two trends tend to cancel out each other, we have not attempted the "fine tuning" of energy demand that would be implicit in a household size adjustment.

Commercial Sector

The commercial sector is a heterogeneous category: it includes wholesale and retail trade, commercial and government office space, schools, hospitals, and hotels. Our energy demand projections for this sector are based on a unit of measurement that is both common to these heterogeneous elements and appropriate to energy use projections, and that is square footage. Unfortunately, there are no official Canadian numbers for commercial space. As a substitute, we assume that Canadian commercial space, per household, is now roughly equal to that of the United States, or 350 square feet. In 1976, there were 7.2 million Canadian households. This implies a

commercial footage of 2.5 billion square feet. For the future, we assume that commercial activity increases at the same annual rate as per capita income, or 2.9 percent. This translates into a commercial footage of 5.0 billion square feet in 2000. See Table 14 for selected years, 1976-2000. The rationale behind this projection is an inference from two sets of factors:

1. Canadian productivity and GNP have grown at substantial rates over the postwar period, and this growth is expected to continue. In the year 2000, with a household total of 10.6 million, we project 472 square feet of commercial space per household, or 35 percent above the 1976 level. This is a sizeable increase, but it is in line with the projected increase in per capita GNP. Energy consumption in the commercial sector grew about twice as rapidly as total Canadian secondary energy consumption between 1962 and 1972.[5]

2. We do not expect commercial space to grow at the projected GNP rate, because this would result in 566 square feet per household in the year 2000--more than 60 percent above the 1976 level, and much higher than the expected U.S. level in 2000.

Table 14. Canada: Commercial Space

Year	Total Space (10^9 sq.ft.)	Space per Household (sq.ft.)
1976	2.5	350
1980	2.8	364
1985	3.2	360
1990	3.7	385
1995	4.3	426
2000	5.0	472

Industrial Production

During the past 15 years, industrial production in Canada grew at an average annual rate of 5.0 percent--about the same growth achieved by GNP. The growth of industrial output traditionally has somewhat exceeded that of GNP, as Table 15 shows. However, in more recent years, industry and GNP have moved at about the same rates.

It will be difficult to resume the high growth rates of 1960-75. Future growth will depend heavily on the rate of new capital formation and labor productivity. Many Canadian firms and some entire industries will need to modernize their plant and equipment if they are to continue to compete with import substitutes and in export markets, and capital will be increasingly drawn to the energy industries. We project that future industrial growth will approximate the GNP path--an output gain of 5.3 percent annually through 1980, declining to 3.7 percent in 1980-85, to 3.6 percent in 1985-90, and to 3.3 percent in the final decade of this century.

Table 15. Canada: Growth of Industrial Output and GNP

(1963 = 100)

Year	Total Industry	GNP
1963	100	100
1964	110	107
1965	119	114
1966	127	122
1967	131	126
1968	140	133
1969	149	140
1970	152	144
1971	159	154
1972	172	163
1973	188	175
1974	195	182
1975	184	184
1976	193	193
1977	200	198

Transportation--The Personal Automobile

The E/GNP ratio in industrialized countries is not a constant, and one of the main reasons for international variation is the unequal distribution of the personal automobile. In Canada, as in the United States, for reasons related to high per capita incomes and the extensive geographic sweep of the nation, about 90 percent of passenger-mile transportation is accounted for by automobiles. Canada is larger than the United States in total area whereas population density is only a small fraction (about 10 percent of that in the United States). Given very low population density, public transportation is not a viable alternative except in urban areas.

Past growth of personal automobile numbers has brought the ownership of cars in Canada from about 160 per 1,000 persons of all ages in 1953 to 377 per 1,000 persons in 1974. This rate of increase was much faster than that in the United States.

We have estimated, earlier in this chapter, that both GNP and per capita income in Canada will continue to increase relatively rapidly throughout the balance of this century. The crude projection of car ownership-income trends, however, cannot be used to extrapolate to the year 2000, since it results in car numbers by the end of the century that cannot reasonably be expected, that is, more cars than population of licensed driving age.

Therefore, our assumption is that Canada will continue to expand personal automobile ownership at a rapid but declining rate, and that saturation will take place at approximately 90 percent of persons 15 years and older (the driving ages) or very close to the level expected in the U.S. by that time. This means that by the year 2000, there

would be 900 automobiles for every 1,000 persons 15 years of age and older, compared with 528 cars for the eligible age group in 1975. Table 16 gives projected numbers of personal cars by 5-year intervals to the year 2000.

Table 16. Canada: Growth of Ownership of Personal Automobiles, 1977-2000

Year	Population 15 and over (10^3)	Automobiles (10^3)	Annual % Increase	Autos per Person 15 and older
1977	17,250	9,625	-	0.56
1980	18,328	10,997	4.5	0.60
1985	19,590	13,125	3.6	0.67
1990	20,603	15,452	3.3	0.75
1995	21,586	17,916	3.0	0.83
2000	22,621	20,359	2.6	0.90

Driver Participation Rates

An enlightening approach to the demand for automotive fuels is to look at the identities

$$E = MI/MPG \quad (1)$$

$$MI = MPD*DRI \quad (2)$$

$$DRI = M*PAR(M)+F*PAR(F) \quad (3)$$

where E is energy demanded (gasoline), MPG is miles per gallon of gasoline, MI is miles driven, MPD is miles per driver, M is the number of males eligible to drive, PAR(M) is the fraction of eligible males actually driving, and F, PAR(F) are similarly defined for females.

This analytical approach breaks the problem into three important parts. The first equation measures the impact of more intensive use of private transport, and the third measures the impact of participation in driving.

Looking at past trends in the United States,[6] one sees a gradual

increase in the number of miles driven per capita. This increase has gone on at the rate of 1.2 percent per year compared with the roughly 2.3 percent growth rate for per capita income. Our investigation showed a strong correlation between income, the price of gasoline and motor oil, and miles per driver.

The strongest influence increasing future automotive demand for energy comes from increasing female participation in automobile operation. Driver participation rates have increased over time for both males and females, but the eligible male population has achieved virtually complete participation. Females have traditionally participated less than males, but in recent years the female rate has increased. Cross-sectional studies show that in the younger age cohorts, females have achieved virtual parity with males.

This finding is an important virtual guarantee that projections for an early peak in miles per capita (not drivers) will not likely be met. In our analysis of data from the United Kingdom we find precisely the same forces at work on the eastern side of the Atlantic as on the western side.

While Canadian male-female driver data are not complete, statistics on licenses are available for four provinces and for two of Canada's largest provinces, Ontario and British Columbia, there are relatively long time series. Participation rates are shown for Manitoba, Ontario, Alberta, and British Columbia in Table 17. We note with interest that more than 100 percent participation is achieved in two provinces. We have also seen this phenomenon in the United States. It most likely results from a combination of population movement and multiple license holdings. In all four provinces, we see both an upward trend in female participation, and a decrease in the relative

and absolute difference between male and female participation rates.

Table 17. Canada: Available Data on Driver Participation Rates of the Population 15 Years and Older (percent)

Year	Males	Females	Total
Manitoba			
1973	-	-	-
1974	81	55	68
1975	81	56	69
1976	82	58	70
Ontario			
1967	81	42	61
1968	82	43	62
1969	82	44	63
1970	83	46	64
1971	83	47	65
1972	83	48	66
1973	-	-	-
1974	83	51	67
1975	84	53	68
1976	86	54	70
Alberta			
1971	104	67	86
1972	102	68	85
1973	-	-	-
1974	107	74	90
1975	108	76	92
1976	-	-	-
British Columbia			
1961	84	38	62
1962	82	40	61
1963	85	42	63
1964	85	43	64
1965	86	45	66
1966	86	47	67
1967	88	49	69
1968	90	58	71
1969	93	54	74
1970	95	57	76
1971	97	59	78
1972	99	62	81
1973	-	-	-
1974	102	66	84
1975	103	68	85
1976	-	-	-

Transportation of Passengers

During the past 15 years, total passenger travel grew at an annual average rate of 5.4 percent, or about the same as GNP. Passenger travel by automobile has accounted for the largest share--roughly 90 percent--of all passenger travel.[7] As Table 18 shows, however, competition from air transportation, especially for longer trips, has been decreasing the automotive share of total passenger movement. Although air transport still constituted only an estimated 10 percent of total passenger-miles in 1976, its rate of increase has been averaging about 12 percent annually during the past 15 years.

Our projections are based on past growth trends, the distribution by mode, and population and income growth. As Table 19 shows, total passenger travel is projected to grow at an annual average of about 4.4 percent through the year 2000. Total passenger-miles in the year 2000 are projected to be 487 billion, or more than two and one-half times the 1976 level.

Table 18. Canada: Total Passenger-Miles by Mode of Travel, 1958-76

(billion passenger-miles)

Year	Total	Bus	Automobile	Air	Rail
1958	69.9	2.5	62.9	2.0	2.5
1960	76.0	2.6	68.5	2.6	2.3
1965	98.3	2.8	87.7	5.1	2.7
1970	N.A.	3.4	N.A.	10.7	2.2
1975	N.A.	N.A.	145.7	17.6	1.6
1976	172.2	3.8	149.2	17.6	1.6

N.A. = not available

Table 19. Canada: Projected Passenger-Miles by Mode of Travel, 1976-2000

(billion passenger-miles)

Year	Total	Bus	Automobile	Air	Rail
1976	172.2	3.8	149.2	17.6	1.6
1990	327.0	5.3	274.7	45.4	1.6
2000	487.2	6.8	389.5	89.3	1.6

Our estimate of automobile travel is based on the historic relationship between GNP, disposable personal income, and the size of the 15-year-old age group of the population. With regard to rail travel, it is estimated that rail passenger-miles will hold steady at about the 1976 level, reflecting a probable deterioration of service, reduction in schedules, and consumer preference for other forms of transportation. We anticipate that passenger travel by air will continue to increase throughout the century at an average annual rate of about 7 percent, or slightly below the growth rate experienced during the past 5 years. By 2000, passenger-miles by air will amount to 89 billion, or five times the 1976 level and air travel will account for 18 percent of all passenger-miles, compared with 10 percent in 1976. This growth reflects the growth in population and incomes, probable cost decreases, especially in long-haul travel, and newer aircraft and airport facilities. Buses probably will continue to offer some competition on shorter trips and we project that passenger-miles by bus will continue to grow at the historic rate of 2.4 percent annually.

Transportation of Goods

Basic freight modes break down into rail, air, water, and trucks. The standard unit of measure is ton-miles.

Rail freight movement grew at 2.63 percent annually between 1956 and 1976, while GNP grew at 4.67 percent. The rail to GNP ratio was 0.56; applying this measure to projected GNP growth to 1990 of 3.95 percent annually and to 2000 of 3.28 percent gives a growth of 2.22 percent a year, and 1.85 percent a year between 1990 and 2000. See tables 20-23 for the development of these intermediate factors.

Air freight has grown very rapidly since the end of World War II, but at a declining rate--14.63 percent annually from 1956 to 1976. Applying a crude GNP ratio to the future, this gives annual growth of 12.37 percent from 1976 to 1990 and 10.28 percent, 1990 to 2000. These growth rates should be further tapered, but have not been because the total volume is still very small--about 0.5 percent of the size of rail traffic in 1976.

Table 20. Canada: Freight Transport, 1946-76

(billion ton-miles)

Year	Rail	Water	Pipeline	Road	Air	Total
1946	55.31	18.37	*	3.50	*	77.18
1956	78.82	39.41	16.19	10.61	0.03	145.06
1966	95.10	64.41	51.01	18.95	0.12	229.59
1976	132.60	95.27[a]	108.10	28.76[b]	0.42	365.15

Sources: UN Statistical Yearbooks, various years; Statistics Canada, Canadian Statistical Review, section 12 and Systems Research Group, Canada Transportation Projections to the Year 2000.

* Less than smallest units used.

[a] Estimate based on historical trends of declining rate of growth averaging 4.0 percent between 1966-76 and roughly stable sector share.

[b] Estimate based on historical trends between 1946-67 and 1973-75 of declining rate of growth averaging 4.3 percent between 1966-76 and declining sector share.

Table 21. Canada: Freight Transport Sector Shares, 1946-76

(percent)

Year	Rail	Water	Pipeline	Road	Air	Total
1946	71.66	23.80	-	4.53	-	100.0
1956	54.34	27.17	11.16	7.31	0.02	100.0
1966	41.42	28.05	22.22	8.25	0.05	100.0
1976	36.31	26.09	29.60	7.88	0.12	100.0

Source: UN Statistical Yearbooks, various years; Statistics Canada, Canadian Statistical Review, section 12 and Systems Research Group, Canada Transportation Projections to the Year 2000.

Table 22. Canada: Freight Transport Projections, 1976-2000

(billion ton-miles)

Year	Rail	Water	Pipeline	Road	Air	Total
1976	132.60	95.27	108.10	28.76	0.42	365.15
1990	180.30	160.81	262.10	51.99	2.72	657.30
2000	216.60	219.70	444.30	73.98	5.72	960.30

Table 23. Canada: Freight Transport Projections, Sector Shares, 1976-2000

(percent)

Year	Rail	Water	Pipeline	Road	Air	Total
1976	36.31	26.09	29.60	7.88	0.12	100.0
1990	27.43	24.46	39.87	7.91	0.33	100.0
2000	22.55	22.88	46.27	7.70	0.60	100.0

Road freight statistics in ton-miles are available for the years 1946-67 and 1973-75. The 1976 estimate is based on growth trends in this time period. Between 1956 and 1976 motor freight grew 5.11 percent annually, and the motor freight to GNP ratio was 1.09. This ratio gives an annual growth of 4.32 percent from 1976 to 1990 and 3.59 percent for 1990-2000.

Pipelines transport petroleum and natural gas. In the 1961-76 period, output grew at an average annual rate of 8.73 percent. By our standard link to GNP technique, growth rates become 6.53 percent, 1976-1990 and 5.42 percent, 1990-2000.

Water transport includes international as well as domestic movement. Data on ton-miles are available for the years 1946-66. The 1976 estimate of 95.27 ton-miles is based on these growth trends along with the total freight transport estimate which has historically roughly matched GNP growth. Water transport grew 4.51 percent annually between 1956-76, which results in a water-to-GNP ratio of 0.97. Applying this ratio to the future gives an annual growth of 3.81 percent between 1976-90 and 3.17 percent between 1990-2000.

These projected sector rates result in growth for total freight transport of 4.29 percent annually between 1976-1990 and 3.86 percent between 1990-2000. These parallel GNP projected rates of 3.95 percent and 3.28 percent annually and are thus consistent with past growth trends. See Tables 20 and 21 for past growth of freight transport and Tables 22 and 23 for future projections.

Chapter 3

Canada: Future Energy Demands and Economic Growth

Historical Relationships

The ratio of annual percentage change in energy consumption to the change in gross national product (E/GNP) in Canada was 0.95 in the period 1960-74, reflecting the growth of energy-intensive industries and relatively inexpensive energy for the economy as a whole. The corresponding planned ratio for 1974 to 1990 is 0.8, which implies significant energy savings in relation to output.[8]

Although the short-range forecast made in 1977 was for a 3.5 percent annual increase in energy consumption, the federal and provincial governments have a comprehensive plan to reduce the annual growth of energy use to 2 percent by 1990. If achieved, this performance would lower the E/GNP ratio well below 0.8.

The future E/GNP (or E/GDP) ratio is a convenient aggregate measure of the expected quantity of energy that will be used to produce the forecast GDP.[9] As industrial economies mature, they generally use less energy to generate a dollar's worth of product, in part because of the faster growth of the less energy-intensive service industries compared with the goods industries.

Present Energy Consumption

Table 24 shows primary energy uses, by sector, for Canada in 1976. Industry was the largest consuming sector, accounting for 37 percent of the total. The remaining three sectors--residential, transport, and commercial--consumed almost equal portions of the total, at 22, 21, and 20 percent.

Table 24. Canada: Reconstruction of Primary Energy Consumption, 1976

	mtoe[a]			(Quads)
	Nonelectric	Electric	Total	Total
Residential	19.89	20.92	40.81	1.67
Commercial, Total	13.65	22.64	36.29	1.49
Commercial	13.14	21.99	35.13	1.44
Public Service	0.51	0.65	1.16	0.05
Industry & Agriculture	33.21	35.08	68.29	2.80
Industry	31.91	34.09	66.00	2.71
Agriculture	1.30	0.99	2.29	0.09
Transportation	37.80	-	37.80	1.55
Totals	104.55	78.64	183.19[b]	7.51

Source: OECD, Energy Balances of OECD Countries, 1974/76, Paris, 1978.

[a] 24.4 mtoe (million tons oil equivalent) = 1 quad.

[b] Net of nonenergy uses of 6.77 mtoe.

Households

Savings of household energy come from two sources: (1) the incorporation in new housing of energy-saving techniques, such as insulation, and (2) the retrofitting of old houses built according to the requirements of the Canadian 1970 Code for Residential Construction or earlier regulations. An additional source of energy savings is the development of standards for furnaces, water heaters, air conditioners, and household appliances.

Specific measures to conserve household energy enacted or proposed include the following:

1. A nationwide 7-year program of grants for insulation, totaling $1.4 billion, is expected to cover 70 percent of dwellings by 1985.

2. A grant program has been instituted in Prince Edward Island and Nova Scotia of up to $350 for material costs or one-third of

contractor costs up to a maximum grant of $500. These two provinces rely heavily on imported oil. They are small, together accounting for 269,000 housing units out of a national total of about 7 million in 1975, or 3.8 percent. Public response is said to have been "overwhelming."

3. British Columbia, Manitoba, and Nova Scotia have instituted a loan program on retrofit. In total, these three provinces have 19.5 percent of Canada's housing units.

4. Energy audit programs are available in many provinces to guide homeowners on savings' potential.

5. New model building codes with significant thermal efficiency standards are being enacted. The new guidelines were expected to reduce the consumption of energy in new units by 38 percent compared with smiliar sized old units. Additional savings are expected from more efficient furnaces.

6. Federal and some provincial sales taxes on insulation products are to be removed.

7. Household appliances will be required to meet minimum efficiency standards.

The Canadian government's strategy for household energy conservation is ambitious. It is built around space heating improvements, which accounted for 68 percent of total household energy use in 1975. As given in An Energy Strategy for Canada, it shows the following for space heating:

	Dwellings	Net Btu
	10^3	10^{12}
1976	6,947	857
1990	10,041	617

The savings are 513 trillion Btu compared with 1975 practice. While dwelling units increase by 44 percent, there is a 28 percent reduction in energy consumption by the household sector. The goal represents about a 50 percent improvement in energy use per household. On new dwellings, revised construction standards are estimated to yield a 50 percent saving, with an additional boost from a 20 percent improvement in oil burner performance.

Studies in the United States by the Institute for Energy Analysis calculated that an improvement in total per household energy efficiency of 21.5 percent by 2000 would be possible under relatively effective conservation policies. We have assumed that about half the Canadian efficiency improvement goals will be achieved by 1990 for total household energy use, or 25 percent per household, and that thereafter gains would be much more moderate, since retrofit would have been completed and efficiency improvements would be limited to new dwellings. Household numbers increase by 10 percent between 1990 and 2000, and would increase household energy demands by about 9 percent. Institute for Energy Analysis (IEA) projections are shown in Table 25.

Table 25. Canada: Household Energy Consumption

Year	Dwelling Units (10^6)	Energy Consumption (10^{15} Btu)
1975/6	7.2	1.67
1990	9.6	1.67
2000	10.6	1.82

Commercial

The government program for the retrofit (insulation) of buildings includes commercial buildings. Insulation and thermal efficiency standards for office and commercial buildings are also being strengthened, while the Canadian government has an internal program aimed at keeping energy consumption 10 percent below the 1975-76 level, and at maintaining energy use at this level for 10 years.

Because all gas and electricity charged at commercial rates is incorporated in the commercial energy consumption statistics, some consumption by light industry and apartments is also included. It is estimated, however, that at least 90 percent of commercial energy consumption is accounted for by commercial buildings. (See Energy Conservation in Canada.)

Conservation potential in the commercial sector is believed to be at least equally as large as that in the household sector. An Energy Strategy for Canada estimates the commercial conservation possibilities in new structures to be greater than the household gains. This would be contrary to U.S. experience.

If we project energy conservation in the commercial sector to approximate that of households, we arrive at the data shown in Table 26. The justification for this is because improvement factors for water heating, cooking, refrigeration, and lighting are the same as for households.

Table 26. Canada: Commercial Space and Energy Consumption, 1976-2000

Year	Total Space (10^9)	Energy Consumption (10^{15} Btu)
1975/6	2.5	1.49
1990	3.7	1.65
2000	5.0	2.17

Transportation of Passengers--Energy Requirements

The anticipated growth in automobiles to 2000 has been specified in Chapter 2. It is the one area where separation from freight is possible. We anticipate that miles driven per car will continue to expand moderately, so that total miles driven will grow at about the GNP rate.

Canadian new car standards for gasoline consumption are identical to those of the United States--20 miles per gallon by 1980 and 27.5 gallons by 1985. (This is 24 and 33 miles per imperial gallon.) The government believes these savings will yield a 40 percent reduction (mpg) in gasoline consumption levels by 1990, which is based on rated miles per gallon improvements for new vehicles and expected fleet replacement times. However, we have noted a growing gap between rated miles per gallon and actual miles per gallon achieved on the highway. There is no way to make a precise quantification of the overstatement of engine efficiency. Arbitrarily, we have allowed for this degradation by assuming a 30 percent improvement in automobile efficiency by 1990 and 40 percent by 2000. The results are shown in Table 27. Finally, our tentative analysis of current Canadian miles per gallon is that efficiencies are significantly below those of the United States, hence the base mpg used for 1976/77.

Table 27. Canada: Automobiles, Miles Driven and Fuel Consumption, 1977-2000

Year	Number of Autos (10^3)	Miles per Autos	Total Miles (10^9)	Miles per Gallon	Total Fuel Cons. (10^{12} Btu)
1977	9,625	9,072	87.3	10.6[a]	1,057
1990	15,452	9,865	152.4	13.8	1,417
2000	20,359	10,632	216.5	14.8	1,877

[a] Base figure is for 1976.

Total Transport Energy Consumption

Data for 1976 show that the passenger automobile consumed the lion's share of energy used in the transport sector (see Table 28).

Table 28. Canada: Transport Consumption of Energy, 1976

	10^{12} Btu	Percent
Total	1,549	100.0
Passenger Cars	1,057	68.3
Trucks	129	8.3
Air	126	8.1
Rail	76	4.9
Pipeline	76	4.9
Water	85	5.5

Sources: OECD, Energy Balances of OECD Countries, 1974/76, Paris, 1978; Statistics Canada, Canadian Statistical Review, sec. 12.

Truck (road) freight calculations include bus energy use, and are shown in Table 29. They assume that efficiency improvements for trucks will be about two-thirds those for passenger cars, or 20 percent by 1990.

Air transport of both passengers and freight is growing rapidly, but data on fuel consumption for each of these two segments are not available. Hence, we assume that an average passenger plus his baggage

weighs 200 pounds. This means that ten passengers weigh, on the average, 1 ton. It follows that 10 passenger-miles are equivalent to 1 ton-mile.

Table 29. Canada: Truck Consumption of Energy, 1976-2000

Year	Total Ton-Miles (10^9)	Average Annual % Growth	Fuel Consumption (10^{12} Btu) Without Conservation	With Conservation
1976	28.76	-	129.0	129.0
1990	51.99	4.32	233.2	186.6
2000	73.98	3.59	331.8	265.5

Canadian commercial aircraft are predominantly of U.S. manufacture. The National Aeronautics and Space Administration has estimated that passenger-miles, for all new commercial aircraft, will double between now and 2000. At least 70 percent of the 1990 fleet will be composed of the more fuel-efficient models, and by 2000, virtually all will be the latter types. Therefore, we assume efficiency improvements of 35 percent by 1990 and 50 percent by 2000. See Table 30 for projected air transport fuel consumption.

Table 30. Canada: Air Transport Consumption of Energy, 1976-2000

Year	Total Ton-Mile Equivalent (10^9)[a]	Average Annual % Growth	Fuel Consumption (10^{12} Btu) Without Conservation	With Conservation
1976	2.18	-	126.0	126.0
1990	7.26	8.97	419.4	272.6
2000	14.65	7.27	846.1	423.1

[a] 10 passenger-miles = 1 ton-mile. Sum of tables 9 and 22, air transport.

Rail and pipeline energy uses in 1976 were virtually identical. Railroad efficiency improvements are expected to be very small, averaging only one-half of 1 percent a year, whereas pipeline improvements could be as much as 1 percent a year (see tables 31 and 32).

Table 31. Canada: Rail Transport Consumption of Energy, 1976-2000

Year	Total Ton-Mile Equivalent (10^9)[a]	Average Annual % Growth	Fuel Consumption (10^{12} Btu) Without Conservation	With Conservation
1976	132.76	-	76.0	76.0
1990	180.46	2.22	103.4	96.2
2000	216.76	1.85	124.2	118.0

[a] 10 passenger-miles = 1 ton-mile. Sum of Tables 9 and 22, rail transport.

Table 32. Canada: Pipeline Transport Consumption of Energy, 1976-2000

Year	Total Ton-Miles (10^9)	Average Annual % Growth	Fuel Consumption (10^{12} Btu) Without Conservation	With Conservation
1976	108.1	-	76.0	76.0
1990	262.1	6.53	184.3	158.5
2000	444.3	5.42	312.4	281.2

Water transport is among the smallest consumers of energy (see Table 33). Vessels are much longer lived than automobiles or trucks; we assume only one-half of 1 percent efficiency improvement a year. (See Table 34, which gives the calculation for each transportation sector.)

Table 33. Canada: Water Transport Consumption of Energy, 1976-2000

Year	Total Ton-Miles (10^9)	Average Annual % Growth	Fuel Consumption (10^{12}+Btu) Without Conservation	With Conservation
1976	95.27	-	85.0	85.0
1990	160.81	3.81	143.5	123.4
2000	219.70	3.17	196.1	176.5

Table 34. Canada: Projected Transportation Energy Consumption, 1976-2000

(10^{12} Btu)

Sector	1976	1990	2000
Total	1,549	2,255	3,142
Passenger cars	1,057	1,417	1,877
Trucks	129	187	266
Aircraft	126	273	423
Rail	76	96	118
Pipeline	76	159	281
Water	85	123	177

Industrial Fuel Consumption

To forecast industrial energy needs, we identify the major energy-intensive manufacturing industries. Seven industries have historically accounted for about 87 percent of energy demand in this sector. They are shown in Tables 35 and 36 together with the annual rate of output growth in recent years.

It can be seen that many of the large fuel intensive industries have been growing more slowly than industry as a whole. The same trend is evident if one takes a value of output/GNP ratio. Food and beverages, for example, have been shrinking at 1.33 percent a year in relation to GNP.

Table 35. Canada: Trends in Output and Energy Purchases of Leading Manufacturing Industries

(output in 1961 constant $, energy consumption in trillion Btus)

	(1) Food and Beverages		(10) Paper & Allied Industries		(12) Primary Metals Industries		(15) Transportation Equipment Industries	
Year	Output 10^6 1961 $	Energy 10^{12} Btu	Output 10^6 1961 $	Energy 10^{12} Btu	Output 10^6 1961 $	Energy 10^{12} Btu	Output 10^6 1961 $	Energy 10^{12} Btu
1962	5373.0	51.68	2313.1	169.31	2599.1	96.49	2412.6	17.62
1963	5550.7	53.34	2423.6	178.90	2798.1	100.15	2871.4	19.01
1964	5906.3	53.95	2652.4	195.76	3130.9	122.30	3246.7	20.59
1965	6163.3	58.25	2781.0	211.91	3432.5	130.97	3926.9	23.00
1966	6439.3	59.93	3003.4	226.05	3489.9	133.60	4206.9	25.82
1967	6720.1	63.23	3012.3	233.80	3548.2	136.69	4623.1	26.76
1968	6856.1	63.99	3153.4	243.75	3879.9	140.01	5410.5	26.98
1969	7022.7	63.82	3430.3	250.52	3951.0	133.58	6124.9	25.06
1970	7267.9	60.92	3434.6	253.28	4142.4	142.40	5300.8	24.09
1971	7528.2	59.52	3440.6	243.28	4085.5	133.65	6290.5	24.34
1972		58.34		253.95		134.41		24.51
1973		54.94		249.53		124.73		24.62
1974		53.13		271.59		128.00		22.30
1975		52.74		224.23		104.59		21.92
Average Annual Growth, % 1962-71	3.43	1.42	4.05	3.69	4.63	3.31	10.06	3.28

Table 35. (continued)

Year	(17) Nonmetallic Mineral Products Industries		(18) Petroleum & Coal Products Industries		(19) Chemicals & Chemical Products		(21) Total All Industries	
	Output 10^6 1961 $	Energy 10^{12} Btu	Output 10^6 1961 $	Energy 10^{12} Btu	Output 10^6 1961 $	Energy 10^{12} Btu	Output 10^6 1961 $	Energy 10^{12} Btu
1962	800.7	53.62	1324.4	4.64	1618.8	57.48	43194.	518.77
1963	820.8	52.67	1413.3	4.84	1902.7	63.16	45303.	545.62
1964	914.2	56.53	1490.6	5.66	2068.4	66.45	48312.	598.31
1965	1013.4	65.04	1522.3	5.59	2241.0	72.00	51901.	648.21
1966	1056.5	67.14	1577.8	5.96	2285.9	83.38	55250.	685.90
1967	984.0	57.64	1562.3	6.25	2414.7	85.52	57027.	696.07
1968	1065.2	52.52	1644.9	6.84	2580.9	81.34	60154.	703.07
1969	1097.8	49.53	1641.5	7.43	2580.9	81.16	63877.	700.90
1970	1059.4	53.29	1747.2	8.07	2598.6	69.90	64713.	701.42
1971	1192.9	53.90	1935.2	8.75	2698.9	71.72	68406.	686.91
1972		62.70		9.40		74.39		717.07
1973		66.25		10.23		82.24		709.08
1974		67.68		10.48		70.34		732.18
1975		59.90		10.99		65.27		637.61
Average Annual Growth, % 1962-71	4.07	0.05	3.86	6.48	5.24	2.24	4.70	2.85

Sources: Statistics Canada, Occasional Series, 15-507E, 57-505, and 57-206. Consider also the following notes in "Energy Demand Projections--A Total Energy Approach," ER-77=74, June 1977. PPS 15, 18, 57-208 CPFE 1975, 57-506 CPFE 62-74.

Notes: Energy consumption does not include self-generated electricity and steam. All energy values are for purchased fuel and electricity only. Energy sources purchased for nonfuel use (i.e., natural gas for petrochemical feedstock, coal for metallurgical coke, asphalt, solvents, etc.) are considered industrial materials by Statistics Canada and are omitted here. Industrial output is valued in 1961 constant dollars and is defined as "value of shipments of own manufacture."

Table 36. Canada: Leading Manufacturing Industries, 1971

Industry	Output 10^6 1961 $	Growth Rate, 1962-71 (%)
Total--All industries	$68,406.0	5.2
Food and beverage	7,528.2	3.4
Paper and allied prod.	3,440.6	4.1
Primary metals	4,085.5	4.6
Transport equipment	6,290.5	10.1
Nonmetallic prod.	1,192.9	4.1
Petroleum and coal tar	1,935.2	4.3
Chemicals and prod.	2,698.9	5.9

These examples indicate wide variations in the progress toward targets and may be explained by a number of factors, the most important one being fluctuations in economic activity. In 1975, for example, the pulp and paper industry experienced a 17.3 percent decrease in output due to labor disputes and generally depressed levels of demand for the industry's products. Output reductions, particularly of this magnitude, make it very difficult to improve energy efficiency per unit of output because a significant amount of industrial energy use is insensitive to production cutbacks.

A weighted average of Canadian-made industrial estimates indicates an improvement in energy consumption of 12 percent in this sector between 1972 and 1980, expressed in Btu per dollar of output. In the period 1980 to 1990, a further improvement of 12 percent is expected by the Minister of Energy, Mines and Resources (see Energy Conservation in Canada: Programs and Perspectives, p. 32). Most conservation actions in industry are expected to be price induced rather than the consequence of government actions.

Energy efficiency targets for three major energy-use groups and progress toward these targets to date are as follows:

Industry	Target	Progress
Chemicals	17 percent decrease in energy use per unit of output between 1972 and 1980.	8 percent decrease by the end of 1976.
Pulp and paper	12 percent decrease in energy use per unit of output between 1972 and 1980.	0.5 percent decrease by the end of 1975.
Transportation equipment	15 percent decrease in energy use per dollar of value added between 1972 and 1980	18 percent decrease by the end of 1974.

For industry, the forecasts of energy growth in the two scenarios from the Minister of energy and resources, those for energy strategy and energy conservation, are almost identical for the year 1990, reflecting a consensus of views on probable levels of industrial conservation.

These are ambitious goals, particularly since conservation has been actively pursued in industry for over a decade. Between 1962 and 1971, output in the leading manufacturing industries, measured in constant dollars, increased 58 percent, whereas energy use grew only about 32 percent. Conservation measures undoubtedly were emphasized even more strongly after the 1973-74 OPEC price increases. For these reasons, the goal of a 1.4 percent a year growth in efficiency between 1972 and 1980, to be followed by a further 1.1 percent a year improvement between 1980 and 1990, may be too optimistic. If we assume that most of the planned savings are realized, and that the annual improvement runs three-fourths of 1 percent, then the 14-year saving, 1976-90, would be about 11 percent per constant dollar of output. Industry consumption, under these assumptions, would be 4.31 trillion Btu in 1990 and 6.15 trillion in 2000.

Total Demand

We now total the projected demands by sector to estimate nationwide totals. These are shown in Table 37.

Table 37. Canada: Energy Demand Projections

(quadrillion Btu)

Sector	1976	1990	2000
Household	1.67	1.67	1.82
Commercial	1.49	1.65	2.17
Transportation	1.55	2.25	3.14
Industry	2.80	4.31	6.15
Total	7.51	9.88	13.28

Energy Supply

The development of approximate E/GNP ratios does not require a detailed analysis of future energy supply in the case of Canada. In the 1970s, Canada was largely self-sufficient in primary energy, exporting larger quantities than she imported. The official policy is not one of self-sufficiency, but of "self-reliance," a somewhat lesser goal. However, national policy is concerned with the vigorous development of domestic energy resources in order to hold net imports to a low level, if they are required. Exploitation of tar sands and heavy oil is now a commercial reality, and frontier areas are believed to have significant reserves of oil and gas, although their exploitation will be capital intensive. Additionally, natural gas reserves in the traditional producing provinces have been increasing, and exports to the United States are expected to increase in the early 1980s.

In the field of electricity, Canada still has considerable hydro potential and abundant supplies of uranium. Canada probably will

continue to be a net exporter of energy throughout most of this century. In any event, it seems unlikely that her requirements would have to be supplied from the international energy market to any significant degree.

Given its state of energy endowment, E/GNP ratios in Canada are not likely to be forced downward by shortage-induced price increases that would reflect the escalation of real energy recovery costs.

Chapter 4

Canada: Analysis of Energy Intensities

Introduction

One of the most useful measures of energy consumption and conservation is the relationship between energy use and the growth of real income, or simply the E/GNP ratio. This statistic is useful for a number of reasons. First, it is a summary statistic. It gives an overall measure of how intensely an economy is utilizing energy, and allows a reasonable comparison of efficiencies over time to be made for a given country.[10] Second, the E/GNP rates clearly link energy use to output levels and demonstrate that meaningful conservation may still be taking place, even if total energy consumption rises. Like all summary statistical measures, many important details must be obscured in the process of aggregation.

To understand what factors are moving the E/GNP ratio, one must look at its determining components. In the preparation of this paper, we have generated energy and GNP projections from their constituent components. This process allows us not only to develop consistent E/GNP measures, but in the process of construction and projection, to gain an understanding of which sectors will be responsible for conservation gains and what factors are the root causes.

Historical Relationships

To place the analysis in perspective, we begin with an analysis of historical E/GNP ratios. The Canadian E/GNP ratios for 1960 to 1976 are given in Table 38. Clearly, for the 9 years from 1962 to 1971, the E/GNP ratio was almost constant. It averaged 36.54 thousand Btu per

1977 Canadian dollar. The highest E/GNP ratio exceeded the average by less than 3 percent, while the lowest ratio was only 3.5 percent below the average.

Table 38. Canada: Energy/GNP Ratios, 1960-76

Year	Gross Energy Consumption (10^{12} Btu)	GNP (10^{6} $1977)	E/GNP (10^{3} Btu per $1977)	E/GNP Index (1976=100)
1960	3,593	90,953	39.5	106.5
1961	3,558	93,533	38.0	102.4
1962	3,649	99,913	36.5	98.4
1963	3,713	105,060	35.3	95.1
1964	4,069	112,105	36.3	97.8
1965	4,361	119,573	36.5	98.4
1966	4,677	127,882	36.6	98.7
1967	4,850	132,154	36.7	98.9
1968	5,118	139,877	36.6	98.7
1969	5,365	147,329	36.4	98.1
1970	5,680	151,028	37.6	101.3
1971	5,963	161,382	36.9	99.5
1972	6,702	171,289	39.1	105.4
1973	6,957	184,213	37.8	101.9
1974	7,362	190,969	38.6	104.0
1975	7,320	193,001	37.9	102.2
1976	7,507	202,448	37.1	100.0

Sources: OECD, Energy Balances of OECD Countries, 1960/74 and 1974/76, Paris, 1976 and 1978; OECD, National Accounts of OECD Countries, 1976, Vol. 1.

During the next 5 years, however, things became more volatile. In 1972, the highest E/GNP ratio for the period was reached. By 1976, the lowest was achieved. The ratio declined from a high of 39.1 in 1972 to 37.1 by 1976. The 1972 ratio was a full 5.4 percent higher than the 1976 ratio.

Future Relationships

The Institute for Energy Analysis (IEA) has also projected E/GNP ratios for 1976-2000 (see Table 39). The E/GNP ratio for Canada is

expected to continue to fall, but at a slightly slower rate than over the period 1972-76. In the following 10 years IEA sees no major conservation or demographic factors sufficiently powerful to upset this trend. However, we forecast a leveling off of E/GNP improvement in the 1990s because Canada began to achieve significant energy savings in relation to output in the 1960s, present conservation programs should be largely carried out by 1990, and rapid further savings cannot be expected to be achieved indefinitely.

Table 39. Canada: Projected Energy/GNP Ratios, 1976-2000

Year	Gross Energy Consumption (10^{12} Btu)	GNP (10^{6} $1977)	E/GNP (10^{3} Btu per $1977)	E/GNP Index (1976-100)
1976	7,507	202,448	37.08	100.0
1990	9,880	348,375	28.36	76.5
2000	13,280	481,091	27.60	74.4

To understand the factors leading to these projections, we first disaggregate energy demand by sector. This has been done in tables 40 and 41.

Table 40. Canada: Energy Demand Projections, 1976-2000

(quadrillion Btu)

Year	Household	Commercial	Industrial	Transport	Total
1976	1.67(22.24)[a]	1.49(19.84)	2.80(37.28)	1.55(20.64)	7.51(100.0)
1990	1.67(16.90)	1.65(16.70)	4.31(43.62)	2.25(22.77)	9.88(100.0)
2000	8.82(13.71)	2.17(16.34)	6.15(46.31)	3.14(23.64)	13.28(100.0)

[a] Numbers in parentheses are percent of total consumption.

Table 41. Canada: E/GNP Ratios by Sector, 1976-2000

(Btu per $1977)

(1976=100)

Year	Household	Commercial	Industrial	Transport	Total
1976	8.25(100.0)[a]	7.36(100.0)	13.82(100.0)	7.65(100.0)	37.08(100.0)
1990	4.70 (58.1)	4.74 (64.4)	12.37 (89.1)	6.46 (84.4)	28.36 (76.5)
2000	3.78 (45.8)	4.51 (61.3)	12.78 (92.5)	6.53 (85.4)	27.60 (74.4)

[a] Numbers in parentheses are percent of total.

These tables show that energy consumption is projected to grow substantially less rapidly than the GNP in the household and commercial sectors. These two sectors account for over 77 percent of the decline in the total E/GNP ratio. The transportation and industrial sectors, which together accounted for about 60 percent of total energy consumption in 1976, have rates of growth of energy consumption much closer to that of the overall economy.

The transport sector's E/GNP ratio declines 14.6 percent between 1976-2000 and the industrial ratio declines only 7.5 percent. Much of the conservation in the transport sector is due to mandated changes in automobiles and trucks.

The E/GNP ratio for the household sector declines 54 percent by the year 2000. This lower ratio results from energy conservation and changing demographic patterns by the year 2000. There are fewer new households and hence energy demand rises much less rapidly than GNP.

We see precisely the same pattern in the commercial sector. Fewer new households means that square feet of commercial floor space grows less rapidly than GNP, and hence a lower E/GNP ratio for this sector. We return once again to the importance of demographic projections. Not only do these estimates affect the level of GNP in the future, and

hence overall energy demand, but also the population projections have a direct impact on the household sector and through this also affect the E/GNP ratio.

The IEA and WAES (Workshop on Alternative Energy Strategies) estimates are compared in Table 42. The WAES study incorporates much less conservation in its E/GNP ratio for all sectors than does the IEA model, and in some sectors it projects an increased rate of energy utilization, or a higher E/GNP ratio over time.

We conclude that in making energy demand estimates, the overall E/GNP ratio is more likely to be accurate if it is constructed from its constituent E/GNP ratios, and that these in turn rest upon the accuracy of demographic, sociopolitical, and economic assumptions. The basic IEA conclusion for Canada is that the overall E/GNP ratio is likely to continue its decline to the year 1990, but that thereafter little additional change is likely to 2000, unless energy costs escalate rapidly, a possible but unlikely event, given Canada's expected energy self-sufficiency over the balance of this century.

Table 42. Canada: E/GNP Ratios for 2000 Projected in the IEA and WAES Studies

(1976=100)

	Residential	Commercial	Transport	Industrial	Aggregate
IEA	46	61	85	93	74
WAES[a]	70	106	114	109[b]	103

[a] NAES estimates are based on 1972 energy and GNP, and so have been scaled by the rates of E/GNP in 1972 to E/GNP in 1976 in WAES case D-7.

[b] Combined industrial and nonenergy use.

FOOTNOTES

1 The Minister of Energy, Mines and Resources, An Energy Strategy for Canada: Policies of Self-Reliance (Ottawa, 1976).

2 There are compelling reasons for believing the fertility rate in industrial nations will remain low. See Charles F. Westoff, "Marriage and Fertility in Developed Countries," Scientific American (December 1978) pp. 51-57.

3 Sources were as follows: GNP from Statistics Canada, National Income and Expenditure Accounts, and employment from Dominion Bureau of Statistics, The Labour Force, both as reported in the Department of Finance, Economic Review (April 1978, Ottawa); work week from Statistics Canada, Aggregate Productivity Measures, 1946-76 (Ottawa, 1977) pp. 22, 47.

4 Economic Council of Canada, Twelfth Annual Review, Options for Growth (Ottawa, 1975) chapter 6.

5 Energy, Mines and Resources Canada, Energy Conservation in Canada: Programs and Perspectives (EP 77-7) (Ottawa, 1977).

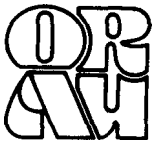
6 See The Future of the Personal Automobile in the United States, (Institute for Energy Analysis, Washington, D.C., July 1978).

7 All transport of passengers in this section is measured in passenger-miles.

8 The basic plan is given in Energy, Mines and Resources Canada, An Energy Strategy for Canada, Policies for Self-Reliance (Ottawa, 1976).

9 The terms GNP and GDP are used interchangeably in this report.

10 While valuable information can be learned in a single country from the E/GNP ratio time series, one should be much more careful in attempting comparisons across countries at a given moment. Structural differences between countries and variations in economic maturity preclude simple conclusions that one nation is being more "efficient" in energy use than another.



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