ENERGY SUPPLY AND DEMAND IN CANADA

1946 - 1961

by

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INTRODUCTION

Man's destiny and his economic welfare have been tied in very closely with his ability to harness and use energy effectively. At first, he used human and animal energy somewhat ineffectively, but use of such energy was replaced by the use of energy available in matter called inanimate energy. The first methods and devices for using inanimate energy were crude and ineffective, but as time passed man has been able to develop the devices needed to make better and more effective use of the energy available for his service. In so doing, he has been able to better his economic well-being in a number of ways. The development of energy-using devices has led to a number of inventions the adoption of which have had far reaching effects on economic development and economic growth. Inventions such as the steam engine, the electric power turbine, the internal combustion engine, the electric motor, the jet engine, the rocket engine, and the nuclear reactor are all examples of innovations that have assisted in the task of using energy more effectively and have affected economic development and growth in those economies in which they have been used. This drive to greater efficiency in the use of energy has led not only to the development and application of new technology, but has also promoted changes in the use of energy which have had important implications on both its supply and demand. Changing supply and demand patterns of energy in turn have had important implications on economic activity.

The purpose of this thesis is to examine and analyze the economic effects of energy supply and energy demand in 1946-1961 in Canada, and to offer conclusions following from this analysis. Energy supply consists of production of energy in Canada and imports of energy. Energy demand is the use of energy as energy and for non-energy purposes in Canada and exports of energy. As mentioned, the period of this analysis is 1946-1961; a period when Canada entered the stage of economic maturity and when its industrial structure became that of a country with a high level of economic development.

Energy is an economic good used in all phases of economic production, and in consumption. Because of the widespread use of energy throughout an economy, the annual amount of energy used in a country is a measure of its stage of technical and economic development. From country to country, large differences of income are usually associated with large differences in energy consumption, and no country at this stage in history can enjoy a high per capita income without becoming an extensive consumer of energy.

The importance of energy to the post war Canadian economy can be seen by the number of different government agencies established after 1946 concerned with different aspects of energy. Included in these agencies are organizations such as the Dominion Coal Board; the Atomic Energy Control Board and Atomic Energy of Canada Limited concerned with regulation of and research in atomic energy respectively; Eldorado Mining and Refining Limited concerned with the mining, production, and marketing of uranium; The National Energy Board concerned with the economic use of all forms of energy in Canada; the Mineral Resources Division of the Department of Mines and Technical Surveys concerned with the production of fuels; the Energy Statistics Section of DBS concerned with the collection and presentation of energy statistics; and the different provincial and municipal electric power commissions which are concerned with the production and distribution of electric power within the areas of their respective jurisdictions. The time is fast approaching when a coordinated approach to the problems of energy supply and demand in Canada will be required. The National Energy Board appears to be the appropriate agency for this purpose. In the post war period, energy has been the subject matter for several royal commissions, Their reports and deliberations have added much to the information on the energy position in Canada in this period and have posed problems requiring further study and analysis. The main pioneering study on energy in Canada was made by John Davis as Canada's Energy Prospects (1957) for the Royal Commission on Canada's Economic Prospects. Many reports, annual and monthly, have been issued by DBS onthe supply of different forms of energy and on the use of energy in different industries such as mining, manufacturing, electric power production, and transportation. DBS must improve the quality of statistics on the use of energy so that these will be comparable in quality to existing statistics on energy supply. A number of studies dealing with electric power production as it relates to the development of nuclear power in Canada have been made and published under the auspices of such organizations as Atomic Energy of Canada Limited, Ontario Hydro Electric Power Commission, and the Canadian Nuclear Association; and other reports and studies made by organizations in Canada concerned with the problems of energy supply and demand are appearing from time to time. Economic analysis on the economic importance of energy supply and demand in Canada is in the initial stages. It is considered that the study of the economic aspects of energy is an important area for more comprehensive economic analysis.

In Chapter I different energy concepts are defined and explained, and a method is developed to measure and compare energy. To provide a statistical background for the economic analysis of Canadian energy supply and demand, a statistical study was made of production and consumption of energy in 1870-1960 and 1946-1961, international trade in energy in 1946-1961, provincial supply and demand for energy in 1961, the distribution of energy among different uses of energy in Canada, and Canada's reserves of energy. Finally, the components of the Canadian energy system and its operation are outlined and explained.

In Chapter II, the economic effects of the supply of energy in Canada in 1946-1961 are analyzed. This analysis deals with: (1) the contribution made by energy supply to economic growth in Canada by its effects on employment, income and output, the balance of payments, regional economic development, and investment; (2) the economic effects of the development of nuclear power from the investment made for this development, and the effects of this development on other forms of economic activity such as the provision of heavy water production capacity and the capacity for production of nuclear fuel; and (3) other economic effects of energy supply as seen by its effect on industrial location, by the establishment of other forms of industrial activity based on the non-energy use of energy materials, and the effects from the external economies and diseconomies of energy supply.

In Chapter III, the use of energy in Canada is analyzed. This analysis examines energy use in aggregate, the per capita and per worker use of energy, and the specific use of energy in different aspects of industrial production, and as a consumer good. The analysis of the aggregate use of energy, studies the statistical correlation between energy use and population, persons working, and real GNP; compares their growth rates; and examines the relationship of the input of energy to unit of real GNP. The analysis of energy use in detail deals with its use in mining, manufacturing, electric power production, in railways, civil aviation and motor vehicles, and as a consumer good in the personal sector. In these areas, the analysis deals with energy use as to: the amount of energy used in each use, the effect of energy use on productivity, improvements in the efficiency of energy use, the effect of energy use on costs, and other aspects of energy use.

Finally, a summary of the analysis is made of the economic effects of energy supply and demand in Canada in 1946-1961, and certain conclusions following from this analysis are set out.

CHAPTER I

BACKGROUND ON ENERGY IN CANADA

Definitions and Concepts in Energy

The nature of energy is so complex that to discuss energy in relation to Economics it is necessary to define energy more precisely. Energy used in economic and human activity can be classified into two broad categories, namely animate energy or the energy of man and animals, and inanimate energy or the energy derived from non-living matter.[1] Inanimate energy can be classed into conventional and unconventional energy. Conventional energy consists of coal, petroleum, natural gas, falling water, and wood fuel. Unconventional energy consists of uranium, solar energy, wind power, chemical energy, energy derived from the sea as waves or surf, and tidal power.[2] There is a two way street

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[1] E.W.Zimmerman, World Resources and Industries New York: Harper Brothers Publishers, 1951, p.41.

[2] International Conference on the Peaceful Uses of Atomic Energy, Proceedings of the First Conference, Vol 1: The World's Requirements for Energy: The Role of Nuclear Power, New York: United Nations, 1956, pp. 71-76.

between conventional and unconventional energy. At the present time uranium is in transition from the unconventional to the conventional category; while wind power which at one time was conventional energy is now considered as unconventional. Both conventional and unconventional energy can be classed as non-renewable or capital energy; or renewable or income energy. Non-renewable energy is a legacy of the past and includes such energy sources as coal, petroleum, natural gas, and nuclear fuels such as uranium and thorium which when used up are lost to mankind. Renewable energy can continuously be renewed, examples are winds, wood fuel, rivers, and peat bogs.[3]

This study will deal with conventional energy resources of coal, petroleum, natural gas, falling water (as hydro-electric power), and wood fuel, and with the use of uranium in nuclear power production.

There are certain concepts in energy which must be defined to relate energy to economic concepts and analysis. These are defined and explained in the following paragraphs.

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[3] John W. Gardner, Electricity Without Dynamos, Harmondsworth, England: Penguin Books Ltd., 1963, p.38.

Primary energy is energy given by nature, some of which can be used in its natural form with little or no processing, and some of which needs a change of form to be usable as energy.[4] Secondary energy is energy produced from primary energy, e.g. coke, manufactured gas, gasoline, and fuel oils:

The energy supply of a country is the total supply of energy available for use in a given period of time. It consists of total domestic supply of primary energy, inventories of energy, and imports of both primary and secondary energy. Domestic energy supply is total domestic production of all forms of primary energy plus any inventories. Energy demand is the total amount of energy used in a country in a given period plus exports of primary and secondary energy. Domestic energy demand is the total demand for domestic production plus imports of energy minus exports of energy.

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[4] Crude petroleum must be refined to be used. Water power must be converted into electric power to get the best use of this energy. Similarly, certain forms of primary energy such as coal, and petroleum can be converted into electric power to be used in that energy form.

Measuring and Comparing Energy

The different forms of energy are usually expressed in terms of commodity measurements, such as cords of wood, tons of coal, barrels of oil, or kilowatt-hours of electric power. Expressed in this way, it is not possible to compare or measure the different forms of energy supplied and used. There is a need for a common denominator,and a number of such common denominators exist, such as tons of coal equivalent, kilocalories, kilowatt-hours, British thermal units (B.t.u.'s) and others. Thus tons of coal, barrels of oil and the like can be converted into terms of some common energy unit by using certain fixed conversion rates determined by physical measurement using scientific methods. In this study, all forms of energy will be converted and expressed in terms of the British thermal unit (B.t.u.)[5]

In energy studies, very large and very small numbers occur, and it is necessary to express such numbers

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[5] The conversion rates between different physical measures of energy and British thermal units are set out in Appendix 1.

in simple terms. To do so you can use a form of arithmetic shorthand. Using this method, the number 100 can be written as 10^2, the power 2 signifying that two times ten are multiplied. In this notation, 1,000 becomes 10^3, and 1,000,000 becomes 10^6. The same method can be used to represent small numbers. If we adopt the convention that 0.1 means 1 divided by 10, then 0.1 can be represented by 10^{-1}. Thus 0.01 is expressed as 10^{-2} and 0.0001 is expressed as 10^{-4}. In this notation, a number expressed as 2.5×10^6 is an instruction to move the decimal place 6 places to the right, and the number is 2,500,000; and a number expressed as 2.5×10^{-3} is an instruction to move the decimal places 3 places to the left, and the number is 0.0025.[6] This method is used in this study.

Statistical Background on Canadian Energy Supply and Demand

In this section, the statistical data necessary for the analysis in the chapters to follow will be outlined and explained. Historical statistics will be presented in the

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[6] Gardner, op. cit., p. 21.

long run by decades for 1870-1960, and in the short run by years for 1946-1961. The energy supply and demand situation in 1961[7] and current uses of energy will be explained, and Canadian energy reserves will be examined.

Long Run, 1870-1960

Historical Summary, 1870-1960 - Historically, energy production and consumption can be discussed within a framework of the stages of industrialization in Canada, because the process of industrialization is one of the significant factors affecting both energy supply and demand. In the very early stages of industrialization only two forms of energy were produced and used, coal and wood fuel. While petroleum was produced and used prior to Confederation, production was small and it was not an important source of energy. By the end of the period, primary energy sources had increased to five and included petroleum, natural gas, and falling water (hydro-electric power). By this time

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7 The year 1961 has been chosen as the final year for this study because this is the last year for which statistical data on all forms of energy are available.

too uranium was being used as a fuel in nuclear research and power reactors in Canada.

Canada has undergone three stages of industrialization[8] which have affected both energy demand and supply in different ways during this process of industrialization.

The stage of pre-industrialization was the period that preceded Confederation and featured the use of wind, water, animals, wood fuel, and some coal as sources of energy. Both supply and demand of energy were at low levels and matched the needs of economic activity at this stage.

The second period was one which could be called the old industrialization of the 19th century extending through the 19th century and into the early part of the 20th century. In this stage, coal was the basic source of energy, iron and steel the basic construction materials, and the steam engine the basic form of motive power. Because of the great supply of wood in Canada, this form of energy was quite important to 1900. As this stage of industrialization progressed the demand for energy shifted from a heavy use of

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[8] W.T. Easterbrook and H.G.J. Aitken, Canadian Economic History, Toronto: The Macmillan Company of Canada Ltd., 1958, pp 515-520.

wood fuel to use of coal as the primary source of energy.

The third stage is what could be called the stage of new industrialization, and commenced in Canada just after the turn of the present century. A great number of technological innovations have occurred along with this process of new industrialization. Such innovations have been the generation, transmission, and the use of electric power; the discovery of new fuels such as petroleum and natural gas; the invention of new forms of motive power such as the internal combustion engine and the electric motor; the development of new means of transport such as the automobile, the truck, and the aircraft; the discovery of new structural materials such as aluminum, light alloys, and alloy steels; and the development of new industrial processes such as electric reduction of complex ores, and the production of synthetic materials. In Canada, this new industrialization has taken place within the framework of these innovations and has modified and supplemented the older patterns of trade and production. Several effects have been noted. While the older forms of production are still the backbone of Canada's economy especially in the export sector, the new industrialization has reduced Canada's extreme reliance on the production of raw materials and staples. As this new industrialization has developed, it has been a dominant factor in the demand for newer forms and larger supplies of energy. Furthermore, since energy is one of the inputs to production, rising costs of energy have promoted more efficient use of energy and use of more efficient forms of energy. These factors explain the increased demand for and supply of petroleum, natural gas, and electric power in recent years and the decline in coal and wood fuel.

The foregoing pointed out three factors in the long run energy situation in Canada which had significant effects on both energy supply and demand in Canada. These factors are: (i) the growth in energy supply and demand, (ii) the substitution of some forms of energy for others, and (iii) the trend to greater efficiency in the use of energy.

Production and Consumption of Energy - Statistical data on the production and consumption of energy by decades starting with 1870 have been calculated and expressed in B.t.u.'s and set out in Table 1. In the early part of the period where only data on production was available, it was

TABLE I

PRODUCTION AND CONSUMPTION OF ENERGY
CANADA, 1870-1960

(Energy Units = 10^{12} B.t.u.'s)

Year	Wood Fuel[a]		Coal		Petroleum		Natural Gas		Hydro Power		Total	
	Prod.	Cons.	Prod.	Cons.	Prod.	Cons.	Prod.	Cons.	Prod.	Cons.	Prod.	Cons.
1870	174	174	17	11							191	185
1880	220	220	39	20							259	240
1890	208	208	83	131	5[a]	5[a]					296	344
1900	186	186	156	270	4[a]	4[a]			17	17	363	477
1910	247	247	348	676	2	19	2[a]	2[a]	17	17	616	961
1920	186	186	458	856	1	78	5[a]	5[a]	19	17	669	1142
1930	220	220	402	892	9	212	29	31	65	59	726	1414
1940	210	210	474	917	50	319	41	43	111	104	886	1593
1950	190	190	517	1188	158	786	67	75	177	183	1109	2422
1960	120	120	297	566	1099	1740	522	383	361	344	2399	3153
Total	1961	1961	2791	5527	1328	3163	666	539	767	741	7513	11931

Sources: Canada, DBS, Canadian Mineral Statistics 1886-1956, Ottawa: Queen's Printer, 1957, p.56; John Davis, Canadian Energy Prospects, a report to the Royal Commission on Canada's Economic Prospects, Ottawa: Queen's Printer, 1957, p.367; O.J. Firestone, Canada's Economic Development 1867-1953, London: Bowes & Bowes, 1958, pp. 257-258; Energy Supply and Demand Tables, National Energy Board, Ottawa (mimeographed)

[a] Production and consumption of energy as indicated have been assumed to be

necessary to assume that production and consumption were identical for wood fuel; and in the early decades for petroleum and natural gas. Table 1 shows that Canada had to rely on the imports of energy to meet the energy gap between domestic production and consumption. While the relationships between domestic production and consumption of wood fuel, natural gas, and hydro-electric power were fairly close, imports were significant for coal and petroleum. Decided shifts have also occurred from wood fuel to coal, and then to petroleum, natural gas, and hydro-electric power. These substitutions are a move to greater efficiency in the use of energy.[9]

Both energy production and consumption have grown over the period. The annual rates of growth for energy production and consumption have been estimated for the period using the method of terminal years.[10] This showed rates of

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[9] Petroleum, natural gas, and electricity (unlike coal) can be used in production processes, in equipment, and with operating techniques which will economize on energy used and hence energy is now being used more efficiently.

[10] W.A. Neiswanger, Elementary Statistical Methods, New York: The MacMillan Company, 1956, p. 287. The method of terminal years is a method for estimating the compound annual rate of growth by using the first and final years of the data.

growth of 2.85% for energy production and 3.12% for energy consumption. As the value of energy production is included in GNP, and energy is used extensively to produce the goods and services included in GNP, the growth rates of energy production and consumption can be compared to the growth rate in real GNP. In 1870-1960, the compound annual growth in real GNP was 3.3% indicating that these two variables grew at a slower rate.

A check was made for 1870-1960 of the changes in energy production and consumption in the United States. Both variables increased at a faster rate of growth than they did in Canada, thus giving evidence to time and structural differences in industrial development as between the two countries.[11]

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[11] The growth rates computed above have all been computed using the method of terminal years as per Footnote 10. With reference to the above comparison as between Canada and the United States, in terms of 10^{12} B.t.u.'s over 1870-1960 in Canada energy production increased from 191 to 2,399 and energy consumption from 185 to 3,153; while in the United States energy production increased from 1,074 to 41,793 and energy consumption from 1,059 to 45,868. This gives a compound annual rate of growth for energy production of 4.1% (Canada-2.85%), and 4.3% for energy consumption (Canada-3.12%). U.S. Dept. of Commerce, Historical Statistics of U.S. Colonial Times to 1957, Washington; U.S. Govt. Printing Office, 1960, p.354; Statistical Abstract of the United States, 1962, Washington: U.S. Govt. Printing Office, 1962, p. 528.

Short Run, 1946-1961

This section will outline and describe the growth of production and consumption in 1946-1961 in Canada. To assist in the description and analysis of the relationships between energy production and energy consumption in this period, Table 2 has been constructed. The data has been converted into B.t.u.'s and set out in Table 2.

Production and Consumption of Energy - Table 2 shows the main trends for total energy and for each form of energy, the shifts as between energy, and the growth in aggregate terms and in particular of energy production and consumption. Each aspect will be examined in turn.

The main trends show a decline in both consumption and production of wood fuel and coal. By the end of the period, wood fuel was no longer a significant source of energy. A significant decline in both production and consumption has taken place for coal, although imports have continued to play an important part in supplying Canadian demand. Production, consumption, and imports of coal have all declined at relatively the same rate. Production and consumption of petroleum and natural gas

TABLE 2

PRODUCTION AND CONSUMPTION OF ENERGY
CANADA, 1946-1961
(Energy Units = 10^{12} B.t.u.'s)

Year	Wood Fuel		Coal		Petroleum		Natural Gas		Hydro-Power		Total	
	Prod.	Cons.	Prod.	Cons.	Prod.	Cons.	Prod.	Cons.	Prod.	Cons.	Prod.	Cons.
1946	136	221	481	1144	44	506	48	51	149	140	888	2062
1947	122	216	428	1164	45	564	53	56	153	155	801	2155
1948	111	210	498	1261	71	617	59	62	152	157	891	2307
1949	110	200	516	1167	124	650	60	65	164	169	974	2251
1950	102	190	517	1188	169	786	68	75	178	183	1034	2422
1951	96	180	502	1181	276	922	79	86	199	205	1152	2574
1952	90	170	475	1102	355	995	89	100	213	208	1232	2575
1953	86	160	429	1017	469	1113	101	112	220	217	1305	2619
1954	78	150	403	862	557	1175	121	133	236	230	1395	2550
1955	72	145	400	912	751	1426	151	170	262	246	1636	2899
1956	72	140	403	906	998	1450	169	164	279	262	1921	2922
1957	71	135	356	798	1055	1500	220	201	284	271	1986	2905
1958	65	130	316	651	960	1533	338	243	309	295	1988	2852
1959	62	125	287	617	1072	1670	417	327	331	317	1752	3056
1960	60	120	270	566	1099	1740	523	384	361	344	2313	3154
1961	60	115	281	538	1281	1792	656	444	355	345	2633	3234

Sources: Canada, Dept. of Northern Affairs and National Resources, Forest and Forest Product Statistics Canada, Ottawa: Queen's Printer, 1957, pp.17,23; Canada, DBS, Canadian Forestry Statistics 1961, Ottawa: Queen's Printer, 1962, pp. 14-15; Canadian Mineral Statistics, *loc. cit.*; Canada, Dept of Mines and Technical Surveys, The Canadian Minerals Yearbook, 1962, Ottawa: Queen's Printer, 1964, pp. 197, 388, 434; Davis, *loc. cit.*; Energy Supply and Demand Tables, *loc.cit.*

increased significantly over the period. While imports of petroleum have continued to be important, the reverse was true for natural gas where surplus production was exported towards the end of the period. These exports were made to the United States overland by pipeline. Canada's National Oil Policy has affected both imports of petroleum and domestic production. By this policy Canada was divided into two markets, Ottawa Valley west supplied from domestic production and Ottawa Valley east supplied by imports. The aim of this policy, which was achieved, was to increase the market for Canadian petroleum and thus increase domestic production.[12] Hydro-electric power production and use continued to increase over the whole period, with the surplus being exported to the United States.

The main substitutions have been from the use of solid fuels of wood fuel and coal to the use of liquid and gaseous fuels of petroleum and natural gas, and an increased use of electric power in relation to fuel energy.

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[12] Canada, National Energy Board, Annual Report 1963, Ottawa: Queen's Printer, 1964, pp. 8-10.

The rates of growth in 1946-1961 for individual sources of energy and total energy are set out below:[13]

Energy	Production	Consumption
Wood Fuel	-6.3%	-4.0%
Coal	-3.3%	-4.6%
Petroleum	23.4%	8.2%
Natural Gas	17.8%	14.6%
Hydro-Power	5.6%	5.8%
Total Energy	7.2%	2.85%

These rates of growth bear out the earlier statements in this section on the growth or decline of particular forms of energy. The high annual rate of growth of aggregate energy production (7.2%) was due to the increased levels of production of both petroleum and natural gas since 1947, and stresses the importance of Canadian energy production, particularly the production of petroleum and natural gas, to GNP in the post-war period.

During the period, energy consumption increased at an annual rate of growth of 2.85% while real GNP increased at an annual growth rate of 3.6%.[13] In the short run period, energy consumption increased at a lesser rate than did real

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[13] The rates of growth have been calculated using data in Table 2, and using the method of terminal years explained in Footnote 10.

GNP; whereas in the long run both rates were almost identical. This could indicate that energy is now being used more efficiently[14] than it was for a long period prior to World War II.

Exports and Imports of Energy - International trade in energy had an influence on the energy situation in Canada. The exports and imports of energy in the period are set out in Table 3, which shows the export and import relationship for all primary energy sources with the exception of wood fuel. This was not important in international energy trade, and is of declining importance in the energy situation in Canada. In this period, an unfavourable balance of trade existed in coal and petroleum, while a favourable balance existed for natural gas and hydro-electric power. Imports greatly exceeded exports for coal, while exports greatly exceeded imports for hydro-electric power. Exports of petroleum and natural gas have been increasing rapidly since 1952. The gap between imports and exports of petroleum have declined since that date, while exports of natural gas have exceeded imports significantly. Table 2 shows that Canada

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14 Efficiency in energy use is measured by the ratio between energy theoretically available in energy input and the lesser amount of energy output appearing as useful heat and work done. See Davis, *op. cit.*, pp. 361-364.

TABLE 3

EXPORTS AND IMPORTS OF ENERGY
CANADA, 1946-1961

Year	Coal (x 10^3 tons)		Petroleum (x 10^3 bbls.)		Natural Gas x 10^6 CF)		Hydro-Power (x 10^6 kwh)	
	X	M	X	M	X	M	X	M
1946	864	26,640	-	63,407	-	-	2,482	10
1947	720	30,306	-	68,447	-	-	2,066	53
1948	1,272	30,819	-	75,536	-	-	1,743	86
1949	432	19,879	-	73,935	-	-	1,757	31
1950	396	26,870	-	78,649	2	3,254	1,926	3
1951	432	26,351	342	83,283	4	3,699	2,376	9
1952	384	24,430	1,424	81,199	7,958	5,982	2,493	20
1953	255	23,265	2,507	79,477	9,408	6,097	2,424	181
1954	219	18,580	2,345	78,772	6,984	6,236	2,718	119
1955	593	19,743	14,834	86,678	11,356	11,166	4,434	158
1956	594	22,908	42,908	106,470	10,828	15,695	5,103	238
1957	396	19,476	55,674	111,905	15,731	30,551	4,830	833
1958	339	14,491	31,679	104,038	86,971	34,716	4,073	246
1959	474	14,236	33,362	115,289	84,764	11,913	4,582	512
1960	853	13,565	42,234	125,560	91,046	5,570	5,490	357
1961	939	12,307	65,222	133,249	168,180	5,575	4,180	1,394

Sources: Canadian Minerals Yearbook, loc.cit.; Canada, Dept. of Mines and Technical Surveys, A.Survey of the Petroleum Industry in Canada 1961, Ottawa: Queen's Printer, 1962, pp.74,85; Canada, DBS, Canadian Statistical Review Historical Summary, 1963 Edition, Ottawa: Queen's Printer, 1963, pp. 64-65.

continues to rely on imports to fill the gap between domestic energy production and consumption, but that the dependence on energy imports is decreasing year by year. While Canada has always had adequate energy reserves, there existed a mal-distribution as between the sources of energy in Canada and the areas of greatest use in central Canada thus making it necessary to import its energy requirements.

Energy Supply and Demand 1961

Table 2 shows that in 1961 both production and consumption of energy continued to grow following the economic decline in 1957, and that both variables increased substantially over the previous period. Production and consumption as reported in Table 2 are related to supply and demand. Production is the supply of energy in Canada in a given period of time. Consumption is the total demand for energy by Canadian users in a given period. Canadian production of energy is to meet the domestic demand for energy and to satisfy foreign demand. Canadian consumption is the demand for energy produced in Canada minus exports plus imports of energy.

The energy situation in 1961 can be described in terms of the changes which have taken place since 1946.

Firstly, the ratio of total production to total consumption of energy has increased from 41.5% to 81.5%. This stresses the increased importance of Canadian energy production in meeting domestic and external demand for energy. Secondly, hydro-electric power has increased in importance over the period. This importance can be measured by the changed ratio of consumption of hydro-electric power to total energy consumption which has increased from 6.8% to 10.7%. Finally, the use of energy has changed from a dependence on coal which in 1946 represented 55.5% of total energy consumed, to a dependence in 1961 on petroleum and natural gas which taken together represent 69% of total energy consumption, while coal consumption declined to 16.5% in this year.[15]

Provincial Supply and Demand - Provincial energy production and consumption are set out in Table 4. The regional energy situation in Canada resembles the world energy situation. In the world energy situation, there are energy surplus areas selling this surplus as a source

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[15] The source of the data used for analysis in this section is Table 2.

TABLE 4

CONSUMPTION AND PRODUCTION OF ENERGY
BY PROVINCES, 1961

(Units = 10^{12} B.t.u.'s)

Province	Coal Prod.	Coal Cons.	Petroleum Prod.	Petroleum Cons.	Natural Gas Prod.	Natural Gas Cons.	Electr.Power Prod.	Electr.Power Cons.	Total Prod.	Total Cons.
Newfndld.	-	4	-	38	-	-	5	5	5	47
P.E.I.	-	1	-	15	-	-	4	4	4	20
N.S.	116	49	-	74	-	-	6	6	122	129
N.B.	24	22	-	74	1	1	7	6	32	103
Que.	-	76	-	501	-	26	170	150	170	753
Ont.	-	326	7	661	15	134	119	130	141	1251
Man.	-	33	26	81	-	17	13	16	39	147
Sask.	60	40	329	100	28	37	9	7	426	184
Alta	55	23	986	155	444	163	13	13	1498	354
B.C., Y.T. &.N.W.T.	26	20	13	180	100	33	46	46	185	279
Totals	281	594	1361	1879	588	411	392	383	2622[a]	3267[a]

Source: Energy Supply and Demand Tables, loc. cit.

[a] Total production and consumption of energy in Table 4 does not exactly correspond to the figures in Table 2 because it shows electric power which is both hydro-electric power and thermal electric power, and because in some cases

of income, energy deficit areas with high levels of economic activity, whose energy needs must be supplied by other countries, and areas with a substantial supply of one or two forms of energy which influence the pattern of industrial development. The provinces of Alberta and Saskatchewan fall into the first group, the provinces of Ontario and Quebec into the second, and the provinces of Quebec and Alberta into the third.

Table 4 indicates that the provinces of Alberta, Saskatchewan, and British Columbia produced all forms of energy. All provinces had to get energy from outside the provinces to meet their consumption needs, with the exception of Alberta and Saskatchewan. The provinces of Ontario and Quebec are the greatest users of energy, and are the provinces with the widest gaps between use of energy and provincial production of energy.

Alberta leads in the production of petroleum and natural gas, with Saskatchewan being the next largest producer of petroleum. Ontario and Quebec are the largest consumers of petroleum. The relation of consumption of particular forms of energy to available supply can be seen by the preference for the use of petroleum and natural gas in Alberta and Saskatchewan which are the provinces with the greatest supply in Canada. All provinces produced electric power and for most provinces production and consumption of electric power were identical. Ontario and Manitoba had to rely on outside sources to meet demand. Quebec and Saskatchewan produced surpluses which were available for supply to neighbouring provinces and for export. The importance of hydro-electric power in Quebec rests in its abundance in that province and in the fact that it is the only source of energy in that province. Coal was not significant in Canada either in production or consumption. Nova Scotia was the leading producer in coal; while Ontario was the leading consumer of coal.

Energy Statistics and Energy Uses

Energy statistics in Canada are detailed and comprehensive in dealing with data on the production of energy but far from adequate in their treatment in the uses of energy. It would greatly assist economic analysis on the uses of energy if statistical data on such uses were as detailed and as comprehensive as those for production. The importance of adequate data on the uses of energy as an aid to analysis are stressed in the following comments:

> There still remains some awkward gaps and unanswered questions. Among these is the analysis of the diverse applications of electricity for which Professor Dales pleads. It scarcely seems possible to understand significant industrial trends unless we can trace how much electricity is used not only for different industries in different provinces, but also for different purposes.[16]

This does not mean that statistical data on the use of energy are wholly lacking. These data do exist but they are not as coordinated or as comprehensive as are those data dealing with the supply of energy. Statistics on the use of energy[17] are presented in two different ways: (i) a presentation which shows supply of energy by the different categories of supply, and the demand or use of energy by certain general categories such as domestic, commercial, industrial, exports and so on, and (ii) comprehensive data on the use of all types of energy for certain sectors of the economy such as mining, manufacturing, electric power production, railway transport, civil aviation, and in motor

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[16] Irene M. Spry, "Energy Sources in Canada: A Further Comment", The Canadian Journal of Economics and Political Science, Vol.24, May 1958, p.278.

[17] Ibid., pp.272-280. This article provides a survey of DBS and other publications on energy statistics on supply and demand of energy in Canada.

vehicle operation.

The first presentation suffers from several limitations. First, the breakdown on the different uses of energy for each form of energy is not the same from one energy source to another. Second, there is no guarantee that a use which may be reported for one source of energy is exactly the same for each form of energy, for example a category under coal use is domestic, while the categories under natural gas and electric are reported as residential and commercial and residential and farm respectively. Thirdly, some uses of energy are peculiar to a particular form of energy, e.g. the use of gasoline to internal combustion engines, and cannot be reported under other forms of energy. This makes it very difficult to compare the different uses of energy from one energy source to the next.

The second presentation is excellent in that it reports for each industry the use of all types of energy by quantities used in a given period and the costs incurred for the energy used, but this presentation covers only a small part of total economic activity. If these statistics could be extended to cover all kinds of economic activity, they would assist and facilitate economic analysis on the implications of energy supply and demand in the economy.

Table 5 sets out a presentation on the use of energy using the first method of presentation outlined above. It does not permit comparisons to be made of energy use from one type of energy to another, but it does give a picture of the main uses of the different forms of energy in Canada at a particular point in time, 1961.

Energy Reserves in Canada

A statement of energy reserves in Canada is made at a point in time and shows non-renewable energy in reserve for use in the future, and the extent of renewable energy, water power, available for development. Table 6 shows these data for 1963.

Such a statement is subject to certain limitations which should be taken into account when a statement is examined. Firstly, it is an estimate and should not be regarded as an absolute statement of actual reserves. Secondly, the reserves of non-renewable energy will be used up by current production but are also

TABLE 5

PERCENTAGE USES OF ENERGY BY MAJOR USES
CANADA, 1961

Coal	%[a]	Petroleum	%[a]	Natural Gas	%[a]	Electric Power	%[a]
Domestic	22.6	Motor gasoline	26.0	Residential and commercial	32.0	Residential and farm	19.0
Industrial	36.8	Middle distillates	27.0	Industrial	28.0	Industrial	58.0
Coal for coke	22.2	Heavy fuels	13.0	-	-	Commercial and other	11.0
Thermal electric	9.6	Other products	10.0	Thermal electric	7.4	-	-
Coal loss and use in production	0.3	Refinery consump. fuel and losses	6.0	Pipeline fuel & distribution losses	2.6	Losses	8.0
Transportation	3.5	-	-	-	-	-	-
Exports	4.8	Exports	18.0	Exports	30.0	Exports	4.0

Sources: Energy Supply and Demand Tables, loc. cit.; Survey of the petroleum Industry in Canada in 1961, op.cit.; p.85; Canada, DBS, Electric Power Statistics 1961, Ottawa: Queen's Printer, 1964, p.12; Canada, DBS, Gas Utilities 1961, Ottawa: Queen's Printer, 1964, p.13.

[a] All percentages for each energy total 100.

TABLE 6

MEASURED AND INDICATED RESERVES OF NON-RENEWABLE ENERGY AND WATER POWER POTENTIAL CANADA 1963

NON-RENEWABLE ENERGY

ıergy	Measured and Indicated Reserves	1963 Production	Years of Supply
ɔal	30.8 billion tons	10.5 million tons	2,900
ıtural Gas	39,000 billion cubic feet	1070 billion cubic feet	36
ɜtroleum and ɹiquid Hydrocarbons	5.8 billion barrels	289 million barrels	20
ɜtroleum (Tar Sands)	300 billion barrels	-	-
:anium	207,000 tons	8,141 tons	25

RENEWABLE ENERGY

ıergy	Undeveloped Potential		
ıter Power	55,000 megawatts[a]		

Sources: R.B.Toombs, Canadian Minerals in National and Internationa ɜrspective, Ottawa: Dept.of Mines and Technical Surveys, 1964, (Report) p.3 .B.Lewis and T.G. Church, Electricity Supply in Canada and the Role of ıclear Power, a paper presented to the Third United Nations Conference on ıe Peaceful Uses of Atomic Energy, Geneva, Switzerland, 31Aug.-9 Sept.1964 .3.

[a] The estimate of undeveloped water power in Canadais at ordinary ıx-month flow. Ordinary six-month flow represents continued operation ıich can be assured during 6 months of the year on the assumption that the ɜficiency in power during the remainder of the year can be profitably :ovided from storage and other means.

increased by new discoveries and revisions of existing estimates. Similarly, undeveloped water power potential will be developed in time, but such potential may likewise be increased by revisions to these estimates because of better methods of stream-flow regulation, diversion of rivers, development of storage capacity, and other similar measures. Depending on the relation between the rate of production and the rate of discovery for non-renewable energy, and also depending on the rate of development and the revisions made to existing estimates of renewable energy, these reserve estimates may either be growing or declining over time. In Canada, for example, reserves of petroleum and natural gas have continued to grow because annual production was much less than the revisions made due to new discoveries and revised estimates of existing reserves. Finally, the extent of the reserves should be related to the cost of production. If costs were no object, it would be possible to show much higher reserves of non-renewable energy and to imply quite incorrectly, that all undeveloped potential of non-renewable energy could be economically developed even though some of these water power locations are too far from a market to be economically developed. In Table 6, the estimates of uranium reserves have definitely been related to the costs of production.[18] Although the actual costs of production are not known for the other forms of energy, they too have been related to production costs.

Coal reserves located in Alberta, Saskatchewan, and Nova Scotia are very large. In general, they are located too remote from the major consuming markets in Ontario and Quebec, and consequently require payment of transportation subsidies

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[18] While the estimate for uranium in Table 6 has been taken from Toombs, loc. cit., the estimate has been compared with that made in the paper prepared by J.W. Griffith and S.M. Roscoe, Canadian Resources of Uranium and Thorium, and presented to the Third United Nations Conference on the Peaceful Uses of Atomic Energy, Geneva, Switzerland, 31 August - 9 September 1964. This estimate was 188,000 metric tons as of Jan. 1, 1964, and constituted tonnages which could be exploited under present technology at a profit to operators at prices ranging from $11.00 to $22.00 (U.S.) per kilogram of U_3O_8 (uranium tetrafluoride). U_3O_8 is the unit of measure used in the uranium mining industry.

from the government. The measured and indicated reserves of 30 billion tons could not all be worked economically at the present time.[19]

Natural gas reserves are presently adequate to meet expanded consumption in the domestic market and expanded exports for a number of years. The measured and indicated reserves of 39 trillion cubic feet have been increased in 1963 by new discoveries of 1.3 trillion cubic feet and by 1.2 trillion cubic feet added as a result of revisions and extensions of existing fields.[20] Production in 1963 of natural gas amounted to about 1 trillion cubic feet.

Table 6 indicates that proven reserves of crude oil and natural gas liquids amount to 5.8 billion barrels in 1963. The addition to these reserves in 1962 was 600 million barrels while 1962 production was 268 million barrels.[21]

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[19] Commercial Letter, "The Canadian Oil Industry", Toronto; Canadian Imperial Bank of Commerce, July 1964, pp. 6-7.

[20] *Ibid.*

[21] The Canadian Minerals Yearbook, *op. cit.*, pp. 435,447.

As with natural gas, additions to reserves of crude oil and natural gas liquids have been much greater than the annual production.

One of the most promising aspects of Canada's energy reserves are those in the Athabaska tar sands. These sands hold between 600 to 700 billion barrels of which 416 billion barrels are recoverable to yield about 300 billion barrels of upgraded synthetic crude oil. The tar sand deposits have greater reserves than total World crude oil reserves which in 1961 were 275 billion barrels.[22] Several methods have been tried to extract the oil from the tar sands and found feasible. Production is expected to begin in September 1967 at a rate of 45,000 barrels a day.[23]

The latest estimate of undeveloped water power potential in Canada at ordinary six-month flow is 55,000 megawatts of available continuous power and is quite

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22 A survey of the Petroleum Industry in Canada in 1961, op. cit., p. 94.

23 Commercial Letter, Canadian Imperial Bank of Commerce, loc. cit.

substantial.[24] Not all of this potential will be developed. Some of the water power potential may go unused because its development may conflict with other forms of economic activity, e.g. the fishing industry in British Columbia and the tourist industry in other areas of Canada. The location of the water power resources, and the extent of these resources must be related to the proximity of a market large enough to absorb the electric power produced, e.g. it makes economic sense to develop a Hamilton Falls project to supply electric energy to the large electric energy market in Canada and in the northern states of the United States; and yet some water power resources may never be developed because they are located too remote from a suitable market. Then again, competing fuels may hinder the development of hydro-electric power, e.g. the cheap and abundant fuels in Alberta and Saskatchewan may limit the development of hydro-electric power sites located in these provinces.

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[24] For source of estimate see Table 6. The explanation of the six-month flow concept is given in note [a] in Table 6.

The Canadian Energy System

Energy in the economy is often discussed in terms of an "Energy System", i.e. the System whereby energy is produced, processed, transported, distributed, and used in the economy. The Energy System is concerned with the processes of energy supply, and with energy demand, i.e. the way that energy is used. It can be said that the Energy System consists of the sources, the flows, and the uses of energy. Each aspect is involved in and influences economic activity. Thus the economic effects of the Energy System can be studied with respect to energy supply and energy demand. Energy supply is equal to energy demand. This relationship can be expressed in the form of an identity which can be arrived at by examining the relationship between energy input and energy output. The input[25] to the Energy System is the amount of energy put into the Energy System, while the output[26] of energy is the amount of useful work rendered by this input. The input of energy will never

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[25] Palmer Coslett Putnam, Energy in the Future, New York: D. Van Nostrand Company Inc., 1953, p. 72.

[26] Ibid.

equal output of energy because of losses in production, in processing, in transportation, and in actual use; and in the diversion of energy materials to non-energy uses. The supply of energy is equal to the input of energy into the Energy System. The demand for energy equals the output of energy, all losses, and the non-energy use of energy materials. If the different factors are represented by symbols so that input is represented by I, output by O, losses by L, and non-energy uses by A, the energy supply: energy demand relationsip can be expressed by the following identity:

$$I = O + L + A$$

While the foregoing has been discussed in general terms, the Energy System and the identity showing energy supply: energy demand relationship can be applied to the Canadian situation.

The Energy System consists of a number of component energy systems, one for each type of energy used. These individual energy systems are alike with minor differences from one type of energy to another. A description of any one component energy system would describe all, and the energy system for coal is now described for this purpose.

The component energy system for coal is discussed in terms of the energy identity set out above: I = O + L + A. The supply side consists of all inputs of coal whether from domestic or external sources. Supply would include the input of primary energy produced in Canada plus the input of imported primary and secondary energy.[27] Economic activity associated with energy supply would include that involving the production of primary energy in Canada, the import of energy, and the processing of energy for the market. The supply side could also be called the sources of energy.

To supply coal, it is necessary to transport it from the sources of supply whether they are domestic or foreign for processing, and then for distribution to the market. The energy used in the economic activity associated with the movement of coal from the sources of supply through the different stages of processing and marketing to those areas where the energy is actually used is a flow of energy. These

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27 Imported secondary energy must be included because it is an input into the Canadian Energy System. Secondary energy produced in Canada from primary energy would not be included because it would be a duplication in that the primary energy from which it was produced has already been treated as an input into the Energy System.

energy flows tie the Energy System into one integrated whole.

On the demand side of the energy identity for coal are all of the sectors using coal in one manner or another. These include: (i) the sector called "losses"[28] which covers all losses of energy from production, processing, transportation of coal, and changing the energy in coal into useful work; (ii) a sector covering uses of coal as energy; (iii) a sector covering all non-energy uses of coal; and (iv) the sector covering the exports of coal.

The Energy System in Canada thus consists of the component energy systems for wood fuel, coal, natural gas, petroleum, electric power, and other forms of energy which may be used in the future.

The statistical outline in this Chapter, and the description of the Energy System which shows the sources, flows, and uses of energy provide a background for the analysis of the economic effects of energy supply and energy demand in Canada following in the next two chapters.

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[28] A sector on "losses" is required in each energy equation to balance energy supply and energy demand.

CHAPTER II

ENERGY SUPPLY AND CANADIAN ECONOMIC DEVELOPMENT

This chapter will analyze the economic effects of energy supply in Canada in 1946-1961, when Canada reached economic maturity,[1] achieved a stage of industrialization which was new and unique in its economic development, and had a high and sustained rate of economic growth,[1] which slowed down at the end of the period. The analysis will deal with the role of energy supply in Canada's economic development; the economic implications of the development of nuclear power; the effect of energy supply on industrial location;and the external economies and diseconomies of energy supply.

Energy Supply and Canada's Economic Development

Energy supply means economic activity associated with the production of energy in Canada, and with importing

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[1] W.W. Rostow, The Process of Economic Growth, New York: W.W. Norton & Co. Inc.,1962, pp. 318,319,321. Economic maturity is defined by Rowtow as: a period when society has effectively applied the range of (then) modern technology to the bulk of its resources. Economic growth, as considered above, is the increase in real GNP over time.

energy. Most of the economic activity in energy production in Canada is carried out by the following industries:

Industries producing fuel:

(i) the coal industry,

(ii) the petroleum and natural gas industries;

Industries engaged in energy product manufacturing:

(i) the petroleum and coal products industries;

Industries producing and/or distributing energy:

(i) The electric power utilities,

(ii) The gas utilities.[2]

The production of energy in Canada requires the use of factor inputs, and by their use energy production contributes to economic activity and economic development. The economic impact of energy supply can be analyzed with respect to its effect on employment, output and income, the balance of payments, regional economic development, investment, and other aspects of economic activity.

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[2] Gas utilities are mainly concerned with the marketing of natural gas in Canada. Canada, DBS, Gas Utilities (Transport and Distribution Systems) 1961, Ottawa: Queen's Printer, 1964, p.13.

The Effect of Energy Production on Employment

Because labour is a factor input, the effect of energy production on employment in the energy supply industries can be measured. The energy supply industries are those producing coal, petroleum, natural gas, petroleum and coal products, and electric power; and operating oil and gas pipe lines. Total annual employment in these industries increased gradually from 65,000 in 1946 to 80,000 in 1953, and gradually declined to 68,000 in 1961.[3] Annual employment in energy supply has been expressed as a percentage of employment in all economic activity each year to measure the percentage contribution of such employment to total employment. The contribution increased from 1.4% in 1946 to 1.78% in 1954, and then declined to 1.36% in 1958 and to 1.13% in 1961. The average contribution by employment in energy supply to total employment was about 1.4% over the whole period. The declining employment in the energy supply industries was caused in large part by the technological changes

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[3] These data have been rounded, and were taken from: Canada, DBS, Central Electric Stations, 1946-1953; Electric Power Statistics, 1954-1961; General Review of the Mining Industries, 1949-1961; General Review of the Manufacturing Industries, 1946-1960, Ottawa: Queen's Printer.

in production in the past several decades which resulted in the substitution of mechanical energy for labour,[4] and the structural change in fuel energy supply which resulted in the expansion of the capital-intensive petroleum and natural gas industries. Declining employment and growing output in the energy supply industries[5] have increased their output per worker. Output per worker can be measured in several ways among which is the measure in dollar value of output in constant or current dollars. Because energy can be expressed in terms of a common denominator, it is possible to measure the productivity of workers in energy supply in real terms[6] by relating their employment to the energy they produce as a commodity. This measure is developed and explained in the following section as the concept of energy output per worker in the energy supply industries.

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4 Canada, Economic Council of Canada, Economic Goals for Canada to 1970, Ottawa: Queen's Printer, 1964, p.153.

5 Table 2 shows that total energy production increased in 1946-1961 from 888×10^{12} to $2,633 \times 10^{12}$ B.t.u.'s in this period - an annual rate of growth of 7.2%.

6 This measure could be a more accurate measure of real output than a measure expressed in constant dollars because the latter method could include certain bias due to the deflators used.

Output of Energy Per Worker

The output of energy per worker in energy supply is obtained by dividing the total output of energy converted to B.t.u.'s and produced in a given period by the number of man-years of employment in the industry or industries producing this output in this period. This concept may be general or specific as to the man-years used, and aggregate or particular as to the energy output measured. It is general if total man-years of all employment in the energy supply industry or industries are used, and specific if only the man-years of production workers are used. It is aggregate if it measures total energy of all kinds produced, and particular if it measures the output of a particular type of energy.

Using this concept, aggregate energy output per worker has been measured for 1946-1961, and particular energy output per worker in 1961 has been measured for coal, petroleum and natural gas, and electric power industries. Aggregate energy output per worker increased from 13,150 $x\ 10^6$ B.t.u.'s in 1946 to 38,700 $x\ 10^6$ B.t.u.'s in 1961. This shows the overall increase in real output of the worker in energy supply in this period[7] in aggregate terms. Energy output per worker in 1961 was 27,000 x 10^6 B.t.u.'s for the coal industry, 465,000 x 10^6 B.t.u.'s for the petroleum and natural gas industries, and 9,050 x 10^6 B.t.u.'s for the electric power industry.[8] These measures show a high productivity for the petroleum and natural gas industries, and variations in productivity from one industry to the next. The low energy output per worker in the electric power industry can be explained by its high labour content. This high labour content is due to the scope of its productive activity which covers the whole process of energy supply from the production of electric power to distribution and marketing. In the coal, and petroleum and natural gas industries production is primarily concerned with producing commodities and not with distribution and marketing. If employment in these other phases of production were included, the labour content of

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[7] The general concept is used to illustrate and compare.

[8] In calculating energy output per worker in aggregate and in particular, the total number of workers per year in each industry or group of industries was used as an approximation of total man-years of employment.

these industries would be higher and their energy output per worker would be lower than those set out above. Thus the concept of energy output per worker can be used in the energy supply industries to measure real output or productivity of the workers engaged in this production.

The Effect of Energy Production on Output and Income

Since energy supply involves the production of energy as a commodity, energy supply will have a direct and immediate effect on output and income. This analysis will measure the nature of this effect in 1946-1960, and relate this effect to changes in economic growth and cyclical changes in economic activity. The effect will be measured by the contribution made by value added in production[9] by

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[9] Canada, DBS, General Review of the Manufacturing Industries of Canada 1960, Ottawa: Queen's Printer, 1964, p.10. This publication defines value added by production as the value added to materials while they are in the establishment which alone is available for the payment of wages, salaries, rent, taxes, repairs, other charges and profits. To arrive at the National Accounts concept of GDP at factor cost, it would be necessary to subtract office supplies used, advertising, insurance, and other such services obtained from other businesses. While the concept of value added contains some duplications, it is nevertheless a useful measure for comparisons and analysis.

the fuel industries and the energy supply industries. The fuel industries are the coal, petroleum, and natural gas industries, whose output will be related to the output of the mining industry to assess the importance of fuel industry output to mining. The energy supply industries consist of the fuel industries as above, the petroleum and coal products industry, and the electric power utilities, whose output will be related to the output of the commodity producing industries, and to gross domestic product at factor cost. These relationships will measured in turn the importance of energy supply to total commodity production, and to total production of goods and services. For each relationship set out above, value added will be expressed as a percentage of the total output to which it is being compared. These percentage relationships have been set out in Figure 1 which is a semi-logarithmic chart showing the rate of growth over the period studied. In addition, the peaks and troughs in economic activity in 1946-1960[10]

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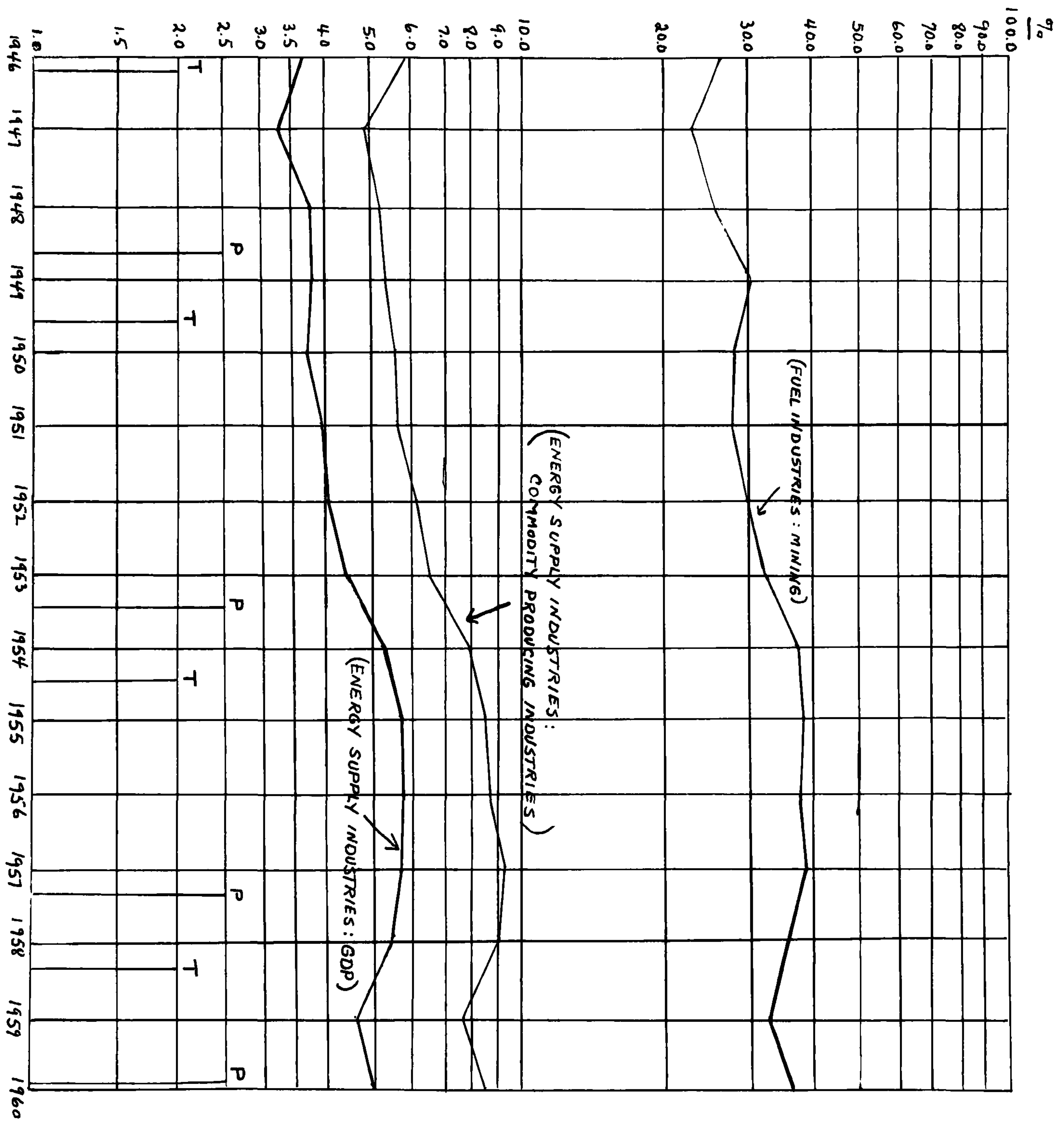
[10] These peaks and troughs in cyclical economic activity are set out in: Ronald A. Shearer, Monetary Policy and the Current Account of the Balance of International Payments, Ottawa: Royal Commission on Banking and Finance, 1962, p. 65.

FIGURE 1

PERCENTAGE RATIOS - FUEL INDUSTRIES OUTPUT:MINING INDUSTRY OUTPUT - ENERGY SUPPLY INDUSTRIES: COMMODITY PRODUCING INDUSTRIES AND TO GDP - 1946-60



Sources: Canada, DBS, Survey of Production, 1960, 1953-57, 1951-55 and 1948-52 issues; General Review of the Manufacturing Industries of Canada, annual issues of 1946-1960; General Review of the Mining Industry, annual issues of 1946-1960, Ottawa: Queen's Printer.

have been shown on Figure 1 to relate changes in the above named variables to cyclical changes in economic activity.

The contribution made by the fuel industries to the mining industry ranged between 23% to 40% over the period, and increased from 25% in 1946 to 35% in 1960. This contribution has shown fluctuations in the period. There was a significant rise from 1951 to 1957 and a significant decline from 1957 to 1959 with a rise thereafter. In conclusion, it can be said that the fuel industries have made a sizable contribution to the output of the mining industry and consequently to economic activity in the period.

The contribution made by the energy supply industries to the commodity producing industries ranged between 4.8% to 9.4%; while their contribution to GDP ranged between 3.2% to 5.9%. The fluctuations in contribution in each case resemble those already outlinedin the relationship of fuel output to mining output. The energy supply industries have made a considerable contribution to both commodity production and to total output of goods and services in the period 1946-1960.

Figure 1 shows that the trend line for each of the relationships set out above rises and declines with similar changes in economic activity as represented by the peaks and troughs set out in Figure 1, and that there has been a growth in all of these relationships over the period 1946-1960. In conclusion, it can be said that the contribution made by energy supply to output and income in 1946-1960 has increased along with an increase in economic growth,[11] butthat such contribution has fluctuated with changes in economic activity caused by the business cycle.

The Effect of Energy Production on the Balance of Payments

Tables 1 and 2 show that since 1870 Canada has had to rely on imports of energy to fill the gap between its

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[11] Indexes of Real Domestic Product by Industry of Origin 1935-61, op. cit., pp.67-68. This publication shows indexes of real output in all energy supply industries, in commodity production, and in GDP. All industries in energy supply, i.e. fuel industries, products of petroleum and coal, and electric utilities have increased faster than either commodity production or GDP; and the fuel industries have increased their output faster than did the mining industry. It follows that since growth in energy supply and the fuel industries has been greater in each case than the production to which it is being related, that contribution by energy supply has increased.

energy production and energy consumption. In the early years of 1946-1961, this reliance on imports of coal and petroleum was heavy and growing increasingly onerous as the pace of post-war economic development proceeded.

However, the discovery of substantial reserves of petroleum and natural gas was made by the blowing in of Leduc No. 1 by the Imperial Oil Company Limited on February 13, 1947.[12] The subsequent development of the petroleum and natural gas industries in Canada had a significant effect on Canada's domestic energy supply situation and on its balance of payments. This section is an analysis of the effects on the Canadian balance of payments, particularly the balance as between Canada and the United States where most of the trade in energy has taken place.

Two concepts are important in the analysis of the effect on the balance of payments. These are the balance of energy and the balance of trade in energy.

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[12] Canadian Mineral Statistics 1886-1956, 1957. p.20. op.cit., p.20

The Balance of Energy - The balance of energy is the relationship between the exports and the imports of primary and secondary energy converted to B.t.u.'s as a common unit of measurement. It is a measure in real terms of the trade in energy.

The Balance of Trade in Energy - The balance of trade in energy is a monetary measure of Canada's trade in energy materials. It measures in current dollars the balance of payments effect of trade in energy.

Both the balance of energy and the balance of trade in energy are related. The first is an energy measure in real terms which shows either a country's dependence on imports of energy or its ability to export energy; while the second is a monetary measure which shows the current dollar effect on the country's balance of payment from international trade in energy.

The balance of energy and the balance of trade in energy for 1946-1961 have been set out in Tables 7 and 8. The Canadian balance of energy shows the individual balances for coal, petroleum, natural gas, hydro electric power, and total energy. The balance of trade in energy has been compared each year with the balance of merchandise

TABLE 7

BALANCE OF ENERGY - CANADA
SELECTED YEARS 1946-61
(Units = 10^{12} B.t.u.'s)

Year	Coal and Prods			Petrol & Prods			Natural Gas			Hydro-Power			Total		
	X	M	Bal	X	M	Bal	X	M	Bal	X	M	Bal	X	M	Bal
1946	24	735	-711	6	58	-52	-	-	-	8	-	+8	39	794	-755
1951	17	747	-730	2	645	-643	-	4	-4	8	-	+8	27	1396	-1369
1953	12	647	-635	15	641	-626	-	6	-6	8	-	+8	36	1295	-1259
1955	21	553	-532	90	578	-488	-	11	-11	13	-	+13	125	1144	-1019
1957	15	551	-536	333	828	-495	16	30	-14	16	1	+15	380	1412	-1032
1959	17	404	-387	201	856	-655	84	11	+72	15	1	+15	318	1273	-955
1961	31	73	-42	385	932	-547	168	5	+162	15	1	+15	600	1013	-413

Sources: Canada, DBS, Trade of Canada, Vol. II - Exports and Vol.III Imports for the years indicated in Table 7.

TABLE 8

BALANCE OF TRADE IN ENERGY
CANADA 1946-1961
(in millions of dollars)

ear	Exports	Imports	Balance of Trade in Energy	Balance of Merchandise Trade	Balance on Current Account
946	18	254	- 236	+ 571	+ 363
947	17	356	- 339	+ 188	+ 49
948	27	503	- 476	+ 432	+ 451
949	17	430	- 413	+ 293	+ 177
950	17	495	- 478	+ 10	- 334
951	17	539	- 522	- 147	- 517
952	28	507	- 439	+ 489	+ 164
953	22	508	- 443	- 58	- 443
954	20	457	- 432	+ 13	- 432
955	58	489	- 431	- 211	- 689
956	138	562	- 424	- 728	-1366
957	184	591	- 407	- 594	-1455
958	103	502	- 399	- 179	-1131
959	118	514	- 396	- 422	-1504
960	146	488	- 342	- 148	-1243
961	233	478	- 245	+ 173	- 982

Sources: Canada, DBS, Trade of Canada, Volumes I, II, III for :he years indicated, and

Canada, DBS, The Canadian Balance of International Payments, .961 and 1962 And International Investment Position, Ottawa: Queen's 'rinter, 1964, p.118.

trade and with the balance on current account.

The balance of energy has shown an improvement over the whole period. While there has always been a deficit which worsened between 1946 and 1950, the balance has shown a significant improvement from 1950 to the end of the period. Coal and coal products have shown a decline in both exports and imports with a significant decline in imports, following from the decline in both consumption and production of coal in Canada. The balance of energy for coal is symptomatic of the declining importance of coal in 1946-1961. Its decline and replacement by petroleum and natural gas have been factors in improving the balance of energy for Canada. Canada relied heavily on the imports of petroleum and petroleum products until 1955. Thereafter both exports and imports have increased to the end of the period with a decline in both exports and imports after 1957 and recovery from 1959. Domestic production of petroleum has become more important in Canada to substitute for imports and to increase exports. Both factors have improved the balance of energy for petroleum and the general balance of energy. From 1955, Canada greatly expanded its domestic production of natural gas. The process of import substitution by domestic production has proceeded to the point in Canada where imports are now quite small. Associated with this substitution has been a substantial increase in the exports of natural gas to the United States. The substantial increase in exports and the virtual elimination of imports have resulted in a sizable surplus in the balance of energy for natural gas and contributed to improving the balance of energy. Canada always had a surplus in its balance of energy for hydro-electric power. The decline of coal, the improved balance for petroleum, the surpluses in natural gas and in hydro-electric power have been underlying factors in improving the balance of energy in Canada in the period 1946-1961.

The balance of trade in energy as shown in Table 8 illustrates the impact of this particular aspect of Canada's external trade on Canada's balance of payments. The balance of trade in energy has been in a deficit position for the whole period, but this deficit has declined since 1951 because the trade position for energy has improved since. The average annual deficit in the balance of trade in energy over the period was $402 million while the comparable deficits for merchandise trade and current account were $20 and $555 millions respectively. While the trade in energy has improved since 1951, it has been a burden on Canada's balance of payments over the whole period. The improvement in this balance and the subsequent relief on Canada's balance of payments has followed from the structural shift in energy production in Canada to oil and natural gas, and the subsequent development and expansion of Canada's production of these energy sources in this period.

The Effect of Energy Production on Regional Development

In Canada, the supply of fuel energy is unevenly distributed over the country, and the economic impact of fuel energy production is different from one province to another. The provinces of greatest fuel energy use are not the same as the provinces with the greatest supply. Hence, the supply and use of fuel energy have been important factors in Canada's regional development in that its production has contributed to economic activity in the provinces of supply, and its availability in Canada permits its use in the provinces of greatest industrial activity and contributes to their continued industrial development.

The distribution of water power potential is uneven over the country, but not to the degree of fuel energy sources. Also, water power potential is very important in Quebec, which has no other source of energy within the province.

This analysis will deal with the impact on output and on employment in each province by coal, petroleum and natural gas industries, and the electric power industry. Production is measured by the value added in production,[13] and employment by the average number of workers employed each year in each of the industries named above.

Table 9 shows value added in 1960 by energy production, while Table 10 shows employment in 1960 in these industries.[14] In Table 9, value added in energy production in each province is compared to provincial value added in commodity production, and is expressed as a percentage of such production. This percentage relationship will be used to study the effect of energy production on provincial output as represented by the value added by

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[13] For an explanation of value added in production see Footnote 9, Chapter II.

[14] 1960 is the latest year for which data are available for all of the industries concerned in this study.

TABLE 9

VALUE ADDED BY ENERGY PRODUCTION IN
PROVINCES OF CANADA - 1960
(in millions of dollars)

Province	Coal	Natural Gas & Petroleum	Electric Power	Value added Total Energy	Net Value of Commodity Production	Percentage of value added Energy:Commodity Production
Newfld	-	-	10.3	10.3	242.6	4.0%
P.E.I.	-	-	2.0	2.0	50.4	4.0%
N.S.	34.2	-	23.5	57.7	430.0	13.0%
N.B.	6.4	0.1	18.6	25.1	346.8	7.0%
Quebec	-	-	229.0	229.0	4955.2	4.5%
Ontario	-	7.1	302.1	309.2	7959.8	3.9%
Manitoba	-	10.5	33.9	44.4	746.8	6.0%
Sask.	3.2	105.6	32.3	141.1	1023.3	14.0%
Alberta	9.7	321.4	48.5	379.6	1565.5	24.0%
B.C.	4.7	8.2	91.9	104.8	1861.8	5.6%
NWT & YT	-	0.2	3.5	3.5	36.3	9.7%

Sources: Canada, DBS, The Coal Mining Industry 1960, Ottawa, Queen's Printer, 1961, p.7: Canada: DBS, The Crude Petroleum and Natural Gas Industry 1960, Ottawa: Queen's Printer, 1962, p.4: Canada, DBS, Survey of Production 1960, Ottawa, Queen's Printer, 1962, pp. 19, 26.

TABLE 10

EMPLOYMENT IN ENERGY PRODUCTION IN
PROVINCES OF CANADA - 1960

Province	Coal	Natural Gas & Petroleum	Electric Power	Total Energy	Total Number of Persons Employed ('000's)	Percentage of Total in Energy:to Total Employed
Newfld.	-	-	602	602	45.2	1.3%
P.E.I.	-	-	172	172	5.8	0.3%
N.S.	7864	-	1603	9466	91.5	10.3%
N.B.	853	18	1124	1955	66.6	2.9%
Quebec	-	8	10133	10141	830.1	1.2%
Ontario	-	226	18312	18538	1188.6	1.5%
Manitoba	-	96	2599	2695	140.6	1.9%
Sask.	259	868	2313	3440	71.8	4.8%
Alberta	1727	3882	1749	7358	166.8	4.4%
B.C.	878	255	2267	3410	258.9	1.3%
NWT & YT	6	11	185	442	-	-

Sources: The Coal Mining Industry 1960, op.cit. p.10; The Crude Petroleum and Natural Gas Industry 1960, op. cit. pp.4,15; Canada, DBS, Electric Power Statistics 1960, Ottawa: Queen s Printer, 1962, p.15; Canada, DBS, Employment and Payrolls June 1960, Ottawa: Queen's Printer, 1960, p.6.

commodity production in each province. In Table 10, annual average employment in the energy supply industries for each province has been expressed as a percentage of total employment in the Industrial Composite[15] of each province, which is used to represent total employment in all economic activity in each province. The relationship between these two will be used to study the impact of employment in energy supply on employment in each province.

An examination of the percentage relationship of value added in energy production to value added in commodity production shows that the largest impact occurs in Alberta, Saskatchewan, and Nova Scotia where the contributions were 24%, 14%, and 13% respectively. In all other provinces, the contribution by energy production was smaller and of less consequence. The contribution by energy production to

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[15] Industrial Composite consists of forestry, mining, manufacturing, construction, transportation, storage, communications, public utilities, trade, finance, insurance, real estate and services. See: Canada, DBS, Employment and Payrolls June 1960, Ottawa: Queen's Printer, 1960, p.8.

provincial value added by commodity production ranged from 3.9% to 24.0%, and was important in provincial production. Since the net value of commodity production, as set out in Table 9, is a measure of the level of industrial activity, it can be said that energy production, particularly fuel production, had the greatest impact on the economic activity of those provinces with the greatest supply and production of fuel energy, where the level of industrial activity was considerably less than Ontario and Quebec.

The impact of employment in energy production on total employment in each province followed a similar pattern. The impact was greatest in Nova Scotia, Saskatchewan and Alberta where employment in energy production, particularly fuel production, was 10.3%, 4.8% and 4.4% of total provincial employment respectively for 1960. These provinces are those with much lower levels of industrial activity than either Ontario or Quebec.

Energy production, particularly fuel energy production, had a differential impact on regional economic activity because it was greatest in those provinces with the greatest supply of fuel energy where industrial activity was considerably lower than Ontario and Quebec. The supply of fuel energy within these provinces has been an element of economic strength.

The Effect of Energy Production on Investment

Energy production requires investment, which has direct and indirect effects on the levels of employment and income in Canada. The economic effects of such investment will be examined and analyzed in the following ways: (i) the contribution of investment in energy production to total investment, (ii) the relationship of new investment in energy production to output in the energy supply industries, (iii) foreign investment in the energy supply industries, and (iv) the return on invested capital in profitable companies engaged in the supply of energy.

Contribution by Investment in Energy Supply to Total Investment

The purpose of analysis in this section is to assess the importance of investment in the energy supply industries as a contributing factor to total employment and income in Canada. This is done indirectly by first relating total investment to GNE to show its importance as a contributing factor to this economic variable, and then by relating investment in energy supply to total investment. Total investment made by all sectors in Canada in the period 1953-1961 varied between 24.9% and 30.6% of GNE.[16] This shows its importance as a contributing factor to total employment and income in Canada for this period. Table 11 which sets out total investment and investment in the fuel and power industries (energy supply industries) for 1953-1961 shows that investment in energy supply varied between 12.0% and 17.9% of total investment and that variations in the levels of investment in energy supply followed similar variations in total investment. This shows the importance of investment in energy supply industries as a component in total investment, and indirectly measures the contribution made by such investment to total employment and income in Canada in this period.

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[16] Canada, Dept. of Trade and Commerce, Private and Public Investment in Canada Outlook 1962, Ottawa: Queen's Printer, 1962, p.5.

TABLE 11

INVESTMENT IN THE FUEL AND POWER INDUSTRIES
RELATED TO TOTAL INVESTMENT, CANADA, 1953-1961
(in millions of dollars)

Year	1953	1954	1955	1956	1957	1958	1959	1960	1961
Fuel & Power Investment	785.4	707.3	791.7	1195	1559	1329	1044	992	1089
Total Investment	5841	5620	6350	8022	8717	8364	8417	8262	8109
% of Investment in Fuel & Power to total investment	13.4	12.6	12.5	14.9	17.9	15.9	12.4	12.0	13.4
% of total Investment to G.N.E.	26.2	25.3	26.3	29.7	30.6	28.6	27.1	25.9	24.9

Source: Annual issues of Canada, Dept. of Trade and Commerce, Private and Public Investment in Canada, Ottawa: Queen's Printer.

The Relationship of New Investment to Output in the Energy Supply Industries

In this section, the capital:output ratios in the energy supply industries in Canada for 1946-1960[17] are computed not only to show the relationship between new investment and output in each of these industries, but also to show which of the energy supply industries are heavy users of capital. The capital:output ratios are computed by relating annual new investment to the annual output in each industry, and then averaging these annual ratios over the whole period. Annual output in each industry will be represented by its value added in production.[18] The ratios computed for the coal industry, and the petroleum and natural gas industries are for industries concerned with the extraction of energy, the ratio in the petroleum and coal products industry for an industry concerned with the manufacturing of energy, while that in the electric power industry is for an industry concerned with the whole process

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[17] The analysis does not go beyond 1960 because statistical data are not available for all industries after that year.

[18] For a definition of value added in production see Footnote 9.

of energy supply from extraction of energy to distribution and marketing.

The capital:output ratios computed by using the above procedure for the energy supply industries are set out as follows:

Industry	Ratio of Investment to Value Added
Petroleum and natural gas	1: 1.53
Electric powr	1: 1.03
Coal	1: 14
Petroleum and coal products	1: 3.50

These data show the average relationship between investment and output, as value added, in each energy industry for 1946-1960. Thus, $1,00 in new investment in the petroleum and natural gas industries resulted on the average in $1.53 in output, in electric power $1.00 of investment gave $1.03 in output, in the coal industry $1.00 of investment gave $14.00 in output, while in the petroleum and coal products industry $1,00 in investment gave $3.50 in output.

The above summary also shows that the electric power, and petroleum and natural gas industries are heavy users of capital because their capital:output ratios are low, while the other two are not, because their capital:output ratios are high. It is not possible to determine the size of this ratio from the stage of energy production, because it varies within the extraction stage and between the extraction and manufacturing stages. It is the nature of the energy production process that determines the amount of capital required. This can be seen in the electric power industry with its heavy capital investment in plants, dams, transmission lines, and production equipment; and in the petroleum and natural gas industries with their heavy capital investment in extraction and processing plants, and in oil and gas pipelines.

Foreign Investment in the Energy Supply Industries

In Canada, foreign investment has concentrated in one area of energy supply - the petroleum and natural gas industries. Foreign ownership and control[19] in these industries in 1961 came to 60% and 69% respectively. Since 1956, however, the trends in non-resident ownership and control in these

[19] Canadian Balance of International Payments, 1961 and 1962, op. cit., pp. 95-97. Foreign ownership is ownership by non-residents of equity and debt instruments in a Canadian concern. Foreign control is the potential control by non-residents of Canadian concerns through stock ownership and includes concerns controlled with less than 50% ownership of stock.

industries have declined.[20] Foreign investment in the petroleum and natural gas industries in 1956-1961 varied between 14.6% and 17.1% of total foreign investment made each year in Canada. Only the manufacturing industries attracted a greater share of the annual inflow.[20] The foregoing data on foreign investment, ownership, and control in the petroleum and natural gas industries shows the importance of foreign investment to these industries, and its importance in promoting their development in Canada.

An estimate of the return on U.S. direct investment in the petroleum and natural gas industries in Canada was made by relating the annual income payments made to U.S. residents holding direct investments to the total U.S. direct investment in these industries. The estimate showed that the return was 1.5% in 1959 and 2.4% in 1961.[21] This

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20 *Ibid.*, The declining trends are shown on pages 133 and 134. Page 130 shows that foreign investment in manufacturing (excluding petroleum refining) was about 27%-29% in 1956-1961.

21 U.S. Dept. of Commerce, *Statistical Abstract of the United States 1961*, Washington: U.S. Government Printing Office, 1961, p. 867; *Statistical Abstract of the United States 1963*, Washington: U.S. Government Printing Office, 1963, p. 856.

estimate measured only the return on U.S. direct investment, and did not include the return on U.S. portfolio investment in these industries, or earnings reinvested in Canada, and for these reasons the return is understated.

The economic effects of foreign investment in the petroleum and natural gas industries in Canada can be seen by the impact on the domestic economy and on the balance of payments. The domestic effects are the impact on employment and income from the increased production of petroleum and natural gas, and the stimulation of other aspects of economic activity. The effects on the balance of payments are the improvement in the relationship between exports and imports of energy, and the effect on the balance from the payment of interest and dividends. The return on investment estimated above is low and even if higher would not be a burden on the balance of payments, but an increase in such payments over time could cause problems on future balances. The future will have to show whether the improvement in the balance of energy trade has been more beneficial than the payments on the investments needed to create this trade.

The Return on Invested Capital in Profitable Companies in Energy Supply

The analysis of investment in the energy production industries would not be complete without an examination of the return on invested capital in these industries. In this analysis, invested capital consists of the outstanding capital stock and surplus, as well as bonds, debentures, notes or other contractual obligations having a term of greater than a year. The return is the percentage return on total invested capital by profitable Canadian companies engaged in different aspects of energy production. The returns are for 1962, and are set out in Table 12. The percentage returns ranged from 3.1% in the coal industry to 10.1% for retail fuel dealers. The most profitable aspects of energy production were pipelines (8.2%), oil and natural gas (7.9%), electric power (5.1%), and gas distribution (4.7%); while coal with a return of 3.1% was lowest. In marketing of energy, the returns to retail fuel dealers were excellent, and the profits in wholesale trade were good (5.7%). The foregoing analysis shows that the returns on invested capital in the different phases of

TABLE 12

RETURN ON INVESTED CAPITAL IN PROFITABLE COMPANIES OF THE ENERGY SUPPLY INDUSTRIES CANADA, 1962.

Name of Industry	Number of Profitable Companies	Percentage return on total invested capital
Coal Mining Industry	41	3.1
Oil and Natural Gas	127	7.9
Total - Mining, Quarrying & Oil Wells	789	5.4
Petroleum Refineries	22	3.8
Other Petroleum and Coal Products	15	8.7
Total - Petroleum and Coal Products	37	3.9
Total - Manufacturing Industries	13,788	7.9
Pipelines	50	8.2
Gas Distribution	39	4.7
Electric Power	108	5.1
Total - Transportation, Storage, Communication and Utilities	3.109	5.0
Wholesale - Coal & Petroleum Products	332	5.7
Total - Wholesale Trade	11,659	10.0
Fuel Dealers (Retail)	389	10.1
Total - Retail Trade	13,167	9.7

Source: Commercial Letter, Toronto: Canadian Imperial Bank Commerce, December 1964, pp.6-8.

energy production were good being in excess of 3.1%, and that several of these aspects of energy production were good investment opportunities.

Indirect Economic Effects of Energy Production

Energy production in Canada has direct and indirect effects on economic activity. The direct effects have been analyzed in the preceding sections of this chapter. The indirect economic effects of energy production can be illustrated by the use of by-products, by the use of energy materials for non-energy purposes, and by the purchase of factor inputs by the energy supply industries.

The Use of By-Products and the Sulphur Industry

Sulphur called elemental sulphur[22] is produced in Canada from sour natural gas, sour crude oil, and metallic sulphide ores. The term sour used to describe natural gas and crude oil means that these materials contain hydrogen

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[22] Elemental sulphur is the element sulphur and is of high purity.

sulphide as an impurity which has to be removed before they can be used. In addition, equivalent sulphur[23] is produce from smelter gas, pyrites, concentrates and other sources. Until 1952, equivalent sulphur was the only domestic production of sulphur in Canada, and elemental sulphur had to be imported. As a result of the development and expansion of the natural gas industry in Canada, and because production includes a large share of sour natural gas from which hydrogen sulphide has to be removed, Canada has become a major producer of sulphur. In addition to the production of sulphur, sulphuric acid is also produced from hydrogen sulphide. As a result, the cost of exploration, production, and treatment of natural gas is shared by sulphur and sulphuric acid production and this lowers the cost of production.[24] Many crude oils contain sulphur as an impurity but Canadian crude oil does not in any significant degree. However, imported crude oils do contain sulphur

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[23] Equivalent sulphur is sulphur-containing material which is usable for some purposes in place of elemental sulphur.

[24] The Canadian Minerals Yearbook 1962, op.cit., pp. 543-544.

which is recovered in refining. Such production amounts to about 35,000 tons per annum, and is carried out at Saint John, N.B. and in Montreal.[25]

The first Canadian plant to recover elemental sulphur from natural gas was built in Alberta in 1952. Other plants have been built from time to time, but the production of sulphur did not reach significant proportions until large scale exports of natural gas were approved and continued to be made after 1960. In 1962, the number of plants in Western Canada had increased to seventeen with a productive capacity of 2,133,000 tons per year, and construction in the next two years may increase the capacity to more than 2,300,000 tons.[26]

The importance of sulphur production in Canada can be seen in the following data on the values and amounts of domestic production, imports, and exports contrasted in 1961 and 1962 and between 1953 and 1962. The value of elemental sulphur production was $7,287,881 in 1961 and

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25 *Ibid.*, p. 546.

26 *Ibid.*, pp. 539,543,547,548.

$9,286,999 in 1962, and exports were valued at $3,967,884 in 1961 and $6,649,943 in 1962.[27] Contrasting the terminal years in the period 1953 and 1962, the following important changes were noted for the sulphur industry:

(i) production of all types of sulphur increased from 377,148 to 1,244,910 tons;

(ii) production of elemental sulphur increased from 18,298 tons to 695,098 tons;

(iii) imports of elemental sulphur declined from 359,205 tons to 195,089 tons; and

(iv) exports of elemental sulphur increased from 4,633 tons to 400,026 tons.[28]

The changes in the values of production, imports, and exports of sulphur in 1961 and 1962 were a continuation in the trends in production and international trade established in 1953-1961.

A further important effect from the recovery of sulphur from natural gas was the increased production of

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27 *Ibid.*, pp. 540-541.

28 *Ibid.*

sulphuric acid[29] in Canada which is widely used in Canadian industry. Production of sulphuric acid increased from 822,608 tons in 1953 to 1,719,000 tons in 1962.[30]

As a result of the development and expansion of the natural gas industry in Canada and the production of a by-product of this natural gas production, sulphur, Canada has become a major world sulphur producer, and has produced all of its domestic requirements of sulphuric acid which is widely used in Canadian industry. Because of their low production costs, Canadian sulphur producers have been able to compete favourably in international trade as can be seen in the above data on sulphur exports.[31] The economic effects of the development of the sulphur industry in Canada can be seen in the increased production of sulphur,

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[29] Sulphuric acid is produced at one of the stages in the extraction of hydrogen sulphide from sour natural gas and its chemical change into sulphur.

[30] Ibid., p.551. Sulphuric acid is widely used in Canadian industry. The major users of sulphur acid in 1961 were in the manufacturing of industrial chemicals (833,400 tons); in the processing of uranium ores (283,300 tons); and in the manufacturing of mixed fertilizers (114,600 tons).

[31] Ibid., p. 544

the replacement of imports, and the increase in exports which have occurred in 1953-1962.

Non-energy Uses of Energy and the Petrochemical Industry.

Petrochemicals are chemicals produced from petroleum and natural gas. Such use is a non-energy use of energy materials. The growth of the petrochemical industry is directly tied in with the growth and development of the petroleum and natural gas industries in Canada.[32]

For many years, the production of organic chemicals in Canada depended on the output of coal tar products which was not adequate enough to supply the growing demand for these chemicals. This has changed with the development of the petroleum and natural gas industries.

The petrochemical industry has a double significance. Petrochemicals compete with other raw materials and have replaced vegetable products, animal fats, and coal tar in the production of organic chemicals. Also petrochemicals

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[32] G.E. McCormack, "The Petrochemical Industry in Canada," Canada, DBS, Canada Year Book 1962, Ottawa: Queen's Printer, 1962, p. 609.

have made many new products available which have significant effects on the Canadian economy. Two such products are synthetic rubber and plastics. Of the inorganic chemicals produced, sulphur and ammonia arethe most important.

About one hundred different organic chemicals are produced by the petrochemical industry as primary and secondary petrochemicals. Primary petrochemicals are those which are obtained directly from natural gas and petroleum, while secondary petrochemicals are produced from primary petrochemicals. Benzene, ethylene, and carbon black are three of the most important petrochemicals.[33]

Petrochemicals require a larger market than the domestic market in Canada to absorb the output which can be produced and part of the output must be exported. The main economic contributions of this industry have been its increased output and the resulting effect on employment and income, the substitution of imported petroleum and natural gas which are raw material inputs for Canadian produced inputs and the consequent improvement in the

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[33] Ibid., p. 612.

balance of payments, and the increase in exports of petrochemicals.

The development of the petrochemical industry in Canada illustrates a non-energy use of energy materials and an indirect economic effect of energy supply.

Energy Supply and Factor Inputs

The energy supply industries require factor inputs which are supplied by other economic units in Canada. The demand for and the use of these factor inputs stimulate economic activity in other sectors of the Canadian economy. Changes in output in the energy supply industries will affect economic activity in economic units supplying factor inputs to these industries, and in this way energy supply will have an indirect effect on other forms of economic activity.

To show how some industries can be affected as suppliers of inputs to the energy supply industries, data on the 1949 input and output of goods and services in Canada have been set out in Table 13.[34] The analysis

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[34] Canada, DBS, Supplement to the Inter-Industry Flow of Goods and Services, 1949, Ottawa: Queen's Printer, 1960, Table 1.

TABLE 13

INDUSTRIES SUPPLYING INTERMEDIATE INPUTS
TO ENERGY SUPPLY INDUSTRIES, CANADA, 1949

(values: in millions of dollars)

Energy Supply Industries and Input Suppliers	Value $
Coal Mining, Crude Petroleum and Natural Gas	
Transportation Equipment	3.4
Transportation, Storage and Trade	3.6
Electric Power, Gas and Water Utilities	4.2
Others	22.6
Total intermediate input	34.0
Electric Power, Gas and Water Utilities	
Coal Mining, Crude Petroleum and Natural Gas	8.2
Wood Products (excluding furniture)	5.4
Electrical Apparatus and Supplies	6.6
Products of Petroleum and Coal	9.4
Chemicals and Allied Products	7.6
Construction	26.1
Transportation, Storage and Trade	13.6
Electric Power, Gas and Water Utilities	92.3
Imports of Goods and Services	27.6
Others	15.2
Total intermediate input	212.0
Products of Petroleum and Coal	
Coal Mining, Crude Petroleum and Natural Gas	65.2
Products of Petroleum and Coal	25.1
Construction	3.0
Transportation, Storage and Trade	46.7
Electric Power, Gas and Water Utilities	3.2
Finance, Insurance and Real Estate	16.0
Imports of Goods and Services	266.0
Others -	49.0
Total intermediate input	476.0

Source: Supplement to Inter-Industry Flow of Goods and Services 1949, op.cit. Table 1.

shows which industries were significant contributors to the energy supply industries in 1949 and the extent of their dependence on energy supply. A significant contributor is taken to be any industry which supplied an input valued in excess of $3,000,000. The energy supply industries for this analysis are represented by three groups called: coal mining, crude petroleum and natural gas; and electric power, gas and water utilities;[35] and products of petroleum and coal, i.e. the extraction, production and marketing, and manufacturing phases of energy production respectively.

Table 13 shows that the energy supply industries as represented above depend on other industrial activity such as construction, transportation and chemicals and their own production to supply the factor inputs needed in energy production. These purchases of factor inputs by the energy supply industries have stimulated economic

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[35] Water utilities have been included because they are included in the <u>Inter-Industry Flow of Goods and Services 1949</u> in this way. See: <u>Ibid</u>., p. 22

activity in other economic areas in Canada, and their continuing demand continues to stimulate economic activity. The patterns of these economic inter-relationships will likely have changed considerably by 1961, but many of the same industries will still be supplying factor inputs and these and other suppliers to the energy supply industries will be affected to a far greater extent because of the greater level of activity in energy supply in 1961.

The Development of Nuclear Power in Canada

A major scientific breakthrough occurred during World War II in the development of the nuclear reactor to bring about the release of energy from the nucleus of the uranium-235 atom, to control this energy release, and to utilize the energy so released for scientific research and other purposes.[36] Canada participated in this development with the United States and the United Kingdom, and at the

[36] Two of the main uses under this category are the production of radioactive isotopes by the irradiation of non-radioactive elements in the reactor, and the use of the energy released by nuclear fission to produce electric power.

end of the war had a nuclear research establishment at Chalk River, Ontario. This establishment has continued to grow and is now the principal nuclear research establishment in Canada. It is operated by a government company, Atomic Energy of Canada Limited (AECL), and is staffed by a research team with a world wide reputation for original scientific work. It uses as its primary research facilities two major reactors, NRX and NRU, and the auxiliary reactors, ZEEP, PTR, and ZED-2.[37] AECL is now constructing a new research establishment at Whiteshell, Manitoba which will use an organic cooled, heavy water moderated uranium-fueled reactor called WR-1.

The development of nuclear power has been the major application of nuclear research in Canada. Canada's nuclear power programme uses the heavy water moderated and cooled[38]

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[37] For a brief description of these reactors see: Canada Year Book 1962, op. cit.,p. 336.

[38] Heavy water is used as a moderator to control the flow of neutrons released by nuclear fission in the reactor, and as a coolant to carry the heat generated by nuclear fission to a spot where heat energy can be transformed into mechanical energy.

natural uranium reactor. Present nuclear power capacity, that under construction, and planned consist of the following:[39] (i) a 20,000 kilowatt nuclear power demonstration generating station called NPD-2 at Rolphton, Ontario, operational in 1962; (ii) a 200,000 kilowatt power station at Douglas Point, Ontario called the CANDU reactor expected to be operational in 1966; (iii) a planned 1,000,000 kilowatt nuclear power capacity of two 500,000 kilowatt nuclear reactors of the CANDU design to be located at a site approved near Pickering, Ontario; and (iv) a planned 250,000 kilowatt nuclear power reactor to be located in the province of Quebec.

Canada has supplied a Canadian designed nuclear research reactor to India located at Bombay which became operational in 1960. A nuclear power plant with a capacity of 200,000 kilowatts is to be supplied to India for location in Rajasthan state. AECL is designing the nuclear portion of this plant, and Montreal Engineering Company Limited is

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[39] Canada, House of Commons Debates, Vol. 109, No. 183, Ottawa: Queen's Printer, Nov. 4, 1964, pp. 9792-9793.

designing the conventional part and is acting as a consultant to the Indian government in the construction of the station.[40] Negotiations are now under way between Canadian General Electric Company Limited and the Pakistan government for the supply of a 132 megawatt nuclear power station of Canadian design for location at Karachi.[41]

Canadian designed nuclear research and power reactors use natural uranium as fuel and heavy water as a moderator and coolant. Natural uranium is a Canadian resource. Heavy water has been supplied until quite recently from the United States. The demand for heavy water in the Canadian nuclear research and power reactor programme is now sufficiently large to warrant the construction of heavy water production capacity in Canada. Two plants will be constructed: (i) one at Glace Bay, Nova Scotia to be operated by Deuterium of Canada Limited with a capacity of about 200 tons of heavy water per year,[42] and (ii) the other at Estevan, Saskatchewan to be operated by Western

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40 *Ibid*.

41 *Ibid.*

42 Canada, *House of Commons Debates*, Vol.108.No 101 Ottawa, Queen's Printer, Dec 2, 1963, p.5314.

Deuterium Company Limited with a capacity of 300 tons of heavy water per year.[43] For each plant, the government of Canada will underwrite production for the first five years at the annual rates of production set out above.

Supporting the nuclear power programme is the uranium mining industry and the uranium fuel industry. There are three principal uranium producing areas in Canada: the east end of Lake Athabaska, Saskatchewan, and Elliot Lake and Bancroft in Ontario. Mining operations are for the greater part conducted by private companies supported by export contracts which have been stretched out to 1966. The revision of these contracts and the decline in the demand for uranium has closed down the less economical operations.[44] Present forecasts indicate a resumption of uranium mining after 1970 following increased demand as the use of nuclear power becomes more widespread in many parts of the world.[45] The production of uranium fuel is carried out in two stages. In the first stage,

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[43] Canada, House of Commons Debates, Vol.109, No. 220, Ottawa: Queen's Printer, Feb. 23, 1965, p.11620

[44] Canada Year Book 1962, op.cit., pp.333-334

[45] The Canadian Minerals Yearbook 1962, op.cit., p.605.

uranium oxide and metal are produced from uranium ore. This first stage is carried out by Eldorado Mining and Refining Limited, a government company, at Port Hope, Ontario. In the second stage, nuclear fuel is fabricated using either uranium oxide or uranium metal. The companies mainly concerned with uranium fuel production are Canadian General Electric Co. Limited at Toronto and Peterborough, and Canadian Westinghouse Company Limited at Port Hope.

The economic consequences of the development of nuclear power in Canada can now be examined within the framework of the foregoing summary digest of this programme.

The development of nuclear power has given Canada another source of energy. There is every indication that the use of nuclear power will compete with thermal electric power production using coal on a favourable cost basis.[46]

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[46] Canada, Atomic Energy of Canada Limited, AECL Review, Vol. 1. No. 4, Ottawa: Atomic Energy of Canada Limited, August-September, 1964, p.12. An estimate made in this publication indicates that a 500,000 kilowatt nuclear power plant will be competitive with an equivalent coal-fired plant in Southern Ontario and would produce electric power at a cost of just under 4.0 mills a kilowatt-hour. The cost of electric power produced in the coal-fired plant has been estimated at 4.0 mills a kilowatt-hour. The cost assumptions for the nuclear power plant and the coal-fired plant are set out in this publication.

Capital has been used for nuclear research and for research in the development of nuclear power. Expenditures have contributed directly to employment in this programme and to other economic units supplying goods and services required. A measure of the expenditures, income, and employment in the nuclear research programme, which also includes research in nuclear power, can be obtained by examining the changes in these variables for Atomic Energy of Canada Limited in a ten year period from fiscal year 1953-54 to 1963-64. In this period, all expenditures increased from $9,942,000 to $59,274,000, internal operating income from $1,203,000 to $2,243,000, commercial income from $868,000 to $4,403,000, and employment from 1,766 to 3,105.[47]

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[47] Canada, 1963-64 Annual Report Atomic Energy of Canada Limited, Ottawa: Queen's Printer, 1964, pp.26-27; 1953-54 Annual Report Atomic Energy of Canada Limited, Ottawa: Queen's Printer, 1954, pp.14-17. In 1963-64, expenditures for research and operation were: $31,458,000, and capital expenditures for buildings, works and equipment needed in research amounted to $13,466,000. The internal operating income mentioned is income earned from housing, accommodation, hospitals, transportation, and similar services provided by AECL to its employees. Commercial income is received from the sale of radioactive isotopes produced in the nuclear reactors at Chalk River. Most of the sales are for export. In addition to expenditures above, $14,350,000 was spent to finance construction of Douglas Point, and for housing at Pinawa, Manitoba.

The nuclear research programme and the development of nuclear power have directly stimulated other forms of industrial activity in Canada. Since the nuclear reactors use natural uranium as a fuel, their demand is reflected in production by the uranium mining industry. Hitherto this demand has been quite small and the main demand for uranium has been for exports to the United States and to the United Kingdom. These contracts have now been completed with the final deliveries stretched out to 1966. It is expected that the greater demand for uranium in Canada for its expanding nuclear research and power programme and expanding world demand for uranium will greatly influence the uranium mining industry in Canada in the future. Similarly, the demand for nuclear fuel and heavy water in the nuclear energy programme has resulted in the setting up in Canada of capacity for the production of nuclear fuel and heavy water. These are an increase to industrial capacity, a diversification of industrial activity, and a direct contribution to employment and output.

In the field of international economics, the development of nuclear research in Canada had several important economic consequences. The reactors supplied and the proposed supply of other reactors to India and to Pakistan call for the use of Canadian materials and services, and because of this demand contribute directly to economic activity in Canada. It should be mentioned that the first nuclear reactor supplied to India and located at Bombay was a contribution made by Canada to India under the Colombo plan, and represents foreign aid given by Canada to assist in the development of an emerging country. In addition, Canada has trained and is continuing to train Indian scientists to operate these complicated research facilities. Finally, the use of uranium for nuclear power production in southern Ontario is import-competing with coal from the United States now used in the thermal electric plants and will cut down on the imports of this fuel, and the export of uranium has been a significant factor in the balance of payments for Canada since 1955.

Other economic consequences of the nuclear research and power programme come from the training and education given to Canadian scientists and technicians, and from the experience gained in designing the complex research facilities used in nuclear energy research. Both aspects have beneficial effects on industrial activity in Canada. Trained personnel are provided not only for employment in nuclear energy research, nuclear power, and nuclear industrial activity, but also for other areas of industrial activity requiring a high degree of professional and technical competence. Similarly, the design experience gained in nuclear design enables Canadian industrial designers to deal with the increasingly complex problems of industrial design now existing and continuing to arise as more and more innovations are applied in the Canadian economy.

Other Economic Effects of Energy Supply

Energy supply has other economic effects on the Canadian economy, but all of these other effects are too numerous and far-reaching to be studied fully here. Instead two other economic effects of energy supply will be examined briefly. These are: (a) the effect of energy supply on the location of industrial activity, and (b) the external economies and diseconomies of energy supply.

With respect to the locational aspects of energy supply, J.H. Dales[48] has shown that hydro-electric power production in Quebec has been a factor in attracting industries to that province, that the type of industries so attracted are such that they require large inputs of electric power and low inputs of heat energy, and that electric power has not been a decentralizing factor to such industries within this region. Also P.R. Odell[49] has pointed out that while the petroleum industry per se does not have a strong locational pull on other industries as in the case of coal, there has been a development along the Gulf Coast in the United States of an industrial complex based on the local production and refining of oil and the associated production and use of natural gas in the chemical and other industries. The petroleum industry has then a locational attraction for specific types of

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[48] J.H. Dales, Hydroelectricity and Industrial Development Quebec 1898-1940, Cambridge, Massachusetts: Harvard University Press, 1957, pp. 191-194.

[49] Peter R. Odell, An Economic Geography of Oil, London: G. Bell & Sons Ltd., 1963, p. 208.

industrial activity. The same type of industrial complex of natural gas processing plants and petrochemical plants is appearing in the province of Alberta close to the natural gas fields, and in Sarnia and in Montreal.[50] The two main criteria which determine plant location are the cost of raw materials and fuel, and the cost of transporting products to the market. In conclusion, it can be said that the supply of energy can be a factor in industrial location particularly that type of industrial activity which may require a high input of a particular energy type whose supply is abundant.

Dealing with the external economies and diseconomies of energy supply, it can be mentioned to illustrate economies of energy supply that the development of hydro-electric power can be performed for multiple ends, i.e. a given project can provide hydro-electric power, aid navigation, prevent floods, reduce pollution in periods of low stream flow, provide irrigation, and regularize the water supply.[51]

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50 "The Petrochemical Industry in Canada", op. cit., p. 611.

51 J.F. Dewhurst, et. al., America's Needs and Resources, New York: American Book-Stratford Press Inc., p. 553.

With respect to the diseconomies, two illustrations can be made. First, the use of water resources for hydro-electric power is only one use of these resources. Its use in this way can have detrimental effects on the water levels of streams and lakes and consequently on animal and fish life and can promote pollution of water resources to have a detrimental effect on the resort and tourist industry by destroying the advantages of certain natural beauty spots. Second, the extraction of toxic hydrogen sulphide from sour natural gas and petroleum can, if it escapes, cause injury to vegetation and to the health of the population in the immediate area. There are other external economies and diseconomies of energy supply, but the examples given above indicate that these can and do occur and can have beneficial or detrimental economic effects on social and economic activity.

CHAPTER III

ECONOMIC EFFECTS OF ENERGY USE IN CANADA

This chapter will examine the use of energy in Canada for 1946-1961. First, the economic aspects of the aggregate use of energy will be analyzed, and then energy use in detail will be analyzed for different aspects of economic production, and in consumption.

Aggregative Analysis

Before examining the relationship between aggregate energy consumption and certain economic variables, it is necessary to establish that a relationship between the pairs of variables exists. Using correlation analysis,[1] the relationship between the following sets of variables was examined by years for 1946-1961: (i) aggregate energy consumption and population, (ii) aggregate energy consumption and persons working, (iii) aggregate energy consumption and real GNP. The following results were obtained:

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[1] The correlation analysis used was two-variable linear correlation. In each case, annual energy consumption in B.t.u.'s was correlated to annual population, to annual numbers of persons working in the civilian labour force,and to annual real GNP in constant 1949 dollars. Data on energy consumption was taken from Table 2, while the balance of the data is reported in Canadian Statistical Review,Historical Summary,1963, op. cit., pp.6,13,26.

Aggregate energy consumption to population - $r = +0.975$

Aggregate energy consumption to persons working - $r = +0.875$

Aggregate energy consumption to real GNP - $r = +0.975$

The coefficient of correlation (r) obtained in each case[2] shows that a high positive correlation exists between aggregate energy consumption and each of the economic variables set out above. As a result, it can be said that an increase in aggregate energy consumption can be explained in turn by an increase in population, by an increase in the numbers of persons working, and by an increase in the rate of economic growth as a result of an increase in real GNP, and by all of these factors acting together.

The rates of growth per annum for aggregate energy consumption and the economic variables set out above have been computed for 1946-1961, and are set out as follows:

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2 All results have been tested using the statistical t test where ($t = r\sqrt{N-2}/\sqrt{1-r^2}$). On the basis of this test, the null hypothesis that correlation between the sets of variables studied above was due to sampling error was rejected in each case at the 0.1% level of significance. For a description of the correlation analysis procedure and the t test see: Neiswanger, _op. cit._, pp. 663-688.

Aggregate energy consumption	-	3.3%
Population	-	2.5%
Persons working	-	1.7%
Real GNP	-	3.9%

Energy use per capita is obtained by dividing aggregate energy consumption in a particular year by the population of that year. The concept of energy use per capita is important because it is a rough measure of a country's stage of economic development,[3] and this measure relates energy use to population changes. In Canada, energy use per capita increased from 168 x 10^6 B.t.u.'s in 1946 to 177 x 10^6 B.t.u.'s in 1961. The annual rate of growth was about 0.14%, while real GNP per capita increased at an average annual rate of 1.3% over the same period.[4] In this period, the overall increase in per capita energy use has not been great, and its rate of growth has been much less than the rate of economic growth as measured by the growth in real GNP per capita.

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[3] John Davis, op. cit., p. 20. This points to the existence of a high correlation between the amount of energy used per capita in a country and its stage of economic development, with a high level of use being associated with a high level of economic development and vice versa.

[4] Economic Goals for Canada to 1970, op.cit., p.13.

The relationship between the growth rate of aggregate and per capita energy consumption to the rate of economic growth as set out above shows that energy consumption did not increase as rapidly as did the comparable rate of economic growth. The relative slower rate of growth in energy use can be explained by factors such as the use of more efficient forms of energy and a greater efficiency in energy use which would have the effect of economizing on energy use and so keep the growth rate of energy use in check.

W. A. Lewis has indicated that one of the three causes of economic growth is an increase in the use of capital and other resources per capita.[5] An increase in per capita use of energy in 1946-1961 has been shown above. Another way of looking at per capita energy use is to relate the use of energy to the number of persons working. This measure is obtained by first obtaining the amount of energy used in production in a particular year and then dividing this amount by the number of workers engaged in

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[5] W.A. Lewis, The Theory of Economic Growth, London: Allen & Unwin, 1955, p.11.

such production in that year. Since most of the energy used in Canada is for production, it is possible to get an approximation of this measure by dividing the total amount of energy used per year by the total number of workers employed in that year. Using this method of computation, the amount of energy used per person working in Canada increased from 448 x 10^6 B.t.u.'s in 1946 to 529 x 10^6 B.t.u.'s in 1961. The overall increase has been much greater than the increase in per capita terms, and its calculated rate of growth per annum, 1.2%, is very close to the 1.3% average annual rate of growth in real GNP per capita mentioned above. Following Lewis, it can be said that the increases in Canada in energy used per capita and per person working have been factors contributing to increased productivity and hence to increasing the rate of economic growth in the period studied.

Having related aggregate and per capita energy use to economic growth, the relationship of energy use and real GNP can be examined by using the concept of energy input per unit of GNP. This concept is a measure which shows the amount of energy used as an input per unit of real GNP in a given period of time.[6] It is computed by dividing total energy consumption expressed in B.t.u.'s in a given year by the dollar value of real GNP in that year. The value of this measure may be constant, increasing, decreasing, or it may fluctuate widely from year to year. Since this measure can be important to indicate a trend, it will be examined for two periods, 1870-1960 by decades and 1946-1961 by years. These values have been computed for these two periods, expressed as indexes and are set out in Figure 2. In 1870-1960, two distinct phases in this relationship occurred. The first phase, 1870-1910 was one in which the energy input per unit of real GNP increased constantly at an annual rate of 0.65% to reach a peak about 1910; while in the second phase this measure declined constantly at an annual rate of 0.8%. The situation in

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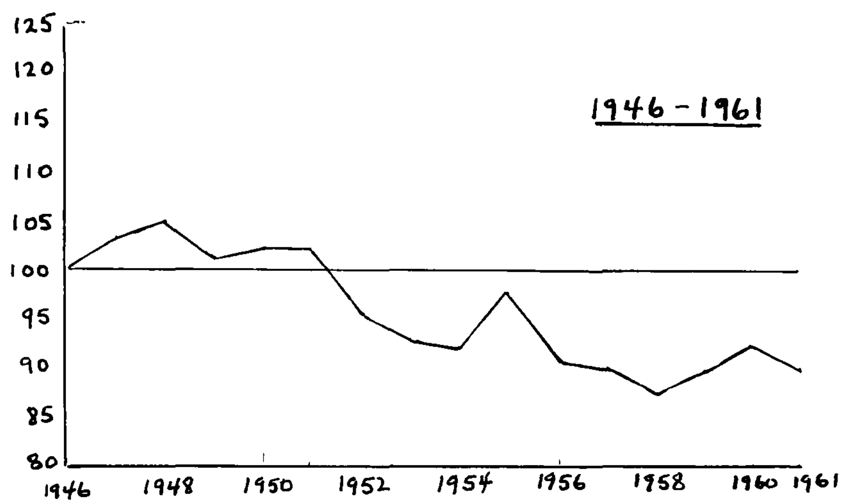
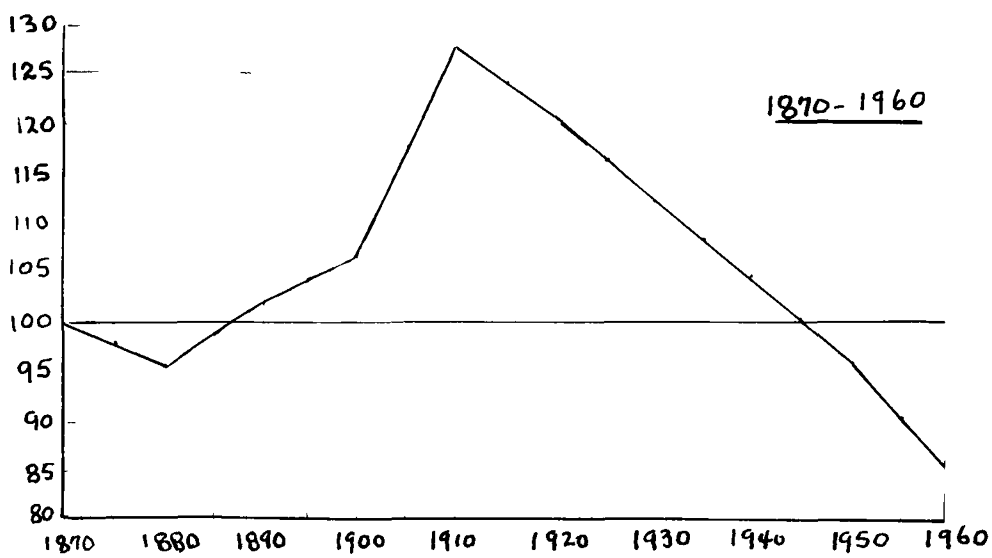
[6] Sam H. Schurr et al., Energy in the American Economy, 1850-1975, Baltimore, Maryland: The John Hopkins Press, 1960, pp. 16-17.

FIGURE 2

INDEXES SHOWING ENERGY INPUT PER UNIT OF GNP 1870-1960 and 1946-1961, CANADA





Source: Computations relating energy consumption to units of real GNP done by author.

Canada reflects a similar situation in the United States.[7] The decline in the relationship between energy input and real GNP since 1910 could be caused by a number of factors such as changes in the nature of the output produced, improvements in productive efficiency in Canada, increased efficiency in the use of energy, and increased use of more efficient forms of energy such as electric power, petroleum, and natural gas. The annual data for 1946-1961 show that energy input per unit of GNP continued to decline. This means that in the future the rate of growth of energy consumption will be less than the rate of economic growth, and that energy demand will not grow as rapidly as growth in economic activity. However, improvements in the efficiency of energy use will reach a technical limit[8] when further economies will not be possible,and there

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7 Ibid., In the United States energy input per unit of real GNP increased constanly (1880-1910); was constant in (1910-20); and showed a constant decline in (1920-1955).

8 There are various wastages and losses in energy use so that the quantity of energy entering the national energy system (input) exceeds the amount of energy effectively used (output). As improvements are made in the methods and devices for using energy, the margin between input and output is reduced. There are technical reasons why this margin can never be eliminated entirely, so that the efficiency in energy use will reach a limit and never be 100% efficient.

will come a time when demand will grow at a constant relationship to economic growth.

The foregoing analysis discloses a close correlation between aggregate energy consumption and population, the number of persons working, and increases in real GNP. It follows that when all of these factors increase at the same time, the effect on energy consumption will be much greater. Despite the effect on energy consumption by changes in these economic factors, it was shown that the rate of growth of energy use in both aggregate and per capita terms was less than the corresponding aggregate or per capita increase of economic growth. This indicates the existence of other factors contributing to the economic use of energy, among which could be changes in the nature of the output produced, improvements in productive efficiency, increased use of more efficient forms of energy, and increases in the efficiency of energy use by developing and using better energy-using devices. An analysis of the relationship between energy input to unit of real GNP further substantiates the conclusion that energy is being used more efficiently. Finally, it can be said that an increase in the use of energy per capita and per production worker associated with this trend in better efficiency of energy use were contributing factors to improving productivity and to increasing the rate of economic growth in Canada in the 1946-1961.

Micro-Economic Analysis

This part will analyze in detail the use of energy in production, i.e. its use in certain industries such as mining, manufacturing, electric power production, and transportation for which statistical data on energy use are available; and its use as a consumption good. In the analysis of energy used in production some of the aspects examined will be: trends in energy use, energy use in relation to output produced in the industry, energy use in relation to employment, and the cost of energy as a factor input. The analysis of energy used as a consumption good will deal with various effects inthe personal sector in Canada such as changing trends in home heating and in energy use, and the factors affecting energy demand in this sector.

Energy Use in the Mining Industry

Production in the mining industry, which consists of metals, non-metals, and fuels requires energy. The use of energy in this industry has been set out in Table 14 for 1953-1960.

Trends in Energy Use

The use of energy in the mining industry as a percentage of total energy used in Canada increased from 1.25% in 1953 to 1.88% in 1960 as a result of an 80% rise in output in this industry.[9] Use of energy in the mining industry has been fairly constant over the period responding only to increased productive activity. This industry is certainly not a significant user of energy. The use of fuels in this period has resulted in a substitution in the use of solid fuels such as wood and coal for the use of petroleum and

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[9] The Canadian Minerals Yearbook 1962, op. cit., p. 68. This publication shows that net production in the mining industry increased from $871 millions in 1953 to $1,579 millions in 1960, a percentage increase of 80%.

TABLE 14

USE OF ENERGY IN THE MINING INDUSTRY
CANADA, 1953-1960

(units = 10^{12} B.t.u. s and as shown)

	1953	1956	1957	1958	1959	1960
Wood Fuel	0.68	0.56	0.55	0.47	0.45	0.29
Coal & Coal Products	16.27	12.67	11.00	11.37	11.47	11.47
Petroleum & Products	6.13	11.82	13.51	15.38	18.66	19.17
Natural Gas	-	6.44	10.07	7.88	5.30	12.87
Electric Power	9.42	13.70	14.51	15.83	16.50	16.84
Total	32.50	45.19	49.64	50.93	52.38	59.20
Total Energy Consumption - Canada	2619	2922	2905	2852	3056	3154
Percentage: Energy Used in Mining to Total	1.25%	1.55%	1.70%	1.78%	1.71%	1.88%
Energy per unit of GDP by Mining Industry (x 10^5 B.t.u.'s)	0.42	0.386	0.397	0.408	0.380	0.426
Index: Energy per Unit of GDP (Mining	100	87	93	96	92	101
Employees in Mining Industry	89,576	103,068	107,572	103,909	103,985	97,571
Energy used per worker in Mining Industry (x 108 B.t.u.'s)	3.68	4.38	4.63	4.89	5.02	5.97

Source: Annual issues of DBS publications: General Review of the Mining Industry for the years indicated published by Queen's Printer and Controller of Stationery, Ottawa.

natural gas. Since liquid and gaseous fuels are more suitable for use in production processes and are more efficient, their increased use is a factor in increasing productivity in this industry. While the use of electric power has increased by about 80% in the period, there has been no change in the ratio of fuel to electric power use in mining.

Energy Use in Relation to Output

The use of energy in the mining industry will be related to its output as measured by its contribution to real GDP.[10] The amount of energy in B.t.u's used in the mining industry has been divided by this measure of its output to give the amount of energy input used in the mining industry per unit of its real GDP. These values

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[10] The values of real GDP by Mining Industry were computed by taking the value for 1949 as the contribution made to GDP by the mining industry which appears in: Canada, DBS, National Accounts Income and Expenditure 1926-1956, Ottawa: Queen's Printer, 1962, p.57. This value is then multiplied by the quantity indexes for the mining industry in: Indexes of Real Domestic Product by Industry of Origin 1935-61, op.cit., p.67 for each year to give the mining industry's contribution to GDP.

and an index based on them are set out in Table 14. Both show a declining trend in this relationship over the period studied with the exception of 1960 when an increase occurred. This increase is a fluctuation rather than a reversal of the trend and can be explained by the more rapid rise in output than the rise in energy use in this year.[11] The decline in this relationship shows that there has been an improvement in the efficiency of energy use in the mining industry in 1953-1960 in that less energy is now being used per unit of output.

Energy Use in Relation to Employment.

The amount of energy in B.t.u.'s used in the mining industry has been divided by the total number of workers per year in that industry to arrive at an average amount of energy used per worker. These values set out in Table 14 show an increase from 3.68 x 10^8 B.t.u.'s in 1953

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[11] Following 1957 in Canada there was a substantial decline in output in the mining industry with a recovery starting in 1959 and continuing into 1960.

to 5.97 x 10^8 B.t.u.'s in 1960. The greater amount of energy used per worker in mining means that on the average each worker had a greater command over energy in production. This has contributed to increased productivity in the industry.[13]

Cost of Energy as a Factor Input

The cost of energy used in mining, which has been constant in 1952-1961, has been expressed as a percentage of net production in the mining industry and set out below:[13]

1952	1953	1956	1957	1958	1959	1960	1961
6.40%	6.72%	5.95%	6.35%	6.32%	5.66%	5.85%	5.40%

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[12] The annual productivity per worker in the mining industry has increased from $8,750 in 1953 to $13,900 in 1960. These values were obtained by dividing the GDP in the mining industry expressed in current dollars by the number of workers employed each year in that industry. The number of workers per year appears in Table 14. GDP in the mining industry in current dollars appears in: National Accounts 1926-1956, op. cit., p. 57, and Canada, DBS, National Accounts Income and Expenditure 1961, Ottawa: Queen's Printer, 1962, p. 32.

[13] Canadian Minerals Yearbook 1962, op. cit. p. 68. Data on the cost of energy and value of net production in the mining industry appears in this publication. The cost of energy as fuel and power has been divided by quantity of B.t.u.'s of energy used in mining for the period 1952-1961 and energy cost was fairly constant over the whole period.

While these percentages fluctuate from year to year, there has been a general decline in the cost of energy as a percentage of net production in mining. This reduction in cost means that energy is being used more effectively.

The substitution of solid fuels for liquid and gaseous fuels in mining, the larger amounts of energy used per worker are factors which have led to the more economical use of energy in the mining industry and to improving productivity. The reduction in the cost of energy used in mining substantiates this conclusion.

Energy Use in the Manufacturing Industries

The use of energy and several aspects of this use in the manufacturing industries in Canada have been set out in Table 15.

Trends in Energy Use.

The amount of energy used in manufacturing in relation to the total amount of energy used in Canada per year has varied between 23%-26% in 1946-1960. The total amount of energy used in manufacturing increased in this

USE OF ENERGY IN THE MANUFACTURING INDUSTRY, CANADA, 1946-1960
(units = 10^{12} B.t.u.'s or as shown)

	1946	1948	1953	1956	1957	1958	1959	1960
Wood Fuel	6.96	6.18	5.98	3.76	3.18	2.46	2.40	2.64
Coal and Coal Products	298.11	390.89	341.17	349.16	343.18	309.56	296.10	257.79
Petroleum & Products	66.58	86.22	150.19	205.00	206.38	202.73	224.60	222.51
Natural Gas	8.74	9.96	21.52	44.36	49.86	66.27	94.51	123.25
Electric Power	94.72	99.81	138.06	157.91	162.65	174.91	180.88	202.61
Total	475.11	593.06	656.92	760.19	765.25	755.25	798.49	808.80
Total Energy Consumption in Canada	2062	2307	2619	2922	2905	2852	3056	3154
Percentage of Energy used in Mfg. to Total	23%	25.6%	25%	26%	26.3%	26.5%	26%	25.6%
Fuel use - Mfg.	380.79	493.25	518.86	602.28	602.60	581.02	617.61	606.19
Power Use - Mfg.	94.72	99.81	138.06	157.91	162.65	174.91	180.88	202.61
% ratio fuel: total energy use in Mfg.	80%	83%	79%	79%	79%	77%	78%	75%
% ratio power: total energy use in Mfg.	20%	17%	21%	21%	21%	23%	22%	25%
Energy use per unit of GFP by Mfg. (10^5 B.t.u. s)	1.29	1.39	1.21	1.215	1.24	1.25	1.24	1.26
Index of Energy use per unit of GDP by Mfg.	100	107	94	94	96	97	96	98
# Employees in Mfg. (x 10^3)	1,058	1,155	1,327	1,353	1,355	1,286	1.300	1.294
Energy used per worker in Mfg industry (x 10^8 B.T.u.'s)	4.50	5.12	4.95	5.52	5.64	5.87	6.13	6.25

Source: annual issues of the DBS publication: <u>General Review of the Manufacturing Industries of Canada</u> for the years indicated published by Queen's Printer, Ottawa.

period by about 70% from 475 x 10^{12} B.t.u's in 1946 to 808 x 10^{12} B.t.u.'s in 1960. The trend to increased use of energy in manufacturing was due to increased output in these industries which has increased in terms of value added by 230%. In addition to this trend to increased use, two other trends in use can be seen. These are the substitution of solid fuels, i.e. wood and coal for liquid and gaseous fuels, of petroleum and natural gas; and an increased use of electric power. In connection with the second trend, the ratios of fuel to electric power use changed from 80%:20% in 1946 to 75%:25% in 1960. The increased use of electric power and of liquid and gaseous fuels means that more energy is being used in forms which are more suitable to control and use inthe different manufacturing processes and contribute to more effective use of energy. In addition to effectiveness in use, these forms of energy are more effectively converted to work. Both these factors are contributing factors in increasing productivity in the manufacturing industries.

Energy Use in Relation to Output

The use of energy in the manufacturing industries has been related to real output of these industries. The measure of output used is the contribution made by manufacturing to real GDP. The procedure used for calculation is identical to that followed earlier for the mining industry. The values each year of the amount of energy used per unit of output in manufacturing have been set out in Table 15. There has been a decline in these values from 1.29×10^5 B.t.u.'s in 1946 to 1.26×10^5 B.t.u.'s in 1960. This substantiates the conclusion made in the previous section that energy in manufacturing is now being used more effectively.

Energy Use in Relation to Employment

The amount of energy used per worker in the manufacturing industries has increased from 4.50×10^8 B.t.u.'s in 1946 to 6.25×10^8 B.t.u.'s in 1960. Over this period and on the average, workers in manufacturing are using more energy per capita to assist them in production. This increased use of energy per worker is one of the factors leading to improving productivity in these industries.

Cost of Energy as a Factor Input

The cost of energy, which has been rising in price slowly since 1946,[14] has been related to output in the manufacturing industries as measured by its value added in production, and the percentage ratios are set out below:

1946	-	6.05%	1951	-	5.41%	1956	-	5.45%
1947	-	5.92%	1952	-	5.27%	1957	-	5.70%
1948	-	6.15%	1953	-	5.15%	1958	-	5.47%
1949	-	5.70%	1954	-	5.35%	1959	-	5.50%
1950	-	5.15%	1955	-	5.23%	1960	-	5.35%

Although these percentage ratios have fluctuated from year to year over the period, there has been a decline in the cost of energy in relation to value added in manufacturing. The reduction in the cost of energy supports the conclusion made earlier that energy is being used more effectively and more efficiently in manufacturing.

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14 Prices per B.t.u. of fuel and power were calculated by dividing data on fuel and power consumption in the manufacturing industries as reported in Table 15 into the cost prices of fuel and power as reported in: Canada, DBS, General Review of the Manufacturing Industries of Canada 1960, Ottawa, 1964, p.118. These costs were found to rise slowly over the period 1946-1961 for both fuel and power.

Energy Supply and Demand in Manufacturing

Energy used in the manufacturing industries is the energy demanded by these industries. Table 15 shows that in 1946-1960 the demand for energy by the manufacturing industries was about 25% of total energy demand in Canada. Because of the size of this demand, energy used in manufacturing has a significant effect on the quantity and the type of energy demanded and supplied.

Some of the important factors affecting the demand for energy are the rate of economic growth, cyclical fluctuations in economic activity, increased efficiency in energy use, and the nature of Canada's industrial structure. With a high rate of economic growth and a high level of output in manufacturing, there should be an increase in the demand for energy in this industrial sector. This has indeed occurred in Canada as shown in Table 15 by the increase in the aggregate use of energy in manufacturing in the period 1946-1960. The use of energy in manufacturing also shows evidence of sensitivity to cyclical changes in economic activity. In Table 15, the use of energy in manufacturing showed a modest increase in 1957, declined in 1958, and increased in 1959. These changes were caused by corresponding changes in economic activity in the years cited. Thus changes in economic activity due to cyclical changes do affect the level of production in manufacturing and in turn affect the amount of energy demanded and supplied. Improvements in the technical efficiency of energy use means that less energy will be used per unit of output, and the demand for energy will not rise as rapidly as production. Technical efficiency in energy use also sets up a demand for specific forms of energy, and hence demand may increase for liquid and gaseous fuels and for electric power. Thus, the need to improve the technical efficiency with which energy is used not only affects the quantity of energy demanded but also the kind of energy needed. Finally, the industrial structure of Canada affects not only the amount but also the type of energy demanded. A comparison of the amount of energy used per unit of real GDP in the mining and manufacturing industries shows that three times more energy is used in manufacturing than in mining. Similarly, among the different industries there will be some of which are more energy-intensive than others. Thus, if the industrial structure is such that it consists of a high proportion of energy-intensive industries, the demand for energy will be greater than if the reverse were the case. Similarly, the nature of Canada's industrial structure will affect the type of energy demanded and supplied. If the industrial structure is such that it uses a high proportion of electric power to fuel, then the demand and the supply of electric power will be emphasized; and if the reverse is the case, the emphasis will be on the demand and supply of fuels. It should be mentioned that the availability of a large supply of a particular form of energy could influence the type of industries set up in the region where this supply is plentiful. This has happened in the case of the use of hydro-electric power in the province of Quebec.[15] The industrial structure once established may develop and perpetuate the demand and the supply of this form of energy.

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[15] Dales, loc. cit.

Energy Used in Electric Power Production

In Canada, electric power is produced from water power and from fuels. Most of the electric power produced comes from water power and is called hydro-electric power, but the production of electric power from fuels, called thermal electric power, is of growing importance in the economy.[16] The annual production of thermal electric power by utilities but excluding industries increased from 165 million kilowatt-hours in 1920 to 7,065 million kilowatt-hours in 1961.[17] This is an annual increase of about 9.5%.[18] Over 1946-1961, the percentage ratio of thermal electric power production to total electric power produced by the electric power utilities in Canada increased from 1.4% to 7.8%. This percentage change shows the increasing importance of thermal electric power production as a component in electric power production.

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16 A type of thermal electric power produced from uranium-235 is called nuclear power.

17 National Energy Board Supply and Demand Tables, loc. cit.

18 This and the two following growth rates have been calculated by the method of terminal years as explained in Footnote 9, Chapter I.

As indicated, fuels are used in the production of thermal electric power. Table 16 has been set out to show the use of fuel for this purpose for 1946-1961.

Trends in Energy Use

In 1946-1961, the use of fuel energy for the generation of electric power increased from 28 x 10^{12} B.t.u.'s in 1946 to 102 x 10^{12} B.t.u.'s in 1961, or an annual rate of growth of 8.4%. In the same period, production of thermal electric power increased from 1,045 to 7,065 million kilowatt-hours, or an annual rate of growth of 12.9%. The use of fuels to generate thermal electric power is now an important use of this form of energy, and will become increasingly more important in the future as the production of thermal electric power continues to increase.[19]

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[19] Canada, National Energy Board, Short-Term Energy Forecast 1960-66, Ottawa: Queen's Printer, 1963, p. 15. This report forecasts an increase in the production of thermal electric power by both industry and utilities from 9,794 million kilowatt-hours in 1961 to 28,600 million kilowatt-hours in 1966. The production mentioned above for 1961, 7,065 million kilowatt-hours, is that produced by electric power utilities

TABLE 16

USE OF ENERGY TO PRODUCE ELECTRIC POWER, CANADA, 1946-1961
(Energy units = 10^{12} B.t.u. s)

	1946	1949	1953	1956	1957	1958	1959	1960	1961
Coal	18.73	30.38	36.14	38.88	47.78	37.14	31.93	39.19	47.17
Petroleum	4.35	5.72	6.75	11.99	11.21	8.68	10.38	11.85	14.44
Mfg'd Gas	5.55	7.55	4.40	-	-	-	-	-	-
Natural Gas	-	2.39	6.52	16.33	22.12	27.89	37.81	37.94	41.35
Total	28.63	46.04	53.87	67.14	81.11	73.71	89.42	88.98	102.96
Total Energy Consumption, Canada	2062	2251	2619	2922	2905	2852	3056	3154	3234
Percentage of Total in Electric Power to total energy consump.	1.4%	2.0%	2.0%	2.3%	2.8%	2.6%	2.6%	2.8%	3.2%
Production of Thermal Electric Power (x 10^6 kwh's)	1045	1445	3836	4404	5483	4782	5281	5954	7065
B.t.u. equivalent of thermal power	3.56	4.93	13.05	15.00	18.65	16.30	18.00	20.30	24.10
Conversion efficiency of Fuels to Thermal Power	12.45%	10.7%	24.3%	22.2%	23.0%	22.1%	22.5%	22.3%	23.4%
Cost of Fuel - (millions of dollars)	5.58	10.8	19.7	20.3	23.7	19.6	19.2	21.3	24.7
Cost of Fuel used to produce one kwh of Thermal Power (in mills)	5.57	7.05	5.15	4.5	4.3	4.1	3.6	3.5	3.5

Source: DBS publications: Central Electric Stations, 1946, 1949, 1953 and Electric Power Statistics, 1956, 1957, 1958, 1959, 1960 and 1961.

Table 16 shows that coal continues to be important in the generation of thermal electric power. Manufactured gas ceased to be used in 1955, and petroleum and natural gas showed significant increases in use over the period. The use of fuel energy is strongly influenced by the regional supply of energy. Canadian bituminous coal is used in Nova Scotia and New Brunswick; imported bituminous coal in Ontario; sub-bituminous coal in Alberta; and Saskatchewan lignite in Manitoba and Saskatchewan. Imported oil is used in the maritime provinces, and domestically produced oil and natural gas are used in Alberta and Saskatchewan.[20]

Cost of Fuel Energy as an Input in Thermal Power Production

The cost of fuel energy used to produce thermal electric power can be measured by the cost in mills to produce one kilowatt-hour. To compute the cost, the cost

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[20] Electric Power Statistics 1961, op. cit., pp.26-29. Data in this publication show annual use of each type of fuel, the annual cost of each fuel used, the annual production of thermal electric power produced by each type of fuel, and the quantity of fuel and the type used in each province for the production of thermal electric power.

of fuel used in a given production period is divided by the quantity of kilowatt-hours of electric power produced in this period. The cost can be computed for all fuel energy used or for a particular type.[21] Using this method of computation, the cost of fuel in mills per kilowatt-hour of electric power produced was computed for each type of fuel used in 1961 and are set out as follows:[22]

Type of fuel used	Cost of fuel in mills per kwh
Canadian bituminous	6.0
Imported bituminous	4.0
Sub-bituminous	1.54
Saskatchewan lignite	1.88
Furnace oil, light	3.3
Furnace oil, heavy	5.0
Diesel oil	15.6
Natural gas	2.1
All fuels	3.5

The cost depends on the type of fuel used and the supply of a particular type of fuel is strongly influenced by location of the fuel supply.

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[21] Ibid.

[22] Ibid

Similar computations were made for all fuels for each of the years shown in Table 16 and are set out in this table. These data show that the cost of fuel per kilowatt-hour of electric power produced has declined steadily from 5.57 mills in 1946 to 3.5 mills in 1961. This improvement in the cost of fuel input came about by the increased use of sub-bituminous coal, Saskatchewan lignite and natural gas,[23] and from greater efficiency in the energy using equipment in central generating stations as these have been improved and more efficient devices have been added to capacity.

Conversion Efficiency

The use of fuel to produce electric energy means that one form of energy has been converted into another. This conversion involves a loss of energy. An estimate of

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[23] The increased use of the different types of fuel energy could not be shown in Table 16. The conclusion set out above was arrived at after an analysis of the date on fuel use appearing in the annual issues of DBS publications: Electric Power Statistics and Central Generating Stations.

the energy loss can be made by relating a given quantity of fuel energy used as an input to produce a given output of electric power. The relation can be made by converting both fuel energy input and electric power output into B.t.u.'s and comparing input to output. If 1000 B.t.u.'s of fuel produces 250 B.t.u.'s of electric power, the loss in conversion is 750 B.t.u.'s or 75% and the efficiency of conversion is 25%. The loss of energy in conversion is the difference between input and output, while the conversion is the ratio of output to input which can be expressed as a percentage ratio.

The conversion efficiency in this use is an important measure of energy efficiency for this particular method of production. An increase in the conversion efficiency means that a greater output of electric power is produced for given input of fuel energy. Table 16 shows that the conversion efficiency of fuel energy for thermal electric power production has improved from 12.45% in 1946 to 23.4% in 1961. These are average rates of conversion efficiency for all types of fuels and all kinds and ages of thermal generating stations. Certain stations with the latest technological improvements and using one of the more efficient fuels will have much higher conversion efficiencies.

The Role of Thermal Electric Power Production

In most areas in Canada, hydro-electric capacity is used as base-load capacity to meet firm demand for power.[24] Thermal electric power capacity has two roles: to meet peaks in power demand in those areas of Canada where most of the firm demand for power is met by hydro-electric power capacity; and to meet firm and peak demand for power in those areas where hydro-electric power capacity is low.

The increased production of thermal electric power in Canada in 1946-1961 has been the cause of an increase in demand for fuel energy for this purpose. The increased use of fuel energy in the production of electric power has been accompanied by an improvement in the efficiency of its use and a reduction in the cost of fuel. The improvement in the

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[24] Canada, DBS, Annual Electric Power Survey of Capability and Load, 1963, Ottawa: Queen's Printer 1964, p.46. This publication defines Firm Energy Requirements as energy required to meet firm obligations which are maximum commitments under contract agreements to accept or deliver power on an irrevocable basis, or the best estimate of firm obligations in the absence of contracts.

efficiency in use has come about because of technological improvements in this area of production and because of a partial substitution of more efficient fuels for less efficient fuels. The improvement in the cost relationship can be attributed to the improvement in efficiency of energy use and to increased use of low cost Canadian produced fuels.

The Use of Energy in Transportation

Another sector using a large share of Canada's energy is transportation where energy is used for production and for personal use as a consumer good. This section will analyze the use of energy by the railways, by motor vehicles and in aviation, and will deal with use trends, efficiency changes in energy use, energy substitutions, and cost relationships. The areas covered constitute most of the transportation sector.

Use of Energy in Railway Transport

The use of energy in railway transport has declined significantly from 275 x 10^{12} B.t.u.'s in 1953 to 56 x 10^{12}

B.t.u.'s in 1961.[25] One of the principal parts of railway transport is freight service where the use of energy declined from 170 x 10^{12} B.t.u.'s to 38 x 10^{12} B.t.u.'s between the same two years. This decline in energy use has come about because of an improvement in the efficiency of energy use rather than from declining activity in railway transport, for while passenger miles[26] did decline from 2.985 x 10^{9} in 1953 to 1.960 x 10^{9} in 1961, freight-ton miles[26] showed an increase between these two years from 6.4267 x 10^{10} to 6.5828 x 10^{10}.[27] The improvement in the efficiency of energy use in railway transport has come about because of the conversion by the railways to the use of diesel locomotives.

The changes in the use of energy in railway transport for the years 1953, 1957, and 1961 are set out in the

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[25] Canada, DBS, Railway Transport 1961 Part III, Ottawa: Queen's Printer, 1962, p.12; Railway Transport 1953 Part III, Ottawa: Queen's Printer, 1955, p. 13.

[26] A passenger mile means one passenger carried one mile; while freight-ton mile means that one ton of freight is carried one mile. These are measures of the use of passenger and freight services in railway transportation.

[27] Canada Year Book, 1962, op.cit., p.771; and Canada, DBS, Canada Year Book 1963-64, Ottawa: Queen's Printer, 1964, p. 761.

following summary in units of 10^{12} B.t.u.'s:[28]

	1953	1957	1961
Freight Service			
Coal	132	55	-
Diesel fuel	16	28	38
Fuel oil	12	20	-
Passenger and other			
Coal	92	35	-
Diesel fuel	-	16	19
Fuel oil	24	6	-
Railway Transport			
Coal	224	90	-
Diesel fuel	16	44	57
Fuel oil	36	26	-

The effect of dieselization of railway transport can be seen by the substitution in the use of energy from coal and fuel oil to diesel fuel. The efficiency effect of this change can be seen by the substantial reduction in energy input over the period even though activity in railway transportation did not decline. To measure the increase in the efficiency of energy use, the annual amount of energy used in freight service has been divided by the

[28] Canada, DBS, Railway Transport 1957, Part III, Ottawa: Queen's Printer, 1958, p.12; Railway Transport 1961, Part III, loc. cit., and Railway Transport 1953, Part III, loc. cit.

number of freight-ton miles in that year to give the amount of energy used per freight-ton mile. Deducting from total energy used in railway transport the amount used in freight service, and assuming that the residual is used in passenger service[29] this residual is divided by the number of passenger miles operated by the railways per annum to give the annual amount of energy used per passenger mile. The results of this computation for 1953, 1957, and 1961 are set out as follows:[30]

	1953	1957	1961
Energy used per freight-ton mile	2.62×10^3	1.45×10^3	0.58×10^3
Energy used per passenger mile	3.85×10^4	1.95×10^4	0.98×10^4

These data show a definite reduction in the amount of energy used in the two main uses of railway transportation, freight and passenger service, and indirectly measure the

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29 Total energy used in railway transport minus energy used in freight service equals residual energy used in rail services other than freight. The assumption made here is that this residual amount of energy is used in passenger service.

30 Energy used has been converted into B.t.u.'s and the data shown are in these units.

increase in the efficiency of energy use in these two services.

To calculate the cost of energy used in railway transport per passenger mile and per freight-ton mile, the cost of energy and the amount of energy used per each different mile are required. The amounts of energy used for 1953, 1957, and 1961 have already been calculated above. The cost of energy used in railway transport in each of these years is calculated by dividing the total annual cost of energy used by railways by the annual amount of energy in B.t.u.'s used. This gives the cost of energy per B.t.u. for railway transport. This cost is then multiplied by the number of B.t.u.'s of energy used per passenger mile and per freight-ton mile to give the cost of energy used for each type of mile. These costs are set out as follows:

	1953	1957	1961
Cost of energy per freight-ton mile	0.095¢	0.072¢	0.046¢
Cost of energy per passenger mile	1.4¢	0.97¢	0.78¢

The financial economies in the use of energy in railway transport are reflected by the reduced cost of energy used in freight and passenger services in the period 1953-1961 and were obtained despite a rise in the average cost of energy during this period.

The Use of Energy by Motor Vehicles

The energy used in motor vehicles can be estimated from the net sales of motive fuels in Canada.[31] Net sales are arrived at by deducting from gross sales of motive fuels tax exempt sales to the federal government and other consumers, exports, and sales on which refunds were paid. Net sales of motive fuels in Canada for 1946-1961 are set out in Table 17 which shows the number of gallons of gasoline and diesel fuel used per year, and the percentage relationship between net sales of motive fuels to total energy use each year. Net sales of motive fuels are assumed to be the equivalent of energy used by all motor vehicles, and do not differentiate between what is used for commercial purposes and what is used in private use. Estimates can be made of the energy used for each purpose by analyzing annual motor vehicle registrations to determine the ratio between

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[31] Canada Year Book 1963-64, <u>op.cit.</u>, pp.776-777.

TABLE 17

NET SALES OF MOTIVE FUELS IN CANADA
1946-1961

Year	Gasoline and Liquified Petroleum Gases (Gallons)	Diesel Oil (Gallons)	B.t.u.'s of Gas & Diesel (x 10^{12} B.t.u.'s	Percentage of Total Energy Uses
1946	934,819,509	10,213,266	150	7.3
1947	1,032,902,444	14,627,564	155	7.2
1948	1,333,233,773	17,282,143	200	8.7
1949	1,253,285,212	16,570,319	188	8.4
1950	1,390,190,447	19,314,263	210	8.6
1951	1,528,905,858	27,338,017	232	9.0
1952	1,718,111,819	31,868,218	260	10.1
1953	1,902,514,817	36,436,126	288	11.0
1954	2,021,002,458	37,760,533	306	12.0
1955	2,226,980,245	50,667,242	338	11.6
1956	2,456,988,356	70,779,820	376	12.8
1957	2,592,225,613	92,832,457	400	13.8
1958	2,731,958,485	95,479,919	421	14.7
1959	2,865,034,346	120,129,508	443	14.3
1960	3,016,820,060	128,954,900	467	14.8
1961	3,140,197,585	143,042,427	491	15.2

Sources: Canada, DBS, The Motor Vehicle 1961-Part II Motive Fuel Sales Ottawa: Queen's Printer, 1962, pp. 6 - 9; Canada, DBS, The Motor Vehicle 1954 Ottawa: Queen's Printer, 1955, pp. 24-26.

commercial and private motor vehicles. An estimate made on this basis shows that between 75% to 85% of all motor vehicles registered are privately owned. The net sales of motive fuels in Canada increased from 150×10^{12} B.t.u.'s in 1946 to 491×10^{12} B.t.u.'s in 1961, and the percentage of this use to total energy used each year increased from 7.3% to 15.2% over this period. As seen before 75%-85% of total motor vehicles are privately owned and hence the use of motive fuels as a consumer good is a major part of this demand. The increase in the numbers of private motor vehicles is a direct result of rising personal disposable income following from increased economic growth in Canada in 1946-1961, or to increasing affluence. Thus, this effect on energy demand due to rising incomes, which increases the demand for energy as a consumer good could be called the affluence effect on energy demand.

The automobile has been the cause of a considerable shift in passenger travel away from the railways and bus travel. On the basis of a rough estimate of automobile passenger miles (one passenger carried one mile), the distribution of total inter-city passenger miles was calculated for the following years and is set out below:[32]

Year	Railways	Buses	Private Automobiles	Aviation
1928	38%	2%	60%	-
1949	19%	11%	68%	2%
1962	6%	4%	82%	8%

These data illustrate that the increased use of private automobiles has resulted in a decline in passenger travel by both railway and bus. They also measure the degree of competition of private automobiles to the other two methods of passenger travel. Consequently, the way energy is used not only affects energy supply and demand, but also affects other aspects of economic activity.

The Use of Energy in Civil Aviation

The use of energy in civil aviation in Canada has been analyzed for the period 1948-1961.[33] The demand for energy in civil aviation in Canada increased from 3.80×10^{12}

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[32] Canada Year Book 1962, op.cit., p.754.

[33] Canada, DBS, Civil Aviation 1963, Ottawa:Queen's Printer,1965,p.8; Civil Aviation 1957,Ottawa: Queen's Printer, 1959, p.8; Civil Aviation 1953, Ottawa: Queen's Printer, 1964, p.8.

B.t.u.'s in 1948 to 34.40 x 10^{12} B.t.u.'s in 1961. This increase was directly related to the increased activity in civil aviation as measured by changes in passenger miles and freight-ton miles flown.[34] In 1948-1961, the amount of energy used per passenger mile and per freight-ton mile increased by about 2 to 3 percent per annum. On the other hand, the cost of energy per B.t.u. was constant for the period 1948-1956, and declined by about 50% from 1956 to 1961. This decline in cost of energy in this period was due to the increased use of turbo fuel which is cheaper than aviation gasoline. The increased use of this type of fuel was in turn due to the changeover from the use of propellor-driven aircraft to turbo-propellor and jet aircraft. Despite the increased amounts of energy used per passenger and freight-ton mile, the reduced cost of energy in aviation was great enough to reduce the cost of energy used per passenger mile and per freight-ton mile. This case illustrates a situation where energy is not being used as

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[34] Ibid. In 1952-1961, the number of passenger miles increased from 8.40 x 10^8 to 3.30 x 10^9, while the number of freight-ton miles increased from 1.27 x 10^7 to 4.45 x 10^7.

efficiently as before but because cheaper fuel can now be used financial economies have been achieved. Innovations in energy-using devices can thus be such as to increase the efficiency of energy use, or to enable the use of lower priced energy to permit economies to be made in the cost of energy used.

The Use of Energy in the Personal Sector

Energy is used in the personal sector in Canada for heating, for cooking and lighting, to operate consumer durables, and to operate private automobiles. The analysis of energy used in this sector will consist of an estimate of total energy used in the sector, and will examine the trends in the use of heating equipment and fuel and some of the factors affecting energy demand.

Estimate of Energy Used

An estimate of total energy used in the personal sector can be made by estimating in turn the energy used in heating and cooking, electric power used, and motive fuels used in private automobiles, and then summing the separate estimates made. To assist in making these estimates the number of households as reported in Census data is used. A household is one dwelling occupied by a person or a group of persons,[35] and the number of households is equal to the number of occupied dwellings.

An estimate of energy used in the personal sector for heating and cooking can be made by multiplying the number of households reported in Census data for 1941, 1951 and 1961 by 175 million B.t.u.'s which is the estimate made by Davis of the average annual amount of energy used per household for heating and cooking.[36]

The amount of electric power used for lighting, cooking, and the operation of consumer durables can be estimated by multiplying the number of households as reported in Census data by the B.t.u. equivalent of the average annual consumption of electric power in domestic

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[35] Canada, DBS, Census of Canada 1961, Bulletin 2.2-4, 1963, p.l. This bulletin defines both household and dwelling. The definition of household is as above. A dwelling is defined as a structurally separate set of living premises with a private entrance from outside of the building or from a common hallway or stairway inside and not through someone else's living quarters. The terms dwelling, dwelling unit, and home are used interchangeably.

[36] John Davis, *op.cit.*, p. 267.

and farm services.[37] An estimate made in this way will duplicate the amount of electric power used in cooking, but since the purpose of the estimate is to show the magnitude of demand in the personal sector, the inclusion of this duplication will not distort the estimate made.

Energy used in private automobiles can be estimated by multiplying the number of automobiles reported as owned by households in Census data for 1941, 1951, and 1961 by an estimate of the B.t.u. equivalent of the annual average consumption of gasoline per automobile. The annual average consumption of gasoline was calculated to be 565 gallons.[38] An estimate of this use of energy is included in order to cover all the energy used in the personal sector.

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[37] Canada Year Book, 1962, op.cit., p.522, Canada, DBS, Canada Year Book 1957-58, Ottawa: Queen's Printer, 1958, p. 571.

[38] Canada Year Book 1963-64, op.cit., pp.774-777. The annual average consumption of gasoline per automobile has been computed by dividing the total number of automobiles registered each year in the period 1953-1962 into the net sales of motive fuels for each of these years in this period. The annual estimates were then averaged and the estimate obtained was 565 gallons.

The estimate of energy used in the personal sector is set out as follows:[39]

	1941	1951	1961
Energy used in heating and cooking	450	598	798
Electric power	14	30	72
Energy in private automobiles	79	123	261
Total energy used in personal sector	543	751	1131

These data show the growth of energy use in the personal sector in the period 1941-1961. This growth is caused by a number of factors. The first and most important is the growth in population and an increase in the rate of net family formation,[40] which with the availability of an adequate level of supply of housing determines the number of households. The number of households in turn determines

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[39] The units shown must be multiplied by 10^{12} B.t.u.'s.

[40] Net family formation is the change in the number of families in any given period. An important factor in net family formation is the rate of marriages which in turn responds to economic conditions and other factors. See: Firestone, op.cit., p.52.

the amount of energy used in heating, cooking, lighting, and to operate consumer durables. Another factor is the growth and the extension of electrification which determines not only the supply but also the demand for electric power. Yet another factor is the rate of economic growth and the effect of this growth on the level of disposable income. In Canada, there has been an increase in the size of personal disposable income, and this rising affluence has not only increased the number of private automobiles used and the demand for energy for this purpose, but also the demand for and the use of consumer durables and the demand for the energy used in this equipment.

Trends in Heating Equipment and Fuel in Households

Table 18 shows the changing trends in heating equipment and fuel used in households in Canada from 1941 to 1961. These trends are: (i) the replacement in use of stoves and space heaters by furnaces particularly hot air furnaces, and (ii) the decline in the use of wood fuel and coal and the increased use of liquid and gaseous fuels in the home. These two main changes have had the effect of increasing the efficiency of energy use in the household.

OCCUPIED DWELLINGS SHOWING PRINCIPAL HEATING EQUIPMENT
AND PRINCIPAL HEATING FUEL - CANADA 1941, 1951, 1961

	1941		1951		1961	
	Number	Percent	Number	Percent	Number	Percent
HEATING EQUIPMENT						
Households	2,575,744	100	3,409,295	100	4,554,493	100
Furnace	997,588	38.8	1,637,685	48.0	3,072,221	67.4
Steam/hot water	367,421	14.3	529,463	15.5	829,984	18.2
Hot air	630,167	24.5	1,108,220	32.5	2,242,237	29.2
Stove or space heater)	1,578,156	61.2				
Other)			47,990	1.4	157,940	3.5
HEATING FUEL						
Households	2,575,744	100	3,409,295	100	4,554,493	100
Coal and Coke	1,206,570	46.8	1,469,520	43.1	480,794	10.6
Wood	1,183,758	46.0	951,325	27.9	590,101	13.0
Liquid Fuel[a]	66,716	2.6	774,525	22.7	2,565,416	56.3
Gas[b]	87,443	3.4	163,165	4.8	857,953	18.8
Other	31,257	1.2	50,750	1.5	60,229	1.3

Source: Census of Canada 1961, Bulletin 2.2-4, loc.cit.

[a] Liquid fuel is mainly fuel oil but it does include kerosene and other liquid fuels. Ibid.

[b] Gas includes piped gas which is gas such as natural gas distributed by pipeline and metered as well as bottled gas such as propane which is distributed in containers under pressure. Ibid.

Furnaces are more efficient converters of heat energy than stoves or space heaters, and more efficient distributors of the heat generated. Liquid and gaseous fuels are more easily controlled so losses can be eliminated by regulating the supply of heat required in cooking and heating with the available demand.

Chapter II has analyzed in detail the economic effects of energy supply in Canada. This chapter has analyzed the economic effects of energy demand. The following part will summarize and draw conclusions from these analyses.

SUMMARY AND CONCLUSIONS

In Chapter I, a statistical analysis was made of energy production and consumption in Canada for 1870-1960 and 1946-1961. This analysis dealt with the annual rate of growth of energy supply and demand, substitutions as between energy, international energy dependence, regional relationships between energy production and consumption and energy reserves.

Energy production or supply grew at an annual rate of 2.85% in 1860-1960 and 7.2% in 1946-1961, while energy consumption or demand grew at 3.12% and 2.85% respectively in each period. The high growth rate of energy production in 1946-1961 reflects the increased production of energy that took place after World War II.

In 1946-1961, the annual rate of growth for both production and consumption of hydro-electric power was about 5.8%. These growth rates are a reflection of the increasing importance of both electric power production and consumption in Canada which has been continuing for a number of years.[1]

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1 Davis, op.cit.,p.203. Davis measured growth of electric power demand for 1935-1955 and found a 6% annual rate of growth in this demand.

Two main substitutions of energy have occurred in the period. These are a partial substitution in the use of fuels for the use of electric power,[2] and a significant substitution in the fuel energy sector of the energy system from the use of wood fuel and coal to the use of petroleum and natural gas.

These substitutions and the discovery, development and substantial increase in the production of petroleum and natural gas in Canada in the post war period have improved Canada's energy supply position; and changed the structure of energy supply in Canada from a heavy reliance on imports of energy to a greater reliance on domestic energy production.

The regional analysis for 1961 of the relationship between production and consumption of electric power[3] and fuel showed a different situation for each. There was a

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[2] Table 2 measures this substitution for hydro-electric power. The percentage ratio of hydro-electric consumption to total energy consumption each year increased over the period from 6% in 1946 to 10.6% in 1961 indicating the partial substitution effect.

[3] Electric power includes both thermal and hydro-electric power.

reasonably close relationship between production and consumption of electric power in all provinces except that Quebec had a surplus of electric power.[4] In the matter of fuel energy, most provinces were dependent on energy supply external to the province, with the exception of Nova Scotia where the balance between supply and demand of energy was close to equilibrium, and Alberta and Saskatchewan which each had surplus fuel energy.

Canada's energy reserves are more than adequate to meet present and future demand. Coal reserves are large and available for use by many future generations. Water power resources are large, but not all of these can be developed because some are located too far away from markets to permit economic development, and the development of others would conflict with other forms of economic activity such as fishing and tourism. Reserves of petroleum and natural gas are adequate to meet demand for 20 to 40 years.[5] It is expected that their reserve

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[4] The surplus electric power in Quebec was hydroelectric power.

[5] The adequacy of reserves to meet future demand will depend on the relation between the growth in future demand for these forms of energy as uses increase and increases to these reserves due to new discoveries and revisions of existing estimates.

situations will follow past patterns where additions to reserves each year by discoveries and revisions of earlier estimates have been considerably greater than the current year's production so that future reserves will tend to grow larger. It is not considered that this situation could continue indefinitely, but it could continue for a number of years and so extend the life of known and recoverable petroleum and natural gas reserves. Canada is exceptionally fortunate in having the petroleum reserves in the Athabaska tar sands which are economically recoverable and are equal to the present world reserves of petroleum. These serve as a second line of reserves for Canada.

The analysis of energy supply and demand in Canada in 1946-1961 shows a number of economic effects for energy supply and energy demand, and certain interactions as between some of these economic effects. To show these interactions, the following identity was used:

> Domestic energy supply + imports of energy = domestic energy use + domestic use of energy for non-energy purposes + losses of energy + exports of energy

This identity sets out the general equality between energy supply and energy demand.

The economic effects of energy supply in Canada for 1946-1961 have been analyzed with respect to the impact of the energy supply industries on employment, output and income, the balance of payments, regional economic development, investment, and on other forms of economic activity.

The production of energy requires labour as a factor input. It might be assumed that the increased production of energy which occurred in the period should involve the increased employment of labour. This has not been the case for energy production, because labour has shown a general decline in this activity over the whole period. This decline was due to: (1) the general trend in production in Canada to substitute capital for labour which has been reflected in the energy supply industries; and (2) the structural shift in energy supply from labour-intensive industries such as coal production to capital-intensive industries such as petroleum and natural gas production. Only in the production of electric power has employment increased. It has increased because electric power production covers all aspects of energy production from the generation of electric power to marketing, and because the electric power utilities resemble in many ways a service industry with its characteristic high labour use. Because employment has declined in the energy supply industries, productivity has increased and has been measured by increases in output per worker in 1946-1961. Productivity has increased due to the change in factor proportions as between capital and labour in the energy supply industries, and because workers in these industries have an increasing amount of capital and energy per worker to assist them in production.

The contribution by the energy supply industries to output and income has been measured by the relationship of value added in these industries to comparable measurements of output and income. Since fuel production constitutes part of the mining industry. the contribution of the fuel industries to the output of the mining industry was measured and found to average about 30% over the period and to show an increase from 25% to 35% from 1946 to 1961. The contribution made by value added by the energy supply industries to the commodity producing industries and to GDP was measured in turn and found to range between 4.8% to 9.4% for the commodity producing industries and between 3.2% to 5.7% for GDP. The limits of each range constitute the rise in this contribution in each case over the period of 1946-1961.

One of the long range economic goals for Canada is to improve its balance of payments by achieving a better balance as between exports and imports of goods and services. This problem cannot be tackled by concentrating on one or two items in the balance of payments, but remedial action must range over and deal with every item in this balance where improvements are possible. One of these items is Canada's international trade in energy. The substitution effect in the fuel energy sector, and the increased importance of electric power consumption in economic activity in Canada have had the effect of increasing the production of energy in Canada and weakening Canada's dependence on the imports of energy. This has improved Canada's balance of trade in energy, i.e. the current dollar measure of this balance, and its balance of energy, i.e. the measure in real terms of Canada's dependence on external supply of energy.

The main effect from energy supply on regional economic development has come from the production of fuel energy. This production has had the greatest effect in percentage terms on employment and output in those provinces with the greatest supply of fuel energy. In Canada, these happened to be the provinces with levels of industrial activity lower than the industrially active provinces of Ontario and Quebec, and were thus a source of economic strength to these provinces.

Investment in 1953-1961 by the fuel and power industries contributed from 12.0% to 17.9% to total investment each year with the level of investment increasing in percentage terms over the period. This investment has been accompanied by more output in these industries as measured by the value added in production than the amount of such investment. Some of this investment was foreign and was concentrated in the petroleum and natural gas industries. In 1961, 60% of these industries were owned and 69% controlled by investors located outside Canada. On the other hand, investment in these industries has increased capacity and production of petroleum and natural gas with favourable effects on employment, income, output, and the balance of payments. A measure of the return on investment in the energy supply industries was made by measuring the return from profitable companies in energy supply in Canada in 1962. The measure made showed a return on investment in excess of 3.1% for all phases of production in energy supply.

The process of energy supply has also affected other forms of economic activity as seen: (i) from the use of by-products and the development of the sulphur industry and increased production of sulphuric acid as a result, (ii) from the use of energy materials for non-energy purposes and the resulting development of the petrochemical industries in Canada, (iii) from the demand for intermediate goods and services from other businesses by the energy industries, and (iv) from the economic contribution made in the development of new sources of energy as seen by the development of nuclear power capacity in Canada. Finally, energy supply has been a factor in the location of certain types industrial activity, and has affected other forms of economic and human activity by the external economies and diseconomies arising from the production of energy.

The analysis of the economic effects of energy use has dealt with an analysis of the aggregative use of energy, and a detailed analysis of energy used in different phases of industrial production and as a consumer good in the Personal sector of the Canadian economy.

The analysis on aggregate use of energy shows a close statistical correlation between aggregate energy use and population, persons working, and increases in real GNP. The relation between rate of growth of energy use in aggregate and in per capita terms showed that in 1946-1961 these have not increased at the same rate as the corresponding rate of economic growth. Furthermore, an analysis of the relationship between energy input to unit of real GNP show that since 1910 the amount of energy input required to produce a unit of GNP has declined. This decline and the slower growth rates of aggregate and per capita energy consumption indicate the existence of factors contributing to the efficient use of energy. Among these factors could be included changes in the nature of output produced, improvements in productive efficiency, increased use of more efficient forms of energy, and increases in the efficiency of energy use through the development of better energy-using devices. Finally, it can be said that the trend to more efficient use of energy taken with an increase in energy use per capita and per worker have been contributing factors to increasing productivity and to increasing the rate of economic growth in Canada in 1946-1961.

The analysis of energy use in different industries in Canada substantiates the conclusions made on the basis of the aggregative use of energy and indicates trends to greater efficiency of energy use, to the use of declining amounts of energy per unit of output, to increased amounts of energy used per production worker, and to declining costs of energy used in production. An analysis of major users of energy shows that the manufacturing industries, electric power production, motor vehicles, and the personal sector are all major users of energy supplied. An analysis of energy used as a consumption good in the personal sector shows that greater efficiency in energy use has been achieved through the use of better home heating equipment and fuels, and that the demand for energy responds to increasing levels of income as Canada continues to grow economically in the post war period, or what could be called the affluence effect on energy demand.

Finally, the analysis of energy use indicates that the demand for energy is the prime motivating factor in the Canadian energy system. The demand for energy is determined by a number of factors such as: (1) the level and the nature of industrial activity, (2) the cost of energy, (3) the need to increase productivity, (4) rising standards of living and comfort, (5) industrial processes which require a specific form of energy, (6) the availability of energy, (7) the efficiency of energy use and the potential to increase this efficiency, (8) the effect of government policies at home and abroad, and (9) the export demand for energy. These factors acting jointly or severally determine the nature and quantity of energy demand, and energy demand in turn will determine the quantity, the type, and the source of energy supply.

The foregoing analysis has dealt with the economic effects of energy supply and energy demand, but something must be said of the energy situation for the future. We believe that the following trends in the energy situation will develop in the future: (1) the trend to increased use of electric power will continue and will grow because of increasing levels of economic activity and it will continue to replace fuel energy in production although at a slower rate. As available water power locations are developed, the time will arrive when most of the economical water power resources will have been developed. This will put a greater reliance on the production of thermal electric power to supply the increasing demand for electric power. Two effects can be seen because of this:

(a) There should be increased use of conventional fuels for production of thermal electric power. It is expected that greater use will be made of domestic fuel energy for this purpose and that thermal generating stations will be located at or near the source of fuel energy supply. Because of this, the imports of fuel energy used in thermal electric production is expected to decline in the future.

(b) There should be increased development of nuclear power to supply this greater demand. The increased development will have favourable economic effects on the Canadian uranium mining and fuel processing industries, on the production of heavy water, and on other forms of economic activity associated with this development.

(2) The trend to increased use of liquid and gaseous fuels will continue as a result of increasing demand due to higher levels of economic activity in the future. This will increase the production of fuel energy in Canada, particularly in the western provinces and be beneficial to these provincial economies. A further effect will be the future development of the Athabaska tar sands to supply increasing domestic and world demand for petroleum. This will have favourable economic effects on domestic output and income and on the balance of payments. (3) It is expected that there will be a greater reliance on the domestic production of all types of energy so that this item in the balance of payments may move into an equilibrium position as between exports and imports or even a small surplus depending on the strength of future world energy demand.
(4) It is expected that the production of coal will continue to decline, and only gain importance when the present reserves of petroleum and natural gas have been largely used up.

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APPENDIX 2

ABSTRACT OF

Energy Supply and Demand in Canada, 1946-1961

This thesis analyzed the economic effects of energy supply and demand in Canada in 1946-1961.

Chapter I defined energy concepts and explained a method to measure and compare energy. A statistical study was made of energy production and consumption in 1870-1960 and 1946-1961, international trade in energy for 1946-1961, provincial supply and demand in 1961, the main uses of energy, and energy reserves. The sources, flows and uses of energy are explained within the framework of the Canadian energy system.

In Chapter II, the economic role of energy supply was studied as to its direct effects on employment, output and income, regional economic development, and investment; and as to its indirect effects as in the development of the sulphur and petrochemical industries, and on other aspects of economic activity. The economic effects of the development of nuclear power in Canada was examined. Other effects of energy supply such as its effect on

industrial location and the external economies and diseconomies of energy supply were examined.

In Chapter III, energy use was examined in aggregate as to its correlation to population, persons working, and real GNP, as to its growth rate, and as to the relationship of energy input to real GNP; and in detail in mining, manufacturing, electric power production, railways, civil aviation, and motor vehicles, and as a consumer good.

Two main substitutions in energy use occurred, namely: from the use of solid fuels to liquid fuels, and to greater use of electric power in preference to fuel. These changes taken with the increased domestic production of energy increased Canada's dependence on domestic sources of energy and improved its balance of trade in energy. Canadian energy reserves are more than adequate to meet demand for several generations. In addition, Canada has substantial petroleum reserves in the Athabaska tar sands. Energy supply had favourable direct economic effects on employment, output and income, the balance of payments, regional economic development, and investment; and its indirect economic effects are seen in the external economies and diseconomies of energy supply, and its effect on industrial location and on sulphur and petrochemical production. The development of nuclear power had far reaching economic benefits in providing a new source of energy and by its effects on other forms of economic activity. Energy use increased in efficiency because of the use of more efficient forms of energy and the development of devices to improve this use. These factors together with increased amounts of energy used per capita and per worker have increased productivity and decreased energy costs and such changes have been measured in mining, manufacturing, electric power production, and transportation. Improvements in the use of energy were noted in the personal sector. Rising incomes have increased the demand for energy because of the greater use of the automobile for personal use, and consumer durables in the home. Energy demand itself is one of the factors affecting energy supply as to quantity and type of energy supplied.

In the future, it is expected that: (i) demand for electric power will increase, (ii) demand for conventional energy for thermal electric power production will increase, (iii) nuclear power will become more important as a source of energy, (iv) increased domestic fuel production will have favourable effects on regional economic development and on the balance of payments, and (v) the use of coal will continue to decline for many years and will become important again when economic reserves of petroleum and natural gas are depleted.