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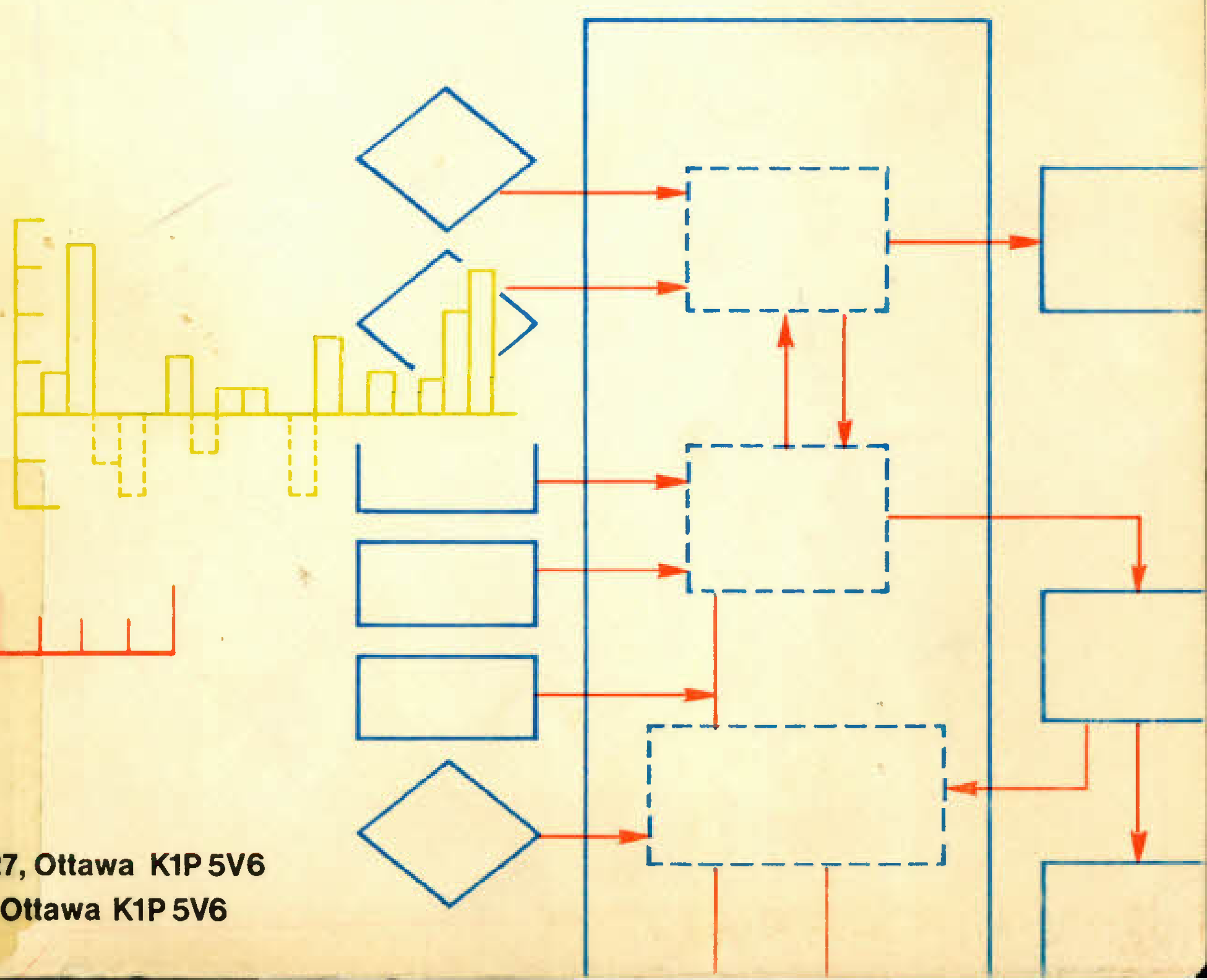

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DISCUSSION PAPER NO. 126

Economic Impact of Low Energy Growth In Canada: An Initial Analysis

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ABSTRACT

This paper reviews the record of Canadian energy consumption in the recent past and evaluates the relationship of energy to household consumption and industrial activity patterns. While it may have been economically rational to evolve a high energy configuration of economic activity while the relative costs/prices of energy were declining during the 1950s and 1960s, economic and other criteria suggest that efforts should now be turned towards reducing the energy content of intermediate and final consumption.

The aim of economics as applied to resource allocation is to employ efficiently *all* factors of production; it is necessary to consider energy conservation in the context of the efficient use of labour, capital and natural resources. In this paper, approaches to demand management in respect of energy resources are evaluated as to their impact on labour demand, productivity, output, incomes and prices in Canada. A survey of other research indicates that opportunities to increase energy efficiency are numerous and, in the main, conducive to increased employment, reduced capital demand and lower inflationary pressures. On the other hand, some negative impacts on the rate of increase of labour productivity and income may be envisioned and, in the absence of offsetting public policy, the costs of some energy conservation programs may fall disproportionately on lower income groups.

From the general perspective, analytical approaches are developed for evaluating some of the benefits and opportunity costs of specific conservation options in the near term, and of overall low energy growth in the longer term, when both direct and indirect effects are included. The simulations indicate that in Canada -- and likely in other nations as well -- conservation offers promise not only for greatly decreased energy consumption, but also for increased short- and long-term employment, reduced pressures on capital and prices and more energy-independence for the economy. Dislocations within industry do not appear to be critical, although the construction and energy supply industries may be rather severely constrained. Household incomes can be expected to continue to improve in the simulations, but the mix of employment and consumer expenditure will evolve to configurations in which the energy intensity will be substantially lower.

It is concluded that a low energy future is not only consistent with sustained improvements in the standard of living, but also with Canadian self-reliance in energy. Public policy, moreover, can be developed to assure that welfare gains are realized by all segments of the population.

RÉSUMÉ

Le présent document examine le dossier de la consommation d'énergie au Canada depuis quelques années, et évalue le rapport qui existe entre l'énergie et les tendances de la consommation des ménages et de l'activité industrielle. Bien qu'au cours des années 50 et 60, il pouvait paraître normal, sur le plan économique, de concevoir une activité économique à forte utilisation d'énergie en raison du fléchissement des coûts et prix relatifs de l'énergie, des critères économiques et autres indiquent qu'il faut maintenant concentrer nos efforts sur la réduction de la teneur en énergie de la consommation intermédiaire et finale.

Dans ses travaux sur la répartition des ressources, la science économique vise à utiliser efficacement *tous* les facteurs de production; à cette fin, il faut considérer la conservation de l'énergie dans le contexte d'une utilisation efficace de la main d'oeuvre, du capital et des ressources naturelles. Dans ce document, nous analysons les diverses méthodes de gestion de la demande de ressources énergétiques, en ce qui concerne leurs effets sur la demande de travail, la productivité, la production, les revenus et les prix au Canada. L'examen d'autres recherches dans ce domaine indique que les possibilités d'accroître l'efficacité de l'énergie sont nombreuses et que, dans l'ensemble, elles sont favorables à un accroissement de l'emploi, à une réduction de la demande de capital et à une diminution des pressions inflationnistes. Par ailleurs, il ne faudrait peut-être pas oublier certaines répercussions négatives sur le taux d'accroissement de la productivité et du revenu, d'autant plus que, en l'absence d'une politique publique compensatrice, les coûts de certains programmes de conservation de l'énergie pourraient peser de façon disproportionnée sur les groupes à faible revenu.

En prenant une vue d'ensemble, nous mettons au point des méthodes analytiques pour l'évaluation de certains bénéfices et coûts possibles rattachés à diverses options à moyen terme en matière d'énergie, et à une faible croissance globale de l'énergie à long terme, lorsque les effets directs et indirects sont inclus. Les simulations indiquent qu'au Canada -- et probablement aussi dans d'autres pays -- la conservation offre non seulement la promesse d'une réduction appréciable de la consommation d'énergie, mais permet aussi d'espérer un accroissement de l'emploi à court et à moyen termes, une diminution des pressions sur le capital et les prix et une plus grande autonomie de l'économie en matière d'énergie. Les perturbations dans l'industrie ne semblent pas sérieuses, bien que l'industrie de la construction et le secteur énergétique pourraient faire l'objet d'une forte compression. Les simulations indiquent que les revenus des ménages devraient continuer à s'améliorer, mais la composition de l'emploi et les dépenses des consommateurs se situeront dans un contexte où la consommation d'énergie sera sensiblement moins élevée.

En conclusion, une plus faible consommation d'énergie dans l'avenir est non seulement compatible avec une amélioration soutenue du niveau de vie, mais aussi avec l'autosuffisance du Canada en matière d'énergie. En outre, il est possible de mettre au point une politique publique visant à assurer que l'accroissement du bien-être profitera à tous les segments de la population.

ACKNOWLEDGEMENTS

The following study would not have been possible without the generous co-operation of many people in the Office of Energy Conservation, Energy, Mines and Resources, and in the Structural Analysis Division, Statistics Canada. The assistance of Kirk Hamilton and Steven Gribble in the Structural Analysis Division deserves special mention. In addition, Michael Sutton provided advice on computer methods and information search. Partial support for this study was provided by the Rockefeller Foundation.

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A NOTE ON TERMINOLOGY

In order to avoid endless repetition, growth rates, unless otherwise specified, refer to energy growth and not to economic growth. Similarly, consumption and conservation refer to energy, not to general economic activity. Finally, energy growth rates and consumption figures will, unless otherwise specified, refer to primary, not secondary, energy. Roughly speaking, primary energy is measured at the point of production whereas secondary energy is measured at the point of consumption. The difference between the two stems from a variety of processing, conversion, transmission and transportation losses, so that primary energy consumption is always considerably in excess of secondary energy consumption. Averaged over all forms of energy, the ratio between primary and secondary energy in Canada is roughly 1.5:1.

Energy discussions also suffer from the fact that each energy form is measured in its own unique units, and that each form gets produced and delivered to the consumer in its own unique way. As a result, direct comparisons of costs, availability and value are difficult. They can be helped by clarity as to whether it is plant cost or delivered energy that is being measured and by placing all measurements in one system of units (here the English). However, electrical measurements throughout the world are normally in watts, and, by a stroke of good fortune, the conversion between a Btu, the most common heat measurement in Canada, and the Kilojoule (the common metric unit) is roughly 1:1.

There is an additional terminological problem that arises with use of input/output tables for energy studies in that the terms "indirect" energy and "indirect" labour are used with exactly the same meaning as "secondary" energy and "secondary" labour in conventional input/output terminology. Direct energy or labour includes those quantities consumed at the plant or during the process in question. Indirect energy or labour includes both prior processes in the chain of events as well as that energy and labour contained in the capital consumed in the process. For example, producing one automobile takes a certain volume of energy and labour; these are the direct quantities. There is also energy and labour employed in mining iron ore, producing steel and transporting it to the auto plant and so forth -- all in volumes just sufficient to produce one automobile; these make up part of the indirect quantities of labour and energy. In addition, there is energy and labour employed in producing the mining machinery, blast furnaces, transportation equipment and so forth, and some small part of this capital is consumed (depreciated) in the production of each automobile; these quantities make up the rest of the indirect labour and energy. In principle the indirect quantities include *all* prior stages -- that is, not just the machinery that produced the mining equipment, but also the machinery that produced that machinery, and the machinery that produced the machine that produced... The method used for calculation does capture the full chain of actions. However, for practical purposes the indirect effects become negligible after a few rounds.

Besides the direct and indirect impacts on labour and energy use, there is also what is called the induced effect. To continue the example, induced effects result when workers spend the wages they receive and when owners of capital spend the returns they receive from the production of one automobile. An induced effect also results when consumers spend any excess income they may have after, say, purchasing a more efficient auto to conserve energy. (Induced effects can be negative if wage or other income is reduced as a result of the shift in expenditure.) This induced spending of course has ramifications throughout the economy and stimulates its own production and investment activities. Such impacts, generally referred to as the multiplier and accelerator impacts, are for the most part *excluded* from the analyses presented in this report. Where induced effects are included, specific reference will be made to the fact.

Therefore, when the adjective "total" is here applied to dollar, energy or labour data, the quantities include the sum of the direct and indirect impacts only. If induced effects are included, the term "total plus induced" will be used.

Economists speak of "industry" as all those firms which produce and sell goods and services through market transactions; however, the term is more restrictive in energy statistics. Some confusion can thus arise in a study on the economic implications of energy issues. The appearance of the word in standard type will imply the economic connotation. Where the word appears as *industry* (i.e., in italics), the terminology of energy statistics will prevail; primary industry excluding agriculture, all manufacturing industry and all the construction industry are, in principle, included in *industry*. The energy supply industry itself is not included in *industry* statistics! A list of energy-consuming sectors provides an overview of the aggregate classifications of energy statistics: Energy supply industries; Transportation; Domestic and farm; Commercial; *Industrial*; Non-energy use; and Losses and adjustments.

Where the Long-Term Simulation Model is discussed in this paper, 'final consumption' will refer to household consumption and 'all other' or 'intermediate consumption' will apply to industrial consumption, consistent with economic terminology.

Chapter 1: Introduction

The conservation of energy *per se* is no longer a very controversial subject. Almost everyone agrees that the energy growth rates experienced since World War II in most industrial nations were not just unsustainable but actually wasteful over the long term.

Reaction to the new energy situation has been fairly substantial in Canada as elsewhere in the West. Whether calculated as a total or by energy form, whether recorded for a nation as a whole or by region, whether measured absolutely or in relation to output, energy growth has dropped sharply since 1973.[1] And innumerable projections and load forecasts suggest that it is likely to stay down well below what used to be considered the norm.

If there is general agreement that energy growth will be lower in the future than in the recent past, there is very little agreement about *how much* lower. There is dispute not only about the overall rates of energy consumption, but also about the consumption rates of particular forms of energy and about the specific ways in which lower rates of growth could be achieved. Indeed, the question of the appropriate rate of energy growth has been one of three continuing and pervasive problems at Federal-Provincial meetings on energy (the others

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1 David J. Behling, Jr., "U.S. Energy Consumption and Economic Growth", *Proceedings of a Conference on Energy Conservation and the Economy*, U.S. House Committee on Science and Technology, 91st Congress, (Washington, D.C.: forthcoming).

being price and the role of the public sector). It has also been a prominent issue at public hearings, in the statements of public and private interest groups and in a growing number of professional articles and essays.

The discussion, while fascinating, is often confused by lack of clarity as to whether statements about possible lower energy growth in the future are intended to be positive or normative and as to the basis for comparison. Generally speaking, information about the technological and even the economic efficiency of various conservation options can be provided in considerable detail. In fact, the technical and financial feasibility of such conservation measures as insulation, double glazing, smaller automobiles, returnable containers and so on are seldom seriously in question. If these were all that were at issue, conservation would be further advanced than it is.

Between the knowledge of specific efficiencies described above and the acceptance of greater conservation in our society come two very important factors: political acceptability and overall economic effects. For a variety of reasons, what appear to be reasonable conservation measures are unacceptable to certain groups in society, and this can delay or even preclude their adoption. In addition, there is concern that conservation will entail adverse economic effects, either for some groups or for the economy as a whole, and this too can delay or preclude shifts toward lower energy alternatives.

This report will look at some of the economic effects associated with energy conservation. (For a first and amusing look at some political aspects, see the report by Sewell and Foster.)[2] Economic worries arise both with respect to the immediate impacts of individual conservation measures at any point in time (for example, a program to insulate existing houses) and with respect to longer term impacts of reductions in the ratio between energy growth and GNP growth over time. The fact that such efforts may be economically efficient in the sense of yielding a good rate of return on investment is not sufficient. The questions at issue are more like the following: How will changes affect the demand for labour, and, even more important, for particular kinds of labour (already the subject of major conferences in Canada[3] and the U.S.[4])? How will it affect lower income people who generally are taking a skeptical view of "the energy crisis"?[5] More generally, what will be the effect on inflation, on the balance of payments and on the competitiveness of Canadian industry? It is over such issues, rather than over the economic efficiency of particular proposals, that conflicts have arisen (witness the controversy over

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2 W.R. Derrick Sewell, and Harold D. Foster, *Images of Canadian Futures*. (Ottawa: Department of the Environment, Office of the Science Advisor, 1976).

3 Canadian Labour Congress, *Report of the Conference on Jobs and the Environment* (Ottawa: 1978).

4 United Auto Workers, *Summary of Proceedings*, Conference on Working for Environmental and Economic Justice and Jobs (Onway, Michigan: May 1976).

5 Vernon E. Jordan Jr., "Energy Policy and Black People", *Not Man Apart* (Mid-March 1978).

smaller cars in the United States and disposable soft drink containers in Ontario), and it is only with better information about these effects that there is any hope of their resolution.

This report is designed to provide preliminary answers to some of these questions within a Canadian context, which basically means using Canadian data and Canadian energy policies as a framework for case studies. By and large, the interest in these issues has, and the techniques applied to their examination have, to now, been restricted to the United States, though there have been a few comparable studies in Europe. This report will look at both of the concerns described above, namely: (a) the economic impacts, and particularly the labour impacts, involved in substituting energy conserving technologies for energy producing technologies at one point in time; and (b) the same sorts of effects when moving over time to a lower growth rate for energy use compared with gross national product. In order to provide quantitative results, the short-term effects will be studied for specific conservation proposals applicable to the residential and the automobile sectors of the economy. Similarly, the longer term effects will be studied for one specific low growth rate for energy use (slightly negative). These two parts of the analysis are complementary in that the former yields short-term whereas the latter yields long-term conclusions. For the purposes of this report, one must assume that there have been prior decisions to adopt particular conservation measures or to move towards a lower growth rate for energy use.

For these reasons, several qualifications to the analysis presented below should be introduced from the outset. First, while the specific conservation measures discussed and the low energy growth rate chosen for longer term analysis are not random choices, neither are they claimed to be either exhaustive or optimum. While the specific measures and the low growth rate represent real and important choices open to Canada, different measures might be taken and a different growth rate might turn out to be preferable. Indeed, it would be of some interest to investigate high growth options as well. There is an unfounded assumption that the economic effects of maintaining something like the status quo in energy growth (3 to 5 per cent growth per year) are known while those of lower growth are not. We really know only what happened in the past for a situation which is most unlikely to continue in the future. Looking ahead, we know no more about the economics of high energy futures, or even of moderate energy futures, than we know of low.

Second, this report consists exclusively of demand approaches. No attempt has been made to study the economic effects of substitution among energy sources nor of attempts to increase the supply of energy. Similarly, the economic effects of the development of renewable sources of energy supply, which are often confused with conservation measures, have not been studied. A full review of alternative energy strategies for Canada must, of course, consider alternative rates and patterns of supply development as well as of demand limitation.

Finally, and most important, the analysis provided must be regarded as preliminary both in terms of the methods used and the results obtained. In fact, the purpose of this report is as much to stimulate additional work in this critical area as it is to present the results obtained from study of a few specific situations. In my opinion such work is far more important now than is further work on developing scenarios, or developing technologies, for energy conservation. We know what is possible, and in most cases we even know how to do it. What we lack is a better idea of what will happen if we go ahead and act on the basis of that knowledge.

The basic techniques that will be used in this report are not new. What is new is the use of Canadian data and models and their application to Canadian conditions. Although the American studies of the trade-offs between energy, labour and capital, and of the effects of lower energy growth are useful, the Canadian economy differs in certain key ways from the U.S. economy -- at least in the greater role of imports and the different energy supply mix. Hence, while one might assume a rough parallelism between the two economies, it would be unwise to use U.S. studies as a basis for policy choices and as a predictor of economic effects within Canada. Moreover, if the economies differ in the short term, there is even greater potential for them to differ in the long term when the policy options pursued on both the demand and the supply sides could turn out to be very different.

The remainder of the report is divided into six chapters. Chapter 2 describes the Canadian energy situation very briefly for those unfamiliar with it. Chapter 3 reviews the empirical literature, most of which has been published in the last few years, on economic effects of energy conservation. Chapter 4 describes the methods of analysis for this study. Chapter 5 presents the results of short-term studies using input-output analysis, and Chapter 6 presents the results of a longer term simulation of low energy growth in Canada. Finally, Chapter 7 presents some conclusions. Throughout, emphasis is placed on the impacts on labour.

Chapter 2: The Canadian Energy Situation: Five Years of Change

In the short space of five years, Canada has passed from a period of apparent abundance in energy supplies to one that might be described as "high-level shortage". Canadians are not suffering real shortages in terms of their ability to obtain energy, nor are they paying excessively high prices compared with the rest of the world, but there is a new recognition that limits of one kind or another will preclude continued growth of the energy economy, at least at rates typical of the past. Actually, if abundance is defined as the ability to *export* energy, the period of abundance was very short. It was essentially coincident with the 1960 to 1975 period which also witnessed an enormous growth in per capita energy consumption in Canada. However, if abundance is measured by the presence of a general perception of Canada as "energy-rich", the period of course extends over a much longer period of time. The change in perceptions about energy in Canada since 1973 has been at least as great, and likely more significant for the long run, than the change in knowledge.

However, as indicated above, so far as today's problems are concerned, the key era covers the 14 years between 1960 and 1974 when the growth rate in primary energy consumption in Canada accelerated from a long-term average of 2 to 3 per cent per year, and from the post-World War II average of 4.2 per cent (1945-1959), to 5.6 per cent per year (1960-1970) and 6.1 per cent (1968-1973), as shown in Table 1. This growth was stimulated on the demand side by a Canada with rapidly increasing material affluence and on the supply side by the first flush of important oil and gas discoveries coupled with new hydro developments. That the former was limited by a variety of economic forces, and the latter was overly optimistic because of a profound misreading of both geological evidence on the availability of oil and gas and economic evidence on the costs of electricity, was ignored by almost everyone. Indeed, the near doubling of per capita energy use in Canada over this period was taken as a mark of success rather than as evidence of failure. No one seemed to notice or care that aggregate measures of energy efficiency were not improving at all while for many products specific energy efficiencies were declining (Table 2).[6]

Over the same period, the price for energy remained stable or even declined in real terms (Table 3). During the decade of the 60s, the price of all energy declined by 10 per cent relative to the consumer price index, and the price of industrial energy declined by 30 per cent relative to wages. In part this was a result of huge new supplies coming on the

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6 Primary energy consumption per dollar of national output is a crude measure of the efficiency with which energy is used in an entire economy. The fact that it was stable over this period is suggestive (but not conclusive) of a lack of interest in conserving energy. Specific efficiencies refer to the consumption of energy in order to accomplish a particular task. The falling level of auto efficiency (declining miles per gallon) is well known; what is less well known is that specific efficiencies for buildings, appliances and industrial motors also declined by about 50 per cent over the same period. As usual with comparisons of this sort, the products also changed, but such sharp changes can hardly be ascribed to increased safety, comfort or quality.

market, and in part it was the result of explicit (in the United States) or *de facto* (in Canada) government policies to keep energy prices down. Under these circumstances the economically rational thing was to substitute energy for labour, and, to some degree, for capital. U.S. data show that the share of the total cost associated with each of the major factor inputs for manufacturing -- capital, labour, energy and materials -- has remained quite stable in recent years.[7] Given the declining prices for energy compared with rising prices for labour and relatively stable prices for capital and materials, inputs were adjusted to minimize costs. Even today the situation has changed only somewhat as energy prices have, in general, not quite climbed back to 1950 levels once allowance is made for inflation (Table 3).

Table 1

ANNUAL GROWTH RATES FOR PRIMARY ENERGY CONSUMPTION IN CANADA AND OECD COUNTRIES, SELECTED YEARS

	Canada	OECD Countries
1945-1959	4.2	N.A.
1945-1970	4.8	N.A.
1960-1970	5.6	5.2
1968-1973	6.1	6.9
1973-1974	3.9	-2.0
1974-1975	0.1	-3.3
1975-1976	3.5	5.4
1976-1977	2.6	N.A.

Source: Canada: Department of Energy, Mines and Resources; Organization for Economic Co-operation and Development, *Environment and Energy Use in Urban Areas* (Paris: 1978).

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7 Marc H. Ross and Robert H. Williams, *Energy and Economic Growth*, Study prepared for Joint Economic Committee, U.S. Congress (Washington: August 1977) p. 15.

Table 2

INDEXES OF TOTAL PRIMARY ENERGY CONSUMPTION IN CANADA

(1971 = 100)

	Per Constant Dollar of GNP	Per Capita
1940	114	46
1945	97	54
1950	107	60
1955	105	67
1960	100	67
1965	99	81
1970	103	98
1971*	100	100
1972	102	107
1973	100	112
1974	100	114
1975	100	113
1976	98	116
1977	98	118

* Absolute values in 1971: 69,179 Btu per $ 1971 of GNP and 302.95 x 10^6 Btu per capita.

Source: Department of Energy, Mines and Resources.

Table 3

AVERAGE ENERGY PRICES IN CANADA, SELECTED YEARS

(1950 dollars)

	Heating Oil (per gallon)	Natural Gas (per 1000 cu. ft.)	Electricity (per 100 kWh)	Motor Gasoline (per gallon)
1950	$0.18	$0.93	$1.14	$0.41
1960*	0.15	0.78	0.94	0.32
1970*	0.07	0.39	0.61	0.19
1976	0.17	0.74	0.98	0.32
1977	0.18	0.77	1.06	0.33

* Estimates

Source: Statistics Canada and Department of Energy, Mines and Resources, *Energy Update: 1977*, Report EI78-2 (Ottawa: 1978).

The bubble burst for Canada, as for the rest of the Western world, in 1973. The world woke up to the fact that it faced a situation in which political curtailment of oil supply was an ever-present possibility, in which higher oil prices were all but certain and in which the eventual economic if not physical depletion of fossil fuel supplies could be foreseen.

For all its political ramifications, the price increase probably did provide the first good example of the impact of a depletable resource being faced with increasing demand.[8] The situation was complicated by a growing recognition that almost all alternative energy sources (including renewable sources) were expensive and faced comparable limitations either because of environmental and safety concerns or because of their capital intensity in the face of a world-wide shortage of capital.

Official Studies: 1973 and 1976

In Canada there has been a series of revisions in the official views of where Canada is going in its energy use and production patterns. The first realization that an overall energy policy was needed, *even* in Canada, was reflected by *An Energy Policy for Canada: Phase I*,[9] which appeared in 1973 just before the energy crisis. This was a rather conventional approach to energy policy, but it did introduce a much wider

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8 O.C. Herfindahl, "Some Fundamentals of Mineral Economics", *Land Economics* (May 1955).

9 Canada, Department of Energy, Mines and Resources, *An Energy Policy for Canada: Phase I* (Ottawa: 1973).

range of concerns than had previous statements and it did put forward the inevitability of higher energy prices. However, the "standard forecast" put forward in that report used a projection that, by the end of the century, would have resulted in a four-fold increase in demand in Canada to about twenty quads.[10] (This and other projections referred to below are shown in Table 4.) This was immediately attacked, even from within the Government, as presenting an undesirable scenario,[11] and alternative projections began to appear.[12] Events then made the standard forecast less undesirable than impossible. By 1975, Gordon MacNabb, one of the authors of the 1973 report, and by that time Deputy Minister of Energy, Mines and Resources, could say that: "The standard forecast does not in any way indicate where Canada is going. Much less where it should be going."[13]

The 1976 Federal energy study, *An Energy Strategy for Canada*, was very different.[14] Not only were distinctly higher energy prices incorporated, but so were much more realistic

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10 A "quad" is a convenient term for large volumes of energy. It represents a quadrillion (10^{15}) Btu's or Kilojoules (Kj). Canada's energy consumption in 1976 was about 8 quads while U.S. consumption was in excess of 70.

11 David B. Brooks and Josette Doe, "Energy Conservation: How Big a Target", *ASHRAE Journal* (August 1974).

12 Hedlin, Menzies & Assoc., *Energy Scenarios for the Future* (July 1976).

13 G.M. MacNabb, Speech to Canadian Electrical Manufacturers Assoc. (November 1974).

14 Canada, Department of Energy, Mines and Resources, *An Energy Strategy for Canada* (Ottawa: 1976).

Table 4

ENERGY GROWTH RATES PROJECTED FOR CANADA IN VARIOUS REPORTS

(per cent per year)

Source	Footnote Reference	Primary Energy	Secondary Energy	Remarks
Energy Policy for Canada - Phase I	9			
1. Standard Forecast (to 2000)		5.6	5.4	Business-as-usual base case with moderate price increases.
2. Low Growth Alternative Forecast (to 2000)		3.0	2.8	Down from 1. by assuming slower population and economic growth.
Energy Strategy for Canada	14			
3. High Price/High Growth (to 1990)		4.3	3.5	Down from 1. largely because of higher prices.
4. High Price/Low Growth (to 1990)		3.7	2.7	Down from 3. because of slower economic growth.
5. Target Rate of Growth (to 1990)		3.5	2.5 est.	
Conservation Strategies (1975 - 90)	17			
6. Energy Conservation in Canada (to 1990)		2.0	1.3	Down from 4. and 5. because of greater emphasis on measures leading to efficiency of energy use.
Reference Cases				
7. Zero Energy Growth per Capita		1.3	0.8 est.	Down from 6. because of greater emphasis on lifestyle changes and structural shifts in the economy.
8. Zero Absolute Energy Growth		0.0	-0.5 est.	

ranges for economic growth and population growth, as well as tempered indications of energy supply potential in Canada. One of the main advances in the 1976 energy report was an integrated demand model for the Canadian economy that provided a fair amount of detail, given certain parameters derived from a run of the CANDIDE econometric model of the Canadian economy, of energy consumption by form, sector and region.[15] Perhaps the best known run of this model, which incorporated relatively low economic growth compared with the past, but a fairly rapid shift towards world energy prices, yielded an average primary energy growth of 3.7 per cent per year through 1990; with either lower energy prices or faster economic growth, primary energy consumption would grow at just over 4 per cent per year. After considering these alternatives, the Government chose as a target an energy consumption rate of 3.5 per cent growth per year.

The 1976 report also suggested that with economically justified non-price conservation measures reinforcing the effects of price elasticity, energy growth could be kept to about 2 per cent per year.[16] This result has now been confirmed in a study by the Federal Office of Energy Conservation (OEC).[17] As important as the numbers themselves in the OEC report is

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15 Canada, Department of Energy, Mines and Resources, *Energy Demand Projections: A Total Energy Approach*, Report ER 77-4 (Ottawa: 1977). For main results, see also footnote 14.

16 See footnote 14, page 95.

17 Canada, Department of Energy, Mines and Resources, Office of Energy Conservation, *Energy Conservation in Canada: Programs and Perspectives*, Report EP 77-7 (Ottawa: 1977).

the fact that, from the technical and economic points of view at least, the growth rate of 2 per cent seems readily attainable. Nothing was included that would significantly change the "system" within which Canadians produce and consume goods; rather, emphasis was on improving the specific efficiencies of buildings, automobiles and industrial processes. (The only major exception is that a shift would be required from commuting by automobile to commuting by public transport, and this requires a moderate change in lifestyles and expansion of the public transport system.) Economically the changes could be readily undertaken because, as a rule of thumb for economic efficiency, only those changes were proposed that would pay back investment costs with direct savings in energy use within five years. This is a conservative limitation for pay-off; there are other savings from conservation besides direct fuel costs (for example, smaller furnaces), and many individuals are willing to invest even if the pay-off is longer than five years.

As shown in Table 1, energy consumption in Canada has already reacted to the price changes since 1973. While there was relatively little government assistance available, except by way of information programs, the overall rates of growth of energy consumption were sharply reduced in the three years following 1974. (This parallels the experience in other Western nations, most of which have found it possible to "decouple" energy growth from economic growth over the past few years (Table 1).)[18] Granted that some of the decrease must be attributed to slow economic growth, sectors that are relatively recession-proof (as with home heating fuels) also stopped growing at rates typical of the first half of the decade. By form, disaggregated consumption patterns remain mixed, with electricity consumption growing above the average at 4 to 6 per cent per year, depending upon province, while natural gas and oil consumption fall below the average at 1 to 2 per cent per year.

Conservation: More Studies

The OEC report also referred to a number of ways in which the growth rate could be cut below 2 per cent per year.[19] Some of these methods are relatively inexpensive, as with load management, but others require sizable investments, as with district heating, or institutional adjustments, as with marginal cost pricing. It is not clear how low energy consumption *could* go in the short to medium term simply on the basis of those measures that would "pay off" economically in the face of higher energy prices, but it is clearly less than 2 per cent. A study for the Joint Economic Committee in the United States suggested that with similar sorts of changes to those suggested by OEC but greater emphasis on use of heat pumps and of co-generation in industry, there need be no growth in U.S. energy consumption after 1985.[20]

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18 See footnote 1.

19 See footnote 17, Chapter 4.

20 See footnote 7, pages 44-47.

There has been no official recognition for targets below 3.5 per cent, although the figure of 2 per cent was cited in a number of statements by Gordon MacNabb while he was Deputy Minister of Energy, Mines and Resources.[21] (MacNabb was always careful to describe this as a "maximum conservation position".) Also, the Minister of Energy, Mines and Resources, has suggested zero per capita energy growth (roughly 1.3 per cent per year) as a target.[22] However, the measures necessary to effect even the shift downward to 2 per cent have by no means all been put into effect. Indeed, of the rather impressive list of conservation measures announced by Mr. Gillespie in February 1975, most remain to be implemented.

Recognizing that the year 1990, which is the terminal date for most of its energy studies, was too short for making deep changes in the energy system, the Department of Energy, Mines and Resources initiated a longer term study. The report, which has just appeared, suggests annual growth of around 2.8 per cent to 2000 and 1 per cent a year thereafter. During this time, sources of supply would shift from fossil fuels to nuclear electricity.[23]

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21 G.M. MacNabb, *The Canadian Energy Situation in 1990*, speech for Third Canadian National Energy Forum (Halifax, 1977).

22 Canada, Department of Energy, Mines and Resources, News Release 7/33 (Ottawa: 27 June 1977).

23 J.E. Gander and F.W. Belaire, *Energy Futures for Canadians*, Canada, Department of Energy, Mines and Resources report (Ottawa: 1978).

Other studies have shown that much lower rates of energy growth are feasible for Canada[24,25,26] and for Ontario.[27] These studies have concluded that vigorous pursuit of conservation options would be adequate to cut average energy growth to nil between now and 2025. For the most part, these studies put to one side possibilities for deeper cuts if changing values and conserver society institutions came to play a greater role; the one study that did incorporate such options concluded that a larger and wealthier population could operate with about half the energy consumed today.[28] Similar analyses have been undertaken for the United States,[29] for some individual states[30] and for a number of European nations.[31,32,33]

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24 Amory B. Lovins, "Exploring Energy-Efficient Futures for Canada", *Conserver Society Notes* (May-June 1976).

25 David B. Brooks with R. Erdmann and G. Winstanley, *Some Scenarios of Energy Demand in Canada in the Year 2025*, report to the Long-Term Energy Assessment Team, Energy, Mines and Resources (Ottawa: April 1977); reprinted in U.S. Senate Select Committee on Small Business and Committee on Interior and Insular Affairs, Joint Hearing, *Alternative Long-Range Energy Strategies*, 2 volumes (Washington, D.C.: 1976 and 1977), Vol. II, pp. 1718-1801.

26 John Robinson *et al*, *Canadian Energy Futures: Alternative Energy Scenarios 1974-2025*. (Downsview, Ontario: Workgroup on Canadian Energy Policy, York University, August 1977).

27 Robert Crow, Peter Szegedy-Maszak and Christopher Conway, *Energy Planning in a Conserver Society* (Toronto: Energy Probe, 1978).

28 See footnote 24.

29 John S. Steinhart *et al*, *A Low Energy Scenario for the United States: 1975-2050* (Madison, Wisc.: Institute for Environmental Studies, University of Wisconsin-Madison, July 1977).

30 U.S. Department of Energy, Office of Technology Impacts, *Distributed Energy Systems in California's Future: Interim Report* (Washington, D.C.: 1978).

31 Amory B. Lovins, *Re-Examining the Nature of the ECE Energy Problem*, draft report to the United Nations ECE (23 January 1978).

32 France, Les Amis de la Terre, Commission Energie, *Tout Solaire* (Paris, France: J.-J. Pauvert, 1978).

33 T.B. Johansson and P. Stern, *Solar Sweden* (Stockholm: Secretariat for Future Studies, 1977).

Demurring at least in part from these optimistic conclusions about the potential for conservation are two studies that find much common ground with the Energy, Mines and Resources long term study. One is the well-known WAES report from MIT,[34] which, in the background paper for Canada, allows only for a drop to 2 to 3 per cent in consumption growth through 2000, even with vigorous policy action.[35] The other, still underway as part of Futures Studies at the Institute for Research in Public Policy in Montreal, seems to be heading towards a roughly similar conclusion.

All of these studies it should be noted, allow for increases in population, GNP and GNP per capita, though of course at varying rates. They all assert that their conclusions are broadly economic in the sense that the changes required over the coming 50 years are well within (or close to) the bounds of technical and economic efficiency even at current energy prices. However, emphasis is placed on ensuring, on a sector-by-sector basis, that lower primary energy growth is feasible from a technical point of view (that is, in terms of matching supply and demand and of ensuring that necessary energy consuming functions are performed). The economic impacts and ramifications of such lower energy growth remain to be worked out, and, as noted, this is one of the purposes of this study.

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34 Workshop on Alternative Energy Strategies, MIT, *Energy: Global Prospects 1985-2000* (New York: McGraw-Hill, 1977).

35 Workshop on Alternative Energy Strategies, MIT, *Energy Demand Studies: Major Consuming Countries* (Cambridge: MIT Press, 1976).

Financing Energy Policy

The 1976 energy report remains the "official" statement by the Federal Government on energy policy. However, there are other matters besides demand that require further work. Perhaps the most important of these is financing. The figure commonly cited is that around $180 billion (1975 $) will be required for energy investments in Canada between 1976 and 1990 simply to maintain our current level of energy self-reliance.[36] This would require that the share of annual capital investment in new energy sources rise some 40 or 50 per cent over what it was on the average in the period since 1950. Similarly, the share of domestic borrowing from Canadian savings that is allocated to energy will have to increase from around 8 per cent to over 18 per cent. The conclusion of studies at Energy, Mines and Resources[37] and at the University of Calgary[38] is that the size and flexibility of the Canadian economic system are sufficiently robust to accept the shifts necessary to accommodate energy financing. However, this conclusion is put forward tentatively, and it depends critically on some economic assumptions about other sectors. For example, social expenditures are projected to decline relatively, and this can be questioned given the growing proportion of aged in our economy.

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36 See footnote 14, pages 106-111.

37 Canada, Department of Energy, Mines and Resources, *Financing Energy Self-Reliance*, Report 77-8 (Ottawa: 1978).

38 J.R. Downs, *The Availability of Capital to Fund the Development of Canadian Energy Supplies*, Canadian Energy Research Institute Study No. 1 (Calgary: November 1977).

Moreover, it does not appear that allowance has been made for energy investments made outside the traditional energy producing sector, particularly investments for energy conservation and for the development of renewable energy. (A considerable proportion of these would appear in the figures for residential construction, motor vehicles etc.)

What becomes clear from these studies is that, one way or another, the system is going to have to shift economically in order to accommodate the new energy realities, and that, regardless of whether energy consumption grows or stops growing, there will be economic implications about which we know relatively little.

Oil: A Special Concern

By about 1990 the situation with respect to the domestic supply of and demand for energy should look better, according to Energy, Mines and Resources. At least, it will look better if all of the supply investments that are foreseen as likely are in fact made and if energy growth is kept to no more than 2 per cent.[39] Since there is hesitancy to implement the latter and since the former includes several additional tar sands plants and extensive use of nuclear electricity, this expectation might not be realized.[40]

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39 See footnote 21.

40 Some of the more recent demand and availability diagrams from Energy, Mines and Resources show that expanded conventional gas and oil production (including West Pembina) would close the projected gap between domestic energy supply and demand by about 15-25 per cent; alternatively, it could reduce pressure for high rates of tar sands and heavy oils development.

On the other hand, looking more closely at the numbers, it becomes clear that Canada's energy problem to the end of this century is not so much a total energy gap as a petroleum gap. All other forms of energy either are or could be in balance (from a supply and demand point of view), but net oil trade is likely to leave a continuing and possibly increasing deficit that can only be made up through imports. While this is not the place to argue for or against greater imports of oil, it is clear that they do entail limitations on Canadian foreign policy, questions about security of supply and deficits in the balance of trade. As a result, immediate attention for Canada's supply augmentation program, as well as for its conservation program, has focused on oil.

The oil import situation for Canada is parallelled by that for most other Western countries. Oil imports continue to increase if at a decreased rate.[41] It is this fact which has led to a spate of recent analyses indicating that there will be, probably in the 1980s, a significant gap between the oil that Western nations will want to import and the oil that producing nations will be able or willing to put on the market.[42] However, as with the Energy, Mines and Resources studies, none of these recent analyses has taken into account the potential of a much stronger conservation program, particularly for transportation. While they typically include conservation policy as a

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41 See footnote 1.

42 See footnote 34.

variable now, the analyses do not go much beyond what would likely be produced by higher prices, insulation and a shift towards smaller cars.

Conclusion

In sum, the present energy situation in Canada remains confused, at least so far as demand and conservation are concerned. While the official target remains "less than 3.5 per cent per year" for consumption growth, the government seems to be moving towards a goal closer to 2 per cent. This would bring it in line with targets for most other OECD nations.[43] On the other hand, there is no clear indication yet that the government is solidly behind a conservation program. Many of the most important measures, such as minimum efficiency standards for automobiles and appliances, remain assertions unbacked by Cabinet, and major statements on energy policy, as with those issued by the Federal government at the time of the First Ministers' meeting in February 1978, treat conservation as an afterthought that lies well down in the list of priorities compared with almost any method for producing fossil fuels or electrical energy.

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43 These targets vary from country to country. Denmark intends to cut its energy growth to 1.5 per cent per year by 1990. The United States has an implicit target of 2.2 per cent through 1981, to be achieved by higher prices (which alone would cut growth to 2.8 per cent) and by an "active conservation program". Germany has one of the most moderate goals; 3.2 per cent annual energy growth after 1980. Sweden, on the other hand, has gone further than any other country in this regard; it has declared its intention to keep energy growth at 2 per cent per year through 1985 and "to try to achieve zero growth in final energy demand from 1990 onwards". Organization for Economic Co-operation and Development (OECD), *Environment and Energy Use in Urban Areas* (Paris: 1978).

Chapter 3: Economics of Lower Energy Growth: A Literature Survey

The 1973 energy crisis and the ensuing higher energy prices, together with the realization that the entire Western world was suffering from a deep-seated economic malaise, have led to innumerable studies of the relationships between energy and the economy. Almost all international organizations including the OECD, the EEC, several of the United Nations' Economic Commissions, as well as the various groups spawned by the crisis, such as the International Energy Agency, have devoted a significant part of their effort and funds to studies of ways to change the existing energy situation.

However, so far as Canada is concerned, the most useful studies have to now all been done on the United States. A bibliography published late in 1976 cited only American studies,[44] and two review articles, one published by the Joint Economic Committee in the United States[45] and one by an environmental group,[46] cite no Canadian studies though they do refer to studies done by Canadians using U.S. data.[47] A recent 2000-page two-volume compendium on long-run energy policy published

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44 Frances A. Gulick, *Energy Conservation, Alternate Technologies and Employment*: Library of Congress, Congressional Research Service (Washington, D.C.: December 1976).

45 See footnote 7.

46 Richard Grossman and Gail Daneker, *Jobs & Energy* (Washington, D.C.: Environmentalists for Full Employment, Spring 1977).

47 For example, see Ernst R. Berndt and David O. Wood, "Technology, Prices and the Derived Demand for Energy", *The Review of Economics & Statistics* (August 1975).

by the U.S. Senate[48] reprints only three Canadian studies, including the one by the author that is used as the base for long-run analysis later in this report.[49]

The economic analyses available in Canada focus largely on price elasticities,[50] aggregated projections of energy consumption[51] or the effects of growing demand for capital in the energy supply industries.[52] None of the back-up studies being undertaken for the Department of Energy, Mines and Resources seems likely to delve further into the labour-energy trade-offs or into the longer term economic impacts of slower energy growth, nor do any of the special commissions dealing with provincial energy policy (e.g., the Porter Commission in Ontario)[53] seem to be studying these issues in an analytic way.

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48 U.S. Senate, Select Committee on Small Business and Committee on Interior and Insular Affairs, Joint Hearing, *Alternative Long-Range Energy Strategies*, 2 volumes (Washington, D.C.: 1976 and 1977).

49 See footnote 25. The other two are: footnote 24 and K.G.T. Hollands and J.F. orgill, *Potential for Solar Heating in Canada*, National Research Council, Division of Building Research (Ottawa: 1977).

50 Reviewed in footnote 15, pp. 5-6 and Chapter 4.

51 See footnote 15.

52 See footnotes 37 and 38.

53 Royal Commission on Electric Power Planning, *A Race Against Time*, Interim Report on Nuclear Power in Ontario (Toronto: September 1978).

This neglect of additional economic analyses in Canada is regrettable. While a number of the United States studies refer to Canada, they are often based on inappropriate information or on assumptions of similarity between the two countries. For example, the study by Darmstadter and his colleagues at Resources for the Future comparing the ways industrial nations use energy does provide helpful information on Canada.[54] However, its conclusions are based in part on an analysis that does not appear to deal adequately with the energy content of non-energy imports and exports (that is, the energy contained in goods and services that are imported or exported). While Darmstadter concludes that there is no net energy trade in non-energy products for Canada (that is, the energy content of our imports about balances that of our exports), a Statistics Canada study indicates to the contrary that our non-energy exports are, on the average, 25 per cent more energy intensive than our imports.[55] Given the importance of external trade in the Canadian economy, this is no negligible difference.

Despite the shortcomings of American studies for analysis of Canadian conditions, they are the most advanced both methodologically and in terms of providing some specific information that might indicate directional if not absolute effect in Canada. Therefore, they will be reviewed along with such data as are available for Canada.

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54 Joel Darmstadter, Joy Dunkerly and Jack Atterman, *How Industrial Societies Use Energy* (Washington, D.C.: Resources for the Future, 1977).

55 Kirk Hamilton, *External Trade and Energy Consumption*, Structural Analysis Division, Statistics Canada (Ottawa: February, 1977).

Labour, Capital and Energy

By all accounts Canada has a very energy intensive economy relative to other industrialized nations (with the exception of the United States).[56] The proximate explanation for this clearly lies in our low energy prices. Compared with other nations (again with the exception of the United States), our energy prices are low; not only did they fall in constant dollar terms over the period 1950 to 1970, but, as shown in Table 3, the subsequent reversal has not yet entirely raised them back to the levels of 1950. Consequently, little attention was paid to increasing the energy efficiency of production or of consumption before the early 1970s, and patterns therefore developed in which energy was substituted where possible for other factors of production.[57]

Since the technical potential exists (and has existed all along) to improve energy efficiency, there is every reason to believe that, over the short and medium term, expenditures to conserve energy will yield high returns. Indeed, given recent increases in the incremental costs of developing energy supplies, it is fair to say that the returns to investment in energy conservation will tend to be higher than those in new energy production.[58,59,60]

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56 See footnotes 35 and 54.

57 See footnotes 1, 9 and 47.

58 Graham Armstrong, *Energy Conservation as an Element of National Energy Policy*, Office of Energy Conservation paper (Ottawa: 16 March 1977).

59 Amory B. Lovins, Testimony for Hearings on Costs of Nuclear Power before a Subcommittee of the Committee on Government Operations, U.S. House of Representatives (Washington, D.C.: 21 September 1977).

60 Clark W. Bullard III and Craig Z. Foster, "On Decoupling Energy and GNP Growth", *Energy*, Volume 1 (1976).

In this setting, there is general agreement that, per unit of energy saved or produced, investments in energy conservation will also tend to be more labour intensive and less capital intensive than will those for energy production. How new investments in energy conservation will compare, per dollar of investment, with the average levels of labour and capital intensity in the Canadian economy is much less evident. The increases in energy prices since 1970 can be expected to shift all new investment towards less energy intensive alternatives, but the absolute impact of such marginal changes on average labour and capital intensities is difficult to predict. Moreover, the principle that, at the margin, factor intensities will be equal across all sectors of the economy is unlikely to hold; there are just too many differences in the pricing schemes (existing and historic) for labour, energy and capital. Hence, one is forced back to comparisons of energy investments where institutions such as building codes, social mores including advertising and -- by no means least -- the underpricing of energy have all until recently favoured energy use over energy conservation.

Available data lend support to the generalizations in the preceding paragraphs. As shown by Table 5, employment created per dollar of investment by the energy industries is the lowest of all heavy industrial groups. In a recent speech, Robert Boyd, Head of the James Bay Development Corporation, gave figures indicating that the investment per employee would be $500,000 during the peak construction phase. The light industry and service sectors of course show much greater labour input per dollar. Typical figures are about $18,000 investment per employee in food products, $11,000 in textile mills and $5,000 to $10,000 in service industries.[61] This evidence is further supported by Table 6, which shows the employment creating potential of Canadian industry. While not entirely consistent with Table 5, the direction of the effects is identical.

Table 5

INVESTMENT PER EMPLOYEE, SELECTED INDUSTRIES
(1976 $)

Electric Utilities	$173,370
Petroleum	150,230
Motor Vehicles	41,660
Chemicals	36,420
Primary Metals	29,990
Stone, Clay, Glass	19,210
All Manufacturing	22,240

Source: Christopher Conway and David B. Brooks, *Energy and Employment Alternatives*, Energy Probe (Toronto: June 1978, revised).

So far as costs are concerned, case studies yield much the same sort of result as suggested by aggregate data. In a comparison developed at the Office of Energy Conservation, an oil sands plant producing 0.24 quads per year would cost approximately $6 billion whereas the retrofit of 70 per cent of the residential dwelling stock to save the same quantity of energy would cost approximately $4 billion (both using a discount rate of 12 per cent).[62] In a study developed at the Ontario Ministry of Energy, about 30 per cent of the electrical

61 See footnote 46.

62 See footnote 58.

Table 6

EMPLOYMENT CREATING POTENTIAL OF CANADIAN INDUSTRIES

(Yearly averages of employment created per one million dollars invested for different periods)

	(1) Agriculture & Fishing	(2) Forestry	(3) Mines, Quarries & Oil Wells	(1)&(2)&(3) Resource Total	(4) Manufac-turing	(5) Construc-tion	(6) Utilities	(7) Trade	(8) Finance	(9) Other Services	(10) Total
1966-75	314	320	62	184	342	750	125	1592	356	226	274
1971-75	242	234	51	141	289	637	105	1438	280	193	230
1956-75	483	480	87	291	441	896	160	1789	452	255	339

Source: *The Labour Force*, Statistics Canada Report 71-001.

power provided to apartment houses in 1976 could be saved over the next 25 years by a switch from bulk meters to individual meters.[63] The cost of that switch would amount to approximately $42 million in capital, operating and maintenance costs, whereas the cost of producing and delivering the equivalent volume of energy would be in excess of $60 million.

An additional factor that is not very well quantified involves the labour effects of more rapid turnover of a dollar spent on most conservation projects compared with one spent on most energy supply projects. Turnover has been given great weight by Gaffney[64] as the main source of employment, and this view has been reinforced in testimony before the U.S. Joint Economic Committee's Hearings on "Creating Jobs Through Energy Policy".[65] The most obvious opportunities for substituting labour and energy occur in the manufacturing sector, where capital turnover is relatively high. Berndt and Wood (using U.S. data) found that such opportunities do exist, and that they are

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63 Ontario Ministry of Energy, *A Study of the Relative Merits of Bulk and Individual Electrical Metering for Apartment Buildings in Ontario* (Toronto: December 1977).

64 Mason Gaffney, "Environmental Policies and Full Employment", in George Rohrlich, editor, *Environmental Management* (Cambridge: Ballinger Press, 1976).

65 For example, see Wilson Clark, Statement before the "Creating Jobs Through Energy Policy" Hearings, U.S. Joint Economic Committee (16 March 1978).

likely to be utilized in response to higher prices for energy.[66] They found that, to a considerable extent, labour and energy can in fact be substituted for one another but that the substitution of capital for energy is rather more complex. Under some circumstances, capital and energy are complementary goods, particularly when direct plus indirect demands are included.

There is, therefore, fair agreement that energy and labour are substitutable inputs in most if not all sectors of the economy, particularly if the concept of labour is taken to include the additional time necessary for good design and planning, which turn out to be very important sources of energy conservation.[67,68,69,70] However, there is less agreement about the substitutability of energy and capital. One can reason that the two are substitutes in the sense that the measures necessary to achieve energy savings will generally be capital intensive (though not necessarily more so than energy production). Or one can reason that energy use is closely tied to

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66 See footnote 47.

67 See footnote 7.

68 See footnote 14.

69 See footnote 17.

70 Data Metrics, *The Industrial Demand for Oil and Gas in Ontario*, Canadian Energy Research Institute Study No. 2 (Calgary: March 1978).

the volume of capital used, so that the two inputs are complements rather than substitutes.[71]

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71 There have been a number of attempts to reconcile the question of whether energy and capital are competing or complementary factor inputs. An analysis by Data Metrics, based on industrial data in Ontario, distinguishes between micro-economic and macro-economic impacts (See footnote 70, page 3, italics in original):

> "The concept enables a distinction to be made between what is termed a *gross substitution* effect, which relates to the energy and capital intensity of providing utilized capital services, and the potentially off-setting *scale* effect, which relates to the amount of capital services purchased, given their price. The combination of these two effects will determine whether energy demand will increase or decrease in relation to relative changes in the prices of capital, energy and other inputs in the production process."

This conclusion seems consistent with that of David O. Wood, who approached the problem from both theoretical and empirical points of view.[72] According to Wood:

> "Engineering studies of energy conservation potential emphasize the substitution possibilities between capital and energy. These studies tend to be supported by several econometric studies indicating E-K substitution in U.S. manufacturing. Other econometric evidence has suggested E-K complementarity, and has been challenged as inconsistent with the engineering studies. Our purpose has been to develop an analytical framework in which we demonstrate that E-K complementarity is not inconsistent with the engineering studies providing that we hold the same things constant. Engineering studies of energy conservation potential typically hold constant the output of utilized capital, trading off energy and capital within the fixed bundle. Such econometric evidence as exists holding the output of utilized capital fixed is entirely consistent with E-K substitutability although there are few comparable engineering and econometric studies."

72 David O. Wood, "Energy Demand and Capital Formation in Manufacturing", *Proceedings of a Conference on Energy Conservation and the Economy*, U.S. House Committee on Science and Technology, 91st Congress (Washington, D.C.: forthcoming).

The essential issue, however, is that strategies designed to reduce energy consumption include both high and low capital intensity measures. This is made clear by specific examples. Because of the importance of sound planning with respect to siting and architectural layout, it has been shown that well designed large buildings (that is, those with heating, ventilating and air conditioning systems) are no more capital intensive even when energy savings of 50 per cent or more are obtained compared with standard alternative designs. Similarly, smaller automobiles are both energy and capital saving. On the other hand, such conservation options as public transit systems or extensive retrofitting of large buildings appear to be just about as capital intensive as new supply.

The exclusion of indirect effects[73] from some of the foregoing data, and of induced effects from all of them, would not change the results. Except for a slight netting effect on the energy savings, it is likely to strengthen them. For one thing, even if one assumes that the indirect effects of energy conservation are equivalent to those of energy production (a very conservative assumption), energy conservation will save all of the additional costs involved with transporting and transmitting energy to the consumer, costs which are by no means negligible.[74] In addition, for electricity generated by burning fossil fuels, there are further savings equivalent to two units of primary energy for every one delivered to the

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73 See note on terminology for explanation of these terms.

74 Footnotes 14 and 17.

consumer as electricity. Moreover, given that the measures are economically efficient, consumers will, in the absence of higher energy prices, have a surplus which they can spend. No matter how they choose to spend (or save) this money, there will be both energy and labour impacts. This means that the net energy savings from conservation will be somewhat attenuated and the labour effects somewhat magnified. Short of spending the conservation savings on energy itself (e.g., buying motor boat fuel with money saved from insulating a home), the netting effect for energy is likely to be small. There is hardly any way that one can spend money that will not be significantly more labour intensive than spending on energy itself.

Trade-Off Between Labour and Energy

A number of studies have tried to estimate the direct and indirect employment effects of alternative energy approaches. One set of numbers, developed at Energy Probe using as much Canadian data on direct employment as was available, yielded the following results for a $1 billion (1977 $) investment in Ontario:[75]

Option	Btu's Delivered or Conserved Over 30 Years	On Site Man-Years Over 30 Years
Conservation	1594×10^{12}	22,250
Methanol Production	450×10^{12}	36,000
Solar Heating	420×10^{12}	9,000
Nuclear Electricity	471×10^{12}	8,000

75 Christopher Conway and David B. Brooks, *Energy and Employment Alternatives*, Energy Probe (Toronto: June 1978, revised).

The addition of operating costs would add most to the costs of nuclear and methanol options, while the addition of off-site (indirect) labour would add most to the labour impacts of the conservation and particularly the solar option which is high in material costs. This study was undertaken in response to the Federal Government's "million man-years" proposal (to the Conference of First Ministers in February 1978) for investment in large-scale energy projects and showed that the same employment could be obtained for half the cost by investing in smaller scale conservation and renewable energy projects.

The most important studies of the labour-dollar-energy trade-offs have been done under the direction of Bruce Hannon at the Center for Advanced Computation, University of Illinois.[76,77,78] By using an expanded input-output table, much like that available at Statistics Canada, Hannon and his colleagues investigated the effects of various shifts in energy policies and in energy consuming habits to see what the direct, indirect, *and induced* effects might be. Some of these results are presented in Figure 1 and Table 7.

Figure 1 shows the labour and energy intensities for a wide range of typical consumer expenditures. For example, cooking food at home is slightly less labour intensive and slightly

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76 Bruce M. Hannon, "Energy, Labor and the Conserver Society", *Technology Review*, Vol. 79 (March/April 1977).

77 Bruce M. Hannon, "Options for Energy Conservation", *Technology Review*, Vol. 76 (February 1974).

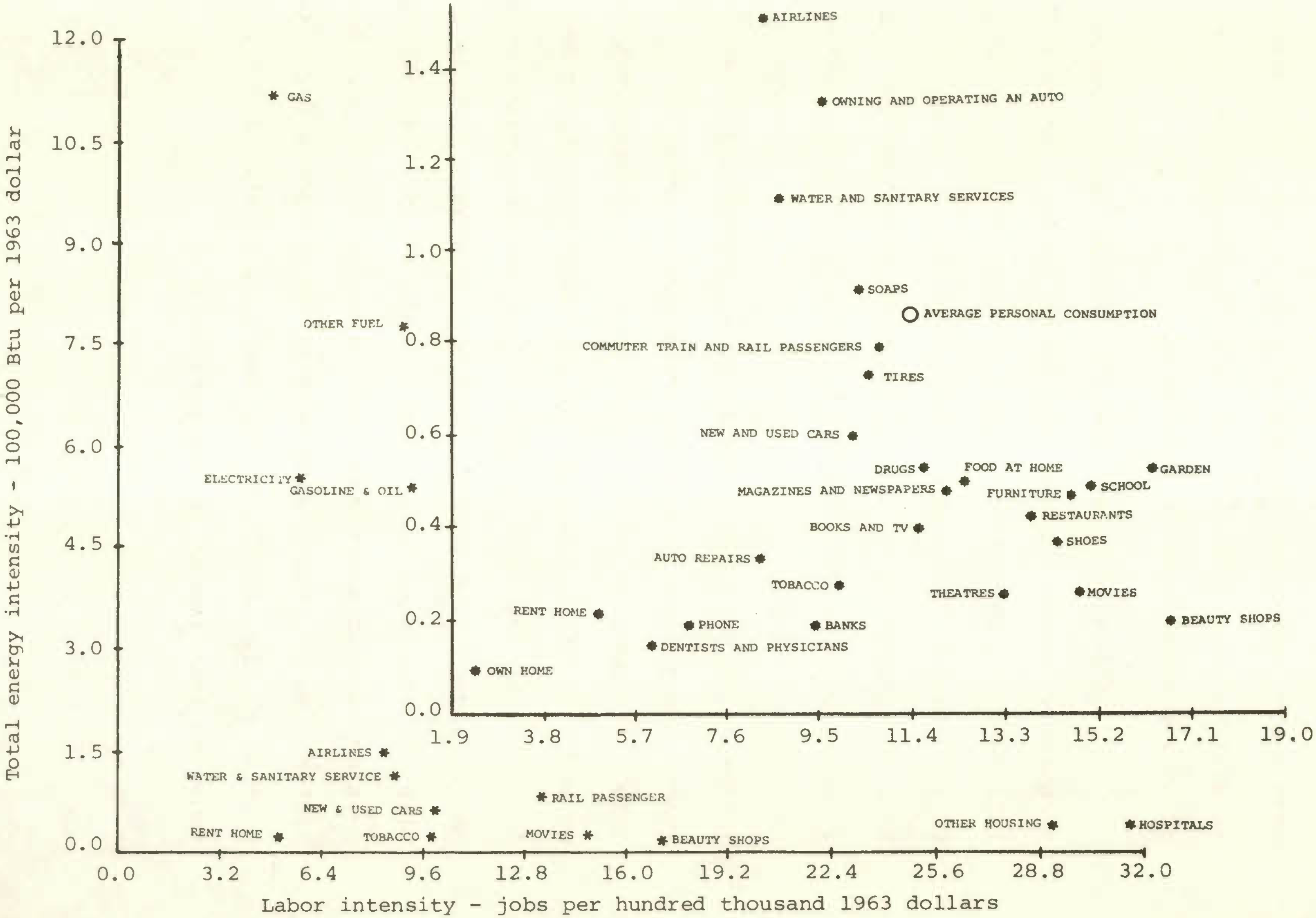
78 Bruce M. Hannon, "Energy Conservation and the Consumer", *Science*, No. 4197 (11 July 1975).

more energy intensive than going to a restaurant. As indicated, there is some tendency for consumer expenditures to lie close to one or the other axis (that is to be significantly more labour than energy intensive or vice versa), though this tendency is exaggerated by direct expenditures on energy itself, which are of course highly energy intensive.

Table 7 lists a variety of options that might be adopted to conserve energy (again, including direct, indirect and induced impacts) in order of the number of new jobs created per unit of energy saved. For example, shifting from a "plush" kitchen with lots of appliances to a more moderately equiped one will create 30,000 jobs for every quadrillion Btu's of energy saved. There are large differences among the options with respect to their job creating potential. Equally important, almost all the things commonly suggested to reduce energy consumption do create jobs. Only a few options were identified in which employment decreased at the same time as energy use decreased (the third section of Table 7) and just one in which employment increased as energy use increased (the second section). Hannon's results are indicative for the Canadian economy as well as for the U.S., but in part because of differences in structure and in part because of differences in method with respect to induced effects (explained further in Chapter 4), direct comparison between his results and those in this report is not possible.

Figure 1

TOTAL ENERGY AND LABOUR INTENSITIES OF VARIOUS PERSONAL CONSUMPTION EXPENDITURES, UNITED STATES 1963
(The Inset is an Enlargement of the Central Portion of the Data)



Source: See footnote 78.

Table 7

ESTIMATED ENERGY-LABOUR IMPACTS OF A VARIETY OF CONSTANT INCOME CHANGES IN THE U.S. ECONOMY

Project	New Jobs Per Quadrillion New Btu (Saved)
(U.S. Economy; 1974)	(940,000)
Changing from....	
....Plane to Train (Intercity)	930,000
....Throwaway to Refillable Beverage Containers	750,000
....Car to Train (Intercity)	700,000
....Owner-Operator Truck to Class 1 Freight Train	675,000
....New Highway Construction to Health Insurance (Federal)	640,000
....Car to Bus (Intercity)	330,000
....Car to Bus (Urban)	210,000
....New Highway Construction to Personal Consumption	200,000
....Car to Bicycle	200,000
....Plane to Car	160,000
....Plane to Bus	140,000
....Electric to Gas Stove	160,000
....Electric to Gas Water Heater	120,000
....Electric Commuter to Car	110,000
....Electric to Gas Clothes Dryer	100,000
....Frost Free to Conventional Refrigerator	60,000
....Plush (25 appliances) to Moderately Equipped (16 appliances) Kitchen	30,000
....New Highway Construction to Railroad and Mass Transit Construction	30,000
....Present to Increased Home (Oil Heat) Insulation	15,000
....Moderate to Spartan (4 appliance) Kitchen	10,000

Project	Jobs Gained Per Quadrillion Btu Lost (Used)
(Average U.S. Economy; 1950-1973)	(1,620,000)
Changing from Electric Commuter to Bus	530,000

Project	Jobs Lost Per Quadrillion New Btu (Saved)
Changing from....	
....Black & White TV to Radio	35,000
....Present to New Electricity Supplies	75,000
....Bus to Bicycle	330,000
....Car to Motorbicycle	430,000
....Color TV to Black-White TV	1,750,000

Project	Jobs Lost Per Quadrillion Btu Lost (Used)
Changing from....	
....Beef Protein to Textured Soy Protein	720,000
....Beef Protein to Direct Bean Consumption	860,000
....Beef Protein to Complete Soybean Meat Analog	970,000
....Class 1 Truck to Container Train	13,600,000

Source: See footnote 76.

Other studies in the United States have reached similar results, though perhaps without such broad-scale analysis.[79] For example, Laitner found that over a five-year period, production of every 1,000 high-efficiency window air conditioners would yield a total of three more jobs than 1,000 low-efficiency

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79 Similar but even more preliminary results have been obtained when comparing renewable energy supply technologies with conventional ones. Employment opportunities range from 1.5 to 6 times higher with renewable energy options (the lower figures for intermediate approaches such as wind without storage and the higher ones with low technology approaches such as wood heating) per unit of delivered energy.[80,81] The one detailed Canadian study deals only with solar heating; it identifies a significant gain in employment for solar compared with conventional heating systems but emphasizes that the gain comes largely during installation rather than in manufacturing.[82] However, the first thoroughly documented study of solar and conservation alternatives on a regional basis is now nearing completion at the Council on Economic Priorities in New York. This "Long Island Jobs Study" focuses on energy-employment relationships on Long Island because two energy plans were possible there: increased use of nuclear power or a combination of conservation and solar energy. Given a specific proposal to construct nuclear plants, and a significant regional unemployment rate, the issue is real. The study will quantify the regional employment and other economic effects of the two alternatives including direct, indirect and induced labour requirements and the comparative impacts of capital investment in different sectors of the economy.

80 See footnote 46.

81 J.A. Potworowski and B. Henry, "Business Opportunities in Renewable Energy", *Conserver Society Notes* (Fall, 1976).

82 Peter A. Victor, George Hathaway and Jack Lubek, "Solar Heating and Employment in Canada", a study prepared by Middleton Associates for the Department of Energy, Mines and Resources (September 1978).

air conditioners.[83] (This figure includes net effects in both manufacturing and electricity production.) Given that some six million air conditioners are produced in the United States each year, the potential of mandatory efficiency restrictions is obvious.

Hannon's work also finds support in the conclusions of Cogan and his associates at the International Institute for Economic Research.[84] In this case study, five alternative government programs by which the United States might cope with the energy situation were investigated to determine their likely economic effects in the near future. Each of the programs that involved higher energy prices (for example, decontrol of oil and natural gas, tax on energy imports, etc.) or which mandated decreased energy consumption had the effect of increasing employment. The effects on real Gross National Product were more mixed and seemed to depend upon the extent to which U.S. energy production was or was not stimulated by the specific program.

Empirical work by McCulla using the 1966 input-output tables for Canada suggests that the same effects found for the U.S. would be obtained here.[85] Using highly aggregated

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83 Skip Laitner, "The Impact of Solar and Conservation Technologies Upon Labor Demand", Paper Presented to the Conference on Energy Efficiency (Washington, D.C.: 20 May 1976).

84 John M. Cogan, Bruce Johnson and Michael P. Ward, *Energy and Jobs: A Long Run Analysis*, International Institute for Economic Research, Original Paper 3 (July 1976).

85 D.J. McCulla, "Minerals in Canadian Economic Development: Recent Quantitative Analysis", *Proceedings of the Annual Meeting of the Council of Economics of the AIME, 1976* (New York: AIME, 1977).

industries, he determined the impact of $1 million of output and calculated multipliers for total production, real domestic product and employment. As shown in Table 8, Petroleum and Natural Gas has the lowest multiplier for production of any of the primary industries, and a very low employment impact. Similarly, Petroleum Products has a low multiplier compared with Semi-Fabricated Minerals and Manufacturing, and an even lower employment impact. (In fact, the direct employment in both Petroleum groups is so low that the employment multiplier comes out high, which is simply a reflection of the fact that any numerator divided by a small enough denominator will give a big number.) Dividing figures for direct employment into the initial impact of $1 million gives a figure for the gross output per worker. These range from a low of just under $28,000 in Other Manufacturing to a high of $200,000 in Petroleum Products and $100,000 in Petroleum and Natural Gas, which are reasonably consistent with the figures cited above.

Income Effects

Distribution of Income

The impact of changing energy use on income distribution has been studied by both Hannon[86] and by the Ford Foundation.[87] They both find that lower income people spend a greater proportion of their income directly on energy, but that, when both direct and indirect energy consumption are included, energy

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86 See footnote 78.

87 Ford Foundation Energy Policy Project, *A Time to Choose* (Cambridge: Ballinger Press, 1974), Chapter 5.

Table 8

IMPACT COEFFICIENTS AND DERIVED STATISTICS FROM $1 MILLION OF OUTPUT IN MAJOR PRODUCING SECTORS IN CANADA

Industry Group	Gross Production Multiplier	Real Domestic Product Multiplier	Direct Employment (man-years per million dollars of output)	Total Employment (man-years per million dollars of output)	Employment Multiplier	Backward Linkage	Forward Linkage	Direct Import Co-efficient	Indirect Import Multiplier	Ratio of Surplus to Value Added
Agriculture, Forestry and Fishing	2.80	1.70	30	105	3.53	.39	.78	.08	.07	.21
Mining	2.30	1.49	33	91	2.76	.33	.56	.26	.08	.59
Petroleum and Natural Gas	1.82	1.25	10	42	4.20	.34	.55	.45	.03	.83
Primary Metals	2.39	1.37	23	101	4.39	.80	.66	.06	.17	.32
Semi-Fabricated Minerals	2.79	1.44	15	108	7.20	.83	.86	.17	.22	.30
Metal Based Manufacturing	2.67	1.37	31	103	3.31	.64	.29	.34	.25	.26
Petroleum Products	2.22	1.00	5	45	9.00	.86	.55	.10	.35	.50
Other Manufacturing	2.84	1.56	36	125	3.43	.62	.49	.13	.24	.31
Average	2.48	1.40	23	90	3.91	.60	.59	.20	.18	.39

Source: See footnote 85.

use appears to be roughly proportional to income. Thus, as stated by Hannon, the results are "...such that the spending of an average additional dollar of income demands nearly the same amount of energy, regardless of one's income level. Thus, doubling one's income doubles one's energy use".[88]

This is an important conclusion because the adverse effects of higher energy prices on poor people have led many observers to oppose higher prices despite their conservation benefits.[89] However, even if the relative impact of higher energy prices is equal across income groups, the opportunity to adopt conservation measures is not. Not only is there a capital (and an information) barrier for many, but the impacts of higher prices are immediate while the conservation savings occur over time. Government programs aimed primarily at conservation of heating fuels, automobile gasoline and electricity use by individuals and families, can help offset the adverse distributional consequence of higher prices while retaining their conservation impacts. Not only will the programs promote conservation in just those forms of consumption that loom largest in low-income budgets, but the effect of equal monetary savings (from, say, an insulation retrofit grant or automobile efficiency standards) will be greater relative to income for lower income groups.[90]

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88 See footnote 78, page 6.

89 See footnote 5.

90 See footnotes 1, 3, 4 and 59.

Unfortunately, it is not clear, and, given the method cannot be clear, whether the general conclusion about income distribution and energy put forward above would apply to a marginal dollar as well as to an average one. That part of income that is spent indirectly is likely to come from discretionary income while the part that is spent directly is largely fixed by living and working patterns that are difficult to change quickly. This means that direct energy expenditures will have a lower price elasticity than will indirect ones, and consequently higher energy prices will have a more severe impact on lower income people. Moreover, because of differences in structure among the industries supplying goods and services, one might doubt whether indirect cost increases resulting from higher energy prices will be passed on as quickly as direct increases in heating fuels, gasoline and electricity have been. In short, while the changing energy situation may not have so adverse an effect on the distribution of income as first appears, the possibility of negative consequences can by no means be ignored and careful monitoring will be essential.

Real Wages

Figures given earlier in this chapter, all of which point to significant opportunities to trade off energy for labour, have the following important implication: as labour is substituted for capital and/or energy, the real per hour compensation of labour would be expected to decline relative to these other inputs. According to Hannon[91] the ratio of labour wages to electricity

91 See footnote 77.

prices, for example, rose throughout most of the post-war period and did not begin dropping until after 1970, and this was also the first time that, according to other indices, employment began to be substituted once again for energy use.

The *cause célèbre* of the returnable beverage container provides a case study. While shifting to a returnable system will cause the total number of jobs to increase, the number of high paying jobs will decline.[92] It is this conflict, of course, and the fact that the jobs are in different unions and different locations, that converts an aggregate complementarity between energy conservation and employment to a specific conflict. Moreover, the number of workers involved in job shifts is substantial. An analysis of the container industry in Ontario indicated that there would be a net increase of 645 in the province's employment as a result of conversion to a fully returnable system for soft drink containers. A decrease of about 1,700 skilled and semi-skilled employees in the metal container and support industries, in the glass container and support industries, and in solid waste and litter collection, would be more than offset by an increase of 2,435 unskilled employees to handle the returnable bottles for the bottlers and retailers.

Corroboration for these conclusions is found in a Swedish study which concludes that, while there is no important conflict between the goals of increasing employment and decreasing energy consumption, there is an important conflict between the

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92 Ontario Ministry of the Environment, Report of the Solid Waste Task Force (Toronto: 1974).

latter and increasing real wages.[93] However, to the extent that the main impact of simple conservation measures will be found in residential heating and in automobiles, direct expenditures on energy by individuals will be reduced, and this will offset to some extent the trend towards lower gains in real wages as labour is once again substituted for energy.

Investment Costs and Inflation

There seems little question but that most energy conservation projects (as well as a few renewable energy schemes) are capital saving. The results obtained do, however, differ critically depending upon whether one is comparing conservation with the average or the marginal costs of new energy supply. If the question is that of undertaking either a conservation scheme or of developing new energy sources, clearly the marginal comparison is appropriate. If the alternative to conservation is within the range of existing production capacity, there is some justification for the average cost comparison.

The most striking differences are obtained with a comparison of marginal costs for the reasons that energy conservation has been neglected for so long, and the price changes have come so suddenly, that it is clearly intra-marginal. Amory Lovins[94] has prepared sets of tables showing that the marginal capital investment for complete energy systems (that is, systems

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93 Mans Lonnroth, Peter Steen and Thomas B. Johansson, *Energy in Transition*, Secretariat for Future Studies (Stockholm: 1976).

94 See footnote 59.

providing delivered energy) in the U.S. range from nil to $25,000 per daily barrel of capacity for extensive conservation in existing buildings,[95] from $2,000 to $10,000 for conventional (or North Sea) oil and gas, from $20,000 to $70,000 for synthetic fuels, and upwards of $200,000 for nuclear electricity (all in 1976 dollars).

Rough comparisons indicate that the situation is no different in Canada. For typical projects, conservation is a good investment even compared with the average costs of supplying energy from waterfalls and from wells in southern Canada; it is a superb investment compared with the marginal costs of nuclear power or of frontier oil and gas. Unfortunately, improved aggregate comparisons have not been made for Canada. What are available are a few specific comparisons of alternative projects. Particularly useful are those for retrofitting existing buildings (a relatively expensive form of conservation), for improved appliances and for conversion of automobile plants to production of more efficient vehicles. These comparisons are not so dramatic as those cited above, though they support the main conclusion. For example, the full costs of retrofitting residential buildings in Canada average $42,000 per barrel per day; the costs for improved thermal efficiency in new residential buildings is somewhat lower at about $35,000 per daily barrel (both in 1976$).[96] North American refrigerators could double their

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95 The unit "dollars per daily barrel" refers to the dollar investment necessary for the capacity to save or to produce the energy equivalent of one barrel of oil (approximately 5.8 million Btu's) a day.

96 Both figures were calculated from data in footnote 17, page 21.

efficiency if manufacturers would add features (such as more insulation and heavier motors) costing the equivalent of $750 per kilowatt of capacity,[97] which is less than the cost of new electrical generation.[98] Improved automobiles yield a benefit-cost ratio of three to six when energy savings are compared with added investment in retooling plants.[99]

For the sorts of conservation projects usually considered first (improved buildings, more efficient autos, etc.), costs tend to be one-third to two-thirds those of new sources of supply. Indeed, an approximate 10 per cent saving is possible through actions, such as thermostat reductions and closing warehouse doors, that are essentially costless. Moreover, there appear to be costless changes in building design (costless in the sense that the costs per square foot of construction do not increase) for commercial buildings that have much larger pay-offs. (Unfortunately, data on this sector are so poor as to preclude calculation of either total costs or direct comparisons of energy savings per dollar with other sectors.) Of course, as noted above, other conservation projects, such as rail transportation schemes, are more capital intensive.

Such conclusions bear on some other matters as well. Among other things, they suggest that energy conservation will be

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97 Lee Schipper and Joel Darmstadter, *What is Energy Conservation?*, Lawrance Radiation Laboratory Report No. 5919 (Berkley: 1977).

98 In 1975 the added features would increase the price of a 16-cubic foot refrigerator by about $50.

99 See footnote 58.

counter-inflationary relative to investments in new energy supply facilities capable of producing and delivering an equivalent volume of energy to consumers; in effect the same result can be achieved with less strain on capital markets (both in Canada and in international markets where Canadians borrow). Also to the extent that the savings are in oil, there is an immediate effect on both Federal expenditure and on international payments. Not only is the total volume of imports lower, but Federal subsidy payments are reduced. (These payments are made to maintain the one-price system for oil within Canada at a level below world prices. When Canadian oil exports matched oil imports, the payments fund was in balance, but as the former have been cut back, the fund has gone into deficit.)

However, by no means all efficient, capital-saving conservation options are adopted. Inexplicably, many are reported to be neglected, even in industry, unless they can show an extraordinarily high rate of return.[100,101] This means that Canada, and other industrial nations, may be ignoring additional weapons to fight inflation.

Longer Term Relationships Between Energy and Economic Growth

We have come a long way in the past few years from the idea that there was some fixed relationship between economic growth and energy consumption.[102] Indeed, in the past few years

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100 G.N. Hatosopoulos *et al*, "Capital Investment To Save Energy", *Harvard Business Review* (March-April 1978).

101 Tom Alexander, "Industry Can Save Energy Without Stunting Its Growth", *Fortune* (May 1977).

102 See footnote 1.

emphasis has turned towards the variability of this relationship rather than its constancy, and this is just as true of the economic literature as of the environmental.[103] Nevertheless, the presumed historic relationship is still commonly presumed to continue, particularly for electricity.

Unfortunately, studies of the longer term effects of slow energy growth are even less common than those for short-term shifts. The only major exception to this generalization involves studies of long-term price elasticity, which is not at issue in this study. The most important analyses available that deal with energy and growth over time are based on work by Hudson and Jorgenson for the Ford Foundation Energy Policy Project.[104,105,106] Using a highly aggregated input-output model of the U.S. economy, Hudson and Jorgenson were able to project the effects of alternative input combinations to the turn of the century.

While this study has been criticized,[107] it remains the most useful that we have -- the more so as the three growth rates (roughly 4 per cent for historical patterns, 2 per cent for

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103 For example, see footnotes 7 and 54.

104 See footnote 87, Appendix F.

105 E.A. Hudson and D.W. Jorgenson, "U.S. Energy Policy and Economic Growth 1975-2000", *Bell Journal of Economics and Management Science* (Autumn 1974).

106 See footnote 60.

107 J.A. Hausman, "Project Independence Report", *Bell Journal of Economics and Management Science* (Autumn 1975).

"technical fix"[108] and zero energy growth) are quite comparable to the options under consideration in Canada.

In truth, few economists actually make an assumption of a fixed relationship between energy growth and economic growth inasmuch as they recognize energy to be only one of numerous inputs to outputs. However, the assumption appears implicitly in many models and conclusions. For example, in Resources for the Future's major study, *Resources in America's Future*, one reads: "Growth of population and economic activity during the remainder of the 20th century is expected automatically to increase the energy needs of all categories...".[109] This report, one of the best of its kind, did go on to add: "But a number of other factors, notably changes in technology and in consumers' tastes and preferences, may have marked effects on how the total increase in energy requirements is shared among the different types of use."

As emphasized in case studies, there exists a great variety of ways to alter significantly the volume and form of energy consumed in order to provide for a given level of economic

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108 The term "technical fix", as used by the Energy Policy Project and later by many others, refers to an energy policy in which economic efficiency is the major goal; governments intervene as necessary (e.g., enforcing building codes, providing mass transit, promoting research) to ensure the attainment of economic efficiency. Although the concept of a technical fix energy policy is useful, the term itself is misleading because it emphasizes the technical feasibility of proposed actions rather than their economic feasibility, which is what is really at issue. Perhaps "economic fix" would be more appropriate.

109 Hans H. Landsberg, Leonard L. Fischman and Joseph L. Fisher, *Resources in America's Future* (Washington, D.C.: Resources for the Future, 1963) page 194.

activity.[110] Darmstadter and his colleagues at Resources for the Future analyzed energy consumption in nine industrial countries and showed that the rate of energy consumption is a multiple function involving: 1) what a country is doing; 2) how it is being done; 3) how much of that activity is going on.[111] For example, energy use depends upon the type of housing being built, upon the specific efficiency of energy use per household, and upon the number of households; again, it depends upon the particular industrial product at hand, the specific efficiency of energy use in its production process and the volume of output. Each of these functions is in turn subject to a variety of influences, both intended and unintended. Perhaps most important, each is subject to adjustment, if not full control, by policy. And each is subject as well to modification as tastes and preferences change.

Two instructive perspectives now emerge as replacements for the simplistic assumption of a fixed monotonic relationship between economic activity and energy use:

1) while, from the perspective of physics, there are limits to the efficient transfer of energy, the gap between actual energy transfer efficiency and these limits is sufficient to permit the maintenance and indeed the expansion of given activities even as energy requirements

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110 See footnote 7.

111 See footnote 54.

decrease by improvements in the efficiency of energy production and consumption; and

2) the ways in which individual and social utility may be achieved are sufficiently numerous to permit the maintenance and growth of aggregate economic activity while reducing energy demand, so long as energy efficiency improves in the delivery (and disposal) of goods and services.

Despite the foregoing, there remain some unresolved issues concerning long range interactions between energy growth and economic growth, issues that, despite the tenor of much of the current debate, relate more to economics than to physics. Energy consumption has, after all, been a factor stimulating the economy even as it has resulted from the growth of the economy. There are at least two partly overlapping views about how the relationship between energy and economic growth might be re-established once a strong program of energy conservation has taken effect. One view, put forward first in the Ford Foundation Energy Policy Project[112,113] and more recently in the CONAES[114] study in the United States,[115] is based on

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112 See footnote 87, Appendix F.

113 See footnote 60.

114 Committee on Nuclear and Alternative Energy Systems, funded by the U.S. National Research Council and the Department of Energy.

115 CONAES, Demand and Conservation Panel, "U.S. Energy Demand: Some Low Energy Futures", *Science*, Vol. 200 (14 April 1978).

engineering and suggests that there will come a point when opportunities for energy efficiency improvements in the economy have been largely exhausted. After this point, the growth of energy consumption may once again be constrained to track the growth of the economy. The other view, stemming from economic models, suggests that the impacts of low energy growth would eventually limit consumption and thus have a damping effect on economic growth. According to one analysis zero energy growth could be achieved if real energy prices rose, on the average, at 6.7 per cent per year to the end of the century; in so doing there would be a 50 per cent energy saving for the year 2000 but a loss of nearly 12 per cent in the GNP compared with results obtained in a base case for 2000.[116] An independent theoretical analysis gave surprisingly consistent results by indicating that energy curtailment of about 50 per cent would be sufficient (unless other inputs are highly substitutable for energy) to cause significant losses of output.[117,118]

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116 David J. Behling, Jr. and Edward A. Hudson, *Policies for Energy Conservation: Potentials, Mechanisms and Impacts*, BNL Report 50792 (Upton, N.Y.: Brookhaven National Laboratory, 1978).

117 Brian D. Wright, "Another View of Conservation", *Proceedings of a Conference on Energy Conservation and the Economy*, U.S. House Committee on Science and Technology, 91st Congress (Washington, D.C.: forthcoming).

118 Discussion of this point at the Conference where these results were presented focussed not just on the conclusions themselves but also on the extent to which the loss of output either was or would be perceived as a loss in welfare by many people. This is an enormously important point in relatively wealthy societies, but one that is well beyond the scope of this review.

In summary, in the short and medium term, factor endowments, the state of the art in technology, individual and social tastes, and the fixed nature of infrastructure all limit the rate at which a more energy efficient economic system can be put in place. Over time, however, the relationship between the level of the economy and the rate of energy consumption is not so limited. While there are thermodynamic laws establishing maximum levels of energy efficiency, these apply rigorously only to well defined tasks, and the number and kinds of tasks that go to make up an economy, particularly a relatively wealthy economy, can vary widely.

Having said that, it remains true that the long-term and dynamic relationships -- or, better, interrelationships -- between energy and economics are far from fully understood, much less those between energy and either standard of living or quality of life. Energy consumption and economic growth may indeed be linked, though not in the same way as in the era of rapid energy growth. This is one field where the past, at least the recent past, is not prologue, so it is important to investigate futures in which energy and economics are "decoupled" to understand better what impacts might obtain. This is exactly what is attempted in the following chapters.

Chapter 4: Analytical Approaches for this Study

This chapter will focus on sources of data and general methods for the analyses undertaken in the next two chapters. The first part will describe some shorter term relationships between energy and the economy, particularly the labour-energy trade-offs, using a static input-output model. The second part will describe longer term relationships using the long-term simulation model.

The basic information for the short-term studies comes from the report of the Office of Energy Conservation,[119] while that for the longer term studies comes from a report by Brooks.[120] The two studies are summarized in an article published in *Alternatives*.[121] In accord with the time frames used in those studies, the short term is taken as including the period 1976 to 1990, while the long term is taken as including the period through the year 2025. There is no unique justification for these two dates. Speaking very generally, no significant changes could be made in the energy system much before 1990 (which is not to say that significant savings could not be achieved); however, the rate of turnover of capital is such that most conceivable changes in that system could take place by 2025. Also, and perhaps more to the point, these are the dates that have been commonly used as benchmarks in Canadian government publications.

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119 See footnote 17.

120 See footnote 25. Appendix "A" provides a summary of this report as an extended background to this chapter.

121 David B. Brooks, "A Real Option: Conservation to 1990 and Beyond", *Alternatives* (Fall 1977).

The difference between these two sorts of economic effects is very much that between the short term and the long term. In the short term it is reasonable to project some base line of energy consumption that is consistent, given some set of assumptions about population, GNP, and energy prices, with the demands of the Canadian economy, and then to compare this with projections in which specific interventions are made to promote greater energy conservation. For this purpose, one is not only justified in using a static model but, given the available data, is practically forced to it.

In the longer run, however, this base line approach is no longer appropriate because the forces that determine the level of energy demand will be far more important than will specific conservation measures. For example, the industrial policy pursued will have more to do with the demand for energy than will the extent to which industry adopts good conservation practices. In short, it is the base line itself that is being called into question, and for that reason assumptions that economic-energy relationships will remain constant are clearly inappropriate. In this circumstance, one must turn not to dynamic models, which are far too complex to use, but to simulations that reflect the impact of selected changes in physical conditions over time. Fortunately, just such a model has been developed at Statistics Canada (the long-term simulation model).

- a discription of the Model used - I think you would only be interested in pages 64 to 73

Short-Term (Static) Analysis of Trade-Offs

Data Sources

In the short-term analysis of the trade-offs between labour and energy, the most convenient approach is to begin with a set of specific conservation proposals which have been worked out in reasonable detail, at least so far as the direct dollar costs and the direct energy savings are concerned. Such a set has been produced by the Federal Office of Energy Conservation (OEC). Its report[122] details a "conservation scenario" for the 1990s that is fully comparable with the high energy price/low economic growth scenario put forward in *An Energy Strategy for Canada*.[123] Whereas the Energy, Mines and Resources scenario resulted in primary energy growth averaging about 3.7 per cent per year through 1990, the conservation scenario would average only 2 per cent. Just as the former was derived by aggregating specific demands on a sector-by-sector basis, given certain demographic and economic parameters, the latter was derived by aggregating specific savings on a sector-by-sector basis, given the same demographic and economic parameters.

It is important to recognize that each of the specific measures incorporated into the conservation scenario had been shown to be of proven effectiveness in saving energy and to be economically efficient in the sense that the investment costs of conserving were repaid by savings in direct energy expenditures within five years. This is a relatively conservative measure for

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122 See footnote 17.

123 See footnotes 14 and 15.

estimating returns in this field. The payback for at least some portion of the investment in Syncrude is no less than 12 years, and in reports to the agencies of the Department of Energy in the United States 15-year payback periods are commonly used for estimating the break-even point for innovative energy systems. It is even more conservative in that operating costs for most conservation measures are negligible compared with those of either conventional or nonconventional supply projects.

Ideally, one would like to analyze the full (direct plus indirect) energy, employment and dollar costs of both the conservation and the energy strategy scenarios. However, the measures are not equally well defined. For example, *industrial*[124] savings are based on estimates developed by a dozen separate *industrial* task forces, which were given similar guidelines in terms of price and GNP, but which were not otherwise made truly comparable. (Indeed, estimation by econometric techniques is so difficult in a sector as varied as *industry* that the energy strategy scenario was adjusted so as to be all but equivalent to the conservation scenario.)

Fortunately, the greatest differences between the two scenarios stem from just a few measures and these are also the ones that are best defined. The conservation scenario yields savings in secondary energy of about $1\frac{1}{2}$ quads, and of this nearly

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124 For energy statistics, the terms *industrial* and *industry* include primary industry, (except agriculture), construction and manufacturing; see A Note on Terminology, for further elaboration of this point. When the word industry appears in standard type the normal economic concept is implied.

two-thirds is accounted for just by three measures: retrofitting of existing buildings, new building codes and more efficient automobiles (Table 9). Therefore, these three measures, plus one additional measure -- the substitution of buses for automobiles for commuting to work -- were selected for analysis.

Table 9

POTENTIAL ENERGY SAVINGS IN 1990,
OEC CONSERVATION SCENARIO

Secondary Energy Consumption		
1975	5.33 Quads	
1990	7.96 Quads (Energy, Mines and Resources Scenario)	
1990	6.48 Quads (OEC Scenario)	
Difference for 1990	1.48 Quads	
Buildings		
Retrofitting existing structures		0.218* Quads
New building codes		0.100*
Furnace and temperature setback		0.154
Other		0.034
Transportation		
New automobile standards		0.594*
Other road		0.236
Other modes		0.100
Industry		0.005**
Energy Supply Sector		0.040

*These three sectors total to 0.912 quads saved.

**The implication of this low figure is not that there are no savings, but that the bulk of the savings is expected to be accomplished by price effects already accounted for in the Energy, Mines and Resources scenario.

Source: Compiled from footnote 17.

Note: One quad equals one quadrillion (10^{15} Btu's) or approximately one quadrillion kilojoules.

Method of Analysis

The method of analysis applied to study the impact of these proposed measures is essentially the same as that applied by Hannon, as described in Chapter 3. The method involves the use of overlapping input-output (I-O) tables.

Input-output analysis will be described only briefly. The tables present a picture of the economy at one point in time in which there is considerable disaggregation of the flows of dollars among industries and commodities through the economy. Given that all activity is destined for some form of final consumption, all of the steps leading to that consumption can be placed in a matrix of transactions in which buyers are on one axis and sellers on the other (with buyers and sellers defined in terms of standardized sets of the industries to which they belong and of the products that they produce). In this way the money spent on machinery purchased by a farmer can be identified and divided among the amounts that went to buy the steel and copper in that machinery as well as that in its fabrication, and this money can then be divided still further into the materials that went into producing the steel, the copper and so on. By use of computer manipulation, such matrices can be made to yield a great deal of information about the direct (initial) impact and indirect (all previous) impacts of any given purchase. Detailed information on the Statistics Canada input-output model has been published.[125] General information about input-output analysis is available in many books.

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125 Canada, Statistics Canada, Structural Analysis Division, *User's Guide to Statistics Canada Structural Economic Models* (Ottawa: February 1976).

In much the same way as dollar flows, energy flows can be modelled in an economy with all purchased or produced energy transactions included. In effect, certain dollar flows are replaced by energy flows using physical energy units (Btu's or kilojoules) to measure the input and output of energy as it is used throughout the system. The result is another matrix that can indicate the direct and the indirect energy requirements for each of the various forms of final consumption. (The energy flows must be related to the dollar flows at given unit prices for this procedure to be effected.) Thus, the process incorporates the use of energy not only in terms of direct impacts (such as miles per gallon) but also in terms of indirect or embodied energy that is included in the automobile itself, in the process to produce the automobile and in the use of the transportation system. However, some energy that is used "free", as with wood wastes burned in some pulp mills and some that is collected "free" as with solar energy is missed by the I-O Tables. In principle, such flows should be included.

In a somewhat similar way, tables of direct and indirect labour use can be prepared. As a result, one can make comparisons among the total (direct plus indirect) dollar, energy and labour impacts of various changes in purchasing patterns. The source of these changes is irrelevant to the I-O model; they could be by fiat or by shifts in preferences. The changes described in this paper would likely come about through a combination of higher energy prices, shifts in preferences and explicit government conservation measures (such as new building codes). The important thing is only that these changes can be described in terms of different bills of goods, i.e., a different pattern of final expenditures, before and after the shifts. Thus, although the Statistics Canada model is based on 1971 structural relationships, it can be run as if the changes indicated for 1990 were already in place and then compared with what would have occurred in the absence of these changes so far as costs, energy use and labour use are concerned.

The application of the model can be illustrated briefly for the case of insulation. Basically, one adds into the existing picture of the economy at one point in time, the production and installation of a given quantity of insulating materials. Then, the energy that would otherwise be necessary (in the absence of the higher insulation levels) can be subtracted from the model. What one is interested in, of course, is the net direct and indirect effect on energy and on labour of those two off-setting effects -- the addition of insulation purchases and the subtraction of energy purchases.

There are a number of general difficulties with I-O models. They are totally static, and technical changes introduced after 1971 will not be captured. It is reasonable to assume that such changes are fairly small over a 15-year period. More important, one must assume that the marginal changes in question are adequately reflected by the average data contained in I-O tables, and also that all processes can be treated as infinitely divisible.

Apart from those difficulties common to all I-O work, some specific problems arise with energy and labour studies. In most cases, there are no commodities in the Statistics Canada model that correspond exactly with, say, any of the insulating materials commonly used in Canada, so approximations must be accepted. Also, since there are a variety of forms of insulation (batts, loose, etc.), it is necessary to estimate quantities by using some general weighted price for all forms of a given type of insulation.

Problems are even more difficult on the supply side. First, the energy savings must be allocated according to fuel in the proportion in which fuel is consumed for heating in Canada. Then each of these sectors must be reduced proportionately in production and, what is more important, in capacity. This involves the assumption that capacity can be reduced by a small amount, and that investment will be correspondingly altered by a small amount, at a time. With automobiles, the difficulties are comparable except that the savings are entirely in gasoline. For example, there is no one price for the steel used in an auto, nor for the variety of alloys and plastics, yet estimates must be made in order to use the input-output tables, which in the first instance are in the form of dollar expenditures.[126] Still greater problems were avoided in the short-term analyses by not dealing with changes in the infrastructure. That is, in the

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126 The only alternative would be to collect the information directly in physical units. Such "process analysis" is underway for a number of sectors, but the cost is high and coverage is nowhere near as complete as for dollar transactions.

case of insulation, houses and buildings were assumed to be built in much the same ways and patterns as today, even though different physical arrangements could save a lot of energy. Similarly the use of bus travel as a substitute for auto avoided the need to build new transit systems, for which data could be obtained only at high costs. It was simply assumed that additional commuting could be accommodated by the addition of more buses but would not require more highways, subway lines or whatever.

There is one important difference between the results obtained here for Canada and those published by Hannon and others for the United States. The impacts on employment and on energy consumption which arise when households spend conservation savings are excluded from our results. These "induced" effects together with those which arise from the impact of expenditures arising from a gain (loss) of income from employment and investment changes created by the adoption of energy conserving practices are reported in Hannon's results but not in ours. The additional conservation savings arise from the fact that the very basis for selecting the specific conservation measures is that they are economically efficient. Dollar savings will occur (unless they are fully absorbed by higher real prices for energy). Given that extra money exists, it will either be spent or saved or taxed away, but one way or another, it will re-enter the economy, creating additional labour demand, income and energy consumption. In any event, whether derived from changes in employment or capital income or from conservation savings, the so-called "multiplier" effects on labour and energy use from consumer spending are not (with one exception to be mentioned below) included in the analyses presented here. Nor, therefore, are the "accelerator" effects resulting from the fact that such changes in consumer spending will induce like changes in investment.

Because all of the conservation measures treated here are economically efficient, the direction if not the size of their induced effects can be predicted with some confidence: both labour and energy consumption will go up, thereby increasing the employment-generating effect of any energy conservation measures discussed here but attenuating to some degree the energy actually saved. In principle, if the money saved from better insulation is entirely and directly spent on energy -- say, motor boat fuel -- the net energy saving could be very low (though not zero) and the induced labour effect small. However, if consumers spend their savings on an average market basket of goods, the energy savings will be much higher and so will the induced labour effects.

Hannon's approach is to treat these "respent" savings as part of the analysis, so that the net figures he presents are direct plus indirect plus induced effects. This amounts to a closed use of the input-output model in which all of the savings are respent in the same time period (except for 10 per cent which is allocated to capital in order to provide the additional goods and services).[127] The problem with this approach for dealing with the induced effect is that households are treated as if they were factories with fixed expenditure patterns. Moreover, all households are regarded as identical, and the savings spent identically, regardless of source.

An alternative and simpler approach was chosen here by reporting in a single side calculation the induced effects on energy and labour of spending an average consumer dollar. For example, for every gallon of fuel oil saved, the average consumer will save so many cents which he can respend in many ways, one of which is shown in a separate simulation. The difference between this and the Hannon approach is that the induced effect is internal to the way he presents his results whereas it is external to the way they are presented here. One is free to add a general induced effect to specific direct and indirect effects or to ignore induced effects altogether.

Longer Term Analysis of Low Energy Growth

Sources of Data

There are few long-term analyses of alternatives for the Canadian energy economy. One of the most detailed is that by Brooks,[128] and this will be used as one of the two basic

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127 This explains some strange results in Hannon's results. For example, using the bicycle to go to work is reported to increase labour compared with driving, while shifting from beef protein to soy protein is reported to increase energy consumption. Both results stem from the induced effect since the average market basket of goods on which consumers are assumed to spend their savings has a higher labour content than motor gasoline and a higher energy content than soy protein.

128 See footnote 25 and Appendix "A" for further elaboration.

sources of data for the long-term simulation. The other source is the information embedded within the Statistics Canada long-term simulation model (LTSM) itself. The LTSM is built upon a demographic model of Canada and the 1971 I-O model of Canada, so these elements become incorporated into the analysis as well. There are opportunities to vary the particular population and economic characteristics used in the simulation, and, to a considerable extent, these can be kept close to those assumed in the energy model developed by Brooks.

Inasmuch as the LTSM is described below, this section will mention briefly the characteristics of the energy model for 2025. Basically, the energy economy of Canada was built sector-by-sector for the year 2025 using specific assumptions about population and GNP, on the one hand, and about energy consumption for different activities, on the other. The latter included separate assumptions about specific efficiencies of energy use and about the extent of energy use (which varied with sector size and with lifestyle choices), much along the lines suggested by Lovins.[129]

By varying the economic and the energy assumptions, a variety of energy economies were built. The one used as a data source here is the lowest of these, the so-called "low income/low *industry*" (which, to repeat, refers to primary -- exclusive of agriculture -- manufacturing and construction industries combined) model (defined in Appendix "A"). This model was selected because it is one of only two that provides detail

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129 See footnotes 24, 31 and 48.

about what a Canada moving towards a conserver society might be like.[130] The characteristics of this model are presented in Table 10 along with data on actual energy use for 1975. It should be noted that the terms "low income" and "low *industry*" are meant relative to other models for 2025, not relative to figures for 1975.

The main characteristics of the "low income/low *industry*" model of Canada in 2025 can best be expressed in terms of growth rates from 1975: population growth is 1.3 per cent and GNP growth is 1.7 per cent per year; thus, per capita real income grows at 1.2 per cent per year, so that by 2025 people have, on the average, 80 per cent more income than they had in 1975. These growth rates reflect changes over the entire period 1975 to 2025. Rates used in developing the model decline with time. In all cases they are consistent with economic and demographic (but not energy) variables in EMR's long-term study.[131]

So far as energy consumption is concerned, the sectors grow unevenly. The share of total energy consumed by *industry* and transportation is low (relative to other versions of the energy model), whereas that consumed by government and the commercial sector is high. Energy use in residences is down absolutely, in part because of greater thermal efficiency and in part because there is less living space per household than today's average in Canada (though still more than is typical of

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130 The other model is described in the reference specified in footnote 26.

131 See footnote 23.

Europe). Compared with other models for 2025, there are fewer private automobiles and fewer appliances.

The result is a model of the Canadian energy economy in which each person would be using only two-thirds as much energy as Canadians do today, but still 20 per cent more than he was using in 1960. Overall energy efficiency would be about $2\frac{1}{2}$ times as great as that of today, which is not a difficult target for a 50-year period. As with all such low-energy models of the future, *industrial* consumption dominates overall energy use.[132] This is true even in the so-called "low *industry*" version of the energy model in which commercial use (including government) accounts for a relatively high share of GDP. Specifically, the *industrial* sector accounts for 40 per cent of energy consumption directly in 2025 (compared with 30 per cent in 1975) and perhaps 55 per cent if freight transportation is included.

The "low income/low *industry* model for the year 2025 is specified for a population of 32 million with a GNP of $183 billion. While both are above today's figures, they represent diminished rates of growth. More important, while the model is basically an energy, not an economic model, the ratio of disposable income to national income is above results recorded since World War II.

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132 See footnotes 31 and 59.

Table 10

LOW GROWTH SECONDARY ENERGY MODEL FOR CANADA IN 2025

	1975 (actual)	2025 (projected)
Consumption by Sector (10^{12} Btu's)		
Residential Space Conditioning	1,250	396
Other Residential		417
Commercial	920	549
Industrial	1,620	1,914
Automobile	820*	453
Other Transportation	720*	1,101
Total	5,330	4,830
Economic Characteristics		
Population (millions)	22.77	32.18
GNP (billions of 1961 $)	$ 79.16	$ 183.62
GNP/Capita (1961 $)	$3,120.00	$5,704.00
Ratios of Energy Use (Indexed: 1975 = 100)		
Primary Energy per Capita	100	66
GNP per unit of Primary Energy	100	248

*Based on modal split in 1972 (See footnote 17).

Source: (See footnotes 17 and 25).

Further details on the economic assumptions and energy consumption results of the model are provided in Appendix "A". It must be emphasized that this model was selected in order to test the economic implications of low energy futures for Canada by looking specifically at one such future. This specific future, which involves a growth rate of energy use of -0.2 per cent per year 1975 to 2025, is in no sense a forecast nor does it purport to represent higher growth alternatives.

Method of Analysis

In the longer term, the assumptions contained in an input-output table are clearly not valid. There are too many substitutions and technological changes possible. Given that the proportions of income spent on energy have remained constant for long periods of time (both for consumers and for industry),[133] the fact that energy prices are likely to continue rising at more than the rate of inflation implies significant changes in the use of energy as an input or as a consumer purchase. Moreover, we are just becoming aware of the enormous opportunities in our economy for improving the efficiency with which energy is consumed. On the basis of the Second Law of Thermodynamics (that is, comparing the amount of energy used with the theoretical minimum to do a given task), our economy is only about 8 per cent efficient, and even European economies, with which Canada is commonly compared, are only a little better.[134,135] While efficiencies of anything close to 100 per cent are impractical, something in the order of 20 per cent to 40 per cent is considered feasible. Even a shift from 8 per cent to 9 per cent efficiency would mean a reduction in energy use, for given output, of more than 10 per cent.[136] Nor does this end the opportunities to conserve, for

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133 See footnote 7.

134 See footnote 54.

135 Thomas F. Widmer and Elias P. Gyftopoulos, "Energy Conservation and a Healthy Economy", *Technology Review* (June 1977).

136 These data are the basis for the statements by Lovins to the effect that we can improve our end-use efficiency by 50 per cent by the end of the century and by another 50 per cent by 2025 (See footnote 59). Similarly, Ross suggests that, without lifestyle shifts, Canadian homes could operate at a total energy level of one to two peak kilowatts rather than the 10 to 12 now deemed necessary.[137]

137 W.A. Ross, "Energy Paths for Canada", *Alternatives* (Fall 1977).

second law efficiencies are defined only for given tasks, and the tasks themselves can be adjusted to make still further gains. For example, heating duplexes instead of single-family units changes the task. And, then, beyond all "efficiency" questions, there are lifestyle options, such as not having a clothes dryer or working at home and not commuting, that magnify enormously the range of possible energy consumption levels for an economy.

The need to investigate these longer term possibilities for low energy growth requires a model that, if not dynamic, is at least related to the physical dimensions and limitations of the system. Such a model is provided by the LTSM. This model is best described as a "strategic simulation" of the Canadian economy in the sense that alternative scenarios can be examined from the point of view of resource availability, technological feasibility and internal consistency. In our case it is the latter two elements that are of concern since an energy constraint is introduced from the start. That is, the model is forced to track as closely as possible onto the energy path set by the "low income/low *industry*" scenario developed by Brooks (see above).

The LTSM is intended to represent the Canadian economic system, viewed as an interface between human needs and the physical universe. Changes in that system are determined by the interactions among economic agents and their reactions to the constraints imposed by the physical system, including the ability to obtain resources, the laws governing their transformation and the need to dispose of wastes. Although descriptions of the LTSM have been published,[138,139] it is not well known; thus, one description of it will be quoted at length:[140]

> "The Long-Term Simulation Model ... represents an attempt to ... provide a method for simulating various economic growth scenarios. The approach taken to accomplish these objectives is in sharp contrast to more traditional economic models which explain the evolution of the economic system as a function of the behavior of economic agents under the assumption that whatever is required from the physical system is available. This model, rather, places emphasis on modelling the flows of materials within the economic system and the ways in which these materials are transformed into finished products. We wish to ensure that these flows and transformations are feasible from the point of view of availability and the physical laws that govern transformations.
>
> "This emphasis on physical flows within the economic system requires, first of all, that the flows be disaggregated by kind of material. It is evident that the supplies of various materials in the physical system vary considerably and that to a large degree materials are not substitutable because of their physical properties. Secondly, the approach requires an accurate and detailed representation of the processes through which materials must pass in order to become finished products. It is clear that the processes vary with materials; some processes require the combination or separation of materials; all processes require energy in varying quantities both for process heat and mechanical energy. Thus our model must be disaggregated both in materials space and activity space.

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138 R.B. Hoffman, *Users' Guide to the Statistics Canada Long-Term Simulation Model*, Statistics Canada, Structural Analysis Division (Ottawa: February 1977).

139 R.B. Hoffman, G. Sayant and B. McInnis, *Statistics Canada Long-Term Simulation Model*, Statistics Canada, Structural Analysis Division (Ottawa: October 1976).

140 S.F. Gribble and K.E. Hamilton, *Energy Futures: Scenarios and Perturbations*, Statistics Canada, Structural Analysis Division Working Paper 77-11-01 (November 1977).

"The physical orientation of the LTSM is achieved by basing the model on a highly disaggregated constant dollar Input-Output system. Resource use, labour demand, and capital requirements are all related technologically to sectoral gross production in constant dollars. Sectoral production is determined by industry technology and the complete set of transactions between sectors necessitated by the demand for final goods. Demand formation is largely driven by population, the major exogenous variables being per capita (constant dollar) consumer expenditures, investment levels, and total exports. The underlying population model starts with a recent population distribution and traces its evolution fairly mechanically using age-sex specific birth and death rates as well as the external effects of emigration and immigration; the major exogenous population variables are aggregate fertility and the rate of immigration. The overall dynamic behaviour of the model may be described by a forward recursion relation in the variable time.

"The name "Long-Term Simulation Model" indicates two more important characteristics of the model. By "long term" is meant a time horizon of twenty to fifty years. In this time horizon the operative constraints on the economic system are essentially those imposed by the physical system: the availability of raw materials, energy, and labour, the ability of the system to accept waste material, and the physical laws governing transformations. The word "simulation" is used to indicate that the model is considerably open to user-specified reactions. As Figure (2) shows, the model tracks supply and demand of both capital and labour separately, with no internal response to disequilibria. In the real world these responses are brought about by the collective decisions of all of the economic agents. In the model system the user of the model assumes the role of economic decision maker.

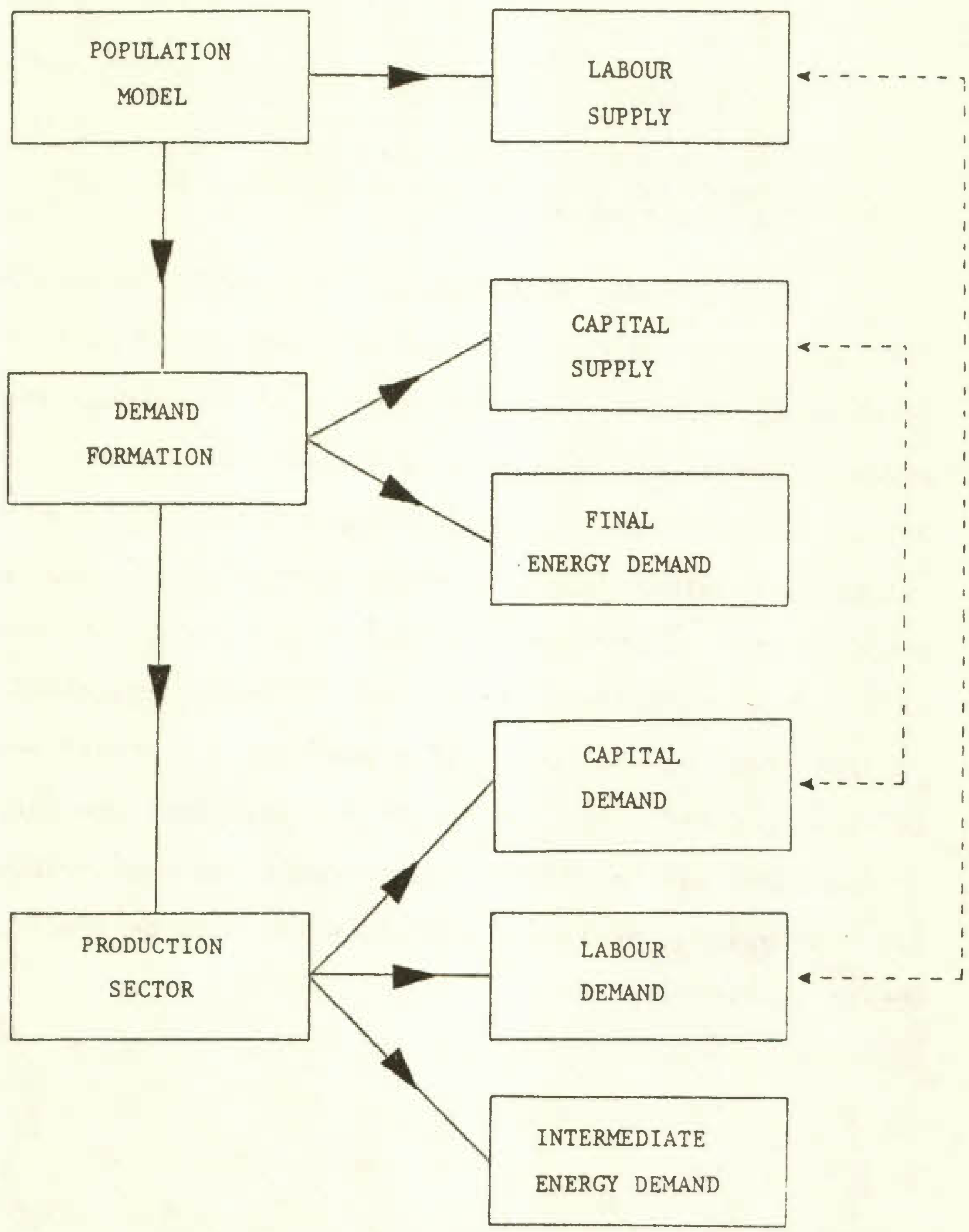
"The limitations of the model are inherent in what has been described so far. In the first place, this is a fixed technology model. Secondly, the use of constant dollars leads to particular difficulty in handling international trade, where relative price changes lead to some of the more interesting phenomena. And finally, it is not clear that the current National Accounts concepts, particularly on the expenditure side, are appropriate for long-term analysis.

> "As seen in Figure (2), the LTSM has been configurated to calculate energy demand. This is accomplished in physical units by means of a unit price transformation in the final demand sector, and by using historical physical consumption by fuel type for each industry in the production sector, assuming the use by each industry is fixed in proportion to gross production in constant dollars. There is no corresponding energy supply calculation as in the case of capital and labour. This is an essential block of the model which is under development."

In our use of this model, the long-term simulation of the Canadian economy is run with an energy constraint (the source of which is irrelevant to the workings of the model) such that average annual rate of growth is slightly negative to the year 2025. The objective is to determine whether this low energy future is feasible from a technological point of view and what other changes might/must be entailed as a result of imposing this energy constraint. To the extent that feasibility is not demonstrated, or that particular problems are identified (a surplus or a deficiency of labour for example), the parameters of the model can be altered to determine how much change, in, say, immigration or labour productivity would be needed to obtain feasibility.

Figure 2

LONG-TERM SIMULATION MODEL SCHEMATIC



Source: See footnote 140.

Chapter 5: Short-Term (Static) Analysis of Energy Trade-Offs

Using the input-output (I-O) model of Canada for 1971 and the methods described generally in the previous chapter, four simulations were analyzed to determine some of the shorter term relationships between energy consumption and the Canadian economy, particularly the labour-energy trade-offs. More specifically, the positive employment impacts of adopting each selected conservation measure were compared with the negative impacts from reduced energy use. On both sides, annual operational impacts are kept separate from one-time capital impacts. As emphasized before, all results should be taken as tentative.

The four simulations were as follows:

1. Production and use of more efficient automobiles in order to reduce the energy consumption of manufacture, and, much more important, of use;
2. the use of buses rather than automobiles for commuting to work as a way of saving gasoline;
3. retrofitting part of the existing stock of housing to improve its thermal efficiency and thereby reduce the consumption of energy for heating; and
4. construction of more thermally efficient dwellings in the future in order to reduce consumption of energy for heating.

In addition, one simulation was run to evaluate the induced impact on labour use and energy consumption from $1 million of general consumer expenditures (exclusive of energy purchases). Note that while the simulations are based on conservation measures suggested as appropriate by the Office of Energy Conservation,[141] no consistent attempt is made to estimate what their

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141 See footnote 17.

national impact would be. For example, an estimate is made of the specific impact on employment from shifting a given number of commuters from autos to buses, but no attempt is made to estimate how many would actually shift.

Details relevant to each simulation will be noted in the specific discussions. However, the general characteristics of the various consumption options, and of the energy production systems with which they are compared, can more conveniently be presented at the start. In addition, conversion factors, energy prices and assumptions need to be stated, as does the procedure for dealing with international trade. This information is all treated in the first section below. Readers interested primarily in results may wish to go directly to the discussion of the simulations (starting on page 93).

Systems Analyzed and General Assumptions

Energy Conversion Factors

The table below indicates the conversion factors used to reduce the three principal energy forms to a common denominator for comparison purposes:

Table 11

CONVERSION FACTORS FOR DIFFERENT FORMS OF ENERGY

Energy Form	Unit of Measurement	Conversion Factor
Crude oil	barrels (bbl)	5.8 million Btu's per bbl
Natural gas	thousand cubic feet (Mcf)	1.0 million Btu's per Mcf
Electricity	kilowatt-hour (kW.h)	3,412 million Btu's per kW.h

Source: Energy, Mines and Resources, Structural Analysis Division, Statistics Canada.

Unless otherwise indicated, imperial units have been used throughout both for natural measurements and for energy measurements. While this is inconsistent with international practice, the Btu is our standard energy equivalent and, as noted earlier, Btu's and kilojoules (the appropriate metric equivalent) can for most purposes be treated as synonymous (that is, a conversion factor of 1:1). Figures for capacity of generating stations, given in terms of kilowatts (kW or megawatts (MW), refer to electrical output (that is, kW_e or MW_e as conventionally abbreviated). In reporting the results of calculation, all figures are rounded to the nearest ten.

Energy Prices

Unit energy prices are assumed as indicated in the following table. Note that 1971 (constant) dollar values are generally employed throughout the next two chapters.

Table 12

UNIT ENERGY PRICES IN 1971
(1971 $)

	Unit Prices			
Energy Form	Producer Per Form Unit	Values* Per million Btu's	Purchaser** Per Form Unit	Values*** Per million Btu's
Crude Oil	$0.078/Gallon	$0.471		
- Gasoline			$0.440/Gallon	$2.95
- Fuel Oil			$0.180/Gallon	$1.08
Natural Gas	$0.156/Mcf	$0.156	$0.640/Mcf	$0.640
Electricity	$0.009/kW.h	$2.638	$0.015/kW.h	$4.369

*Measured at mine, refinery, wellhead or generating stations as appropriate.
**Net of taxes.
***Households.

Source: Energy, Mines and Resources, Structural Analysis Division, Statistics Canada.

Except for home heating systems, no efficiency losses were allowed for in the simulations (apart from those built into the input-output tables themselves). That is, it is assumed that 100 barrels produced at an oil well are delivered without loss or in-plant consumption via the refinery to the final consumer. This tends to understate by perhaps 10 per cent the labour impact of reductions in energy supply. The understatement in the case of coal (or other fossil fuel) generated electricity would of course be much higher, but these systems were not incorporated into the analysis.[142]

Energy Production Systems

The energy supply systems analyzed were as follows:

(i) 200 Megawatt (MW_e) dam and hydro plant;

(ii) a 2,000 MW_e Pickering-type nuclear station made up of four 500 MW_e CANDU units;

(iii) on-shore gas well and gathering system rated at 1,095 million cubic feet (MMcf) per year (3 MMcf per day);

(iv) on-shore oil well and gathering system rated at 77,000 barrels per year (bpy) or 210 barrels per day (bpd);

(v) high-gasoline oil refinery rated at 61,000,000 bpy or 167,000 bpd.

Details on the materials consumed, imports and employment for each of these energy production systems analyzed are presented in Table 13; separate sections of the table refer to annual operations and

142 This omission would be significant if a greater part of the electrical capacity were based on coal than is the case in Canada. (About 13 per cent of Canadian electrical generation in 1975 was based on coal.) As shown by Table 13, per megawatt of capacity, coal-based systems are more labour intensive in their operations, even ignoring the mining stage, than are hydro electric or nuclear generating plants (when total employment is considered).

to construction of new plants. This information, all standardized to 1971 dollars, was largely derived from the Bechtel model of energy supply in the United States[143] except that information on CANDU nuclear systems was derived from a report by Winstanley and colleagues at the Office of Energy Conservation in Canada.[144] As with all I-O tables, the results appear as if they were instantaneous.

For the purposes of this study, it is assumed that each of these systems runs full time -- 24 hours per day, 365 days per year -- at its rated capacity. Where relevant the life of the system is taken as 35 years. Moreover, each plant is assumed to be infinitely divisible, both in operating characteristics and in construction. For example, if 20 million barrels per year of oil can be conserved, direct employment for operation of the model refinery is assumed to be reduced by a proportion equal to 20/61 (see Table 13, high gasoline refinery). For labour, 235 working days per year were assumed in most cases except that construction labour was assumed to work 245 8-hour days per year.

A number of difficult problems arose from the need to distribute conservation impacts among energy sources and, further, to allow not just for cutbacks in annual energy consumption but also for reduced capital expenditures on new energy production

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143 M. Carasso *et al*, *The Energy Supply Planning Model*, 2 volumes (San Francisco, Ca.: Bechtel Corp., August 1975); available through NTIS, PB-245383, Springfield, Virginia.

144 G. Winstanley and others, *Energy Requirements Associated With Selected Canadian Energy Developments*, Office of Energy Conservation Research Report RR13 (Ottawa: May 1977).

Table 13

IMPORTS AND LABOUR REQUIREMENTS FOR SELECTED ENERGY PRODUCTION SYSTEMS IN CANADA (1971 dollars)

	Total Value of Materials Required ($000)	Imports of Materials Required ($000)		Employment (man-years)	
		Direct	Total	Direct	Total
A. Annual Operating Expenses at Existing Plants					
Dam and Hydro Plant (200 MWe)	222	68	85	12	23
Coal Electric Plant* (800 MWe)	2,433	338	510	109	226
CANDU Nuclear Plant** (4 x 500 = 2,000 MWe)	0	0	0	450	450
Onshore Oil Production (77,000 bpy)	25	7	9	5	6
High Gasoline Refinery (61 million bpy)	29,336	3,188	5,839	551	1,755
Onshore Gas Production (1,095 MMcf/year)	20	4	6	10	11
B. Total Capital Expenses for New Plants					
Dam and Hydro Plant (200 MWe)	30,635	10,500	12,449	2,385	3,803
Coal Electric Plant* (800 MWe)	84,160	21,548	28,640	4,800	9,148
CANDU Nuclear Plant (4 x 500 = 2,000 MWe)	429,644	78,313	137,764	16,263	41,285
Onshore Oil Production (77,000 bpy)	2,368	624	810	94	212
High Gasoline Refinery (61 million bpy)	198,759	57,688	73,031	14,590	24,324
Onshore Gas Production (1,095 MMcf/year)	2,083	521	689	94	199

* Included for comparison only.

** Annual materials consumption assumed to be negligible. Thus, import on mining industry of one year's burn-up of uranium is ignored, and there is no indirect labour component. Minor imports are also ignored.

Source: See footnotes 143 and 144 plus Structural Analysis Division, Statistics Canada.

projects. These were resolved on a case-by-case basis. For simplicity, emphasis was placed on the primary production of energy including mines, wells, refineries and generation systems, rather than on transportation facilities. That is, it was assumed that energy transportation systems required little direct labour and that existing capacity was sufficient to accommodate any changes in use implied by the simulations.

Energy Consumption Options

As noted just above, the simulations indicate changes in the use of labour in Canada when options to conserve energy are compared with production of the energy that would otherwise be required. Therefore, in parallel with the analysis of energy production systems was that of the consumption options. These are listed in Table 14, and data on materials consumption, imports and employment presented. Most of the data to form these tables is embedded directly in the existing Statistics Canada input-output tables. However, some had to be provided from studies undertaken in or on behalf of the Office of Energy Conservation. Sources for information that do not appear in the OEC Report 77-7[145] will be cited as appropriate. Each option is treated as if it occurred instantaneously.

Fuels Use

In addition to the use of materials (some of which is domestic and some imported) and labour each of the energy production systems and each of the energy consumption options described just above also creates requirements for energy, which must also

145 See footnote 17.

be considered. Table 15 presents the various direct and indirect energy inputs to these production and consumption activities in terms of primary resources actually involved: coal, crude oil, natural gas and electricity. However, there is double-counting between the coal and electricity columns that results from the use of thermal coal to produce electricity in some provinces. Since about 20 per cent of Canadian electricity supply is produced from fossil fuels, a rough elimination of this double-counting can be obtained by including only 80 per cent of the electricity production, so that data for total energy use (whether measured in dollars or Btu's) equal the sum of those for coal, crude oil, natural gas and 0.8 times those for electricity.

Impact of Trade

International trade has a number of effects on the use of input-output data. Perhaps most important, in an economy as open as that of Canada income and employment must be adjusted to allow for "import leakages", that is for expenditures on materials imported as final goods and as intermediate inputs to domestic production. All data presented in this report allow for import leakages. These are shown in the columns entitled "Direct Imports" and "Total Imports"; the difference between the two represents indirect imports. Direct imports refer to that proportion of the product imported as final products (in value terms) whereas indirect imports refer to imported items used in domestic production of final products. As a result of the adjustment for import leakages, all figures for Total Employment in this report are net of imports.

Table 14

IMPORTS AND LABOUR REQUIREMENTS FOR SELECTED CONSUMPTION OPTIONS IN CANADA (1971 dollars)

Energy Consumption Options	Used in Simulation No.	Total Value of Activities ($000)	Imports ($000)		Employment (man-years)	
			Direct	Total	Direct*	Total
Materials for production of 1,000 new 1970-type autos*	1,2	453	73	131	N.A.	24
Materials for production of 1,000 new 1990-type autos*	1,2	449	75	143	N.A.	24
Auto operations (7,000 autos)**	2	3,067	158	372	0	205
Urban transit operations***	2	1,000	0	30	101	114
Materials for production of 1,000 new buses*	2	10,139	0	4,196	N.A.	465
Producing enough mineral wool to retrofit 1,000 existing houses*	3	310	4	35	N.A.	21
Producing enough mineral wool for additional insulation in 1,000 new houses*	4	188	2	21	N.A.	13

*Expenditures on materials only; supplementary information from a variety of sources indicates that there are 31.5 to 62.5 man-years directly employed at auto plants in fabricating 1,000 autos; 158 in fabricating 1,000 buses; 20 in installing insulation in 1,000 existing houses; and a little over 12 in installing insulation in 1,000 new houses.

**Total expenditures for one year's operation of 0.1 per cent of 1971 fleet of 6,697,247 registered autos.

***Per million dollars of operating revenue.

Source: Structural Analysis Division, Statistics Canada.

Table 15

DIRECT AND INDIRECT FUEL USE FOR SELECTED CONSUMPTION OPTIONS
AND ENERGY PRODUCTION SYSTEMS IN CANADA, 1971
(1971 Producer Values)

	Coal	Crude Oil	Natural Gas	Electricity
A. Consumption Options				
Operation of 7,000 autos for one year	$ 1,844	$ 187,072	$ 3,330	$ 28,729
Urban Transit Operations ($1 million in revenue)	775	8,074	181	19,282
Production of $310,000 worth of mineral wool	649	2,684	1,329	5,656
Production of 1,000 buses	23,364	28,530	8,051	80,957
Production of 1,000 1970-type autos	3,699	2,278	761	7,726
Production of 1,000 1990-type autos	6,937	2,418	976	8,599
B. Annual Operation of Existing Energy Production Facilities				
Hydro Plant (200 MWe)	463	792	212	1,976
Oil Refinery (61 million bpy)	210,720	3,005,808	1,309,160	5,529,486
Natural Gas Wells (1,095M Mcf/yr)	84	118	24	225
Oil Wells (77,000 bpy)	86	127	26	248
C. Construction of New Energy Production Facilities				
Hydro Plant (200 MWe)	67,528	478,331	23,687	209,674
Oil Refinery (61 million bpy)	778,586	1,084,032	191,538	1,644,870
Natural Gas Wells (1,095M Mcf/yr)	11,027	23,406	2,643	22,163
Oil Wells (77,000 bpy)	11,738	26,055	2,867	24,162
Nuclear Station (CANDU) (2,000 MWe)	1,853,392	3,180,514	436,380	8,051,202

Note: See Tables 13 and 14 have more complete description of the energy production facilities and consumption options, respectively.

Source: Structural Analysis Division, Statistics Canada.

There is a further adjustment that needs to be made to both employment and energy use data as a result of trade in non-energy products. This stems from the fact that, although the model incorporates such imports, it does not directly allow for exports to balance them. Some adjustment is required in order to keep the balance of payments balanced. The easiest way to do this, and the method adopted for this report, is called the balanced trade adjustment. This calculation assumes that Canada's general 1971 exports (exclusive of energy exports) are increased or decreased by an amount equal to the change in imports. If imports increase, so do exports, and *vice versa*. Say a simulation involves the expansion of bus production in Canada; this in turn involves an increase in imported components; therefore, exports are assumed to increase by an equal amount; and, as a result, estimation of Canadian employment and Canadian energy consumption will be higher than they would be in the absence of a balanced trade calculation.

The balanced trade calculation for any simulation is made by multiplying the Total Imports columns in Tables 13 and 14 by a figure that represents the average labour or energy content of Canadian non-energy exports. These multipliers are as follows:

Employment	89×10^{-6}	man-years	per	1971	dollar	of	imports
Coal	$3,689 \times 10^{-6}$	dollars	"	"	"	"	"
Crude Oil	$10,508 \times 10^{-6}$	"	"	"	"	"	"
Natural Gas	$2,253 \times 10^{-6}$	"	"	"	"	"	"
Electricity	$23,206 \times 10^{-6}$	"	"	"	"	"	"

For example, according to Table 14, the construction of 1,000 new buses implies that $4,196,000 worth of materials will be imported (i.e., the imported components of buses manufactured in Canada). Given the assumption that Canadian non-energy exports increase by an equal amount, one calculates the increased requirements for labour in Canada stemming from these exports by multiplying $4,196,000 by 0.000089 man-years/dollar of imports for an export-generated increase of 373 man-years; similarly, coal use in Canada goes up by $4,196,000 times $0.003689 of coal per dollar of imports or $15,479; and so on for the other fuels. Therefore, the full employment gain in Canada is 465 (from Table 14) plus 373; the total increase in coal consumption is valued at $23,364 (from Table 15) plus $15,479; and so on.

Not to be confused with the consumption of imported materials in Canada are direct imports of fuels themselves. For the most part, these are not relevant to our analysis. However, the import of 30 per cent of total crude oil consumption and 25 per cent of total thermal coal consumption has been allowed for in the input-output calculations. The same share of imports is included in estimating employment impacts. For example, if 100 barrels of crude oil are displaced by conservation, the employment impact in Canada is equivalent to a reduction of only 70 barrels because the other 30 is assumed to be imported. The reduction will occur only for the crude as most of the oil refining would still occur in Canada.

Simulation 1: More Efficient Automobiles

Automobile efficiency in use can be improved most directly by reducing the weight of the automobile. This, in turn, can be accomplished by reducing its size and by substituting lighter for heavier materials. Both approaches were adopted in this simulation. Table 16, taken from a report on the potential for energy conservation in personal transportation,[146] shows data on materials use in two automobiles, one typical of the early 1970s and the other anticipated for 1990. The 1990 automobile is about 2/3 of the total weight of the 1970 automobile. In order to highlight substitution effects, the third column in Table 16 shows the effects of strict downsizing of the 1970s automobile by one-third without any materials substitution. Comparison of the two right hand columns shows that the major substitutions are aluminum and plastics for iron and steel. The smaller automobile also increases relative use of rubber, glass and alloy steel (not listed separately).

Labour Impacts

Table 14 permits comparison of the employment impact of producing the materials to make 1,000 of each of these two automobiles. As can be seen, despite the difference in materials use, the resulting employment effect is negligible. The only difference is that, for the lighter automobile, the total import component is about 9 per cent higher. Inasmuch as the direct employment in building automobiles (not shown on Table 14) is not significantly

146 International Research and Technology Corporation, *The Potential For Energy Conservation With Particular Application To Personal Transportation and Residential Space Heating*, (Arlington, Virginia: October 1975), appendix Table IV-I.

Table 16

PROJECTION OF MATERIALS IN AN AVERAGE AUTOMOBILE BY WEIGHT
(weight of materials in pounds)

	Typical auto of early 1970s	Auto anticipated by 1990	2/3 x 1970s auto
Cast Iron	557	87	373
Other Iron and Steel	2,102	1,034	1,409
Total Aluminum	99	543	66
Copper, Brass Stampings (Radiators)	14	0	9
Other Copper and Brass	20	15	13
Zinc	28	8	19
Rubber	159	128	107
Glass	83	70	56
Plastic	119	173	80
Other	219	187	146
Total	3,400	2,245	2,278

Source: Footnote 146.

affected by size but only by the number of operations,[147] it is safe to conclude that the shift from heavier to lighter automobiles will have no immediate impact on employment in the automobile industry, and that it will result in some shift, but neither an aggregate loss nor an aggregate gain for the industries providing materials for automobile manufacturing.

Because direct and indirect labour for making the auto are the same, the only significant impact on employment from production and use of lighter automobiles will be derived from the reduced demand for gasoline, which will be felt in oil well and refinery operations. (There is no reason to assume that the labour costs of servicing and maintaining automobiles will change with size.) The average automobile in the early 1970s in Canada got 17 miles per gallon. It has been announced that Canada will adopt fuel economy standards identical to those in the United States, which means that automobiles produced after 1985 will, on the average, get 33 miles per gallon.[148] For convenience, it can be assumed that by 1990 all automobiles are at the more efficient level, so we can compare the effects of an automobile fleet that is almost twice as efficient as it might otherwise have been.

Greater automobile efficiency will affect all use of automobiles, which in Canada averages about 10,000 miles per auto per year or, for the entire 1971 fleet of about 7 million

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147 United States Department of Transportation, *Passenger Auto Fuel Economy Standards*, Summary Report (Washington, D.C.: 28 February 1977).

148 See footnote 17.

automobiles, roughly 70 billion miles per year. At 17 miles per gallon (mpg), this would require 4.1 billion gallons or 118 million barrels per year;[149] at 33 mpg it would require 2.1 billion gallons or 61 million barrels. The annual difference in energy use by the two auto fleets is therefore 57 million barrels. Approximately 30 per cent of this 57 million barrels is assumed to be imported as crude oil, so calculations are made on the basis of a decrease in oil well production of 40 million barrels per year and of refinery production of 57 million barrels a year.

Table 17, based on Table 13, shows that, if the 1971 auto fleet made 33 rather than 17 mpg, more than 3,100 jobs per year would have been lost directly in the energy supply sector and another 1,600 jobs would have been lost in supporting sectors, for a total (direct plus indirect) job loss of nearly 4,800.[150] In addition, because imports decrease with oil production, exports must also decrease and another 900 jobs are lost this way. On the other hand, some or all of the loss will be made up as consumers spend their dollar savings on non-energy products (see below).

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149 There are 35 imperial gallons per barrel.

150 The calculation in the case of oil wells run as follows (with all results rounded to the nearest 10). (1) Table 13 indicates that direct employment in crude oil production is 5 employees per 77×10^3 bpy of output. For 40×10^6 bpy of energy savings, therefore, direct employment loss can be estimated as: $(40 \times 10^6/77 \times 10^3)5 = 2600$. (2) In the same way total employment loss is: $(40 \times 10^6/77 \times 10^3)6 = 3120$. (3) Table 13 also indicates that \$9,000 of imports are required for each 77,000 bpy and, as indicated above, 89×10^{-6} jobs in exporting sectors are, on the average, created for every dollar of imports. Therefore, a reduction of imports by $(40 \times 10^6/77 \times 10^3)$ 9×10^3 creates an additional job loss of this product multiplied by 89×10^{-6}: $(40 \times 10^6/77 \times 10^3)$ (9×10^3) (89×10^{-6}) $= 420$.

Table 17

ANNUAL EMPLOYMENT IMPACTS THROUGH REDUCED GASOLINE CONSUMPTION OF A SHIFT TO MORE EFFICIENT AUTOMOBILES*
(man-years per year)

	Direct Labour Loss	Total Labour Loss	Balanced Trade Adjustment	Adjusted Labour Loss
Refinery	520	1,640	490	2,130
Oil Wells	2,600	3,120	420	3,540
Total	3,120	4,760	910	5,670

*1971 auto fleet compared at 17 mpg and 33 mpg average fuel efficiency.

Source: See Table 13.

In addition to the annual loss of employment in operations, one might assume that, over time, fewer refineries and oil wells would be constructed. If one assumes that the impact of reduced gasoline supply capacity is equivalent to the need for construction of one new refinery plus the supplying oil wells, there would be an additional significant one-time loss of construction labour.[151] However, this assumption is not necessarily reasonable, given that Canadian crude oil production is likely to be running at capacity because of depletion of reserves. Moreover, there will also be a significant one-time labour increase through retooling at auto manufacturing plants to meet the new efficiency standards. It is reported that the increased capital investment over normal spending levels in auto plants will amount to 15 to 25 per cent for facilities and equipment alone.[152] Unfortunately, limitations of time and data do not permit the comparison of capital impacts to be carried any further.

151 As indicated in Table 13B, construction of the refinery alone provides 14,600 direct and 24,300 total man-years of employment.

152 See footnote 58.

Energy and Dollar Savings

Given the 7 million autos registered in 1971 and the average of 10,000 miles driven per auto per year, one can calculate that a fleet average fuel efficiency of 33 mpg would have saved 57 million barrels of gasoline per year compared with the actual fleet efficiency in that year of 17 mpg. By increasing automobile registrations at the rate assumed by OEC,[153] one can estimate comparable savings of about 125 million barrels by the year 1990. This is a little above OEC's own estimate of 1990 savings of 113 million barrels per year through an improved auto fleet.[154]

Direct dollar savings to automobile users are self evident in this shift since both operating costs and initial outlays are reduced relative to what they would otherwise have been. From a national point of view, additional savings are incurred through reduced land use impacts and pollution, offset perhaps by higher costs of accidents. These impacts are all too complex to follow through in the absence of a special study. However, the benefit-cost ratio comparing the investment in retooling for the automobile industry with the savings in energy production and imports for the United States was reported to be between 3 and 6 to 1.[155]

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153 Increases of 4.9 per cent per year to 1980, 3.7 per cent per year 1981 to 1985, and 3.5 per cent per year 1986 to 1990. (See footnote 17, page 27.)

154 See footnote 17, page 28.

155 See footnote 58.

Summary

The shift of the Canadian passenger auto fleet from less to more efficient autos, at least insofar as that can be accomplished by making cars smaller and using lighter materials, appears to be both capital and energy saving. It obviously economizes on the use of natural resources. The effect of the shift appears to entail no aggregate labour impacts in the automobile industry itself, though there will be some shifts among the industries that provide goods and services for automobile manufacturing. The major effect of building more efficient automobiles will come through reduced levels of operations in the oil industry, an effect which could amount to a maximum annual decrease in employment of 5,700 (based on 7 million automobiles), about half of which would be lost directly at wells and refineries and the other half indirectly or through lost exports. The net labour impact from increased capital expenditures for retooling in the automobile industry and decreased capital expenditures in the oil industry was not determined.

Simulation 2: Shift from Autos to Buses for Commuting

Table 14 shows the direct and indirect effects of the operation of urban transit systems and of manufacturing buses. Data for urban transit operations are based on revenues of $1 million (1971 dollars), which (at 25 cents per ticket) equals 4 million person trips or 2 million round trips. Most of the labour is obtained directly but a little is obtained indirectly for a total of 114 man-years of employment. Data for manufacturing are based on the construction of 1,000 buses. In this case most of the labour is obtained indirectly and there is a high import component.

Data on commuting habits are obtainable from an unpublished survey undertaken by Statistics Canada in 1975 on the "Travel to Work Habits of Canadians". A summary of the results of that survey is presented in Table 18. Assuming that distances less than 2 miles can be taken as 1 mile, and assuming that distances greater than 10 miles can be taken as 13 miles, the table shows that automobile commuters go 6.7 miles to work, on the average, while public transit riders go 4.2 miles to work. According to other information collected by the survey, the median travel distance for auto commuters is somewhat over 5 miles between home and work. And 80 per cent of "metro" commuters who live within 5 miles of work have access to public transportation. Thus, it is significant to identify from the table that approximately 32 per cent of Canadian commuters both drive and live within 5 miles of work. It can also be estimated that the load factor for automobile commuting is approximately 1.3 persons per auto, which is just under the United States figure of 1.4 persons per auto. Finally, note that the "other" mode included in Table 18 includes those who walk or cycle to work, a significant factor from the perspective of energy conservation.

In order to compare the labour impacts of driving to work as opposed to use of public transport, we will assume that approximately 10 per cent of those automobile commuters who live within 5 miles of work shift from using automobiles to using public transit. The simulation will be analyzed in two stages: first, it will be assumed that no new buses need be purchased nor are any fewer automobiles purchased as a result of the shift;

Table 18

COMMUTERS CLASSIFIED BY PRIMARY MODE OF TRANSPORTATION AND ONE-WAY DISTANCE TO WORK, CANADA, 1975

Primary Mode		Distance to Work in Miles: Less than 2 miles		3 - 5 miles		6 - 10 miles		10 miles		Total
Private Auto	(No.)	1,218,719		1,250,810		1,093,211		1,279,925		4,842,665
	(%)	15.6		16.0		14.0		16.4		62.0
	(%)	25.2	50.4	25.8	62.3	22.6	66.3	26.4	73.4	
Public Transportation	(No.)	220,242		434,646		342,694		187,082		1,184,644
	(%)	2.8		5.6		4.4		2.4		15.2
	(%)	18.6	9.1	36.7	21.6	28.9	20.8	15.8	10.7	
Other	(No.)	976,622		323,508		212,870		277,939		1,790,939
	(%)	12.5		4.1		2.7		3.6		22.9
	(%)	54.5	40.4	18.1	16.1	11.9	12.9	15.5	15.9	
Total	(No.)	2,415,583		2,008,964		1,648,775		1,744,946		7,818,268
	(%)	30.9		25.7		21.1		22.3		100.0

Number	
% of Total Commuters	
Row%	Column%

Source: Statistics Canada Information, Travel to Work Survey.

then it will be assumed that new buses are purchased and some former auto commuters give up automobile ownership. The two simulations are complementary since the first deals with differences due to operations and the latter to new capital expenditures. The number of commuters who shift in both stages of the simulation is 250,000 per day; each travel 2.5 miles per trip (the average travel distance for those automobile commuters living within 5 miles of work).

Bus and Auto Fleets Remain the Same

The only effect of the shift to public transit in this simulation will come from an increase in bus operations and a decrease in auto operations (see Table 14). At 25¢ per trip and two trips per day, the 250,000 new riders will spend $125,000 per day or $29.375 million per year (235 days). The impact on bus operations is shown in Table 19; it amounts to an increase of approximately 2,970 direct jobs and 3,350 total jobs. Table 14 shows that bus operations provide 101 direct and 114 total man-years of employment for each $1 million of revenues. Therefore, $29.375 million of revenues will provide about 2,970 direct and 3,350 total man-years. The balanced trade adjustment is negligible in this case.

The employment gains from increased use of buses must be compared with the losses from reduced use of automobiles. The reduction consists of 192,000 vehicles (250,000 divided by 1.3 riders per auto) travelling an average of 5 miles per day (round trip) for a total of 226 million miles per year. Two alternatives were used to estimate the labour impact of a reduction in driving of this amount. In the first, it was assumed that the average automobile was driven 10,000 miles per year, which given the 7 million registered autos in 1971, means a total of 70 billion miles per year of driving in Canada. The ratio between the two figures indicates that the reduction in driving amounts to 0.32 per cent which, according to Table 14, would have an impact of reducing total employment by about 660 man-years per year for the total fleet of 7 million autos (0.0032 x 205,000). In the second approach, it was assumed that the cost of commuting in 1971 was approximately $0.1 per mile (for auto operations alone). Making a ratio between this and the total value of auto operations in Table 14 indicated that the reduced effect was about 0.73 per cent, which in turn gave an employment impact of 1,500 man-years per year. Neither approach is exact, but it is reassuring that the ratio derived from costs is higher than that derived from distance, which is reasonable given the higher cost of commuting compared with highway driving.

The net effect of the increase in bus operations and the decrease in automobile operations resulting from a shift of 250,000 commuters who live within 5 miles of work is to increase employment by 1,850 to 2,690 man-years per year. If the impact of balanced trade is taken into account, the net labour increase is reduced (because many more imports are required for auto than for bus operations) to 1,610 to 2,600 man-years per year. The balanced trade calculation shows a loss of about 90 to 240 man-years depending on whether the 0.32 or the 0.73 percentage approach is used. To create the biggest spread in final results, 240 was subtracted from 1,850 and 90 from 2,680.

Table 19

EMPLOYMENT IMPACTS WHEN 250,000 COMMUTERS LIVING WITHIN FIVE MILES OF WORK SHIFT FROM AUTOMOBILES TO BUSES
(man-years; losses in parentheses)

	Annual Gains or Losses			One Time Gains or Losses		
	Direct	Total	Total after balanced trade adjustment	Direct	Total	Total after balanced trade adjustment
Bus and Auto Fleets Remain the Same						
Bus operations	2,970	3,350	3,350			
Automobile operations	0	(660 to 1,500)	(750 to 1,740)		not applicable	
Net gain or loss	2,970	1,850 to 2,690	1,610 to 2,600			
More Buses and Fewer Autos are Purchased*						
Bus construction		not applicable		990	2,910	5,200
Auto construction				(0 to 8,700)**	(0 to 13,300)**	(0 to 15,640)**
Net gain or loss				Not calculated; could lie anywhere between figures cited depending upon how many commuters give up auto ownership.		

*Figures are additional to those for operations in upper part of table.
**Depends upon the number of affected commuter/owners who give up auto ownership (zero to 192,000). Direct employment in auto production is based on productivity of 22 autos per man-year (see footnote 157).

Source: See Tables 13 and 14.

Savings in the use of motor fuel would create some additional losses of employment in the energy production industry. This effect has not been calculated here in order to highlight the effect of the shift in vehicle use and because there are differences in the fuels typically used by automobiles and by buses. In any event, the effect would be small (see further below).

New Buses and Fewer Autos

In this simulation, it is assumed that new buses must also be purchased but that all other capital, notably highway capacity and bus servicing capacity, is adequate. It will be assumed that the buses will be built in Canada and that one new bus must be purchased for every 40 new riders. Using the same starting data as in Case A, 6,250 new buses will be required which, according to Table 14, will create 990 man-years of employment directly and another 1,920 indirectly for a total of 2,910 new jobs. Because of the high net import component in automotive manufacturing, almost as many jobs again (2,330) would be created through the balanced trade effect.[156] In summary, then, some 5,200 new man-years of employment would be created on a one-time basis through the purchase of buses to transport the additional commuters. These one-time gains are additional to the annual gains shown above, which result from the operation, not the construction, of buses.

156 The 250,000 new riders will require 6,250 new buses at 40 riders per bus. Data presented in Table 14 for construction of 1,000 new buses must therefore be multiplied by 6.25 to derive the results in the text. (e.g., 6.25 x 158 = 990 direct man-years.) The balanced trade adjustment, which in this case is positive, is calculated as: 6.25 x 4,196,000 x 89 x 10^{-6} = 2334 man-years.

To balance the impact of bus purchases, it could be assumed that some automobile commuters give up their automobiles. There is no way to know how big this effect might be. If all 192,000 automobiles were eliminated, there would be a loss of about 4,600 jobs from materials purchases (Table 14) and another 8,700 jobs in the auto plants themselves.[157] After adjustment for reduced imports and exports, the full impact could be a loss of about 15,640 man-years of employment.

Of course, it is unlikely that all or even most commuters would give up their automobiles as they are also used for shopping, recreation and other activities. For purposes of comparison, the labour impacts of increased bus manufacture and decreased auto manufacture balance at between 43,000 and 77,000 fewer cars per year in this simulation. That is, if fewer than these numbers of automobiles are given up, the labour impact of the purchase of 6,250 buses balanced against the reduction in automobile production will be positive. If more are given up, the effect will be negative. As before any such losses would be attenuated by employment gains resulting from reduced automobile operations and increased bus operations.

Energy and Dollar Savings

The calculation of dollar savings to the consumer depends upon so many assumptions that no calculations were made. The figures used in the initial simulation are in balance. That

157 Sources differ on the number of direct jobs required to produce one automobile. Estimates range from 16 autos per man-year on the floor to 28.5 autos per man-year. For purposes of calculation, a figure of 22 autos per man-year was used. Other figures are derived in the same way as those for bus construction.

is the 50 cents per day for public transportation is the same as the 10 cents per mile (for 5 miles) assumed for daily automobile operation. However, the role of parking fees, depreciation and the like is too complex to take into account here.

Petroleum savings can be roughly calculated. Table 15 shows the difference in crude oil use between automobile operations and urban transit operations. When automobile fuel consumption is decreased by 0.5 per cent (an average of 0.32 per cent and 0.73 per cent) and bus fuel consumption increased, as described in the first simulation above, the effect is to decrease expenditures on crude oil by 75 per cent in operations.[158] At a 1971 producer price of 7.8 cents per gallon ($2.73 per barrel), this amounts to a saving of 256,000 barrels per year. Thus, the total energy savings from a shift of 250,000 commuters is not great; it amounts to about two days' operations of the model refinery shown on Table 13. An alternative approach based on load factors (number of riders per vehicle) gives the same result. Given that, for typical load factors, buses have nearly five times the fuel efficiency of automobiles,[159] one might expect gasoline consumption to drop by four-fifths for the 226 million miles of reduced driving in this simulation. At an average fuel efficiency of 17 mpg, there would be a saving of

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158 The effect on auto consumption is calculated as 0.005 x $187 million (from Table 15) = $935,000; the effect on bus operation is calculated as 29.375 (million dollars of new revenue) x $8,074 (from Table 15 representing the expenditure on fuel from $1 million of revenue) = $237,000. The ratio between these two is roughly 1:4.

159 See footnote 17, Table 8.

approximately 10.6 million gallons or 300,000 barrels of oil per year. Thus, for the refinery shown on Table 13, which has a capacity of 61 million barrels per year, the employment loss can be ignored.

However, these calculations showing small energy savings assume that each new bus rider requires a marginal increase in bus operations, which is not at all likely. If buses have excess capacity, the marginal impact is negligible and the energy savings would be correspondingly greater.

The energy impact of bus manufacture was not compared directly with that for auto manufacture. However, Table 15 indicates that bus manufacturing is roughly ten times as energy intensive per vehicle as is auto manufacturing. Such a shift makes energy sense, then, so long as one bus replaces ten or more automobiles in manufacturing (assuming buses and autos have equal half-lives). Nevertheless, it is clear that the main effect comes from operations, not manufacture.

Summary

The net effect of a shift of some 250,000 "close in" commuters is likely to be strongly job creating so far as labour impacts are concerned. If there is no new capital involved, between 2,000 and 3,000 new jobs will be created; if buses must also be purchased (and purchases are made in Canada), as many as 5,200 more jobs could be created. However, depending upon the number of commuters who give up their automobiles, employment losses in automobile manufacturing could be significant. Dollar savings in these simulations could not be calculated. Energy savings from a shift of those 250,000 commuters are small.

Simulation 3: Retrofitting Existing Residences with Insulation

This simulation will estimate some effects of retrofitting (adding insulation to) one million existing residences in Canada to improve their thermal efficiency. Basic data on the existing housing stock and potential improvements in it are provided in a background paper prepared by the Central Mortgage and Housing Corporation (CMHC).[160]

In 1975, there were approximately 7,033,000 residences in Canada consuming 680 trillion Btu's per year. At a moderate level of retrofitting, energy consumption for space heating in these buildings could be reduced to 430 trillion Btu's per year, for a total saving of 250 trillion Btu's per year (one quarter of a quad). OEC data indicate that the average cost ($1976) would be $1,000 per unit of which about 45 per cent would be direct labour. If one converts this to 1971 dollars, the materials cost is $310. Direct labour use is 5 man-days per unit. For convenience, it is assumed that all of the insulating is done with mineral wool, and that this level of retrofitting is applied to 1 million units in the existing stock regardless of the heating system used in the houses. The CMHC data show that the impact of retrofitting the average residence in Canada with $310 of mineral wool plus 5 man-days of labour would be an energy saving of 35.5×10^6 Btu's per year per dwelling. (These savings refer to "tertiary" Btu's, the amount finally delivered as warmth, which will be less than the amount purchased by the consumer by a factor equivalent to the efficiency of his heating system.)

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160 Central Mortgage and Housing Corporation, *Thermal Efficiency in Existing Housing and The Potential For Conservation: Background Papers*, Report by Scanada Consultants Ltd. (Ottawa: 1976).

Labour Impacts

Table 14 shows that the total (direct plus indirect) increase in employment from producing enough mineral wool to retrofit 1,000 homes is 21 man-years of employment; in addition, there are 5,000 man-days or 20 man-years of employment in installation, for a total employment gain of 41 man-years. Increasing these impacts from 1,000 to 1 million residences yields a total employment gain of 41,000 man-years. Incorporation of balanced trade effects increases the gain to 44,120 man-years.

The energy saving resulting from this investment is 35.5 trillion Btu's per year. The energy used for heating dwellings in 1971 is shown in Table 20. After eliminating the minor fuels, one can say that 61 per cent of Canadian residences were heated with oil, 33 per cent with gas, and 6 per cent with electricity. (Note that in 1971, about 4 per cent of Canadian dwellings were still heated with wood, 60 per cent as many as were heated with electricity.) The efficiency of an oil system is assumed to be 60 per cent, of a gas system 75 per cent and of an electric system 100 per cent. Distributing the energy savings of 35.5 trillion Btu per year for one million retrofit residences over the three fuels leads to annual savings in energy for heating as shown in Table 21. All of the energy is assumed to be produced domestically except that 30 per cent of the oil is imported as crude. Therefore, Canadian oil wells would have been producing only 70 per cent of the secondary oil savings shown in Table 21 (that is, 4.3 million barrels per year).

Table 20

DISTRIBUTION OF HEATING SYSTEMS
BY NUMBER OF DWELLINGS
CANADA, 1971

Energy Form	No. of Dwellings ($x\ 10^3$)	Proportion (%)	Adjusted Proportion (%)
Oil	3,441	57	61
Piped Gas	1,865	31	33
Bottled Gas	71	1	-
Electricity	353	6	6
Coal & Coke	66	1	-
Wood	213	4	-
Other	22	1	-
Total	6,031	100	100

Source: Structural Analysis Division, Statistics Canada

Table 21

ANNUAL ENERGY SAVINGS BY FORM FROM THE RETROFIT
OF ONE MILLION EXISTING RESIDENCES IN CANADA
WITH MINERAL WOOL INSULATION

Energy Form Used for Heating	Annual Tertiary Energy Savings (Trillion Btu's)	Assumed Efficiency Factor of Heating System	Annual Secondary Energy Savings	
			Trillion Btu's	Natural Units
Oil	21.7	0.60	36.2	6.2 million bbls.
Natural Gas	11.7	0.75	15.6	15.6 million Mcf
Electricity	2.1	1.00	2.1	615.5 million kW.h
Total	35.5		53.9	

Note: Tertiary energy refers to heat provided to living areas. Secondary energy refers to heat content of energy purchased by the consumer. The two differ by a factor equal to the efficiency of the heating system.

Source: See footnote 160 and Table 20.

The one-time labour gains from producing and installing insulation are compared with the annual labour losses from reduced operations at existing energy supply facilities in Table 22. Calculations are made exactly as in previous simulations except that the reduced consumption is distributed over different forms of energy. All electricity is assumed to be produced by hydropower. The 615.5 million kilowatt hours of heating demand is assumed to be distributed over the full year (8,760 hours) so that a capacity of 70,000 kilowatts (70 MW_e) is required. As noted above, all plants are assumed to run full time over the course of the year; no correction is made for efficiency levels or downtime. The job loss from the reduced energy production is approximately 800 man-years per year whereas the one-time gain is over 44,000. Most people would agree that the latter is preferable from an employment point of view even though the gains cannot be repeated.

In addition to the operational losses, one could argue that there is further loss in the energy production sector because there will be no need to replace existing capacity given the reduced levels of demand for energy for heating. For example, if it is assumed that refinery capacity can be reduced in proportion to the reduced energy demand for heating in the 610,000 oil-heated homes, and if it is further assumed that the remaining life of these homes is equivalent to that of the plant that would otherwise be constructed, there is an additional one-time direct employment loss of about 1,430 construction man-years at a refinery (Table 13-B). Adding in the indirect job losses and the impact of balanced trade would increase the employment loss

Table 22

EMPLOYMENT IMPACTS FROM THE RETROFITTING OF ONE MILLION EXISTING RESIDENCES IN CANADA WITH MINERAL WOOL INSULATION

One-Time Labour Gains From Retrofitting (man-years)				Annual Labour Losses in Energy Production (man-years)			Possible One-Time Labour Losses from not Building New Energy Production Capacity (man-years)***		
Direct (Installation of Mineral Wool)	Indirect (Production of Mineral Wool)	Total* (Including Balanced Trade Adjustment)	Energy Form Used for Heating	Direct	Indirect	Total (Including Balanced Trade Adjustment)	Direct	Indirect	Total (Including Balanced Trade Adjustment)
20,000	21,000	44,150	Oil wells	280*	60*	390*	--	--	--
			Oil refineries	60	120	230	1,430	990	3,080
			Natural Gas	140	20	170	1,340	1,500	3,710
			Electricity**	--	10	10	830	1,330	1,720
				480	210	800	3,600	3,820	8,510

*Adjusted to eliminate imports of crude oil equal to 30 per cent of the saving.
**Hydroelectricity (70 MWe) supplied at a constant rate.
***Assumes that capacity is reduced in proportion to loss of output (except for oil wells, which continue to be drilled) and that new production facilities have the same life as existing housing.

Source: See Tables 13 and 14.

to approximately 3,100 man-years. Extending the calculation to the other energy forms (but excluding oil wells which, because of the depletion of reserves in Canada, will not likely lack for markets) one can estimate that there could be a one-time employment loss of about 8,500 man-years in construction of energy production facilities because of the reduced levels of demand for heating in the one million homes under study (Table 22).

The foregoing simulations have used hydropower to represent all electricity production. Had coal thermal electric or nuclear electric capacity been used in place of hydro, the results would not have been much different. So far as operating labour is concerned, total (direct plus indirect) labour requirements for a coal-fired station (and the supplying coal mines) are about three times as great (per unit of production capacity) as those to operate the hydro station (Table 13A) so that around 825 man-years, rather than 800 as shown in Table 22, might have been lost each year. Labour requirements to operate nuclear stations are in between those for coal stations and hydro plants. So far as construction labour is concerned, Table 13B shows that the three generating systems do not differ greatly in total (direct plus indirect) labour demand per unit of capacity.[161]

Energy and Dollar Savings

The energy savings from retrofitting an average residence in Canada to a moderate level were calculated by CMHC to

161 Table 13-B shows that total employment in construction of hydro plants is 19 man-years per megawatt of capacity whereas for nuclear stations it is 21. For coal stations the comparable figure is 11 but this does not include construction of the supplying coal mines.

be 35.5 million Btu's per year. For one million homes, the savings would be 35.5 trillion Btu's per year. This represents a reduction of more than 35 per cent in the heating load and even more in the annual demand for energy (inasmuch as oil heating, which is the least efficient system -- *at the final consumption stage* -- is used in about three-fifths of all Canadian residences). Energy savings by form are shown on Table 21; they are calculated to be 6.2 million barrels of oil plus 15.6 million Mcf of natural gas plus 615.5 million kW.h of electricity. Had the same level of retrofit insulation been applied to the entire housing stock in Canada in 1971, final consumption would have been reduced by approximately 250 trillion tertiary Btu's or 380 trillion secondary Btu's;[162] this would have been over 7 per cent of total secondary energy demand in that year.

It is also possible to calculate dollar savings from this level of insulation retrofit. Information provided by OEC[163] indicates that the national cost of retrofitting 5 million homes is $4.4 billion (1976 dollars), which means that the cost would be $880 million for 1 million homes. Using 1976 consumer energy prices of 43 cents per gallon for heating fuel, $1.84 per Mcf for natural gas and $0.0244 per kilowatt hour,[164] the annual dollar savings for consumers can be calculated from figures for secondary energy in Table 21. These amount to $93.3 million for heating oil, $28.7 million for natural gas and $15.0 million

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162 This calculation assumes that the ratio between secondary and tertiary energy put forward in Table 21 (53.9:35.5) can be applied to the entire 1971 housing stock.

163 See footnote 17, page 21.

164 Canada, Department of Energy, Mines and Resources, *Energy Update: 1976*, Report EI77-2 (Ottawa: 1977).

for electricity; the sum, representing total annual saving to consumers, is \$137 million. Comparing this figure with the \$880 million cost of the program one can estimate that the payback would take around 6½ years.

Summary

The energy, dollar and employment benefits of retrofitting the existing housing stock in Canada are all significant. Under a moderate program, 35 per cent of the average heating load could be saved per year for costs that will pay back (in direct energy savings at 1976 energy prices) in six to seven years. So far as labour is concerned, direct ratios are difficult to put forward inasmuch as gains occur once while the losses are annual. In the simulation studied, one million homes were retrofitted with improved insulation. Something over 44,000 man-years of employment were created in making and installing the insulation whereas only 800 man-years of employment were lost each year because of reduced energy output and up to another 8,500 man-years might be lost (on a one-time basis) through elimination of the need to build replacement production capacity.

Simulation 4: Improved Insulation in New Residences

This simulation will estimate some effects of adding more insulation while building one million new residences in Canada. The information for improving insulation in dwellings to be built between now and 1990 was derived in part from OEC data and in part from CMHC data. In order to simulate the impact of new building codes fairly, this simulation treated the direct and indirect impacts of the added insulation that would be required for buildings constructed after 1976 compared with that typically used in buildings built in the 1961 to 1975 period. This would require approximately $188 (1971 dollars) of extra mineral wool per dwelling and would yield added savings of 27.6 million tertiary Btu's per dwelling per year.[165] Other information indicates that the marginal labour required is approximately 3 man-days per dwelling.

OEC data indicate anticipated savings from new building codes for residences to be about 30.7 million Btu's per dwelling per year, about 3 million Btu's above the figure used here. The difference between the two estimates is likely attributable to the impact of double glazing, which is not included in this simulation. As in the retrofitting simulation, the only improvement in the residence is the addition of mineral wool insulation. This difference also accounts for the lower cost reported here compared with that reported by OEC. However, in contrast to the retrofitting simulation, the impact of improved insulation in *new* buildings will not be on operations at existing energy production facilities but on the construction of *new* capacity.

Labour Impacts

The energy saving from improved insulation in every one million new residences built will amount to 27.6 trillion Btu's per year. The employment impact of obtaining this saving is shown on Table 23. It amounts to 3,000,000 man-days of direct labour (12,250 man-years) for installation of the mineral wool

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165 See footnotes 17 and 160.

Table 23

EMPLOYMENT IMPACTS FROM HIGHER LEVELS OF MINERAL WOOL INSULATION IN ONE MILLION NEW RESIDENCES IN CANADA

One-Time Labour Gains from Additional Insulation (man-years)			Energy Form Used for Heating	One-Time Labour Losses from Not Building New Energy Production Capacity (man-years)		
Direct (Installation of insulation)	Indirect (Production of insulation)	Total (including balanced trade adjustment)		Direct	Indirect	Total (including balanced trade adjustment)
12,250	13,000	27,150	Oil (Refineries* only)	1,150	760	2,420
			Natural Gas	1,040	1,160	2,880
			Electricity** Hydro	680	400	1,400
			Electricity** Nuclear	460	720	1,530
				2,650-2,870	2,320-2,640	6,700-6,830

*Drilling of oil wells is assumed to continue.

**Hydro and nuclear are alternatives; the results are not additive. In either case 57 MWe of capacity are involved and electricity is furnished at constant rate.

Source: See Tables 13 and 14.

plus 13,000 man-years of indirect labour for its production (calculated from Table 14), which yields a total employment gain of 25,250 man-years. If the balanced trade impact is included, the total employment gain from improved insulation in 1 million new residences will amount to about 27,150 man-years.

In order to estimate employment losses in energy production because of improved insulation in 1 million new residences, energy savings must be distributed among different heating systems. This is done in Table 24. Just as in the retrofitting simulation, it is assumed that 61 per cent of the new dwellings will be oil heated, 31 per cent gas heated and 6 per cent electrically heated; and that the efficiency of oil systems is 60 per cent, of gas systems 75 per cent and of electrical systems 100 per cent. This no doubt overweights the future use of oil heating, but it does not likely affect the final results significantly. Indeed, a full analysis of future heating alternatives and their labour impacts would have to take serious account of solar heating in Canada.[166,167]

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166 K.G.T. Hollands and J.F. Orgill, *Potential for Solar Heating in Canada*, Report to the National Research Council of Canada (Ottawa: February 1977).

167 M.K. Berkowitz, *Implementing Solar Energy Technology in Canada*, Renewable Energy Resources Branch, EMR Report EI77-7 (Ottawa: 1977).

Table 24

ANNUAL ENERGY SAVINGS BY FORM FROM IMPROVED MINERAL WOOL INSULATION IN ONE MILLION NEW RESIDENCES IN CANADA

Energy Form	Annual Tertiary Energy & Saving (Trillion Btu's)	Efficiency Factor	Annual Secondary Energy Saving (Trillion Btu's)	Annual Secondary Energy Saving (Natural Units)
Oil	16.8	0.6	28.0	4.8 million bbls
Natural Gas	9.1	0.75	12.1	12.1 million Mcf
Electricity	1.7	1.0	1.7	498.2 million kW.h
Total	27.6		41.8	

Note: Tertiary energy refers to heat provided to living areas. Secondary energy refers to heat content of energy purchased by the consumer. The two differ by a factor equal to the efficiency of the heating system.

Source: See footnote 160 and Table 20.

Labour losses in the energy production system are derived from Table 13B and shown on Table 23.[168] As in the previous simulation, it is assumed that the need for new oil is such that wells will continue to be drilled even if the demand for heating oil falls off. (Some balance must be maintained in a refinery between the output of heating oils and of gasoline, but this is too complex an adjustment to include here.) However, in contrast to the previous submission, figures are shown for both hydroelectric and nuclear electric facilities; the two are of course alternatives in the simulation so the figures for them in Table 23 are not additive. In either case the demand for electrical power is assumed to be distributed over the full year (8,760 hours) so that generating capacity of 57,000 kilowatts ($57MW_e$) is required to furnish the 498 million kilowatt hours required.

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168 Calculations for the case of natural gas run as follows: From Table 20 one learns that 33 per cent of Canadian homes are heated with gas. Given that we are dealing here with one million "average" residences, this means that 33 per cent of the anticipated tertiary energy savings of 27.6 trillion Btu's per year or 9.1 trillion Btu's per year can be attributed to natural gas. Since, as specified, natural gas heating systems are assumed to have an efficiency of 75 per cent, the saving will require consumer purchases (secondary energy) of 12.1 trillion Btu's which, at one million Btu's per Mcf (Table 11), implies annual savings of 12.1 million Mcf of natural gas saved per year in these one million residences. Data in Table 13B show employment effects for a natural gas production system of 1.095 million Mcf per year, so, to accord with our example, these data must be multiplied by 12.1/1.095 = 11.05. Hence, direct employment is calculated as 11.05 x 94 = 1039 man-years. Indirect employment is (11.05 x 199) - 1039 = 1160 man-years (that is, total employment less direct employment). The impact of balanced trade is calculated as 11.05 x \$689 x 10^3 x 89 x 10^{-6} m-y/\$ = 678 man-years; this figure is then added to the direct plus indirect employment to get the final total including balanced trade adjustment = 2878.

As shown on Table 23, the direct employment loss calculated for the energy production sector is about 2,650 to 2,900 man-years (depending upon which electrical system is in use) and the total loss including indirect and balanced trade impacts is about 6,700 to 6,850 man-years. These are of course both one-time losses stemming from the fact that new production capacity is not built. Had oil well drilling also been deferred, the losses would have been considerably larger.

Comparison of employment gains and losses from improved insulation in new residences requires an assumption about the lives of residences and of energy production facilities. If they are equal, direct comparison is appropriate. If, as is more likely, residences are twice as long-lived as energy facilities, the employment losses must be doubled in order to compare them with the gains.

Within the limits of this analysis, the employment impacts of improved new residential construction as opposed to construction of energy supply facilities tend to be positive. As an approximation, one can conclude from Table 23 that, even if residences last twice as long as energy supply facilities, two jobs would be created through higher insulation standards for every one lost because of reduced need for new energy production facilities.

Energy and Dollar Savings

In lieu of calculating savings for the variety of conditions assumed in this simulation, one can deal simply with oil-heated residences. At a cost of $188 for mineral wool and

$260 for labour (both 1971 dollars), the 1976 cost of making and installing the additional insulation would be about $700 per average residence. The energy savings amount to 4.8 barrels or 168 gallons per residence per year. At 43 cents per gallon (1976 prices), the dollar saving would have been a little over $72, for a payback period of between nine and ten years. At current prices, the payback period would be a little less.

Some 3.25 million new residences are expected to be built over the period 1976 to 1990. If all were improved to the same extent as those in this simulation, the energy savings in these units would amount to about 140 trillion Btu's more than what would have been saved at lower standards of thermal efficiency.

<u>Summary</u>

Just as with retrofitting existing residences, it appears that there are significant energy, dollar and employment benefits to improving the insulation standards (probably through stricter building codes) in new residences in Canada. Very moderately improved standards would save about one-eighth of a quad each year in the 3.25 million units projected to be built between now and 1990. The pay-off for the homeowner would require nine to ten years (at 1976 energy prices).

So far as labour is concerned, there will be a positive impact from higher insulation standards. The exact size of the projected gain depends on a number of assumptions, including the heating alternatives for new residences. Among the alternatives considered here, oil systems tend to require somewhat more labour than do the others. Electrical systems tend to be the most labour intensive in the construction phase but the least so in operation, and gas systems tend to be the least labour intensive in construction (at least if additional pipelines need not be built). In any event, the net employment gain from improved insulation in new residences can reasonably be said to amount to something between 10,000 and 20,000 man-years per million new residences, depending upon the specific assumptions made about the heating systems and the lifetime of the facilities.

Consideration of the Induced Effect: Consumer Expenditures

For reasons explained earlier in this report, none of the previous simulations in this chapter has included the "induced" effects of shifts in expenditure patterns on employment and on energy consumption. That is, the subsequent impacts, that occur when households spend conservation savings and when they spend (reduce spending) as a result of incomes received (lost) from any employment or investment changes arising from the adoption of various practices to conserve energy, have been ignored.

In order to provide some idea of the importance of induced impacts, one special simulation was analyzed. In this simulation, $1 million of new consumer expenditures was added to a version of the Statistics Canada I-O model including households as a sector. Direct expenditures on energy were excluded from the analysis as were direct and indirect taxes. In effect, the simulation measures the increase in employment and in energy consumption stemming from the adddition of $1 million of general consumer expenditures (exclusive of fuels and taxes) as a result of direct, indirect and induced effects.[169]

The results of the simulation of increased consumer expenditures are shown in Tables 25 and 26, which use much the same column headings as earlier tables in this chapter except for the additional ones to include induced effects.

Labour Impacts

As shown on Table 25, just over 21 per cent of the value of consumer expenditures (exclusive of expenditures on energy and taxes) went to imports, and, after allowing for this leakage, there was a total (direct plus indirect) impact of 65 man-years resulting from the remaining expenditures. Just under two-thirds of these man-years were obtained directly (in producing plants, retailing and service industries),[170] while the remaining one-third came through indirect impacts in the supplying industries. Balanced trade effects increase the employment gain by 19 man-years (per million dollars of expenditures) and direct employment in the home (mostly domestic help), which is not captured in the other information, adds another 7 man-years.

The most important comparison to be made from the figures presented in Table 25 is that between the figure for Total Employment (equivalent to Total Employment in Table 14

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169 By definition, the direct impact on energy consumption is of course zero.

170 Because of the way I-O tables are constructed (retailing being defined as a separate sector), the direct employment impact of, say, purchasing an auto includes both the auto salesman and the workers in the auto factory.

Table 25

INCREMENTAL IMPACTS ON EMPLOYMENT OF
$1 MILLION OF NEW CONSUMER EXPENDITURES
(EXCLUSIVE OF ENERGY AND TAXES)

(1971 dollars and man-years)

Total Value ($000)	Imports ($000)		Employment (man-years)				
	Direct	Total	Direct*	Indirect*	Total	Total Including Induced	Adjusted Total Including Induced**
$1,000	$73	$214	41	24	65	107	133

*Direct employment occurs in the shops and the plants from which consumers buy products and indirect in the supplying industries.

**The adjustments include a balanced trade effect of 19 man-years plus direct employment in the home (mostly domestic help) of 7 man-years, which is not captured elsewhere in the I-O model.

Source: Structural Analysis Division, Statistics Canada.

and elsewhere) and the figure for adjusted total employment including induced employment. The difference between then is nearly 65 per cent, which means that employment gains calculated in any of the input-output simulations presented above are understated by a significant amount. Correspondingly, employment losses are also understated.

Energy Impacts

The indirect and induced effects on energy use from an increase in consumer expenditures (other than energy and taxes) can also be obtained from input-output information. These are shown in Table 26. Once again the induced effect is significant; it is almost twice as large as the indirect effect. However, the sum of all of these expenditures, about $32,500 per million dollars, is not very large. Even with the addition of balanced trade effects it only amounts to $40,000. Hence, it is fair to conclude that, apart from direct expenditures on energy itself, the energy savings calculated as resulting from conservation actions, such as those analyzed above, are *not* significantly overstated.

The analysis of household use of energy can be carried one step further by looking at Table 27, which presents data on the direct purchases of energy by Canadian households in 1971. These figures can be compared with those in Table 26 for indirect and induced purchases by relating both sets of figures to average expenditures per household. If for convenience, average 1971 income per household is taken as $10,000 (actually $9,600) and the number of dwellings as 6 million (actually 6,030,590), direct

Table 26

INCREMENTAL IMPACTS ON ENERGY USE OF
$1 MILLION OF NEW CONSUMER EXPENDITURES
(EXCLUSIVE OF ENERGY AND TAXES)

(1971 dollars and energy prices)

	Direct*	Total (= Indirect)	Total Including Induced	Adjusted Total Including Induced**	
				dollars	approx. quantities
Coal	0	$ 93	$ 1,361	$ 2,149	215 tons
Crude Oil	0	3,356	11,440	13,684	175,000 gallons
Natural Gas	0	767	2,027	2,508	16,100 Mcf
Electricity	0	7,810	22,129	27,085	3,010,000 kW.h
Total	0	$10,460***	$32,530***	$40,010***	

*Direct expenditures are excluded by definition. Therefore, total and indirect impacts are identical.

**Adjustments are from balanced trade effect exclusively.

***Totals exclude 20 per cent of electricity use to avoid double counting between fossil fuels used to generate electricity and the electricity itself.

Source: Structural Analysis Division, Statistics Canada. For energy prices see Table 12.

Table 27

DIRECT EXPENDITURES ON ENERGY BY HOUSEHOLDS, CANADA, 1971

		Producer's Value $000	Purchaser's Value $000	Implicit Purchase Price
Coal	733,000 tons	11,809	12,047	$16.44/ton
Gasoline	3,024,074 x 10^3 gallons	377,309	1,395,817	0.45/gallon
Fuel Oil	3,932,730 x 10^3 gallons	480,412	696,585	0.18/gallon
Natural Gas	431,229 x 10^3 Mcf	70,435	277,493	0.64/Mcf
L.P.G.*	144,875 x 10^3 gallons	8,900	17,607	0.12/gallon
Electricity	54,909 x 10^6 kW.h	836,525	848,336	0.015/kW.h

*Liquified petroleum gases.

Source: Structural Analysis Division, Statistics Canada.

and indirect plus induced energy use per household can be estimated as shown in Table 28.[171]

As Table 28 indicates, except for coal, which is a special case because of the almost total lack of direct household purchases, the energy purchased indirectly in goods and services by the average Canadian household in 1971 was 1½ to three times as much as that purchased directly for heating, lighting, cooking and driving. This further supports the conclusion stated above to the effect that energy impacts of additional consumer expenditures are small. Therefore, if consumers spend conservation savings (that is, added dollars saved from not having to buy energy directly) as they spend their average dollar, the impact on energy consumption can safely be ignored.

Summary

The analysis of the effects on employment and on energy consumption from the addition of $1 million of general consumer expenditures (exclusive of direct expenditures on energy itself and of direct and indirect taxes) has simulated the impacts that occur when households receive and spend their incomes. Such *induced* effects are additional to those incorporated in any of those measured in previous simulations which analyzed the *direct* and *indirect* effects of selected actions to conserve energy.

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171 Data on indirect plus induced energy use in Table 26, which are in terms of $1 million of expenditures, are divided by 100 to obtain the average per household. Data on direct energy use in Table 27, which are in terms of national totals, are divided by the number of households to obtain the average per household.

Table 28

IMPUTED DIRECT AND OTHER USE OF THE FOUR MAIN FORMS OF ENERGY BY AN AVERAGE CANADIAN HOUSEHOLD IN 1971

	Direct Use*	Indirect and Induced Use**	Total Including Induced Use
Coal (tons)	0.12	2	2
Crude Oil (gallons)	1,190	1,750	2,940
Natural Gas (Mcf)	70	160	230
Electricity (kW.h)	9,150	30,100	39,250

*From Table 27 after dividing by 6 million households.
**From Table 26 after adjusting to expenditures of $10,000 rather than $1 million. Balanced trade effects are incorporated.

Since almost any such action will impact on household incomes -- either because of wages gained or lost or because of money saved from reduced purchases of energy -- the induced effect is important to consider. Unfortunately, because it can only be measured in terms of the *average* rather than *marginal* impact of changes in household income, it is treated here as a side calculation.

The simulation of the induced impact of consumer expenditures has shown that consideration of direct and indirect impacts alone will result in a significant understatement of the changes in employment but no major overstatement of the changes in energy consumption. Therefore, if some proposed conservation will increase (decrease) direct and indirect employment by, say, 100 man-years, it is reasonable to suggest that the full impact on employment will be perhaps two-thirds larger (smaller) just from the effects of spending the added income (not being able to spend the decreased income). Similarly, where consumers save money from conservation (as with use of smaller autos), the employment gains from spending these savings will work strongly to offset losses in the energy supply industry.

On the other hand, except to the extent that consumers spend this additional money directly on energy, there will be no great impact on total energy consumption from increases or decreases in household income. Around 7.5 per cent of household income is spent, on the average, directly on energy (mostly heating fuel, gasoline and electricity), and this percentage decreases with income, so even including the direct impact should not change the overall conclusion very much.

Chapter 6: Longer Term Analysis of Low Energy Growth

This chapter describes some of the longer term relationships between energy consumption and the Canadian economy when energy is constrained to low growth rates. The analysis is based upon simulations produced by the Long-Term Simulation Model (LTSM) developed and run at Statistics Canada. There is no direct connection between the longer term simulation of growth rates in this chapter and the shorter term simulations of trade-offs in Chapter 5. Nor, unfortunately, is any reference case available for the longer term with similar economic and demographic but different energy assumptions. A few comparisons will be made with scenarios in a discussion paper from the Structural Analysis Division of Statistics Canada,[172] but this is not adequate to indicate whether the results obtained with low energy growth to 2025 are more or less favourable (for, say, employment) than those that would have been obtained with higher rates of energy growth.

Details of the LTSM Run[173]

As described in Chapter 4, the LTSM consists of a demographic model (Model A) and an economic model (Model B). The former includes population, household formation and labour force information, while the latter includes final expenditures, production and employment. Model B is itself composed of a

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172 See footnote 140.

173 Much of the general information in this section is taken from an as-yet unpublished user guide to the LTSM. See also footnote 138.

final demand determination submodel (B1), an output and employment determination submodel (B2) and several consistency checks on supplies of labour and of capital (B3). Given demographic results from Model A, Model B1 calculates final demand by category and the stock of houses. Model B2 calculates final demand, output, imports and employment by commodity and by industry. Model B3 compares the required capital stock with estimates of available stock; it also compares the number of persons in the labour force with total employment and makes other consistency checks. All commodity markets are cleared and industrial activity is consistent with final demand; trade is balanced on current account.

Note that, so far as energy is concerned, total consumption is divided into final consumption by households and all other (intermediate) consumption. Of the commonly used energy sectors, residential falls entirely in the former category and most other sectors (energy supply, commercial, *industrial* -- here, including most primary and all secondary and construction activities)[174] fall into the latter. However, transportation is split according to type of use with most auto travel falling to final consumption and other transportation to intermediate use. Fortunately, this same disaggregation had been adopted in the energy model that the LTSM was made to track (see Table 10).

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174 In the remaining pages of this chapter the terms "industrial" and "industry" refer to all intermediate energy consumption and, therefore, take on the meaning as applied in economics. See A Note on Terminology, for elaboration.

This section will describe the specification of the model in terms of the major exogenous variables which the user must provide. In addition, there are many minor exogenous variables, some of which have been specified and some of which have been set by default values. Those specified for this study will also be described. In several cases, submodels from previous runs of LTSM or from other sources were used as inputs in order to conserve time and money.

The demographic model originated in one specific estimate for population growth in Canada, an estimate that is towards the low end of the range considered reasonable for years after 2000. Net immigration is held constant at 90,000 per year, and the fertility rate is taken as 1.8 each year after the first few years.[175] This yields a 2025 population of 32.264 million, quite close to the 32.181 million in the energy model being tracked.[176] However, this demographic model yielded a figure for the number of households that was considerably in excess of those used in the energy model: 13.1 million households with an average of 2.5 persons per household compared with 9.2 million households with an average of 3.5 persons per household. To correct for this difference, headship rates were fixed at 1973 values (which itself reduced the number of households by about 1 million) and the resulting figures adjusted as needed in the LTSM by a time linear correction to obtain the desired number

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175 This is the age-specific fertility rate which is defined as the sum over all age cohorts of the probability that a woman in each cohort will have a baby in that year.

176 See footnote 25 and Appendix "A".

of households in 2025. For labour force, a pre-existing medium trend extrapolation of participation rates was incorporated. All remaining variables, including age-sex distribution of the population and of the labour force, were determined by the model or were set at default values.

The population/labour force figures generated by the demographic model tend to grow a little more rapidly to the turn of the century than do those in the Energy, Mines and Resources short-term energy model,[177] even as extended.[178] The overall participation rate in the labour force increases to the 1990s as young people move into the economy, but then, reflecting the aging population (18 per cent are projected to be 65 or older by 2025), begins to decline and by 2025 is slightly under the figure for 1975. The participation rate for women follows the same general pattern but rises so much more rapidly than that for men up to 2000 that it is significantly higher at the end of the simulation than it was at the beginning. The dependency ratio (the ratio of the sum of those under 15 or over 65 to the total population) exhibits the reverse pattern. The ratio first declines with the lower birth rate, then increases with the number of aged; its 2025 level is coincidentally equal to its 1975 level.

The final demand model (B1) in the LTSM was built using figures from the energy model for 2025[179] that was

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177 See footnote 15.

178 See footnote 25, Appendix B.

179 See footnote 25.

described in Chapter 4 (especially Table 10 and Appendix "A"). In this scenario population grows overall at a rate of 0.6 per cent per year 1975 to 2025, and GNP at 1.7 per cent per year; per capita GNP grows at 1.2 per cent per year. As noted, these rates of growth correspond to one of the scenarios assumed by the Energy, Mines and Resources study of long-run energy issues,[180] and they were adopted specifically to test the energy and economic implications of one possible low energy ("conserver society") future for Canada. Energy was the focus of the previous report;[181] economics is the focus of this one.

Certain variables were specified in terms of the energy figures from the energy model itself (see Table 10). As with other energy figures in the model, they were precisely determined only for 1975 and 2025. In particular, final consumption of electricity was linearly decreased with time at a rate that makes the ratio of electricity consumption in 2025 to that in 1975 equal to 0.9653, which is the ratio of "Other Residential" consumption in 2025 in the energy model to the comparable figure for 1975.[182] Similarly, the final consumption of fuel oil and

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180 See footnote 23.

181 See footnote 25.

182 Other Residential consumption is largely final electric demand. The low-population, low-GNP model in the energy study (see footnote 25) indicates consumption of 417 x 10^{12} Btu's for residential use other than space conditioning in 2025. (Space conditioning is the sum of energy used for space heating and for air conditioning. In Canada the latter term is negligible for residences but not for the commercial sector.) Energy, Mines and Resources data indicate that the comparable figure for 1975 was 432 x 10^{12} Btu's (see footnote 15; Tables 6 and 7). The ratio of the two is 0.9653.

of natural gas were each reduced linearly to make a 2025:1975 ratio of 0.4859, and the consumption of gasoline and oil (for automobiles) was reduced linearly to make a 2025:1975 ratio of 0.4063.[183] These changes constrained final energy consumption to the levels developed from the energy model and shown in Table 10.

A number of other final consumption categories were specified either according to population projections or to household projections. For example, expenditures on food and laundry were projected on a per capita basis, while those on rent and imputed rent were projected on a per household basis. Finally, a number of final expenditure categories related to automobile use (apart from fuel use itself) were specified in terms of the growth rate for the automobile fleet derived in the energy model (0.58 per cent growth per year yielding 0.436 autos per capita in 2025). All other final consumption categories were projected linearly using default share extrapolations but in such a way that total consumer expenditures grow at the specified rates of 3 per cent per year to 1985, 2 per cent per year between 1985 and 2000 and 1 per cent per year thereafter.[184] The model

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183 Consumption for residential space conditioning and for automobiles in the energy model for 2025 are, respectively, 396×10^{12} Btu's and 453×10^{12} Btu's. Energy, Mines and Resources data for 1975 are 815×10^{12} Btu's and 1,115 Btu's. The ratios are 0.4859 for space conditioning and 0.4063 for automobiles. See previous footnote for sources.

184 A few final consumption expenditures, notably those related to health and education, are determined directly from the demographic model, and shares for these are set prior to other allocations for final expenditures. None of these services is of particular interest for this study.

ensures that there is an appropriate relationship among the specified variables, the unspecified variables, and total consumer expenditures.

Exports and imports were set at levels typical of the 1960s and held to between 22 and 25 per cent of output. Some structural changes were incorporated by essentially eliminating exports of energy, by decreasing the shares of agricultural, fishery and forestry products, and by stabilizing the share of minerals. Otherwise, merchandise exports were distributed among the consumption categories in the same manner as the unspecified consumer expenditures, that is, according to a set of default shares (which are equal to the average shares observed from 1970 to 1973). The model as usual ensures that the individual export categories sum to the appropriate total. Since a balanced trade version of the LTSM was used, imports were made equal to exports and were distributed among commodities by the model.

Residential construction was taken from the projection of households in the energy model. In effect, the model relates the needed stock of housing to the existing stock (lagged by a year) and assures that investment in residential construction is sufficient to bring the two into balance. Adjustment is made for depreciation. The constant demolition rate in that model corresponds roughly to the 0.5 per cent depreciation rate used for LTSM. The price of housing was increased slightly to reflect the costs of retrofitting the existing stock and of improving the new units. Otherwise, the LTSM specifies total investment in residential construction to be a constant ratio of construction costs in order to allow for other alterations, fees, insurance etc. The LTSM distinguishes single from multiple dwellings. However, there was no simple way to adjust the LTSM so as to correspond to the higher proportion of multiple units (and the various types of multiple units) projected in the energy model. Whereas the ratio of single detached units to total housing units in the 2025 stock of housing in the energy model is 0.42, for the run of the LTSM the ratio is nearly 0.57. This is not likely to result in a significant increase in total energy use inasmuch as the share of residential energy use in total energy declines in all projections.

Business non-residential investment figures were taken from another run of the LTSM that gave values every five years for the annual value for total business investment and for business machinery and equipment. These values are a little high, particularly before 2000, but not so much so as to alter results by the year 2025.

Government current expenditures are all determined endogenously to the model. Government investment is largely determined exogenously except that certain of the components depend upon specified consumer expenditures. For example, government investment in highways is a function of consumer expenditures on automobiles.

Finally, a few other items, including net inventory accumulation, government revenues and total imports, are specified in the LTSM but need not be described here. They are simply required for later stages of the model.

All of the information specified or generated to this point, including the final demands and the other parameters, form submodel B1 of the economic model, and they become inputs to the output/employment determination submodel (B2). It is submodel B2 that actually performs the input-output transformation and that calculates demand, output and imports by commodity and output by industry. Further, using a value for average labour productivity, which must be specified, submodel B2 calculates employment by industry. For this run of the LTSM, labour productivity was specified to rise at the historic trend through 1980 and then remain constant.[185] This is a strong assumption, but it is intended to reflect both the shift away from primary production and towards manufacturing and services in the economy, and, as explained below, the substitution of labour for energy throughout industry. A similar approach has been used in other work with the LTSM aimed at developing low energy scenarios.[186] Clearly it is total factor, not just labour, productivity that is of concern, and the scenario used here models a society moving towards greater energy productivity.

All of the standard assumptions needed for input-output analysis are of course carried over into the results of submodel B2. In particular, the model is based on the industrial structure

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185 Labour productivity is defined as constant dollar GNE per man-year. In this mode of use of the LTSM there is no alternative but either to make some assumption about labour productivity or to do mechanical trend analysis (see footnote 140, page 10).

186 See footnote 140, Scenario A.

in Canada in 1961 and on the assumption of constant technology, except as modified.[187] This structure is moved through time largely on the basis of physical relationships (see Chapter 4).

The preceding two submodels generate levels of demand and of output without consideration for the availability of factors of production. Final demand is specified or calculated from population and household data, and the input-output transformation determines the industrial output and employment for that demand to be satisfied.

Submodel B3 generates or gathers information to indicate the extent to which the supply of factors of production will likely be adequate to meet the demand. No new data are required. In principle, the submodel should deal with labour, capital and natural resources, but, as noted above, there is as yet no natural resource supply component. Total employment generated in submodel B2 can be compared with the labour force determined in the demographic model A. Required capital stock (calculated from the industry outputs from submodel B2 and from projected trends in capital-output ratios) can be compared with actual capital stock (determined internally in the LTSM by adding new investment less depreciation each year to the existing capital stock). Several other comparisons can also be generated by submodel B3, but none are directly relevant to this study.

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187 The 1961 input-output tables were modified for a few industries, including pulp and paper and automobiles, where it was felt that the 1961 input structure was particularly out of date. Also, adjustments were made to the inputs for quite a number of industries to reflect the observed downward trend in in-house production of electricity. Finally, energy efficiency was increased for industry as a whole in the 2025 results. This modification is discussed below.

Finally, although there is no energy supply component, submodel B3 does provide information on energy demand throughout the simulation period. All energy information is presented by energy form and in terms of primary energy measured as terajoules (10^{12} joules or 10^9 kilojoules or 0.95 x 10^9 Btu's). In order to report primary energy, all energy regardless of source is calculated at its primary fossil fuel equivalent. Notably, coke is converted back to coal at an efficiency ratio of 1/0.75; derivatives of crude oil (fuel oil, gasoline, still gas, etc.) are converted back to crude at specified efficiency levels; and all electricity, regardless of source, is treated as if it had been generated from fossil fuels at an efficiency of 1/0.3.

Submodel B3 calculates "domestic disposition" of energy, which is the sum of final consumption demand and intermediate demand. The former is obtained from submodel B1 and the latter from energy input-output tables incorporated with submodel B2 (and described briefly in Chapter 4). Considerable detail is provided on industrial disposition. Energy use by form is calculated for each of five major sectors (one of which -- Commercial, Transportation and Other -- is not usually treated as a single sector), and in addition for energy use by form in each of the 50 most important energy consuming industries. All of these calculations are of course performed under the standard input-output assumption of constant technology, about which more will be said below.

"Domestic supply" of energy is defined in submodel B3 as identical to domestic disposition and also equals domestic production plus imports minus exports. Given the figures already derived for the latter two quantities, domestic production is *calculated* as a residual.

Results of the LTSM Run

The LTSM is quite expensive to use and prints out an enormous amount of detail, by no means all of which is relevant to this study. In particular, the print-out includes information on many variables at five-year intervals from the initial through the final date of the simulation. However, the energy demand model of the Canadian economy that is the basis for the analysis is defined in detail only for the year 2025, and for most variables the LTSM is constrained to approach this final result along a linear trend that is not likely to be a good representation of developments in the economy over time. Hence, for the most part only the model output for 2025 will be noted. Similarly, for the purposes of this study, a high degree of aggregation -- 50 commodities and 50 industries -- was selected from the total of 679 commodities and 211 industries. For presentation of energy demands, the 50 largest consuming industries were reviewed. Finally, a considerable amount of information is also provided by the LTSM about population and labour force characteristics that, while realistic (e.g. an aging population with more female workers), can be put to one side as not terribly important to the energy/economic relationships.

The principal question asked of the LTSM in general is: What are the implications of an economy growing at some given rate? For this study the question is a bit more specific: What are the implications of an economy experiencing slightly negative growth in energy consumption, other things being equal? Of course, other things are not entirely equal in that moderately low growth rates for population and for income growth were also incorporated into the model. Ideally, one would have liked to run the model for a number of variations of population and industrial structure so as to identify more clearly the impact of energy constraints. Time and financial limitations precluded such an approach. Nevertheless, the model is specified in sufficient detail to allow specific reductions in energy consumption, as described in the previous section, to be reflected in the final consumption figures and for side calculations to introduce them into the industrial disposition figures.

From the point of view of this study, perhaps the most important result is that this run of the LTSM did in fact run. No energy values were so remote nor were any economic inconsistencies so great that the model refused to deal with them. An economy, albeit one with some problems (see further below), was successfully projected. This economy will be described, first in terms of aggregate growth and characteristics and then in terms of industrial growth and characteristics. After this has been done, supply/demand comparisons will be made for labour and for capital, and energy use in industry will be analyzed.

Aggregate Economic and Energy Impacts

The overall shifts in the economy resulting from the simulation of low energy growth to 2025 are shown in Table 29. Consumer expenditures grow, as specified, at annual rates of 3 per cent to 1985, 2 per cent from 1985 to 2000 and 1 per cent thereafter. Of these expenditures, the share of semi-durables

Table 29

MAIN DEMOGRAPHIC AND NATIONAL INCOME CHARACTERISTICS
SIMULATED IN 1975 AND 2025

Demography	1975	2000	2025
Population (millions)	22.690	29.134	32.264
Households (millions)	6.736	--	9.197
Dependency Ratio*	53%	45%	54%
Labour Force (millions)	9.844	14.598	15.015
Participation Rate*	53%	63%	57%

National Income	Values of Final Demand (Billions of 1961$) 1975		Values of Final Demand (Billions of 1961$) 2025		Average Annual Percentage Growth 1975 - 2025	Shares of Final Demand (Consumer Expenditure = 100) 1975		Shares of Final Demand (Consumer Expenditure = 100) 2025	
Consumer Expenditure		$53.4		$124.0	1.7		100.0		100.0
Durables	9.5		27.1		2.1	17.8		21.8	
Semi-Durables	7.2		25.1		2.5	13.5		20.2	
Non-Durables	18.0		27.1		0.8	33.7		21.9	
Services	18.8		44.7		1.7	35.2		36.0	
Business Investment		15.0		11.6	-0.6				
Residential	2.9		1.3		-1.6				
Non-Residential	5.2		3.3		-1.2				
Machinery & Equipment	6.9		7.0		0.0		33.6		16.2
Government Investment		3.4		8.6	1.9				
Non-Residential (ex. highways)	1.9		5.4		2.1				
Machinery & Equipment	0.4		1.3		2.4				
Highways	1.1		1.9		1.1				
Government Current Expenditures		13.6		26.3	1.3		25.4		21.2
Exports		18.6		37.5	1.4		34.7		30.3
Sum of All Categories of Final Demand**		102.5		205.6	1.4				

*These ratios are defined in terms of a "source population", which excludes people in the armed forces, those living in the Territories and some other categories. Anyone under 15 or over 65 in the source population is defined as a dependent, and anyone who has or is looking for work is considered a part of the labour force. There is of course some overlap between the categories of dependent and labour force.

**The sum of all final demands does not quite equal the sum of consumer plus business plus government expenditures because of minor adjustments internal to the LTSM.

Source: Results of the LTSM Run.

increases by about one-half to just over 20 per cent of the consumer's budget; the share of durables increases more slowly but also grows to more than 20 per cent. In contrast, non-durables decline from about one-third to just over 20 per cent of the budget while the share for services holds steady. Over the simulation period, the share of consumer expenditures in the GNE grows from just over 50 to just under 60 per cent of the total. If exports are excluded from consideration (on the basis that net exports are by definition zero), the share of consumer expenditures still rises by about 10 per cent from just over 60 to just over 70 per cent. Corresponding to the increased share of consumer expenditures, the share of government plus business investment drops by about the same 10 per cent.

Changes in consumer expenditures on energy are shown in Table 30. Both the absolute expenditure and the share of total consumer expenditures spent directly on energy drop sharply -- the former by nearly 50 per cent and the latter by about 75 per cent. The slow growth rate assumed for the economy is in part responsible for these results, but the major source of the change lies in the shift in the composition of final demand. In other words, the efficiency gains and shifts in consumption patterns are more important than low economic growth. A similar result was obtained by the Structural Analysis Division while demonstrating the impact of restraints on consumption:

> "It is evident ...that even for very moderate per capita GNE growth rates, ...the domestic disposition of primary energy to the year 2000 exceeds that for a higher

Table 30

DIRECT CONSUMER EXPENDITURES ON ENERGY
SIMULATED IN 1975 AND 2025
(1961$)

	Value (Billion $)		Share of Consumer Expend.	
	1975	2025	1975	2025
Electricity	$0.9	$0.9	1.6%	0.7%
Natural Gas	0.4	0.2	0.7	0.1
Fuel Oil	1.1	0.5	1.9	0.4
Auto gas and oil	1.6	0.7	3.0	0.5
Total	$4.0	$2.2	7.4%	1.8%

Source: Results of the LTSM Run.

> growth scenario in which final consumption of energy is restrained."[188]

With the exception of electricity, each of the main energy forms shows roughly the same pattern. Absolute expenditures on electricity remain constant and its relative place in consumer expenditures drops by only 50 per cent. This reflects continued growth in non-space conditioning residential demand (e.g. lighting, appliances), much of which depends upon electricity, relative to other forms of energy consumption.

Total investment grows hardly at all in absolute terms in the simulation, as business investment falls but government investment grows at a steady though declining rate (Table 29). There is a sharp decline, both absolute and relative, in the annual investment in residential construction, which is to be expected given the demographic characteristics of the population. By 2025 it amounts to 6.5 per cent of all investment (business plus government) compared with 16.3 per cent at the start. Other categories of business investment decline over the first half of the simulation but begin to pick up again during the second half, though not by enough to offset the decline in residential construction. For some reason, investment in machinery and equipment recovers more quickly and more strongly than does that in non-residential construction. Government investment is up by a factor of three to four in all categories, except that highway investment does not even double because of the slow growth of the automobile fleet.

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188 See footnote 140, pages 30 and 35.

None of the other aggregate components of the economy is of much relevance to this study. Exports go up in proportion to the GNE in order to remain within a range of 22 to 25 per cent of the total. As specified, oil and gas exports fall off, and other primary exports stabilize, so slow but steady gains are registered in primary and secondary materials and in finished products. Government current expenditures grow more or less in proportion to the size and characteristics of the population.

Industrial Growth and Energy Use[189]

Turning now to the results of the input-output transformations shown in Table 31, all industrial sectors show continued growth, though, as would be expected, the rates of growth decline with time. Average annual rates of growth lie between 1.5 and 2 per cent per year with lower rates for construction and the primary sector. These are of course well under the growth rates historically observed, with the fall off particularly sharp for durable and non-durable manufacturing. Nevertheless, total industrial output increases by 100 per cent over the period 1975 to 2025 ($255 billion compared with $122 billion). As a result of relative shifts within the several sectors, the shares of each of the major sectors grow by about 10 per cent except that the share of the primary sector falls by nearly 20 per cent and that of construction by 35 per cent. These shifts

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189 Here, the term "industrial" refers to all intermediate consumption sectors and, therefore, is applied as is usual in economics. See A Note on Terminology for elaboration.

Table 31

SECTORAL OUTPUT AND EMPLOYMENT
SIMULATED IN 1975 AND 2025

Sector	Value of Output (millions of 1961$) 1975	Value of Output (millions of 1961$) 2025	Value of Output Avg. Annual Growth (%)	Share of Ouput (%) 1975	Share of Ouput (%) 2025	Total Employment (thous. workers) 1975	Total Employment (thous. workers) 2025	Share of Employment (%) 1975	Share of Employment (%) 2025
Primary	10.6	18.3	1.1	8.7	7.2	908	1,466	12.8	10.4
Non-Durable Mfg.	25.9	59.7	1.7	21.1	23.4	847	1,734	11.9	12.3
Durable Mfg.	23.0	52.4	1.7	18.8	20.5	744	1,236	10.5	8.8
Construction	13.3	17.7	0.6	10.9	6.9	677	673	9.5	4.8
Services	49.5	107.1	1.6	40.5	41.9	3,931	8,984	55.3	63.8
Total	122.3	255.2	1.5	100.0	100.0	7,106	14,092	100.0	100.0

Source: Results of the LTSM Run.

are still roughly in line with historic patterns, which is a little surprising given the sharp changes in energy consumption that were incorporated.

Turning now to employment, also generated via the input-output transformation, total demand for labour nearly doubles from 7.1 to 14.1 million. All sectors except construction (which does not grow at all) show continued but declining growth in the rate of employment with the biggest relative gains registered by the service sector (growth of 130 per cent) and the smallest by the primary sector (growth of 60 per cent). By the end of the simulation period, nearly two-thirds of all industrial employees are in the service sector compared with 55 per cent at the beginning of the period.

Labour and Capital Use (1)

Table 32 presents the initial simulated comparisons of the supply of and demand for: construction capital, machinery and equipment capital, and labour. In contrast to other tables, these figures are presented as a time series because this is the only way to show the changes in trend common to all three time series. However, it must be remembered that the imput data for intermediate years are not, in most instances, specified independently but are linearly extrapolated between 1975 and 2025. (Overall growth rates and demographic data are exceptions.)

Having recognized that qualification, it is nevertheless useful to note that all three time series show, first, an increasing surplus of capital and of labour that peaks towards 1990 but, then, a slowly declining surplus through about 2025,

Table 32

INITIAL COMPARISONS OF SIMULATED SUPPLY AND DEMAND
FOR CAPITAL AND FOR LABOUR, 1975 TO 2025*

	Construction Capital (million 1961$)			Machinery & Equipment Capital (million 1961$)			Labour (million workers)		
	Available	Required	%Diff.	Available	Required	%Diff.	Available	Required	%Diff.
1975	93.2	83.8	10.0	79.1	70.5	10.9	9.8	8.9	9.8
1985	126.4	107.6	14.9	114.8	98.6	14.1	12.5	10.4	16.8
1995	144.6	123.7	14.4	128.2	116.4	9.3	14.0	12.1	13.9
2005	157.4	140.2	10.9	140.4	135.1	3.8	15.1	13.9	7.9
2015	160.2	149.0	7.0	143.7	145.5	-1.3	15.3	15.0	2.0
2025	155.8	160.0	-2.5	141.2	158.6	-12.4	15.0	16.4	-9.6

*Comparison made prior to detailed analysis of conservation opportunities in industrial use of energy.

Source: Results of the LTSM Run.

after which a deficit appears for both capital and labour. While the exact differences between supply and demand are largely a function of the assumptions and the initial data, the trends are cause for some concern. Clearly, they are related to factors specified in the low energy model for 2025. The low growth rate for consumer expenditures will itself dampen business investment; the low growth rate for population and the even lower growth rate for households will limit residential construction and purchase of durables; the reduced rate of growth of the automobile fleet will cut government investment in highways; and so on.

On the other hand, it is reassuring to find that the surpluses are worst during just those years when the growth rates are highest and that they turn around to deficits by the time the low energy future has worked its way through the economy. This suggests that the surpluses may be transitional phenomena and not inherent in the low energy future itself. Or they may represent a lagged effect inasmuch as capital, even with slow growth, must eventually be replaced. Certainly higher growth in the primary, manufacturing and construction sectors, which was considered in other scenarios of the energy model (see Appendix "A"), would have absorbed much of the surplus as they are much more energy intensive per dollar of output than is the service sector (which includes government). Moreover, the transition may not be as serious as indicated by the LTSM. Growth rates of certain variables (including energy use itself) would likely be higher in the next couple of decades and lower thereafter than is indicated by a linear extrapolation between 1975 and 2025.

Most importantly, however, the comparisons shown in Table 33 are not at all the end of the simulation story. The nature of the LTSM is such that low energy alternatives could be specified directly for final consumption expenditures, but, except as these reflect on diminished growth in intermediate consumption, there is no way to specify low energy technologies for industry (which, here, it must be remembered, includes the commercial sector and transportation except the automobile). The LTSM is based on constant technology. To incorporate improved energy efficiency, it is necessary to look directly at industrial energy use. Then we can return to the question of labour and capital use.

Energy Use in Industry

Table 33 presents some detail on final (consumer) and intermediate (industrial) energy demand as produced by the LTSM. The information on final consumption use can be accepted more or less as it stands (i.e., as it was specified according to the energy model). That for industrial use cannot be so accepted since it must be adjusted for improved energy efficiency to accord with the results of the long-term energy model.[190]

It must first be noted that the tracking of the long-term energy model by the LTSM was not perfect, in large part because the two began from different data bases and different

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190 See footnote 25 and Appendix "A".

Table 33

SIMULATED ENERGY CONSUMPTION IN 1975 AND 2025
(thousands of terajoules)

			Detailed Industrial Disposition by Shares of Primary Energy				
Energy Form	Final Consumption*	Other Consumption**	Non-Energy Use	Energy Supply Industries	Primary Industries	Manufacturing Industries	Commercial Transp., Other
			1975				
Coal	237	314					
Natural Gas	396	759					
Electricity	483	641					
Coke	2	150	4.5%	17.1%	9.1%	37.5%	31.8%
Gasoline	508	493					
Fuel Oil	1,044	1,333					
Other	16	142					
Total Secondary	2,685	3,845					
Total Primary	4,036	5,650					
Grand Total	9,686						
			2025				
Coal	296	690					
Natural Gas	245	1,420					
Electricity	542	1,396					
Coke	1	332	4.8%	11.8%	8.1%	41.5%	33.8%
Gasoline	277	931					
Fuel Oil	637	2,785					
Other	10	243					
Total Secondary	2,005	7,796					
Total Primary	3,404	11,697					
Grand Total	15,501						

*Incorporates improved energy efficiency.
**Does not incorporate improved energy efficiency.

Source: Results of the LTSM Run.

sectoral definitions. Moreover, the LTSM calculates in joules rather than Btu's, so there is an initial adjustment to be made. Comparison of the 1975 figures for secondary energy use in the LTSM, converted to Btu's, and those from the long-term energy model show that the former is about 16 per cent too high with the bulk of the difference being found with industrial use. Assuming that this same difference also exists in 2025, total secondary use in the LTSM results would be about 8,000 x 10^{12} Btu's and industrial use would be about 6,000 x 10^{12} Btu's. Inasmuch as the long-term energy model calculated industrial energy demand to be 3,564 x 10^{12} Btu's, it is apparent that something more than a doubling of industrial energy efficiency (again, including consumption in the commercial or services sector and in non-automobile transportation) is required over the next 50 years. That is, comparison of the figures suggests that total industrial consumption needs to be reduced by 40 per cent; hence, *specific* efficiency of industrial energy use (energy use per unit of output) would need to be improved about 70 per cent, given the growth in output. If this can be accomplished, the saving of 2,500 x 10^{12} Btu's would reduce total secondary energy use in 2025 to about 5,500 x 10^{12} Btu's, which is right on the target for the slightly negative rate of secondary energy growth for 1975 to 2025, as shown below:

	LTSM	Energy Model
Total secondary use in 1975 (Btu's)	6,190 x 10^{12}	5,330 x 10^{12}
Total secondary use in 2025 (Btu's)	5,500 x 10^{12}	4,830 x 10^{12}
Average annual rate of growth	-0.24%	-0.20%

An improvement in the specific energy efficiency of what might better be called intermediate energy consumption of 70 per cent over the next 50 years is not an impossible target. Lovins has suggested that technical fixes across the entire economy could achieve a 75 per cent reduction in specific energy use (that is, two doublings of efficiency).[191] Savings of this much are already being achieved in a few cases (and at no additional capital cost), as with the operation of the Ontario Hydro building in Toronto.

Reviewing the simulation results in more detail, information on disposition of energy by the largest consuming sectors indicates that the pulp and paper industry alone is projected to be using 15 per cent of intermediate energy consumption; the iron and steel industry, 6 per cent; industrial chemicals, nearly 5 per cent; and a cluster of industries including aluminum, smelting and petroleum refining, between 3 and 4 per cent each. Truck transportation, rail transportation and air transportation follow behind at about 3 per cent, 2.5 per cent and 2 per cent respectively.

Each of these major consuming industries can anticipate major gains in energy efficiency over the next 50 years. It is quite conceivable that pulp and paper will be using internally generated energy (largely from waste products) for the bulk of its power requirements, and far more energy-efficient metallurgical processes are already being installed. The

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191 See footnotes 59 and 136.

chemicals industry projects a 17 per cent improvement in specific efficiency by 1980, and as much as 85 per cent savings are anticipated in new plants.[192] Admittedly, each successive unit of conservation will become more difficult, but it has been so long since research attention has been directed at energy use that there is good reason to assume that an average improvement in energy efficiency of 1 per cent per year, which is about what is required, is quite within reach.[193]

Labour and Capital Use (2)

Returning now to the question of surpluses and deficits in capital and labour in the low energy growth scenario under analysis, it is apparent that the preceding analysis leads in opposite directions for labour and for capital. As shown in Chapter 3, there is good reason to believe that labour and energy are substitutes for one another, while capital and energy tend to be complements, particularly in industrial production. To the extent that this is true, and insufficiently reflected by the assumption of constant labour productivity after 1980, the labour surpluses predicted by the LTSM will not necessarily occur. The constant industrial technology approach of the model has led to an apparent inconsistency that may not be real. On the other hand, the surpluses in capital could be aggravated if the macro complementarity of energy and capital remains stronger than the micro substitutibility.

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192 See footnote 17, pages 29 to 32.

193 See footnotes 115 and 135.

There is no way of telling, from the information at hand, the extent of these opposite effects on capital and on labour; only the direction seems clear. The result should be an industrial structure in 2025 that is less efficient in terms of labour than we now think essential, but that is much more efficient in terms of capital and of energy. Moreover, if, contrary to what is indicated in this run of the LTSM, there is capital stringency over the next decades, any additional degrees of freedom that can be obtained through energy policy may be welcome and may, in addition, dampen the impact of inflation.

The one major shift in structure that is indicated by the simulation is the reduction by nearly one-third in the share of industrial energy going to the energy supply industries (see Table 33) -- just the sector where so much Canadian and imported capital is projected to be needed in the next few decades.[194] A smaller decline in the share of energy use is indicated for primary industries with most of the gain going to the manufacturing and the services and transportation sectors. At least part of the reason for the relative shift in position of the energy supply industries is the reduced growth of electricity. While there is no direct way to allocate improved efficiency among the different forms of energy, even the figures of Table 33 indicate that total growth in electricity consumption over the 50-year period would be only 1 per cent per year, a far cry from what is anticipated today.

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194 See footnotes 14, 37 and 38.

Finally, it is important to recall that there is no good reference case with which to compare the low energy growth path analyzed here. It could be that the results for capital and labour would be still more difficult if Canada attempted to increase her energy consumption (and presumably production) at more rapid rates. Indeed, some have asserted that this is the case, at least for some time. What is needed for pursuing the implications of long-term simulations are better analytic separations of the effects of energy growth from those of economic growth.

Chapter 7: Conclusions and Policy Implications

There is no longer much purpose in proving that there are great opportunities to conserve energy. Clearly, growth of all kinds has been so much a way of consumer and industrial life in the recent past, and energy has been so cheap to use compared with other factors of production, that there has been little financial incentive to conserve energy. When growth in population and, perhaps, consumer income begin to fall off, and when the price of energy begins to rise, it is hardly surprising that the incentives turn in favour of conservation. In short, it is now economically efficient to conserve energy where it was not a decade ago. Moreover, for a variety of reasons, including the pollution inherent in energy production and use, and the strange pricing and industrial structure of many of the energy supply industries, the efficiency gain is probably even greater from a public than from a private point of view.

This study began from the assumption that there were enormous opportunities not just to conserve energy within the context of the existing system, but also to reduce energy consumption by altering the rate of growth and through changing the mix of goods produced in the economy as a whole. The purpose of the study was to investigate the economic effects in Canada of adopting: (1) specific energy conserving measures in the short and medium terms, and (2) a generally lower energy economy in the long term. Particular attention was paid to the impacts on the use of labour. The major conclusions, stated most generally, are:

(1) given the implementation of specific energy conservation programs in the short and medium term, it appears that trade-offs in Canada are positive in the sense that, on balance, the demand for labour increases, whereas the demand for capital decreases; and

(2) given the simulation of low energy patterns of growth in the long term, it appears that the Canadian economy can accommodate the necessary shifts while maintaining reasonable growth in output, employment and income and without demanding major life-style adjustments on the part of Canadian households.

From one point of view, these conclusions may seem obvious. In an economy as mature as that of Canada, one would expect that shifts in the rate of use of inputs could be accommodated over time without impossible disruptions. However, from another point of view, the two conclusions are anything but obvious. How often has energy conservation been charged with contributing to unemployment or inflation, and how often has energy consumption been linked in some direct relationship to growth in GNP![195]

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195 For example, the distinguished physicist Hans Bothe has written (with reference to the United States): "This country needs power to keep its economy going. Too little power means unemployment and recession, if not worse." *Scientific American* (January 1976).

The Near Term

Dealing first with the economic impacts of specific energy-saving programs, the employment, income, capital and operating aspects of each conservation measure were compared with those required for the production of an equivalent quantity of energy in the absence of conservation. In each case, the effects stemming from both direct (final stage of production or use) and indirect (prior stages) consumption were incorporated into the analysis. The use of Canadian data and Canadian circumstances supports the contention, cited in other studies, to the effect that energy conservation measures will generally be more labour intensive and less capital intensive than equivalent energy production operations. However, the extent of the difference depends upon the time frame:

(1) In the short term, when only operation of the existing energy supply system is involved, the employment gains from energy conservation programs generally far outweigh the losses at the energy supply facilities. Exceptions arise only for cases, such as lower thermostat settings in winter, where no additional labour is required for the conservation program itself. Even in such cases, the spending by consumers of money saved through energy conservation can generate enough employment to offset the losses.

(2) In the medium term, when construction of new or replacement energy supply capacity is involved, the employment gains from conservation still outweigh the losses at energy supply facilities, but the differences are no longer so lopsided. However, the case for conservation is buttressed by the fact that most of the demand for labour in conservation will occur in the near term whereas many of the losses in construction of energy supply facilities will not occur for some years in the future.

(3) When households spend any savings or incomes received as a result of energy conservation programs, the resulting expenditures will, in general, tend to magnify strongly the positive employment impacts while mitigating only to a small extent the direct energy savings of conservation. There is little likelihood that the so-called "conservation dividends" will redound significantly to promote energy consumption; indeed, they are more likely to promote the production of low energy goods and services.

The preceding conclusions are based on analysis of the economic impacts of four specific conservation programs simulated in a Canadian context. These are summarized below, along with the public policy considerations to which the programs give rise.

1) A shift to lighter and therefore more energy-efficient automobiles promises sizable petroleum savings. The major net impact on employment would occur in the industries supplying the gasoline that would otherwise be required; according to the 1971-based simulation, a modest loss of jobs could occur. However, public policy could effect a transfer of such job loss to foreign suppliers by reducing imports of crude oil to the full extent of the conservation savings in petroleum requirements.

More efficient cars, requiring significantly fewer resources in construction and in operation, should be somewhat cheaper to buy and will definitely be cheaper to operate. Both of these influences are counter-inflationary. Average pollution emissions will be reduced as will the allocation of both funds and scarce urban land to parking and roadways. The reduced cost of owning and operating more efficient cars can also lead to lower overall capital demands and higher personal savings and expenditures, and the latter are likely to induce employment and output by enough to offset the (theoretical) losses in the energy supply sector of the economy.

From a policy perspective, given Auto Pact arrangements, it is probably sufficient for Canadian authorities simply to accept U.S. regulations which require auto manufacturers to meet higher fleet or average fuel efficiency standards over the coming seven years. The realization of these targets, primarily by the reduction in average car weight, will have the effects on energy and employment noted in our simulation. Of course, federal and provincial governments in Canada could further encourage a shift to lighter cars through taxation and licensing policies that penalize heavier cars. Such strategies would tend to be progressive in that lower income households could avoid such taxation by bying smaller/lighter cars, which they might do in any event. Increased gasoline taxes, which would be consistent with fiscal policies in every industrialized country other than Canada and the United States, would also encourage the shift, but the effect would be proportional across income classes or, perhaps, somewhat regressive.

2) Shifting "close in" urban commuters from their cars to buses does not promise great net savings in energy or capital requirements, but, it could have a very strong positive employment effect. It should be noted that public transit systems handle only about 15 per cent of all urban commuter travel in Canada, so expansion of bus systems sufficiently to make a major dent in auto commuting would be a large and expensive undertaking for the public (municipal) purse. Personal savings can be significant, but only if bus commuting substitutes for automobile ownership. Should most people who switch to bus commuting retain, at least, the family car, household savings from the shift in commuting mode will not be significant.

Given the continued household preference for a family car, the deficits of public transit operations, and the non-responsive tax base from which their subsidies normally come, any shift such as considered in the text would require a considerable reorientation in government policy. The benefit of such a shift would be general (social) in nature: reduced parking facilities in urban employment areas, reduced air pollution, reduced traffic congestion and lower demands for urban highways, as well as increased employment. It would, therefore, be critical for governments to provide both negative and positive incentives to induce commuters to shift commuter modes. And, given the distribution of taxing/regulatory powers, this would require a substantial reallocation of such powers and/or greater intergovernmental revenue transfers. Unlike the option for more efficient autos, shifting commuters from cars to buses requires more political will and commitment.

3) Since over 60 per cent of the housing stock in which people will be living in the year 2000 is already built, the retrofitting of existing residences with more insulation provides an opportunity for a large reduction in energy consumption. The one-time employment creation potential of this program far exceeds the annual and one-time employment losses which could arise in the energy supply industries. Even these losses would be attenuated to the extent that Canadians pass on employment losses by reducing crude petroleum imports. (Almost three out of five Canadian homes are heated by oil.) Moreover, employment creation would occur in the near term (when unemployment rates are very high), whereas any employment losses would be spread out into the future. Annual savings in residential heating/cooling will pay back investment in insulation in under seven years and, therefore, the longer term effect on prices should be counter-inflationary.

Despite the fact that insulation can be installed by homeowners themselves (which would reduce the employment-creating influence of the program as measured by economic statistics), the initial "capital" costs might still be beyond the reach of low-income households. Clearly, government policies which provide loans, tax subsidies or grants for retrofitting existing homes (perhaps on a selective -- by income -- basis) should be considered by the senior levels of government. Alternatively, they could be financed through loans arranged through utility firms.

4) Improved insulation of residences constructed from now on, compared with the continuation of past standards, will yield net benefits in terms of large energy savings, moderate gains in employment and reduced household expenditures on space heating/cooling. While the capital cost of new homes would be somewhat higher, the added costs would be paid back in under ten years, so that such a program is counter-inflationary over the longer term. While fewer oil-heated homes are being built now, improved standards of new home insulation will nevertheless help to conserve our scarcest energy resource -- petroleum -- notably in the Atlantic provinces, which are still largely dependent upon oil heating and which are served entirely by imported oil.

A parallel with insulation retrofitting can be drawn in respect of capital costs; public policies and programs that provide loans, subsidies or grants, particularly to low-income families, can offset higher capital (initial) costs of home ownership caused by energy conservation requirements in the building code. Again, it seems reasonable to expect that governments or utility firms could readily devise effective programs to obtain both energy efficiency and social equity. Improved insulation, as one dimension of passive solar heating, not only economizes on oil consumption but can also be used as a step towards the substitution of alternative (including solar and wood) heating for oil, in the longer term.

The four simulations were chosen because it was possible to obtain objective information to evaluate the energy and economic impact of each. Moreover, these programs, except possibly for the shift to bus commuting, are things we can do *now* and over the next few years to lower energy consumption without individual hardship or significant industrial dislocation. All options are "economic" in the narrow sense and create net socio-economic benefits in the broad sense.

Energy conservation must involve action programs on many other fronts as well. Numerous opportunities exist for economically efficient programs for energy conservation to be instituted. These, as is broadly true for those options specified, should be consistent with economic goals for employment, price stability and trade (particularly in energy commodities).

Finally, in consideration of the specific (short-and medium-term) programs, it must be recognized that governments have a responsibility to make adjustments to reduce negative impacts on low-income households and on certain sectors of employment. (Aggregate labour gains by no means preclude particular losses; for example energy supply industries could be significantly depressed by conservation.) Where social benefits greatly exceed social costs, the procedures for compensating the (short-term) losers should not be difficult.

The Longer Term

Turning now to the longer term simulations, the conclusions have less to do with specific changes in existing production and consumption patterns and more to do with learning to live within our energy means in general. As stated in a summary of a major study in the United States, "Many possible configurations of technology and lifestyles are compatible with (lower) energy use ... at twice today's GNP".[196]

What has been done here is to illustrate, objectively and conclusively, that low energy alternatives are achievable in Canada without impossible economic disruptions or dislocations. In the fifty-year time frame of the long-term simulation, it was possible to develop an internally consistent picture of the Canadian economy even though total energy consumption was lower at the end of the period than at the beginning and there has been a 33 per cent reduction in per capita energy consumption and a 60 per cent reduction in the ratio of energy consumption to GNP.

While it is difficult to be precise as to excesses or shortages in labour supply for intermediate dates within the fifty-year time horizon (given the methods of interpretation

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196 Panel on Demand and Conservation of CONAES (Committee on Nuclear and Alternative Energy Systems) *Science* (14 April 1978), p. 150.

from the target year back to the present), the simulation does indicate that there may be periods of labour and capital surplus during the transition to a new, lower energy equilibrium. (By the end of the simulation period, labour and capital shortages are projected.) However, given that the transition is likely to be gradual with higher (than the 50-year average) rates of energy growth in the early years and lower rates in the later years, such surpluses may be purely theoretical. Moreover, as indicated earlier, short-term, energy-conserving, employment-generating programs can mitigate some of our current and medium-term employment problems.

Given the scenario considered in this study, the low energy future seems most disruptive for the construction industry, the energy supply industries and, to some extent, industries involved in automobile production. What is unfavourable to one industry may represent a boon to others. Certainly one expects a growth in service industries. The net effect may be an increase in the demand for labour in lower-productivity sectors simultaneous with a decreased demand in relatively high productivity industries. This would lead to a decline, on average, in the rate of increase in labour income.

Offsetting losses in labour productivity/income, the capital-saving nature of a conservationist future could well ease price inflation tendencies in energy supply and other capital intensive industries. The extent to which lower price rises reduce the need (desire) for increased real incomes is not known; however, the scenario, as simulated, is based on an *increase* in real income per capita (if at a slower rate than in recent decades). Over fifty years into the future, consumer and social tastes (demands) will evolve to something as different from today as today is from fifty years ago. A preferred mix of low energy goods and services in the future could be as satisfying to Canadians as is our high energy basket of purchases today.

In the international setting, "competitiveness" depends on many relative advantages in factor productivity. A more energy-independent Canada, which will be a more energy-conserving Canada, will have national options that would be unavailable to an energy-wasteful Canada. General policies to reduce energy consumption, such as a continued rise in the real price of energy, together with specific strategies to encourage energy-efficient production and consumption, are the foundations of a Canada which economizes on its finite inventory of scarce, generally non-renewable, resources.

Finally, it is worth repeating what was stated at the outset: namely that this study should be considered as preliminary in nature, and that my intention is to stimulate further studies. It bespeaks no lack of confidence in the results presented here to say that far more work is needed, particularly in terms of disaggregating the impacts in the shorter term and developing additional perspectives in the long term. The economy is seldom analyzed from the low growth point of view.

The most critical gap in energy policy lies with the absence of good economic information linking changes in energy policy to our standard of living and our quality of life. Whatever happens, Canada will need an energy policy, and the one policy that is infeasible is a continuation of the past. Surely it would be preferable to make changes in energy policy in the light of better knowledge of their economic -- and their social and their political -- impacts.

APPENDIX "A"

Appendix "A": Summary of the Low Energy Model for Canada in 2025

All of the material in this appendix is taken from the report on long-term energy demand by Brooks, Erdmann and Winstanley,[197] which was made to the study by Gander and Belaire at Energy, Mines and Resources.[198] The full report contains many demand scenarios including some with higher income growth and higher population growth than the one described here. As emphasized throughout, the purpose of the present study is not to investigate a range of alternative energy futures for Canada but only to look at one possible low energy future and obtain a better idea of its economic implications. This appendix is designed to provide an extended background to Chapter 4 for the interested reader.

The method used for the demand study followed, to a considerable degree, that advocated by Lovins as a "soft energy path".[199] It focused on energy demands and reviewed them initially in categories that had some homogeneity from a thermodynamic point of view (low-temperature heat, high-temperature heat, fluid fuels, essential electric).[200] However, limitations of time and of data prevented a full assessment of the economic

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197 See footnote 25.

198 See footnote 23.

199 See footnotes 24, 31 and 48.

200 The key point is that it is likely to be economically efficient, as well as thermodynamically efficient, to minimize the number of energy transformations between producer and consumer. Therefore, space heating demands should, if possible, be satisfied with low-temperature energy sources, electricity reserved for unique functions (motors, lighting, electroprocesses, etc.), etc.

potential for conservation of each thermodynamic category, so data are presented according to conventional sectors (in the terminology normally employed in energy studies -- see A Note on Terminology). No attempt was made to distribute the final and intermediate energy demands in 2025 among various sources of energy. Hence, "low energy" in this case refers exclusively to consumption and, in particular, makes no assumption about greater use of active solar or other renewable energy sources.[201]

Table A-1 presents the growth rates for GNP and for population that were used in the energy model. These rates were developed by the Long-Term Energy Assessment group to represent a Canada that was growing more slowly than historically. Over the whole period 1975 to 2025, GNP grows by 1.7 per cent per year and population by 0.7 per cent per year. By the end of the period, real GNP per capita has risen by 80 per cent, which is substantial but of course much below its rate of growth in the decades following World War II.

Other figures needed for the energy model were derived from those in Table A-1. Real domestic product (RDP) and personal income were assumed to bear the same relationship to GNP as they have in recent years. In addition, it was necessary to make some assumption about the distribution of RDP among the sectors representing non-personal energy consumption (that is, all sectors except residential and automobile transportation). The full report included several variations including high

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201 See footnotes 166 and 167 for an evaluation of the potential in Canada for active solar systems.

industry, low *industry*, and intermediate models as shown in Table A-2. In order to maintain the focus on low energy futures, only the low *industry* model, which is correspondingly high in commercial and government activity, is shown here. This model has nearly half of RDP in trade, financial and service sectors with less than one-third in primary industries, manufacturing and construction (which is what is meant by *industry* in energy statistics).

The combination of assumptions about slower economic and population growth together with those about the relatively low proportion of *industry* (primary, secondary and construction) in the RDP create the "low income/low *industry*" model described in the text and analyzed in Chapter 6. Energy consumption in each of the major consuming sectors (residential, commercial, *industrial* and transport) was then built on the basis of this model.[202] Throughout, changes in efficiency of energy use[203] were distinguished from changes stemming from "lifestyles", from income or from the volume of activity in some sector.

Energy consumption in the residential sector was divided into that for space conditioning (heating plus air conditioning) and "other", which mainly includes water heating, lighting and appliance use. For today's stock of housing still

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202 Data for historic energy consumption was largely found in the Statistics Canada annual, *Detailed Energy Supply and Demand in Canada*.

203 As used in this report, efficiency refers strictly to "first law" not "second law" efficiency; that is, it only compares energy output to energy input and does not deal with theoretical minima of energy use.

Table A-1

POPULATION AND ECONOMIC ASSUMPTIONS
IN "LOW INCOME/LOW *INDUSTRY*" ENERGY MODEL
(1961 $)

	1975	Annual Growth Rate (%) 1975-1985	1985-2000	2000-2025	1975-2025	2025
GNP (billions)	$79.161	3.0	2.0	1.0	1.7	$183.62
Population (millions)	22.77	1.1	0.75	0.5	0.7	32.18
GNP per capita	$3120	-	-	-	1.2	$5704
Households (millions)	6.81	-	-	-	0.6	9.20
RDP (share of GNP)	89.7%	-	-	-	-	89%
Personal Disposable Income (Share of GNP)	63.4%	-	-	-	-	60%

Source: See footnote 25.

Table A-2

DISTRIBUTION OF RDP BY SECTOR,
1974 AND ASSUMPTIONS FOR 2025
(percentage)

Sector	Actual	High Industry Variation	Moderate Industry Variation	Low Industry Variation
	1974	2025		
Industrial (primary, manufacturing, construction)	39.7	48	40	32
Commercial (trade, finance and insurance, services)	41.7	32	40	48
Public administration and defense	7.1	6	8	10
Transport, communications and utilities	11.5	14	12	10

Source: See footnote 25.

remaining in 2025, the efficiency of space conditioning was assumed to improve by 38 per cent over current average heating requirements (95 million Btu's per year for detached houses), while for new housing improvements of 75 to 80 per cent were assumed depending upon the type of housing. (All of these assumptions can be justified on the basis of current or anticipated levels of economic efficiency. In fact, so well are they justified that the same efficiency improvement could be used even when -- for other scenarios not described here -- energy prices were assumed to remain constant in real terms.) The main impacts of the low income model on residential energy consumption for heating derived from assumptions of more people per household (3.5 compared with 3.3 at present) but the same floor space as now (1000 square feet per household). These assumptions permitted the calculation of national requirements for space conditioning in 2025 for each of three types of housing: apartments, other multiple and single detached. After adjusting for differing efficiencies of heating systems, final consumption of just under 400 trillion Btu's in 2025 could be derived, as shown in Table 10 in the text.

The remainder of residential energy consumption was calculated by assuming that the energy efficiency of water heating could be improved by 20 per cent and that for lighting plus appliance use by 10 per cent. (Proposed new standards in the United States will raise appliance efficiency by 8 to 11 per cent by 1990.) Consumption for water heating was related to population while lighting and appliance use was related to the number of households. The low income scenario assumed that hot water consumption per person did not change from 1975 to 2025 and that all other consumption decreased by 20 per cent per household. The net effect of efficiency and lifestyle changes gave consumption in 2025 of just over 400 trillion Btu's per year -- more than would be required for space conditioning. (This is consistent with results of other studies: in a very well-insulated house, energy demand for space conditioning is less than that for water heating and other uses.)[204]

Total residential energy consumption projected for 2025 is almost 35 per cent below that in 1975 (Table 10) despite the growth in population and income. The result is of course sensitive to both population and income (in the sense that higher incomes are associated with fewer people per household and more floor space per person). This is particularly important in that almost all attempts to project conservation savings in the residential sector show that a decline in energy use is quite feasible through the end of the century, so the impact of population and income growth beyond that point (when all new housing is likely to be well insulated) is critical. However, in this model no allowance was made for active solar heating or independent electricity (e.g., photovoltaics); if they became important, *measured* (that is, centrally distributed) energy consumption could be even lower than the figures suggested by this model.

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204 R.S. Dumont *et al.*, *Passive Solar Heating in Residences: An Analysis for the Southern Canadian Prairie Climate*, Dept. of Mechanical Engineering, Univ. of Saskatchewan, Saskatoon.

Lack of data on the existing stock of commercial buildings prevented the making of any direct relationships between energy consumption and the physical characteristics of the commercial sector. The approach taken was to make a relationship between energy consumption and the dollar "output" of the sector. Recent values of this relationship in the early 1970s were around 28,000 Btu's per constant 1961 dollar. Given the enormous opportunities for improvement of efficiency levels in new buildings (already demonstrated to be economic by Hydro Place in Toronto and elsewhere), substantially reduced intensity of energy use was assumed for the efficiency in 2025, namely 7,000 Btu's per dollar.

The level of activity in the commercial sector was implicit in the economic assumptions presented in Tables A-1 and A-2. For the low *industry* (as defined in Table A-2) model analyzed here, economic activity in the sector amounted to $78.4 billion (1961 constant dollars) and energy requirements therefore amounted to just under 550 trillion Btu's per year in 2025. In 1974 the sector had an output of $32 billion (1961 $) and an energy consumption of 770 trillion Btu's.

The approach taken for the *industrial* sector was similar to that for the commercial. (The problem here is less the deficiency of data on physical characteristics, though this is not negligible, than the great variations in type and efficiency of use among industries.) Energy efficiency in this sector was assumed to improve by 40 per cent by 2025 to an average level of 36,000 Btu's per dollar of output. This figure is loosely based on current *industry* projections which indicate that, by 1990, overall efficiency will have improved by about 25 per cent per unit of output.[205]

The level of activity for this sector was derived in the same way as that for the commercial sector. This gives an output for the sector of $52.3 billion in 2025 (compared with $24.5 in 1972, both in 1961 constant dollars). Combining the efficiency and the activity variables indicated that energy consumption in 2025 would be 1,914 trillion Btu's compared with 1,494 in 1972. Needless to say, product mix, international trade and other factors could create further variations around this figure, but these refinements could not be taken into account. However, for purposes of the model it is irrelevant whether the level of *industrial* energy consumption projected for 2025 represents a smaller amount of highly energy intensive products or a larger amount of less energy intensive products.[206]

Projections of energy consumption for the commercial and the *industrial* sectors are sensitive to the assumptions about GNP and to those about the distribution of GNP between the two sectors. Given some level of energy efficiency, the sum of energy consumption for the two sectors (for the purposes of these projections) is sensitive only to the level of GNP. Projected energy consumption is of course also sensitive to changes in the assumptions about the efficiency of energy use, but for both sectors to a smaller extent than to assumptions about the economy.

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205 See footnote 17, pages 29 to 32.

206 The difference in product mix would affect the type of energy used and therefore the efficiency of energy supply; see footnote 4.

Energy consumption in transportation was divided into two parts: automobile consumption and other. Automobile consumption was determined using an extension of a model available at Transport Canada. The automobile fleet in 2025 was divided into four size categories, each with its own level of efficiency (ranging from about 38 mpg for full size autos to 75 mpg for subcompacts). These efficiencies were not varied among the various scenarios studied but the mix of auto sizes was. For the low income scenario studied here, 70 per cent of the fleet in 2025 was assumed to be made up of compact and subcompact autos while only 10 per cent was full size. The number of miles travelled and car purchases both depend on personal income and population.

Given personal disposable income in 2025 of $110.2 billion (constant 1961 dollars), the model at Transport Canada provided projections of vehicle miles travelled per household (about 17,600 per year) and this, together with the fleet fuel economy (53 mpg compared with 17 in 1975), gave a figure of 453 trillion Btu's consumed for automobile travel in that year. This can be compared with consumption in 1975 of about 820 trillion Btu's; the difference is largely attributable to the large gains in vehicle fuel efficiency. The results for energy consumption in 2025 are relatively insensitive to changes in the distribution of personal income but very sensitive to changes in the level of GNP.

Energy consumption for other transportation (rail, air, marine, truck and bus) was based on a variety of sources. So far as the level of activity in 2025 is concerned, those parts related closely to freight transportation were tied to the projection of RDP whereas those parts related to passenger travel were tied to the projection of population. However, the split is not perfect; for example, most non-charter air travel is for business purposes and thus also related to RDP. In any event, the data base for projections of demand for transportation is notably weak. Much the same can be said about possibilities for efficiency improvements, which for the purposes of this model were set after discussions with staff in the Office of Energy Conservation. Combining the two sets of assumptions gave a figure of just over 1,100 trillion Btu's for non-automobile transportation in 2025. (This is relatively high compared with other studies.) The sum of automobile and other transportation consumption in 2025 is not much different from what it was in 1975 (Table 10).

Total secondary energy consumption in this model of Canada in 2025, which more or less corresponds to an efficiency-oriented conserver society, amounts to 4,830 trillion Btu's. This should be compared with 1975 consumption in Canada of 5,330 trillion Btu's. The growth rate from 1975 to 2025 is therefore -0.2 per cent per year. Increasing the role of *industry* (again, including only primary -- except agriculture -- manufacturing and construction activities) in the economy (and decreasing that for the commercial sector) increases consumption only moderately -- to about 5,800 trillion Btu's in 2025 for a growth rate of 0.17 per cent per year. The model is also relatively insensitive to changes in the level of population. However, it is quite sensitive to increases in the level of income. For example, under the same assumptions with respect to population and to the share of industry as presented above, a doubling of GNP leads to an increase in energy consumption by a factor of 2.5, and to a growth rate of secondary energy consumption from 1975 to 2025 of 1.7 per cent per year. On the other hand, it is not difficult to think of additional conservation techniques and measures that would cut energy consumption well below the 4,830 trillion Btu's projected for 2025 in the "low energy" future.[207] Lifestyle and product mix changes could go well beyond the efficiency gains that formed the heart of this model of a conserver society. In any event *industry* is likely to become the major consuming sector and is now the one most needing further analysis.

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207 See footnote 24, pages 12-13, and footnote 25, pages 32-34.