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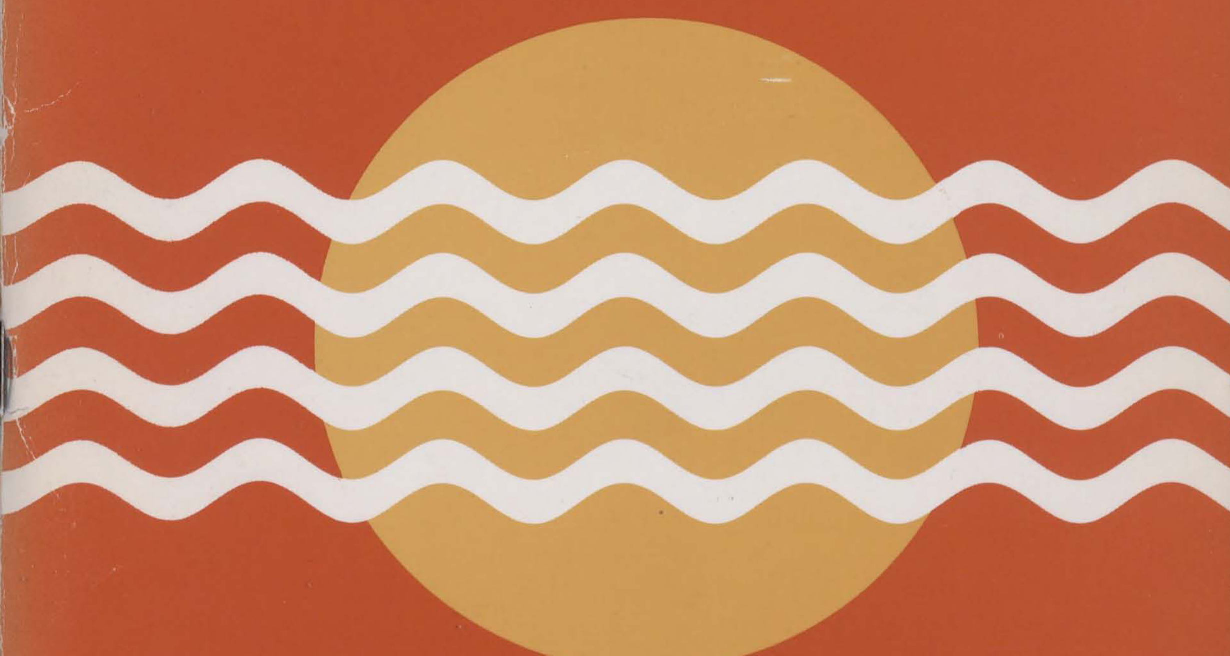
# Energy Conservation Technologies and their Implementation

**A Report by the Task Force on Energy Conservation Technologies**



Canada

# Energy Conservation Technologies and their Implementation

A Report to the
Minister of State
for Science and Technology
by the Canada
Task Force on Energy
Conservation Technologies

## Abstract

Conservation is as important to the solution of the energy problem in Canada as is increasing the supply of renewable and non-renewable forms of energy. Indeed, in comparison with new energy supply projects, conservation can offset the need for additional energy, at considerable cost savings. The federal government's commitment to energy conservation will be fulfilled when it makes a financial and human resource investment in conservation comparable to that which it is now making in energy supply.

The widespread adoption of energy conservation measures is not held back by the lack of suitable technologies. The methodical exploitation of existing technologies can open up numerous Canadian industrial opportunities while greatly reducing the country's consumption of non-renewable energy resources.

The federal government's priority in energy conservation should be to identify and implement the strategies and support mechanisms necessary to ensure the dissemination and marketing of existing technologies, rather than to develop new technologies.

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## Foreword

On May 5, 1981, the Minister of State for Science and Technology, the Honourable John Roberts, announced the establishment of a Task Force to identify opportunities for technological development in the area of energy conservation and to suggest mechanisms for the pursuit of these opportunities and the dissemination of the resulting technologies.

The Minister emphasized the importance of dissemination, as research and development on energy conservation technologies will only have a significant impact if the relevant technological developments reach the end user. The Minister also noted that the need has been made more urgent by rapidly escalating fuel costs which in turn have created enhanced opportunities for the manufacture of energy conservation equipment.

The terms of reference of the Task Force are:

(1) To identify the most promising technological and industrial opportunities in the field of energy conservation - from a cost-effectiveness as well as an energy-saving viewpoint - concentrating on the industrial, transportation, building (commercial as well as residential), and energy conservation equipment manufacturing sectors of the economy. In seeking out these opportunities, the following should be among those matters considered:

(a) energy-saving systems and devices (such as programmable thermostats, insulation, automobile computers, and hybrid heating systems);
(b) energy-saving processes (such as energy cascading and cogeneration); and
(c) alternative macrosystems (such as new urban transportation systems and multidwelling systems of heating and cooling).

(2) To explore the most appropriate mechanisms for undertaking the development of these opportunities to commercial viability.

(3) To determine the best means for diffusing and exploiting these technologies, as well as other relatively undiffused existing technologies. In doing so, full consideration would have to be given to institutional barriers (such as regulations) to the exploitation of these technologies. At the same time, the social, environmental and distributional (e.g., regional) impacts of their dissemination should be taken into account (i.e., the potential problems of applying these new technologies).

(4) To identify means of effectively marketing conservation technologies on a wide scale to all potential end users.

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During its deliberations, the Task Force was greatly assisted by the knowledge and advice of several individuals, organizations and institutions. Although the findings and recommendations of this report are solely the responsibility of the members of the Task Force, the contributions of others (Annex I) are acknowledged and are most appreciated.

In addition, the Task Force expresses its appreciation to the following members of the Ministry of State for Science and Technology for their administrative and research assistance: Mrs. Lise Picknell, Administrative Assistant to the Task Force; Miss Carol Barton, Chief Librarian and Miss Carol O'Rourke, Library Technician; and Mr. Pierre Joncas, Project Director and Mr. Don Quinsey, Policy Advisor.

# Executive Summary and Recommendations

## Conservation

The federal government's commitment to energy conservation is well known. It is reasserted clearly in the 1980 National Energy Program. This commitment will be fulfilled when the federal government makes a financial and human resource investment in energy conservation comparable to that which it is now making in energy supply. Government policies, regulations and incentives can expand markets for energy conservation technologies in much the same way as they now encourage the enlargement of energy supply (e.g., grants for nuclear R&D; tax concessions for oil and gas exploration).

At present, vast resources are being invested to bring on-stream new supplies of energy. This represents the largest single investment of capital in Canada. As such, it is shaping the economic environment of the country by favouring the development of energy supply at the expense of other needs. The resolution of the problems of higher energy costs and insecurity of oil supply will hinge on how well Canada develops sources of renewable energy, increases the supply of non-renewable forms of energy, and reduces energy consumption. The last of these - energy conservation - can be achieved primarily by altering human attitudes and lifestyles concerning the use of energy through education and increased public awareness. It can also be achieved by improving the efficiency of the use of energy in the various sectors of the Canadian economy. As the National Energy Program clearly states:

"Conservation provides the cleanest, most enduring, and, in many instances, the cheapest part of the solution to the oil problem of the 1980s, and to an improvement of the basic energy balance."[1]

This conclusion has also been emphasized by the Special Committee on Alternative Energy and Oil Substitution which noted that:

"Witness after witness extolled the importance of conservation practices by pointing out that conservation is the easiest and least expensive means of reducing the energy supply-demand gap."[2]

It is important to remember that, compared to new energy supply projects, conservation makes energy available at considerably less cost. As an illustration, the cost of energy-conserving projects which would improve efficiency in industry by 40 percent has been estimated at $11 billion. By comparison, equivalent energy from new supply projects would cost about $30 billion for oil sands plants, or $18 billion from frontier natural gas.[3] For economic considerations alone, it is urgent that conservation programs be emphasized, to decrease energy demand in a socially and economically acceptable way. Indeed, the cause of conservation will be enhanced if reduced energy waste is thought of as an equivalent source of additional energy.

In an address to the Canadian National Energy Forum, Peter Middleton of Middleton Associates reinforces this position.

"Conservation mega projects on the national or provincial scale may be the most reasonable and cost effective way of providing new energy supply. Certainly a conservation mega project appears to offer an excellent distribution of benefits to communities across the country. . . . It is time, therefore, to apply the same level and sophistication of planning and management to conservation and renewables as to the mega project."[4]

The United States' Energy Research Advisory Board's report on *Federal Energy R&D Priorities* reached a similar conclusion.

"Relative to their potential contributions to the solution of the near and medium-term energy problems, there is an imbalance in the allocation of R&D funds between the conservation programs and those directed at supply. The budget needs a reordering of priorities to reflect better the opportunities that exist for efficiency improvements and the unique Federal role in conservation R&D."[5]

**Task Force**

Energy conservation presents important business opportunities for the development and dissemination of associated technologies. To help Canadian industry take advantage of these opportunities, the Minister of State for Science and Technology convened a Task Force composed of persons with knowledge in the conservation field. In brief, the terms of reference of the Task Force were to:

(a) identify the most promising technological opportunities in the area of energy conservation;
(b) suggest the best mechanisms for undertaking the development of these opportunities to commercial realization; and
(c) determine the most appropriate means of transferring the required technologies throughout the relevant economic sectors in Canada, including the best means of encouraging the end-user to adopt them.

The terms of reference do not require the Task Force to examine energy conservation, as such. Conservation has been studied extensively by others. However, relatively little attention has been paid to the various business opportunities that would result. Nor have many studies identified the economic and social benefits to Canada which would arise from the development and the dissemination, here and abroad, of these technologies. These are the areas the Task Force was directed to explore.

**Industrial Opportunities**
The "energy crisis" has created many opportunities for the development, manufacturing and marketing of a wide range of energy conservation goods and services that can be produced in Canada. The Task Force estimates that current Canadian sales of energy conservation goods and services exceeds $1 billion a year. This market can be sub-divided as follows:

(a) products which reduce thermal loss, such as insulation, weather-sealing materials, and glazing materials;
(b) energy transfer devices such as heat exchangers and heat pumps;
(c) control systems, from simple timed thermostats to complex commercial and industrial systems;
(d) cogeneration equipment such as waste heat boilers and steam turbines;
(e) energy conservation services, including auditing, designing and consulting engineering.

Additionally, many end-use devices can and are being made more energy efficient (e.g., home appliances; furnaces; heating, ventilation and air conditioning (HVAC) equipment; electric motors; lighting systems; and transportation equipment). The substitution of alternate modes of travel (e.g., from cars to trains) is an important consideration in this latter context.

**Technology**
Most of the scientific principles leading to energy conservation have been known for some time. As a result, energy conservation does not have the glamour of recent scientific discovery or technological breakthrough. Nor is it likely to excite enthusiastic curiosity or attract the same aggressive entrepreneurship as the "high technology" industries. Yet, it is an extremely important element in Canada's energy future. If the technological/industrial opportunities arising from conservation are methodically exploited, they can benefit not only the consumer and the entrepreneur but also the national interest, by reducing Canada's consumption of non-renewable energy resources.

That aspect of the Task Force's mandate which calls for the identification of the "most promising" technological and industrial opportunities in the field of energy conservation poses some difficulty. As was pointed out in a background paper on research and development by the Ministry of State for Science and Technology:

"The major objection to this approach is that it involves a higher degree of risk. It is often described as 'picking winners', a process, it is argued, in which governments do not excel."[6]

The Task Force holds the view that the pre-selection of winners, however carefully chosen, can be very costly, as history has shown. When possible, the premature choice of technologies should be avoided, so that as more becomes known directions can be changed without incurring too heavy a penalty. If technologies are to be successfully exploited on a major scale, this will only be accomplished by natural market forces. Commercial development will support the engineering programs needed to implement energy conservation technologies. The government's involvement should be to encourage and accelerate normal market development.

The Task Force has identified a number of existing technologies in each of the major sectors of energy consumption. Such technologies, if properly disseminated and implemented, can lead to significant reductions in energy consumption in Canada. It must be noted, however, that they are not meant to represent a complete or definitive listing. They are described for illustrative purposes only, to show that much can be done to induce energy conservation using available technologies, without the need to develop new ones.

Some technologies were seen to have significant potential and are described in greater detail. The Task Force also identified the government's role in accelerating the normal market development for technologies which offer major opportunities for energy conservation.

**Priorities**

The energy conservation technologies of particular interest to the Task Force are those already in existence, or close to realization, rather than in the early stages of research. These are the technologies which will have an early impact on the consumption of energy and can create more immediate industrial opportunities. Since, by and large, these technologies are available, the priority should be to identify and put into place the strategies and support mechanisms necessary to disseminate and market existing technologies, rather than to develop new technologies. Further equipment and process development and refinement of existing technologies should also facilitate their effective exploitation.

**Dissemination and Marketing**

Canada has historically emphasized energy supply. The major industry sectors with vested interests in supply reinforce the financial and institutional barriers which impede the adoption of energy conservation technologies. The Task Force has identified several of these major impediments. There is a need to develop coherent strategies which will overcome these barriers and encourage the management of energy demand and which will accelerate the dissemination of energy conservation technologies.

*Financial Constraints*

One of the disincentives to energy conservation has been the Canadian price of oil-based products which has been controlled at lower than "world prices". Uncertainty concerning the future cost of energy has caused much confusion and has hindered industry, in particular, in making long-term investments. However, as a result of the recent energy pricing agreements between the federal government and the Western oil-producing provinces, energy prices are now rapidly approaching world levels. This will encourage conservation.

There is an understandable reluctance among corporate purchasers and domestic consumers to invest in technologies which require large capital outlays. This hesitancy is more pronounced when interest rates are high and when pay-back periods are correspondingly longer. Indeed, in times of high interest rates, industrial companies seem to prefer investments in production expansion rather than in processes and technologies which would result in energy conservation. Since investment to increase sales appears to be given preference, increased investment in energy conservation technologies will only take place if it is encouraged with additional financial incentives.

The Task Force is called upon to identify "cost-effective" technological and industrial opportunities in energy conservation. In theory, if a technology is cost-effective, the market will adopt it. However, due to the counter influence of those benefitting from energy supply (and, thus, energy consumption) and because of the financial and institutional barriers to the implementation of conservation technologies, the market has comparatively limited interest in energy conservation. These factors are hindering the achievement of a level of conservation which is sufficient to satisfy the national interest. Therefore, financial and other incentives need to be introduced to hasten the adoption of energy conservation technologies.

*Information and Communication Constraints*
Another barrier to the widespread adoption of conservation technologies is the lack of comprehensive, reliable and up-to-date data on technical performance and cost-effectiveness. Lacking this information, individuals and industries will defer investing in conservation techniques, if they believe they may be premature, ineffective, unsafe, or too costly for the savings they yield.

A related impediment is less than effective communication on this subject. Although the federal and provincial governments, power utilities and others have distributed extensive information, there still remains a need for better consumer understanding. A large proportion of the population still does not believe that Canada is facing an energy crisis. One observer has made the following comment:

"It has been customary to blame the failure of public information campaigns upon general apathy, but it is quite possible that the target client is less culpable for his failure to take account of the message than the communicator who may have sent boring, incomprehensible messages through poorly selected media."[7]

Energy conservation programs must satisfy the end-users' need for specific information as to why and how they should invest in related technologies. If more consumers knew the very large energy savings which could be realized, they would take the action necessary to adopt energy-saving technologies. The most effective method of informing the public is through comprehensive marketing programs designed and implemented by specialists in the strategies and methods for prompting people to action.

Many industrial firms report frustration and disillusionment with current government programs designed to encourage the adoption of technologies for energy conservation. Industries frequently lack clear information concerning program objectives, criteria for eligibility, means of application, and resultant potential net savings. Furthermore, many companies report such serious administrative difficulties and lengthy delays in attempting to take advantage of these programs that they have withdrawn from participating. The Task Force has received criticisms that many programs suffer from excessive regulation, overly-strict controls and a lack of co-ordination with other government programs. This is the principal reason why industry advocates the use of more general tax incentives and like fiscal measures rather than specific grants and other closely administered government programs.

*Shortage of Skilled Personnel*
Yet another obstacle is a shortage of highly skilled personnel needed to develop and implement energy conservation technologies. This is true for all areas of conservation but will be illustrated with a reference to the building sector.

Builders and their tradespeople have had little experience or training in the new techniques necessary to build energy-efficient homes. Extreme care is required for correct vapour-barrier installation and the prevention of air infiltration. Many tradespeople do not have the knowledge needed to implement these conservation measures. A well-sealed home requires controlled ventilation, but this technology is not well known throughout the industry. Furthermore, there is currently no facility for training architects, engineers and construction personnel in the proper techniques of retrofit. The present practice of sub-contracting to the lowest bidder, with limited technical performance criteria, does not encourage extra effort or attention to energy conservation details. Similar examples of the need for specific training can be found in the industry and transportation sectors.

*Lack of Industry Association*
Limiting the use of energy-saving technologies is the lack of a unified voice for firms manufacturing energy conservation equipment and those providing conservation services. At present, a large number of unrelated manufacturing firms, wholesalers and retail outlets provide equipment and hardware, while unrelated companies deliver diagnostic, installation, and maintenance services. Although the absence of an overall industry association representing and speaking for these manufacturers and service companies poses a problem, any attempt to form such an association is judged to be not practical, at least at this time.

In this situation, one role of government should be to ensure that reliable information is made available to the public. A further role should be to provide administrative support and financial assistance for the dissemination of conservation-related technical information. Some newer firms are offering complete energy service packages (auditing, design, hardware, installation and maintenance). Other firms - so-called "energy stores" - offer a wide range of energy conservation products for a particular sector of the economy. These developments enhance the effective dissemination and marketing of conservation technologies and should therefore be encouraged.

*Regional Differences*
Another major impediment to the effective dissemination of energy conservation technologies is caused by varying regional and local circumstances. It is important to ensure that the measures for the implementation of technologies be flexible enough to accommodate regional differences. For instance, some regions have large quantities of relatively inexpensive electricity readily available. In other areas, electricity is very expensive. Since climatic conditions vary widely in Canada, consideration of regional differences is especially necessary in the design of new buildings and in retrofitting existing buildings.

## Role of Governments

*Leadership*
The Task Force recognizes that the implementation of strategies for energy conservation and for the adoption of related technologies is a complex problem which will require changes in the nature of our social, economic and political frameworks. These changes will require clearly defined and publicized objectives and will only be accomplished over a long time period.

The implementation of these changes will depend on the political will of governments at all levels who must provide the leadership and motivation to offset the financial and institutional barriers which currently impede the introduction of energy conservation strategies and technologies.

Governments see numerous advantages in exploiting the supply side of the energy equation — in terms of tax revenues, balance of payments, employment opportunities and others. Less appreciated are the significant political, economic and social benefits which can be derived from conservation, not the least of which is the increase in the disposable income of consumers. Consequently, governments should immediately become more knowledgeable about these benefits, so that they can provide the leadership to effect the required changes.

*Use of Public Funds*
The government's role in encouraging and funding energy conservation must be well justified as a prudent and equitable use of public funds.

In the short term and under present circumstances, the federal government subsidizes the cost of imported crude oil. Energy conservation, of course, is not aimed solely at saving oil. However, as energy forms can frequently be substituted, the conservation of energy from sources other than oil often contributes to relieving the federal treasury of the burden of import subsidies. In these conditions, providing a financial incentive for conservation is not more onerous to taxpayers than subsidizing the importation of oil.

To avoid additional expenditures by the federal government, financial incentive programs to encourage energy conservation could be structured in such a way that the amount of the incentive relates to the foregone federal subsidy on the imported oil (or oil equivalent of energy) saved over a specified time period. The compensation paid by the federal treasury on imported oil would be reduced as a result of conservation. As the users will be the principal beneficiaries from lower energy prices, they should expect to pay much of the cost of a conservation technology. The government's financial incentive should thus always be less than the total cost of implementing the technology.

**Specific Conclusions**

The more widespread adoption of energy conservation is not held back by the lack of suitable technologies but by financial and institutional constraints. The following conclusions and recommendations, which relate to specific sectors, indicate some ways to alleviate these constraints.

*Buildings*

To accelerate the adoption of energy-efficient measures in the residential and commercial market, the Task Force concludes that interim financial incentives are needed. These should be in the form of interest-free loans (such as are provided in Saskatchewan) or low interest loans, to assist builders and developers (in the case of new buildings) and owners (for existing buildings) to offset the cost of implementing energy conservation technologies.

These incentives should be offered for a period sufficient to demonstrate the advantages of adopting energy conservation technologies and to train designers, tradespeople, inspectors and construction personnel. The period will also allow time to determine recommended energy performance levels. It should be left to a later time to decide whether these recommended levels should be incorporated ultimately into mandatory standards, promoted through a labelling system, or continued merely as guidelines. The period should be such that there is time for buyers to be made aware of the value of conservation devices, that sellers can publicize energy performance statistics for their buildings, and that the advertised level of performance can be certified.

Adopting and recording the performance of energy conservation technologies in new buildings would, with time, make it possible to effectively predict the financial return to the user. Where such technologies can lead to significant savings, programs financially assisting the demonstration of their benefits would encourage their widespread adoption.

In general, owners and operators have the knowledge and skill to evaluate energy conservation proposals for new commercial buildings. The major investment barrier is that the person who makes the investment is not the one who receives the benefits (with the exception of owner-occupied buildings). The tenant generally does not differentiate product offerings on the basis of energy cost, particularly with net, net, net leases where the tenant pays all occupancy costs. (Energy costs may be substantial in total but are usually less than one percent of total business expenses or less than three percent of lease cost.)

Generally home buyers do not possess the information required to recognize an energy-efficient dwelling easily. Nor are people well aware of the economic justification for energy efficiency. Saskatchewan is one province where this generalization does not hold true. An analysis of the programs that have resulted in public awareness of energy efficiency in that province should be undertaken before establishing information programs for the rest of Canada.

Difficulties with urea formaldehyde foam insulation and unethical business practices by some firms have created serious suspicions in the minds of the public toward companies providing both equipment and services promising a reduction in energy consumption. As a result, the cause of conservation has been temporarily set back. The availability of independent, trustworthy energy audit and diagnostic services, unassociated with contracting firms specializing in conservation, would help correct this situation. A few such firms have now begun to emerge. This trend should be encouraged. A major opportunity exists for reliable, reputable businesses to offer diagnostic services to home-owners for measuring energy efficiency using techniques such as thermographic analysis or infiltrometry for detecting air infiltration, and for providing information on the corrective measures needed to resolve the problems identified.

As well, to increase public awareness of the benefits of energy conservation technologies, governments should ensure the availability, or subsidize the costs of, energy audit and diagnostic services for residential housing. Quebec and Ontario are providing audit services through electric utilities and it would be desirable to have the information gathered made available in a data bank for analysis and planning. There is also an ongoing need for energy conservation materials to be tested and certified for safety as well as for effectiveness.

A number of energy conservation technologies, processes and procedures are available to reduce energy consumption in the building sector. The question of which are most suitable depends on the type of building and whether it is new construction or an older building requiring retrofit.

The most promising techniques for conserving energy in residential buildings are those which minimize the heating, ventilation and cooling loads by producing airtight, well-insulated building shells, either at the time of construction or through retrofit. Much has been done in Canada to increase the level of insulation in homes, but little has been done to reduce air infiltration. Simple methods to ensure airtightness and to solve the problems associated with disposing of odours, toxic contaminants and moisture, while rejecting as little heat as possible in the process, are known and the necessary equipment is available "off-the-shelf". The challenge is to disseminate such technologies. This can open up industrial opportunities for Canada.

As more existing residences are retrofitted and new ones built to very high energy-efficiency standards, smaller heating, ventilation and air conditioning systems will be required, not only to ensure that buildings are energy efficient but also that they are healthy for the occupants. The manufacturing and marketing of these systems offer another attractive technological and commercial opportunity for Canadian industry.

Existing small commercial buildings offer the same opportunities to improve energy efficiency as domestic residences. Varying energy usage demands dictate that more emphasis should be placed on automatic and integrated control systems, on the heating of water and on commercial equipment. In existing large buildings, the focus should be on lighting, as this is where most energy can be saved. Next in importance are the systems for the scheduling of heating, ventilation and air conditioning equipment.

In new large, commercial buildings, primary emphasis should also be placed on lighting. Next in importance are airtightness of the shell, cooling systems and heat reclamation techniques.

*Transportation*
There are two basic methods of conserving energy in the transportation sector. One is based on increasing the energy efficiency of all transportation modes. The other aims at encouraging the public to switch to transportation modes (e.g., trains, buses) which consume less energy than do others (e.g., airplanes, automobiles). The successful application of both types of measures can contribute significantly to the reduction of energy consumption in this country.

The most attractive energy conservation opportunity in the transportation sector is in the area of greatest energy consumption - road transportation (especially automobiles). Significant savings can be achieved in the transportation sector by a reduction in the size and weight of all vehicles, but particularly automobiles. This can be achieved by reductions in aerodynamic drag and in the rolling resistance of tires, and through the use of lighter components, such as high-strength, light alloy steels, aluminum and fiber-reinforced plastics.

Major opportunities for energy conservation can also be realized from improved engines and drive trains, such as small diesel engines and continuously variable speed transmissions. The most efficient existing engine for transportation purposes is the diesel. The increased use of diesel engines would provide significant energy savings for Canada and would lessen this country's dependence on costly and insecure supplies of foreign oil. The establishment of an automotive diesel engine manufacturing plant in this country would also have significant industrial development, employment and export potential.

Increased efficiency could also be achieved by proper maintenance of the existing fleet of automobiles. Information dissemination programs can do much to encourage car owners to maintain their vehicles properly. Inspection and maintenance stations can also be effective. Although the new automobiles coming onto the market have carburetion systems which are supposedly "tamper-proof", tests indicate that they are being maladjusted. Regulations should be instituted to ensure that tamper-proof carburetors remain so.

In the aviation sector, the largest energy efficiency improvements have come by increasing seating densities and load factors and through the retirement of many fuel-inefficient planes. The most significant opportunities for Canadian development are in the areas of specialized (frequently small) aircraft and in turbo-prop engines where this country's capability is well developed.

However, many of the significant opportunities for developing energy conservation technologies in automobile and aviation transportation are beyond the control of Canadian industry. Design and manufacturing decisions rest with multi-national companies headquartered outside this country. It follows that most of the industrial opportunities for Canada in these areas depend on production-sharing and world product mandate agreements with foreign manufacturers.

The public transit sector, in which the Task Force includes intra-urban transit and inter-city bus and rail transportation, offers very important technological opportunities for Canadian industry, as well as significant potential for energy conservation. Considerable savings could be achieved by a shift from the use of other less energy-efficient modes of transportation (especially automobiles) to public transit.

The technological opportunities are particularly attractive in rail transit because, unlike other areas, Canadian industry possesses both the product design technology and the manufacturing expertise to develop the entire transportation system.

The growing acceptance of rail transit as an energy-efficient means of moving people, and the inevitability of future increases in energy prices prompt a demand for new and improved types of rail passenger vehicle. As an example, main line, self-propelled rail coaches capable of providing service as independent units on non-electrified lines will be needed for operation in medium density traffic corridors. These are known as rail diesel coaches (RDCs). The potential North American market is about one billion dollars. As approximately one third of this market is in Canada, it is important that it be developed and produced in Canada. The Task Force believes that if the federal government were to underwrite half of the industrial development cost of a new rail diesel coach, the private sector would fund the other half.

The extent to which rail transit technologies will be developed and disseminated will depend more on government transportation policy than on support for energy conservation technologies. Nevertheless, it should be noted that rail transit is a major opportunity not only for industrial development but for energy conservation as well and this should be given due weight when making transportation policy decisions.

The various levels of government in Canada - municipal, in some cases regional, provincial and federal - make it difficult to co-ordinate programs for the adoption of certain energy conservation technologies, particularly in the transportation sector. Local streets and transit systems are under municipal jurisdiction. Inter-urban transit systems and most highways are provincial responsibilities. Competing long distance systems, air and rail, are primarily under federal jurisdiction. There is no central body to develop and co-ordinate policies and programs for the more efficient transportation of people and goods or the production in Canada of appropriate transit equipment.

*Industry*

Canadian industry has used energy more efficiently in recent years. The voluntary industry-government task force program for energy conservation has led to significant energy savings. As oil prices increase, the attractiveness of conservation in the industrial sector increases further. The federal government should expand its policies to assist industry to improve its energy conservation programs.

Although decisions to develop or adopt energy conservation technologies will be made by the energy user, there are a number of measures governments can take to encourage industry in this area. As industries tend to invest to increase production in preference to projects aimed at conserving energy, the government should provide such fiscal measures as subsidized interest rates and tax incentives to accelerate the adoption of energy conservation technologies and processes in the national interest. These would result in greater investment in energy conservation than is the case with grants and accelerated capital cost allowances which characterize existing federal incentive programs.

One device would be to provide a tax credit for any expenditures directed towards energy conservation, subject to previously established program criteria. Similar credits have been allowed for petroleum exploration, investment in Canadian movies and in R&D, with notable success.

Another incentive would be to subsidize low-interest loans through existing financial institutions for energy conservation projects meeting specified criteria. We believe banks should be willing to extend such loans from their own resources, providing the difference between the rates at which they are offered and the going rates for other loans is made up by a government subsidy.

Although fiscal measures should be the primary choice of incentives, there is still a limited need for government grant programs. If they are to be more effective, however, such programs must be streamlined and rationalized, to remove the difficulties identified in this report.

The barriers to the widespread adoption of some industrial energy conservation technologies and processes are essentially institutional. A specific example is cogeneration. The difficulties are caused mostly by the relationship between the industrial cogenerator and the electrical utility. Utilities, in general, have not been active in promoting cogeneration as their mandates usually do not encourage or authorize them to do so. The potential for cogeneration is enhanced when excess electrical power can be made available, without restriction or penalty, by the cogenerator to a utility or other user.

If cogeneration facilities could be financed at the lower interest rates now enjoyed by utilities, this would provide a strong incentive to the increased production and use of cogeneration equipment. A further incentive would be for utilities to purchase power produced by cogeneration at the utilities' cost of generating power.

## Recommendations

### General

The Task Force recommends that:

1. governments at all levels should become knowledgeable about the political, social and economic benefits which could result from the implementation of energy conservation strategies and technologies, so that they can provide the leadership necessary to move society in this direction.
2. the federal government should fulfill its commitment to energy conservation by making a financial and human resource investment in conservation comparable to that which it is now making in supply.
3. since, in the near term, the adoption of currently available technologies is more important for the reduction of energy consumption than research into and development of new technologies, the federal government should give high priority to the dissemination and marketing of existing energy conservation technologies.
4. the federal government should provide financial incentives to help offset the cost and accelerate the adoption of energy conservation technologies. A guiding principle for all such federal financial incentive programs could be that the amount of the incentive be tied to the federal subsidy on the imported oil (or oil equivalent of energy) saved over a specified time period. Specific incentives are described in the recommendations for each sector.
5. the federal government should support continuous and aggressive marketing programs, designed and implemented by experts and aimed at promoting the adoption of energy conservation technologies. Such programs should be responsive to the varying regional needs of the country.
6. the federal government should establish and maintain comprehensive, reliable and regionally-oriented data bases on the technical and economic performance of specific energy conservation technologies. These data bases should be widely publicized and should be made readily available to corporate and individual users.
7. government agencies responsible for education and training should give high priority to the knowledge and skills required for the design, manufacture, installation and operation of energy conservation technologies. This includes both *better* training and the training of *more* skilled personnel.

### Buildings

The Task Force recommends that:

8. for residential and commercial buildings, governments should provide loans at no interest (e.g., as in Saskatchewan) or at preferential interest rates, to be offered through Canadian banks or other lending institutions, to assist builders and developers (in the case of new buildings) and owners (in the case of existing buildings) to offset the incremental cost of approved energy conservation technologies.
9. the federal government should extend the accelerated write-off for capital expenditures by industry on specified energy conservation technologies listed in Class 34 of the Income Tax Regulations to include conservation technologies for new and existing commercial buildings.
10. governments should establish and publicize energy performance level standards for all commercial buildings and use financial incentives and penalties to encourage their implementation.
11. governments should require that information concerning an existing residential and commercial building's annual energy consumption be made available to buyers.
12. (a) to increase public awareness of the benefits of energy conservation technologies in residential housing, governments should ensure the availability, or subsidize the costs of, energy audit and diagnostic services;

(b) to ensure consumer safety and security, energy audit, diagnostic and retrofit delivery services should be certified by appropriate licensing bodies.

**13.** (a) the performance of energy conservation materials should be certified through the Canadian Standards Association, or Underwriters' Laboratories of Canada, or other recognized testing agencies; and
(b) labels should be affixed to energy conservation materials and products indicating their energy efficiency.

**Transportation**

The Task Force recommends that:

**14.** the federal government should initiate the formation of a federal-provincial-municipal transportation committee to develop and co-ordinate policies and programs which will cause travellers to switch from automobiles to more energy-efficient modes of transportation and encourage the acquisition of appropriate equipment from Canadian manufacturers.

**15.** (a) in order to show that high frequency passenger rail service would result in increased usage, the government should immediately initiate a demonstration program providing such service between two medium-to-large-sized Canadian cities, employing modern, rapid passenger trains, running on tracks maintained to current Canadian standards;
(b) subject to the results of (a) above, the government should put into place modern facilities dedicated to passenger rail for inter-city corridors of up to 500 miles, where the potential traffic warrants the investment.

**16.** the government should provide industrial funding of up to 50 percent of the development cost of a new rail diesel coach.

**17.** since immediate reductions in energy consumption can be substantial, governments should:
(a) promote a program of public education and technical assistance on the proper maintenance of motor vehicles;
(b) institute regulations to prohibit the maladjustment of "tamper-proof" carburetors.

**18.** the federal government should support the private sector in examining the feasibility of the manufacture in Canada of a small automotive diesel engine available for sale to all domestic and foreign markets.

**19.** due to the relationship between energy consumption and vehicle weight, the federal government should encourage Canadian vehicle manufacturers and component suppliers to develop and apply lighter-weight materials for all modes of transportation.

**Industry**

The Task Force recommends that:

**20.** the federal government should provide financial incentives to encourage and assist industry to adopt energy conservation technologies. Due to the number, diversity and particular needs of companies within the industrial sector, these incentives should be varied enough to provide industry with a choice of alternative means of assistance. The following programs should be made available to industrial companies so they can select whichever one best suits their needs. Accordingly, the federal government should:
(a) retain as an option the present accelerated write-off for capital expenditures on specified energy conservation technologies listed in Class 34 of the Income Tax Regulations;
(b) provide the option of a one-time refundable tax credit, administered through the income tax system, for capital expenditures on approved energy conservation technologies;
(c) provide a further option of subsidized loans at preferential interest rates, to be offered through Canadian banks or other lending institutions, for investment in approved energy conservation technologies.

**21.** the federal government, in consultation with industry, should undertake a detailed examination of its incentive programs in support of industrial energy conservation to increase their utility and accessibility.

**22.** governments should promote the use of industrial cogeneration by:
(a) providing financial incentives so that cogeneration facilities can be financed at the lower interest rates now enjoyed by utilities;
(b) encouraging utilities to remove restrictions and penalties for the use of power produced by cogeneration;
(c) encouraging utilities to purchase power produced by cogeneration at the utilities' cost of generating power.



## Footnotes

### Executive Summary and Recommendations

1 Energy, Mines and Resources Canada, *The National Energy Program*. Ottawa, 1980. p. 69.

2 Special Committee on Alternative Energy and Oil Substitution, *Energy Alternatives*. Ottawa, 1981, p. 57.

3 Acres Consulting Services Limited, *A Study of the Potential for Energy Conservation in Canadian Industry*. Prepared for Energy, Mines and Resources Canada.

4 Middleton, Peter, *The Industrial Impacts of Conservation and Renewable Energy*. Address to the Canadian National Energy Forum, Ottawa, November 10, 1981.

5 Energy Research Advisory Board, *Federal Energy R&D Priorities*. Washington, D.C., November 1981, p. 29.

6 Ministry of State for Science and Technology, *R&D Policies, Planning and Programming*, Background Paper 13, Ottawa, January, 1981, p. 16.

7 Vertinsky, Patricia, "The Use of Mass Communication Strategies to Promote Life-Style Change: The Case of Energy Conservation in Canada", in Peter N. Nemetz (ed.) *Energy Policy: The Global Challenge*. Toronto, 1979, p. 397.

# 1

# Energy Use and Conservation

## Energy Use

To set the stage for this report and its recommendations, a brief examination of Canada's energy consumption and supply patterns will be presented to indicate the significance of energy to Canadian economic activities and to make clear the importance of conserving our energy resources.

In late 1973, when member nations of the Organization of Petroleum Exporting Countries (OPEC) reduced oil shipments and unilaterally set the price of oil at a level much higher than had previously existed, most of the world's industrialized nations were faced with the dual prospects of much more expensive oil and uncertainty of supply. This situation was aggravated by the revolution in Iran in late 1978 and the conflict between Iraq and Iran, which resulted in the effective reduction of world oil production by approximately 8 million barrels a day.

Complicating these developments in Canada, the economy, heavily dependent on non-renewable resources, was consuming energy supplies at ever-increasing rates. In addition, there has been growing concern in recent years about the extent of Canada's oil and gas reserves and the country's ability to meet its domestic energy needs, while serving large export markets.

Between 1973 and 1979, the consumption of total primary energy by member countries of the International Energy Agency (IEA) increased at an average annual rate of 1.2 percent, down from an average growth rate of 5.6 percent per year between 1968 and 1973. The slow-down in energy demand occurred in all IEA countries, partly as a result of the implementation of energy conservation measures. The annual growth rate in primary energy consumption for Canada fell from 6.9 percent in 1968-73 to 2.2 percent from 1973-79, one percentage point more than the IEA average. The total consumption of oil in IEA countries increased by only 0.7 percent in 1973-79 (1.0 percent in Canada) compared with 7.5 percent in 1968-73 (5.3 percent in Canada).[1]

Canada's energy consumption per capita is one of the world's highest. According to IEA data, from one perspective Canada is the least efficient user of energy among major countries of the Organization for Economic Co-operation and Development (OECD). In Figure 1:1, efficiency is measured by each country's position relative to the diagonal line, which represents the average income per energy input for all OECD countries. According to the chart, Switzerland is the most efficient user of energy (relative to income) whereas Canada is the least efficient.

The special and predominant characteristics of Canada's industrial structure, its scattered population, vast geography and climate may explain why this country is an inefficient user of energy. A recent study by the Royal Bank of Canada, however, does not find such explanations and arguments altogether satisfactory. The study concludes that

"it would seem that special factors do not provide an adequate explanation for the large gap between Canada's output/energy ratio and that of most other major industrial countries. At the same time, it is difficult to avoid the conclusion that there is a close relationship between efficiency in energy use and the price of energy . . . the higher the relative price, the higher the relative efficiency in use."[2]

In a paper presented to the Conference on International Energy Issues in Cambridge, England, in June, 1980, Steven Diener, Senior Economist of Acres Consulting Services Limited, also commented on the significant differences in energy efficiency in all end-use sectors between North American (specifically Canadian) and other industrialized nations. In it he said:

"As far as reasons for this variance are concerned, climate and geography have been shown to be less important than the market prices of fuel and electricity and the penetration of so-called 'best practice technologies'."[3]

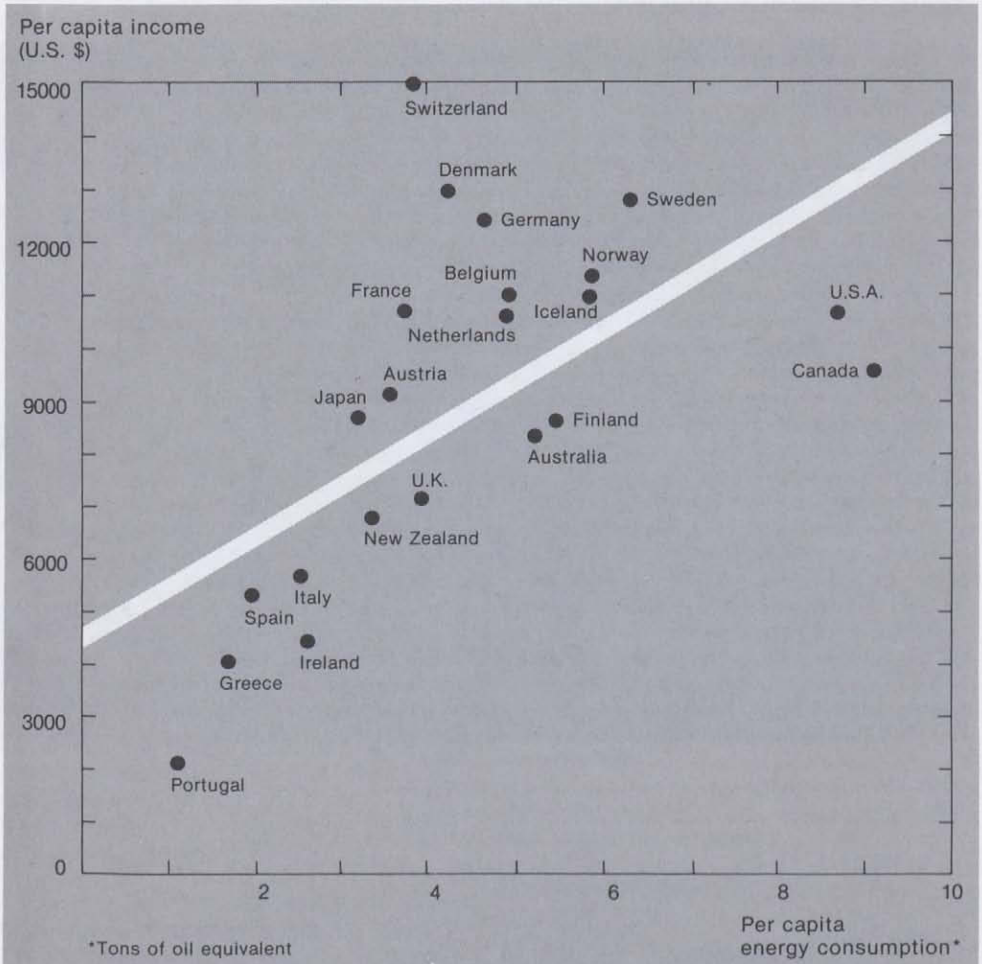
The recent energy pricing agreements between the federal government and the oil-producing provinces have set in motion the process of removing the constraints which low cost energy has placed on conservation, since energy prices will be significantly higher in the years ahead.

It can not be said, however, that price is the sole determining factor for the level of energy consumption, or conservation, in Canada. As economist Donald Dewees wrote in a recent paper:

"Demonstrations that higher prices yield lower energy consumption do not prove that other policies are unnecessary, only that there is some role to be played by prices themselves."[4]

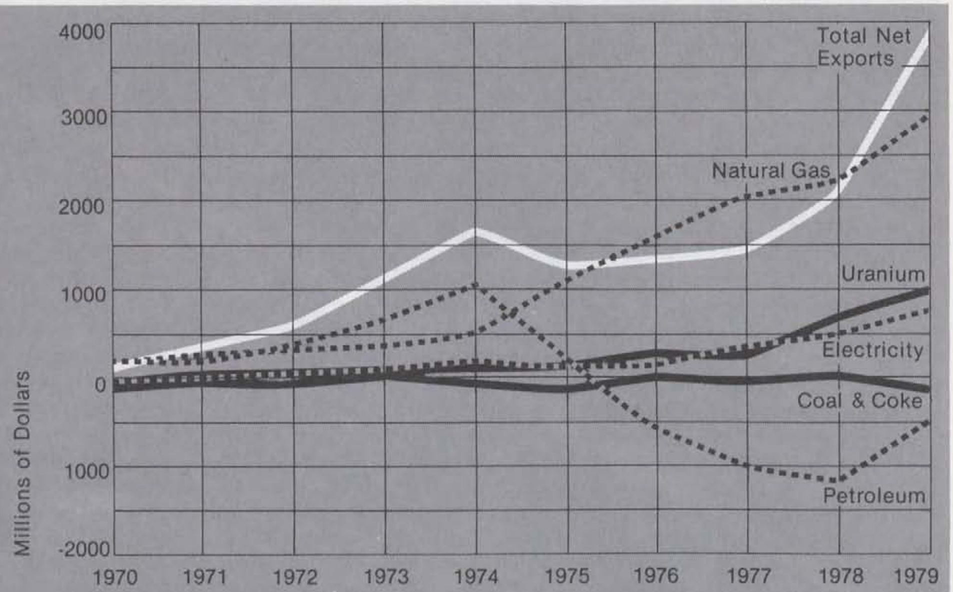
The environment created by government policies and by specific measures to encourage conservation can increase the rate of expansion of markets for energy conservation products and services. Present government policies are used effectively to encourage the enlargement of energy supply (for instance, grants for nuclear R&D and tax concessions for oil and gas exploration). The government should encourage energy conservation and the development and dissemination of related technologies by committing to them a level of human and financial resources comparable to that which it is now investing in energy supply.

*Figure 1:1*




*Source: OECD Observer*. March, 1981.

*Figure 1:2 Canada's Dollar Trade In Energy Commodities: 1970-1979*




*Source: Energy Alternatives.* Report of the Special Committee on Alternative Energy and Oil Substitution, p. 37.

**Energy Supply**
It must be remembered when discussing the energy issue that Canada's position vis-à-vis most other countries is somewhat unusual. Canada became a net exporter of energy in the late 1960s and, in dollar value, our current exports of natural gas and electricity are greater than our imports of oil and coal. In 1979, Canadian trade in energy commodities resulted in a net export balance of $3,844 million.

Although Canada is presently dependent on imported oil for approximately one quarter of its total consumption, it is blessed with an abundance of energy resources and, as was pointed out in the 1980 National Energy Program, has the potential to become self-sufficient in energy.

"Canada produces more than enough energy to displace all of our oil imports, and still have substantial quantities of energy available for export if desired. We have significant excess capacity in the natural gas and electricity production system, and considerable potential in coal and renewable energy. With determined efforts to restrain energy demands, giving us time to develop new energy sources, our self-sufficiency capacity could last for the foreseeable future."[5]

It is also important to follow the trends in the sources of supplies of energy, that is, the relative contributions made by each of the primary energy forms in Canada. Bruce Willson outlines this development in a study prepared for the Canadian Institute for Economic Policy:

"At the time of Confederation, Canadians derived over 90 per cent of their inanimate energy supplies from wood. By 1900 coal and coke had become the most important source of energy, directly supplying more than half of the energy consumed in Canada. This share continued to rise into the 1920s when coal and coke clearly dominated all other forms of energy supply, and the contribution of wood fell below 20 percent of total consumption. By then petroleum and related products accounted for nearly 10 percent of energy consumed, already double that supplied by electricity and natural gas.

"As recently as 1950 coal and coke still provided close to half of the energy used in Canada. However, by this time the share of both petroleum and electricity had overtaken that of wood, with petroleum and natural gas capturing slightly over 30 percent of the total market. Within a short period, their share surpassed that of coal and coke and by 1960 they supplied over half of the energy used in Canada. . . .

"Thus in the space of one hundred years Canada has gone from a reliance on essentially renewable sources of energy (wood) to dependence on non-renewable fossil fuels - first coal and then oil and gas - supplemented to a degree by hydro and nuclear electricity."[6]

This dependence on non-renewable forms of energy is illustrated clearly in Table 1:1. In 1980, the net domestic energy consumption by source in Canada was:

*Table 1:1*

| Source | Percentage |
|---|---|
| Oil Products & Liquefied Petroleum Gases | 54.9 |
| Natural Gas | 23.8 |
| Electricity (hydro & nuclear) | 17.1 |
| Coal & Coal Products | 3.5 |
| Steam (primarily nuclear) | 0.6 |

*Source:* Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada, 1980: IV.* pp. 4-5

The consumption of primary and secondary energy in Canada by each of the major economic sectors of the economy is illustrated in Table 1:2 below.

*Table 1:2*
Primary and Secondary Energy, 1980

| Sector | Terajoules | Percentage |
|---|---|---|
| Residential, Commercial & Other Institutional | 1,969,882 | 32.0 |
| Industrial* | 1,948,447 | 31.6 |
| Transportation | 1,928,455 | 31.3 |
| Agriculture | 189,592 | 3.1 |
| Public Administration | 121,472 | 2.0 |
| Energy Use - Final Demand | 6,157,848 | 100 |

*includes manufacturing, forestry, mining and construction industries.

*Source:* Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada, 1980: IV.* pp. 10-11

The demand for energy services in Canada is illustrated in Table 1:3, below, showing that half of the energy used in Canada is for heating applications.

*Table 1:3*
*Estimated Energy Services Demand in Canada, 1981*

| Function | Percentage | |
|---|---|---|
| Heat (space, hot water, etc.) <100°C | 30 | |
| Heat (including steam) >100°C | 20 | |
| *Total* heating | | 50 |
| Transportation | 25 | |
| Electric drive | 12 | |
| Other - lighting, specialized electric processes, cooling | 13 | |
| *Total* demand for energy services* | | 100 |

*Excluding non-energy (feedstocks, etc.) uses of energy.

*Source:* Energy, Mines and Resources Canada, Conservation and Renewable Energy Branch, 1981.

**Energy Conservation**

The resolution of the problems of higher energy costs and insecurity of oil supplies hinges on the country's ability to develop alternative sources of energy, to increase the supply of existing sources of energy, and to reduce energy demand and consumption. The last of these - conservation - will be brought about by altering human attitudes and lifestyles concerning the use of energy, through education programs which increase public awareness. Conservation will also result from improving the efficiency of the use of energy, in all sectors of the economy.

There are numerous benefits to be derived from the implementation of a vigorous conservation effort. Some of these have been outlined by the Special Committee on Alternative Energy and Oil Substitution in its report, *Energy Alternatives*.

"Conserved energy represents a special class of alternative energy, not dependent on bringing forth new supplies. Conservation saves consumer dollars and capital, and contributes to an improved balance of payments through reduced expenditures on foreign oil. Conservation programs will likely create employment and income through expansion of that part of industry which supplies conservation goods and services. Other important and extensive benefits will derive from a conservation-oriented economy as well, not the least of which is the reward of long-term energy self-sufficiency.

"The consequences of conservation decisions and policies are complex and numerous but a successful program of conservation would moderate the rate of growth in energy demand and lessen the pressure to find alternatives to present means of supplying energy. Conservation programs and energy supply programs require long-term planning, but through providing time, conservation increases the range of energy alternatives which may be evaluated and pursued. In other words, conservation can increase Canada's supply options if we seize the opportunity."[7]

There are numerous definitions of energy conservation. Daniel Yergin, one of the editors of the report of the energy project at the Harvard Business School, differentiates between three types of conservation: first, curtailment or enforced energy saving; secondly, overhaul, i.e., dramatically changing the way people live and work; and, finally, a form of adjustment which is more acceptable and which Yergin calls

"*productive conservation*, which encourages changes in capital stock and daily behavior that promote energy savings in a manner that is economically and socially nondisruptive. Its aim is to use less energy than has been the habit to accomplish some task — whether it be to heat a home or to make a widget — in order to prevent disruption later".[8]

In a study by Energy, Mines and Resources Canada (EM&R), the statement is made that:

"Energy conservation has been defined in many different ways, but always with the central idea that energy resources can be used more efficiently. Basically, this means accomplishing - on the basis of acceptable technical, economic and social criteria - a given task using fewer units of energy."[9]

Contrary to the belief of many, conservation does not necessarily mean curtailment or doing without. As Denis Hayes pointed out in *Rays of Hope: The Transition to a Post-Petroleum World*:

"Curtailment means a cold house; conservation means a well-insulated house with an efficient heating system. Curtailment means giving up automobiles; conservation means trading in a seven-mile-per-gallon status symbol for a forty-mile-per-gallon commuter vehicle. Energy conservation does not require the curtailment of vital services; it merely requires the curtailment of energy waste."[10]

Conservation takes several forms, including the following:

(a) using *less energy* by:
  (i) reducing energy waste, and
  (ii) enhancing the efficiency of energy use;
(b) using *energy of a lower* rather than of a higher *quality*, where possible;
(c) putting to use *energy that would otherwise be lost*.

To illustrate, (a) insulation results in less energy being used in space heating; (b) crushed glass can be recycled industrially at much lower temperatures than new glass can be made from raw sand; and (c) a hybrid petroleum/electric heating system can utilize the energy of falling water which would otherwise be lost at times of off-peak demand.

Although much has been done, there remains a significant potential in Canada for improving the efficiency of conventional energy use by generally acceptable means. A recent study[11] indicates that Canadian industry can achieve considerable energy savings by improving the efficiency with which it uses energy. Between 1978 and 2000 it is estimated that the industrial sector's purchased energy per unit of output could fall by between 36 and 40 percent. Industrial conservation has the potential to contribute over 16 Quads from 1978 to 2000[12] with short lead times, relative to other large-scale approaches to increasing energy supply.

Additional large opportunities exist in the building and transportation sectors of the economy. For instance, more than one-third of the total 6.8 Quads of energy consumed annually in Canada is utilized in heating and cooling residential and commercial buildings. Cost-effective savings of 35 to 60 percent can be realized through conservation efforts directed to our new and existing structures.

In relation to the development of new supplies of energy, conservation can usually make energy available at considerable cost savings. For example, a recent study of a set of energy-conserving projects in the industrial sector, designed to improve efficiency by 40 percent, indicated that about $11 billion worth of spending on energy conservation could replace $18-$30 billion worth of new energy supplies (depending on whether the new supplies were frontier gas or oil-sands projects).[13]

A 1977 report by Energy, Mines and Resources Canada[14] outlines a "conservation scenario" which shows that significant decreases in levels of energy consumption could be achieved in each of the residential, commercial, industrial and transportation sectors of the economy by 1990. The report suggests that annual energy growth in Canada could be reduced from 3.7 percent annually to about 2 percent. This would result in a net annual saving that would approximate $14.5 billion ($ 1980) by 1990.

# Footnotes

## Chapter One

1 International Energy Agency, *Energy Conservation: The Role of Demand Management in the 1980's*. Paris, 1981, p. 19

2 "Energy Trends in OECD Countries", *Econoscope*. Royal Bank of Canada, July, 1981, p. 17

3 Diener, Steven G., *Comparative Resource Costs and the Economic Limits to Energy Conservation in Canada*. Paper presented to Conference on International Energy Issues, Cambridge, England, June 24, 1980, p. 3

4 Dewees, Donald N., "Energy Policy and Consumer Energy Consumption" in P. Nemetz (ed.), *Energy Crisis: Policy Response*. Montreal, 1981, p. 137.

5 Energy, Mines and Resources Canada, *The National Energy Program, 1980*. Ottawa, 1980, p. 8

6 Willson, Bruce F., *The Energy Squeeze: Canadian Policies for Survival*. Toronto, 1980, pp. 3-4

7 Special Committee on Alternative Energy and Oil Substitution, *Energy Alternatives*. Ottawa, 1981, p. 91

8 Yergin, Daniel, "Conservation: The Key Energy Source" in Robert Stobaugh and Daniel Yergin (eds.), *Energy Future: Report of the Energy Project at the Harvard Business School*. New York, 1979, p. 138-139

9 Energy, Mines and Resources Canada, *Energy Conservation in Canada: Programs and Perspectives*. Ottawa, 1977, p. 2

10 Hayes, Denis, *Rays of Hope: The Transition to a Post-Petroleum World*. New York, 1977, p. 87

11 Acres Consulting Services Limited, *A Study of the Potential for Energy Conservation in Canadian Industry*. Prepared on behalf of Energy, Mines and Resources Canada.

12 1 Quad or $10^{15}$ British thermal units (BTUs) of energy equals approximately 172 million barrels of crude oil. Also, 1 Quad per year is approximately equal to half a million barrels of oil per day.

13 Acres Consulting Services Limited, *op. cit.*

14 Energy, Mines and Resources Canada, *Energy Conservation in Canada: Programs and Perspectives*. Ottawa, 1977, p. 2

# 2

# Development and Dissemination of Energy Conservation Technologies

## Energy Development

The federal government has identified a number of areas in which effort should be concentrated to reinforce Canada's technological capabilities. One such area is energy development and utilization. Within this broad area, there is the more specific field of energy conservation.

In the National Energy Program of 1980 the government pledged its commitment to the promotion of energy conservation in Canada. This commitment will be fulfilled when the federal government makes a financial and human resource investment in energy conservation comparable to that which it is now making in energy supply. Government policies, regulations and incentives can expand markets for energy conservation technologies in much the same way as they now encourage the enlargement of energy supply (e.g., grants for nuclear R&D; tax concessions for oil and gas exploration).

At present, vast resources are being invested to bring on-stream new supplies of energy. This represents the largest single investment of capital in Canada. As such, it is shaping the economic environment of the country by favouring the development of energy supply at the expense of other needs. For economic considerations alone it is urgent that conservation programs be emphasized, to decrease energy demand in a socially and economically acceptable way. Indeed, the cause of conservation will be enhanced if it is thought of as being an equivalent source of additional energy.

In an address to the Canadian National Energy Forum, Peter Middleton of Middleton Associates reinforces this position:

"Conservation mega projects on the national or provincial scale may be the most reasonable and cost effective way of providing new energy supply. Certainly a conservation mega project appears to offer an excellent distribution of benefits to communities across the country. . . . It is time, therefore, to apply the same level and sophistication of planning and management to conservation and renewables as to the mega project."[1]

The United States' Energy Research Advisory Board's report on *Federal Energy R&D Priorities* reached a similar conclusion:

"Relative to their potential contributions to the solution of the near and medium-term energy problems, there is an imbalance in the allocation of R&D funds between the conservation programs and those directed at supply. The budget needs a reordering of priorities to reflect better the opportunities that exist for efficiency improvements and the unique Federal role in conservation R&D."[2]

Despite policy and program initiatives by the federal government aimed at stimulating and encouraging research and development, the level of R&D in Canada, expressed as a percentage of the Gross National Product (GNP), continues to be one of the lowest among member countries of the OECD. A marked improvement in Canada's R&D effort is essential to an upturn in the performance of the Canadian economy. Indeed, this has been recognized by the government which has set a target of expenditures on research and development equivalent to 1.5 percent of the Gross National Product.

There exists in this country a number of factors which impede efforts to increase the level of R&D. The manufacturing sector is small relative to the size of the country as a whole. It is concentrated primarily in sectors where R&D intensity is low. Many of those sectors of the economy which are R&D-intensive are characterized by a large number of small firms distributed across the country. These firms usually must purchase their technology needs, as performing in-house R&D is much too costly. Many sectors of Canadian industry are dominated by foreign-owned multi-national corporations which perform much of their R&D in their country of origin. As was noted in a background paper by the Ministry of State for Science and Technology entitled *R&D Policies, Planning and Programming,*

". . . in many sectors, fragmentation of the domestic market makes it difficult for industries to invest in R&D. More effective use of legislation, regulation, and government procurement could help in stabilizing and aggregating the domestic market. Aggressive pursuit of the international market will also be necessary if Canada is to produce more world-class competitive industries."[3]

No country is scientifically and technologically self-sufficient. Canada, however, is scientifically and technologically over-dependent. As a resource-oriented economy, with a relatively weak and largely foreign-owned industrial sector, at a time when the pace of innovation has declined, we face a critical period when the establishment of a technologically dynamic economy will be extremely difficult. As the chairman of the Task Force said in a recent address:

"We in Canada are now, belatedly, beginning to turn our attention . . . to policies for the enhancement of our technological capability. We are beginning to stress the need for building and supporting indigenous companies equipped with the entire range of innovative functions, from research to production. We are urging multi-nationals to assign world product mandates to their Canadian subsidiaries. We are studying tax incentives for innovation, and are advocating the use of government purchasing as an aid to strengthening industry. We are trying to see where, in which sectors, we might specialize in order to turn our national advantage into competitive strength."[4]

While important technological breakthroughs have been achieved in recent years in highly specialized fields (e.g., microprocessors, satellite systems, and advanced information storage, retrieval, communication and display systems), industry must continue to develop and improve everyday products and that commitment must continue into the next century. We have, therefore, not confined our study of energy conservation technologies to the field of so-called "high technology".

The understandable reluctance of manufacturers to reveal detailed information about recently developed energy conservation technologies has limited the amount of technical data the Task Force was able to obtain. Accordingly, the specific technologies identified are described in general terms only.

The terms of reference of the Task Force call on it to identify the most promising technological and industrial opportunities in the field of energy conservation. The advantage of this approach is that it would lend itself to longer-term planning and programming. It would allow for a greater concentration of resources. Those technologies identified could be more easily supported through existing incentive programs and through any new programs which might be established.

Conversely, the overwhelming difficulty associated with an attempt to identify the best technologies was pointed out in a background paper on research and development by the Ministry of State for Science and Technology.

"The major objection to this approach is that it involves a higher degree of risk. It is often described as "picking winners", a process, it is argued, in which governments do not excel."[5]

The Task Force holds the view that no one can be certain what the "best" technologies will be. The pre-selection of the wrong technologies can be very wasteful of resources and very costly, as history has shown. It is beneficial if many technological paths are explored simultaneously, to encourage competition among technologies and, thus, the rapid development of superior technologies. This strategy is based on the principle that a choice should not be made until all attractive avenues have been explored. Premature choice should be avoided so that direction can be changed without incurring too heavy a penalty.[6] Such an approach assumes, by implication, that sufficient financial and other resources are made available to support a wide range of technologies. This is not always possible however.

If technologies are to be successfully exploited on a major scale, this will only be accomplished by natural market forces. The government's involvement should be to encourage normal market development and to establish a commercial environment which will promote the development and engineering programs needed to implement energy conservation technologies.

**Dissemination and Marketing**

The Task Force believes that the widespread adoption of energy conservation measures is not held back by the lack of suitable technologies. Existing technologies, if methodically exploited, can open up numerous industrial opportunities for Canada, while greatly reducing this country's consumption of non-renewable energy resources. However, as Canada has historically emphasized energy supply, there are numerous financial and institutional barriers which impede the adoption of energy conservation technologies. The Task Force therefore concludes that high priority should be given to identifying and implementing the strategies and support mechanisms necessary to ensure the dissemination and marketing of existing technologies, rather than to developing new technologies.

In the dissemination and marketing of energy conservation technologies, the Task Force distinguishes between three types of potential purchasers. The first is the individual consumer, who may be buying the technology as a home-owner or as a person needing transportation; the second is the corporate user, who may be purchasing equipment for an industrial process or for use in large real estate holdings; and the third, which in some ways is similar to the corporate user (its purchasing power is concentrated) and in some ways to the individual consumer (it is not primarily profit-motivated), is institutional, a category which includes schools and hospitals.

Marketing strategies for energy conservation seem to involve two basic areas of concern. The first is the modification of day-to-day behaviour (examples would be the lowering of thermostat settings, turning off lights, decreasing driving speed). The second has to do with decisions as to whether or not to make specific investments and purchases that will result in energy savings, such as insulating one's home, installing a heat pump, using automatic thermostat controls, or driving a more energy-efficient car.

Although these two areas are affected by the same market factors, the one which is most directly related to identifying strategies for the dissemination of energy conservation technologies is that of investment decisions. This is not to say that the modification of day-to-day behaviour is not important. Even though an examination of this area does not fall within the Task Force's specific terms of reference, the promotion of greater energy consciousness and public awareness of the benefits of conservation can create a more receptive market environment for the development and dissemination of specific technologies. For example, the desire to save fuel in the home provides a market opportunity for such technical products as automatic thermostat controls, heat pumps, diagnostic instruments, and many others.

Those investment decisions with which the "average" individual consumer is most likely to be concerned are the purchase or the improvement of a home, and the purchase of an automobile. When buying one or the other, the consumer must choose from a range of "ready-made" products: seldom are homes or automobiles "tailor-made", even if on occasion they are "customized" from a set of standard options. If a consumer is to purchase a more energy-efficient home or automobile, these products must be available from the home-builder or the automobile manufacturer, or from the re-sale market. If energy-efficient homes and automobiles are neither available nor affordable, the energy-conscious buyer's search for them will be in vain.

If most consumers are not now in the market for a new house or automobile, one area where they can act is that of home or car improvement. In the case of housing, this usually involves incorporating into the existing dwelling conservation equipment and materials, such as caulking and insulation; it may include newer energy-saving technologies, such as heat-pumps, automatic thermostat setback systems and individual room temperature controls. In the case of automobiles, significant energy savings can be realized by proper care and maintenance. The question we have to ask is how can the consumer be informed of the best energy conservation technologies available, and be persuaded to adopt them.

The corporate purchaser usually has more ready access to technical and accounting expertise than does the individual consumer. As a result, the former is in a much better position to know and compare the technical merits of the various options available, and be familiar with life-cycle costing and the savings implied. Also, the profit motive is central to corporate success whereas saving is not the consumer's only concern, and seldom his or her paramount concern. Moreover, the corporate buyer, because of large purchases, also enjoys more "clout" in the marketplace than does the "average" consumer, and while this factor should not be overstressed, neither can it be overlooked. The market will respond more quickly to the changing demands of a few large buyers than it will to those of a great number of "average" consumers. In short, the rising costs of energy give the corporate buyer a strong reason to be receptive to, and indeed to seek out, effective energy conservation technologies. If they are not available, because of their strong purchasing power corporate consumers can often cause them to be developed and produced to meet their needs. However, many companies seem to give priority to investments in production expansion rather than in technologies which can lead to energy savings. Therefore, as will be discussed later in this report, incentives to invest in energy conservation should be provided by governments in the national interest.

At the time of acquiring energy-conserving materials, equipment or technologies, the consumer (individual, corporate, and institutional) takes many factors into consideration. If the future savings do not appear to warrant the present expense; if the potential buyer does not have sufficient cash and the cost of borrowing is high; if there are doubts about safety; if the product is inconvenient or difficult to install, repair, or replace; or if it seems likely soon to become obsolete, the product will be difficult to sell. Also, the fact that a technology is new and more sophisticated, rather than old and simple, poses a marketing challenge because the connotation of "untried vs proven" can affect one's willingness to adopt energy-saving technologies.

Any successful marketing program must demonstrate that a product is economical, affordable, safe, convenient, and unlikely to become obsolete — whether the product is new or has been around for years. The public will insist on more product information for new than for tried technologies, and will need more persuasion before adoption. For instance, it is one thing to tell the buyer a new insulating material is "just the thing". It is quite another to convince that buyer, especially after the performance of urea formaldehyde foam insulation. For these reasons, the marketing of new energy-conserving technologies will have to overcome the fears of potential buyers towards products about which little is known.

The Task Force examined the question as to whether more information and communication on the benefits of energy conservation technologies was needed. In recent years, governments at all levels have produced and distributed a large number of pamphlets, brochures and other material encouraging energy conservation and providing practical hints for energy savings. It was hoped that such efforts would help bring about a gradual transition from a fixation on aggressive consumerism or, as a Science Council report termed it, "growthmania".[7] Also, there seemed to be a need to offset the general apathy and skepticism prevalent in Canada about the concept of an "energy crisis" and the concomitant need for energy conservation. In recent years, ever-increasing energy prices and the flood of information concerning energy shortages and the benefits of conservation have moderated the growth of energy consumption, not only in Canada but generally in the developed world.

The Task Force concluded that if more consumers knew what specific energy savings could be realized, they would more readily take advantage of energy conservation technologies. The best means of informing them is to have marketing programs designed and run by specialists in the strategies and methods involved in prompting people to action. As Patricia Vertinsky has written:

"It has been customary to blame the failure of public information campaigns upon general apathy, but it is quite possible that the target client is less culpable for his failure to take account of the message than the communicator who may have sent boring, incomprehensible messages through poorly selected media."[8]

The strategies and techniques involved in disseminating information about energy conservation, as such, and about energy conservation technologies, in particular, are complex. Again, to quote Ms. Vertinsky:

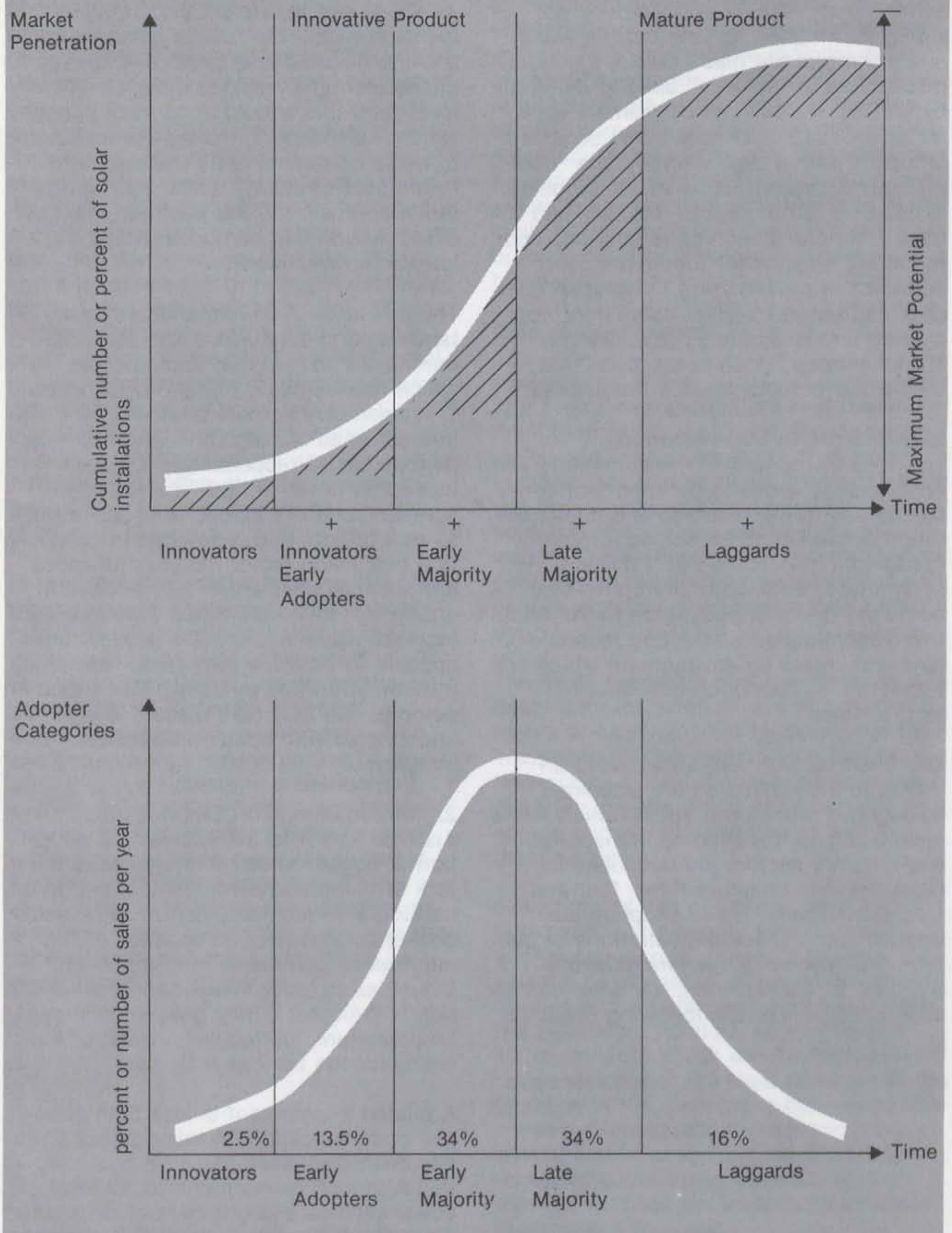
"A popular conception of mass communication depicts the media as a giant hypodermic needle jabbing indiscriminately to stimulate or depress the passive masses, yet this idea presupposes a direct and immediate response from the receiver. The process, of course, is far more complex, for mass media information is received, passed on, distorted, assimilated, rejected, or acted upon in ways which are, in part, determined by the operation of various social and social-psychological systems at various points of transmission and reception as the flow of information takes place. The communicator is thus challenged to develop complex skills where he must understand the various subcultures, language habits, and other aspects of his audience in appraising the content of the message he is sending.

"There are literally thousands of biological, physical, and social environments which each pose quite distinct challenges for the communicator. For each environment there is an audience, and for each audience the message must differ in language, method of presentation, content, and medium. Thus, messages sent through the mass media must be adjusted to the nature of existing institutions and communication channels. The success of the communicator, who must compete for the attention of his audience, will depend upon his ability to adapt his message so that it has immediate meaning to the audience."[9]

The Task Force underlines the need for an effective marketing and information dissemination program run by professionals and entrepreneurs who understand the intricacies involved. Governments and utilities often lack the necessary intensity or motivation to spread the message effectively.

One frequently-used model of market penetration places the adopters of a new product or technology into five categories: "innovators", "early adopters", "early majority", "late majority", and the "laggards". Although innovators may be the pioneers in new product areas, it is the "early and late majority" who account for most of the technological diffusion. Figure 2:1 shows the role of each category of adopter in contributing to total market penetration of a technology.

*Figure 2:1*
*Market Penetration and Adopter Categories*




Source: Middleton Associates, *Energy Conservation: Retrospect and Prospect*, background paper prepared for seminar sponsored by Energy, Mines and Resources Canada, Ottawa, December 2, 1981, p. 25.

A 1978 Queen's University study[10] suggests four approaches which, suitably adapted, could be applied to the dissemination of technologies for energy conservation. The "educative" approach aims at achieving an attitudinal change by providing information, chiefly but not exclusively through the mass media; the "identification of influentials" aims at doing so by getting the mass of consumers to adopt products endorsed by persons of influence with a high visibility; the "compliance" approach, as its name suggests, is coercive rather than persuasive, and uses techniques such as regulations and rationing; finally, the "foot-in-the-door" approach is proselytizing rather than coercive, and seeks to enlist users into propagating a message (e.g., advocating a 100 km/h speed limit) in the hope that they will eventually heed it themselves.

**Impediments to Dissemination**

The Task Force judges the comments and observations above to be important considerations in the planning and implementation of marketing strategies for energy conservation technologies. Furthermore, such strategies should attempt to overcome the major impediments to the effective dissemination of existing technologies and create an environment which will accelerate the adoption of relevant technologies.

The financial and institutional impediments to dissemination are examined throughout this report. Those which relate specifically to the building, transportation and industry sectors are described in more detail in chapters three, four and five, respectively. These chapters also contain some specific illustrations of barriers that involve all sectors generally. For the sake of convenience, the latter can be categorized under the following headings:

1. *Financial Constraints*

One significant barrier to dissemination has been the Canadian price of petroleum products which has been and continues to be lower than "world prices". However, as a result of the recent pricing agreements between the federal government and the oil-producing provinces, energy prices are rapidly approaching world levels and this should encourage conservation. Furthermore, the agreements help to dispel the uncertainty concerning the future cost of energy which has caused much confusion in the past and has hindered industry, in particular, in making long-term investments.

There is also an understandable reluctance among consumers and corporate purchasers to invest in technologies which require heavy initial capital outlays. This hesitancy is more pronounced when interest rates are high and when pay-back periods are correspondingly longer. Indeed, in times of high interest rates, companies in the industrial sector seem to give priority to investments in production expansion rather than in processes and technologies which would result in energy conservation. Since investment to increase sales in profitable product lines appears to be given preference, increased investment in energy conservation technologies will only take place if it is encouraged with additional financial incentives.

2. *Information and Communication*

Another barrier to the widespread adoption of conservation technologies is the lack of comprehensive, reliable and up-to-date data on technical performance and cost-effectiveness. The absence of this information can cause individuals and industries to defer investing in conservation techniques if they believe they may be premature, ineffective, unsafe, or too costly for the savings they yield.

A related impediment is less than effective communication on this subject. (This has been discussed earlier in this chapter.) Although governments at all levels, power utilities and others have distributed extensive information, there still remains a need for better consumer understanding in this area.

3. *Shortage of Skilled Personnel*
Yet another obstacle is a shortage of highly trained and skilled personnel such as scientists, engineers, designers, systems operators and maintenance personnel who are needed to develop and implement energy conservation technologies. This is true for all areas of conservation and for each sector of the economy.

4. *Lack of Industry Association*
A limiting factor in promoting the use of energy-saving technologies is that there is no single voice for firms manufacturing energy conservation equipment and those providing conservation services. At present, a large number of unrelated manufacturing firms and wholesale/retail outlets provide equipment and hardware, while other groups of companies deliver installation, maintenance and other services. Although the absence of an overall industry association representing and speaking for these manufacturers poses a difficulty, any attempt to form such an association is judged to be not practical, at least at this time.

In this situation, one role of the government should be to ensure that reliable information is made available to the public and to provide administrative support and financial assistance for the dissemination of technical information. Some firms are now emerging to offer complete energy service packages (auditing, design, hardware, installation and maintenance). Other firms - so-called "energy stores" - offer a wide range of energy conservation products for a particular sector of the economy. These developments enhance the effective dissemination and marketing of conservation technologies and should therefore be encouraged.

5. *Regional Differences*
Another major impediment to the effective dissemination of energy conservation technologies is caused by varying regional and local circumstances. It is important to ensure that the measures for the implementation of technologies be flexible enough to accommodate regional differences. For instance, some regions have large quantities of relatively inexpensive electricity readily available. In other areas, electricity is very expensive. Since climatic conditions vary widely in Canada, consideration of regional differences is especially necessary in the design of new buildings and in retrofitting existing buildings.

## Role of Governments

*Leadership*
The Task Force recognizes that the implementation of strategies for energy conservation and for the adoption of related technologies is a complex problem which will require changes in the nature of our social, economic and political frameworks. These changes will require clearly defined and publicized objectives and will only be accomplished over a long time period.

The implementation of these changes will depend on the political will of governments at all levels who must provide the leadership and motivation to offset the financial and institutional barriers which currently impede the introduction of energy conservation strategies and technologies.

Governments see numerous advantages in exploiting the supply side of the energy equation, in terms of taxes, balance of payments, employment opportunities and others. Less appreciated are the significant political, economic and social benefits which can be derived from conservation, not the least of which is the increase in the disposable income of consumers. Consequently, governments should immediately become more knowledgeable about these benefits, so that they can provide the leadership to effect the required changes.

*Use of Public Funds*
The government's role in encouraging and funding energy conservation must be well justified as a prudent and equitable use of public funds.

In the short term and under present circumstances, the federal government subsidizes the cost of imported crude oil. Energy conservation, of course, is not aimed solely at saving oil. However, as energy forms can frequently be substituted, the conservation of energy from sources other than oil often contributes to relieving the federal treasury of the burden of import subsidies. In these conditions, providing a financial incentive for conservation is no more onerous to taxpayers than subsidizing the importation of oil.

To avoid additional expenditures by the federal government, financial incentive programs to encourage energy conservation could be structured in such a way that the amount of the incentive relates to the foregone federal subsidy on the imported oil (or oil equivalent of energy) saved over a specified time period. The compensation paid by the federal treasury on imported oil would be reduced as a result of conservation. As the users will be the principal beneficiaries from lower energy prices, they should expect to pay much of the cost of a conservation technology. The government's financial incentive should thus always be less than the total cost of implementing the technology.



## Footnotes

### Chapter Two

1 Middleton, Peter, *The Industrial Impacts of Conservation and Renewable Energy*. Address to the Canadian National Energy Forum, Ottawa, November 10, 1981.

2 Energy Research Advisory Board, *Federal Energy R&D Priorities*. Washington, D.C., November 1981, p. 29

3 Ministry of State for Science and Technology, *R&D Policies, Planning and Programming*. Background Paper 13, Ottawa, January, 1981. p. 16

4 Price, Frank O., "Technology Transfer Internationally: Why Governments Are Concerned", *Journal of the Society of Research Administrators*. Spring, 1980, pp. 15-16

5 Ministry of State for Science and Technology, *op. cit.* p. 26

6 See *Mémoire du Comité de Promotion Economique de Montréal (COPEM) Concernant Le plan des installations, 1981 à 1990 d'Hydro Québec*. Soumis à la Commission Permanente des Ressources Naturelles de l'Assemblée Nationale du Québec. Le 6 février 1981.

7 Science Council of Canada, *Canada as a Conserver Society*. Ottawa, 1977, p. 18.

8 Vertinsky, Patricia, "The Use of Mass Communication Strategies to Promote Life-Style Change: The Case of Energy Conservation in Canada" in Peter N. Nemetz (ed.), *Energy Policy: The Global Challenge*. Toronto, 1979, p. 397.

9 *Ibid.* p. 392

10 Arnold, S.J. and R.E. Turner, *Change Strategies for Transportation Energy Conservation*. Queen's University, Kingston, Ontario, September, 1978.

# 3

# Energy Conservation Technologies for Buildings

## Distribution of Energy Use in Buildings

The building sector - including residential, commercial and industrial buildings - accounts for 32 percent of all energy consumption in Canada. The estimated breakdown by type of building is as follows:

*Table 3:1*

| Type of Building | Total Canadian Energy Use | Total Energy Use in Buildings |
|---|---|---|
| Residential | 16% | 50% |
| Commercial | 11% | 34% |
| Industrial | 5% | 16% |
| | 32% | 100% |

*Source:* Conservation and Renewable Energy Branch, Energy, Mines and Resources Canada, 1981.

Energy is used for various building services, as illustrated in the following table:

*Table 3:2*

| Service | Total Canadian Energy Use | Total Energy Use In Buildings |
|---|---|---|
| Space heating | 25% | 79% |
| Water heating | 3% | 9% |
| Appliances, business machines | 2% | 6% |
| Lighting | 1% | 3% |
| Space cooling | 1% | 3% |
| | 32% | 100% |

*Source:* K.F. Tupper, *Building Research Note 176*, National Research Council, 1981.

The greatest immediate and short-term potential for saving energy is to be found in existing buildings. Analyses by Energy, Mines and Resources Canada in 1980 indicate that energy savings, with an investment payback of six years or less, could approach 50 percent. Savings could become greater as energy prices rise and as higher efficiency heating systems become available to replace older units.[1] Table 3:3 shows the economic potential for conservation in Canadian buildings erected before 1975.

*Table 3:3*
*Energy Conservation Potential in Existing Buildings*
(Economic* at 1980 prices)

| Residences | Average energy savings |
|---|---|
| Insulation (attics, basement and walls) | 30% |
| Improved airtightness (caulking, weatherstripping) | 10% |
| Windows, doors | <5% |
| Oil furnace maintenance, retrofit and replacement | 3-20% |
| Gas furnace maintenance, retrofit and replacement | 2-50% |
| Temperature set back (to 20°C) where desired | 0-20% |
| **Commercial Buildings** | |
| HVAC** - improved systems maintenance, modified systems and controls. Lighting - control, reduction of lighting levels. | 55% |

* Investment payback of six years or less (rate of return at least 12 percent real)
**Heating, ventilation and air conditioning

*Source:* Armstrong, Graham T., *Conservation Energy - Potential and Practice in Canada.* Presentation to the Conservation Energy Seminar Series, Regina, Saskatchewan, June 24, 1980. (Revised October 1980) facing p. 20.



## Energy Conservation Technologies for Buildings

Several energy conservation technologies for buildings have been examined by the Task Force. Which are most suitable depends on the type of building and whether it is to be newly constructed or already exists and can only be retrofitted. For convenience, these have been grouped under several broad headings below. Technologies and processes to produce airtightness and those related to more efficient lighting are described in greater detail in the next section, as they were seen to have considerable potential. The technologies identified by the Task Force are described for illustrative purposes only, to show that a great deal can be done to reduce energy consumption using existing technologies, if they were methodically exploited and disseminated.

*List of Technologies*

1. *Energy loss diagnostic technologies*
   (a) Thermographic analysis by such means as infra-red cameras and building enclosure testing and diagnosis;
   (b) Computer programs for energy use analysis;
   (c) Computer programs for the design of energy, lighting and solar heating systems.

2. *Energy loss prevention technologies*
   (a) Technologies to reduce air infiltration (see section on airtightness later in this chapter);
   (b) Improved insulation (opportunities lie in improving product quality and consistency and manufacturing materials with high insulation values and fewer application problems);
   (c) Low-leakage dampers: Many commercial and industrial HVAC systems have "closed" dampers that are leaking 15 to 20 percent of their energy. New low-leakage damper designs result in significant energy savings at reasonable cost.

**3.** *Energy efficiency*

(a) Energy-efficient heating and cooling systems:

(i) high efficiency furnaces and other efficient heating systems (oil or gas, electric hybrid);

(ii) heat pumps - a conservation technology for space heating applications. The ability of heat pumps to make use of low-temperature heat increases the efficiency of electricity in space heating. Heat pumps are particularly cost effective in heating/air conditioning applications. They are also attracting interest for hot water heating and for a wide range of industrial processes in sectors as diverse as pulp and paper and food processing. (Industrial applications of heat pumps are examined in greater detail in Chapter Five.)

(iii) passive solar energy for space and water heating;

(iv) district heating - a technology which provides residential, commercial and industrial space heating from a central location. Required are a heat source and a distribution network.

(b) Energy-efficient lighting systems (see section on lighting later in this chapter);

(c) Energy-efficient appliances.

**4.** *Controls for efficient energy use*

(a) Control systems that deliver energy in the required amount, place and time can frequently reduce energy consumption. The trend towards integrated automatic controls is clear. In industrial processes and buildings, in the operation of commercial buildings, in residential appliances, space and hot water heating systems, and in all forms of transportation, control systems are being used increasingly to improve energy efficiency. Examples in large building systems include the following:

(i) *Zero energy band thermostats:* Many buildings use heating and cooling systems simultaneously. The zero energy band thermostat allows space temperatures to float within the comfort zone without using energy for heating or cooling. Separate heating and cooling set-points and separate throttling range adjustments can be provided for virtually any type of heating, ventilation and air conditioning (HVAC) system.

(ii) *Variable speed controls:* Modern electronic variable frequency alternative current and eddy current clutch drive systems are showing significant savings in both chiller and fan-drive systems. The savings come from reduced power consumption when the machine is operating at part load. Typical savings are 25 percent of power when a variable speed chiller control system operates a chiller at 50 percent load.

(iii) *Variable pitch airfoil fans* vary the airflow according to need, thus reducing energy demand when the system operates below maximum load.

(b) Efficient end-use electric load management for heating and other purposes.

(c) Energy storage for heating.

**5.** *Recovery of energy from waste heat and combustible waste materials*

(a) Heat exchangers are being used increasingly to recover energy from waste heat in the commercial and industrial sectors. The use of air-to-air heat exchangers in super-sealed buildings is likely to increase rapidly over the next 5 to 10 years. Other heat exchange technology trends include the greater use of heat pipes (evaporate/condense cycles) and the integration of heat exchangers with heat storage and upgrading (e.g., heat pump) systems.

(b) Controlled air incineration using domestic garbage as fuel for on-site disposal and high efficiency heat reclamation (e.g. CANWEL® - Canadian Water and Energy Loop). The concept uses off-the-shelf technology in an innovative way. Laboratory and pilot-plant scale development have been completed. A commercial prototype will be demonstrated in 1982. In a typical apartment building, a reduction in fuel consumption (by about 65 percent) for the production of hot water is expected. In addition, all of the fuel normally used to incinerate the garbage at a central plant, and more than 60 percent of the energy used to collect and transport the garbage are saved.

*Specific Technologies*
More detailed information is provided in this section on two technologies which offer significant opportunities for energy conservation in the building sector.

1. *Airtightness*
The two major causes of heat loss or gain in residences are the infiltration of outside air through many small openings and the conduction of heat through walls, windows, ceilings and floors. Air infiltration is the most significant of these. It has been demonstrated that 20 to 40 percent of the heat lost from an average residential dwelling is due to excessive air leakage. Further, it has been demonstrated that this air infiltration can be reduced by 50 percent on average, although this varies widely from house to house.

According to a U.S. study[2], houses in that country have infiltration rates in the order of one air change per hour (ac/h). In a house with a floor area of 1500 square feet and a ceiling height of 8 feet, this means that 200 cubic feet per minute of outside air must be heated. In the winter, this is done by the home heating system. Uncontrolled natural infiltration of outside air places an unnecessary load on the home heating system and causes uncomfortable drafts.

Several energy-conserving homes have been built in Sweden and Canada with natural infiltration rates as low as 0.2 ac/h. These low infiltration rates have been achieved by using tight-fitting windows and doors, and installing a plastic air/vapour barrier in ceilings, walls and floors. As a result, home heating costs have been reduced considerably. Indeed, energy-conserving homes built in Saskatchewan have shown drops in energy consumption, sufficient to reduce heating bills by 80 to 90 percent.[3]

In reducing the rate of air changes, it is important to recognize the potential for air quality problems associated with the large reduction in ventilation. These may include excessive humidity levels, migration of moisture into insulating material through cracks in walls, increased odours, and higher levels of chemical contaminants in the indoor air. The desired minimum number of air changes in residences cannot be generalized. Lasting odours can be due to the occupants (including pets), the amount of time a house is occupied, cooking and eating habits, the internal configuration of the residence, the use of certain construction materials, and even geological formations beneath the structure which can cause chemical contaminations. Thus it would be difficult to establish building codes to specify a standard ac/h rate which could also provide for the various factors which determine minimum acceptable air quality for a given dwelling.

One solution to the problems associated with airtightness is controlled forced ventilation, which can also incorporate heat exchange equipment to recover waste heat. Simple methods to ensure airtightness and to solve the problems associated with disposing of odours, toxic contaminants and moisture are known and the necessary equipment is becoming fairly standard and available "off-the-shelf". The challenge is to disseminate such technologies. This can open up industrial opportunities for Canada.

It may seem strange that one would bother to build a house that is virtually airtight, as it then becomes necessary to incorporate additional equipment to ensure that it is properly ventilated. However, a recent Canadian study[4] concluded that, for a 5 to 10 percent cost increase over current "typical" construction, a 60 to 85 percent reduction could be achieved in space heating requirements. At 1981 energy prices in eastern Canada, the payback period of the increased cost would be 5 to 7 years.

The success achieved in producing airtight housing will be affected by the initiative taken by tradespeople to exceed minimum standards and to adopt practices necessary to ensure airtightness in buildings. This is further complicated by the sequence in which construction tasks are performed, occasionally requiring a properly completed task to be partly undone by a person in a different trade. Accordingly, the knowledge and skill of those in the building trades need to be upgraded, and care and attention to energy conservation technologies must be developed.

Improved airtightness in existing buildings will result from eliminating the more obvious losses due to convection currents around windows, doors and vents. Even more can be done by retrofitting for airtightness and with controlled ventilation and heat recovery through heat-exchange systems, where economics warrant such action.

Due to the nature of restaurant operations, mechanical ventilation is necessary to expel cooking odours and the heat generated in ovens, grills, and fryers. This exhaust air can provide a source of "waste" heat for space heating and cooling.

If problems of odours, chemical contamination and moisture can be solved, airtightness technologies can have the potential to reduce substantially the energy used in Canadian buildings, and their development and dissemination can open up many industrial opportunities.

Interest in and support for airtightness is increasing, as evidenced by increased funding from the federal government and the interest shown by the Housing and Urban Development Association of Canada (HUDAC). However, the various government authorities have not as yet been able to agree on guidelines for appropriate levels of airtightness and for the associated problems. There is no agreement on the most suitable approaches to its implementation, and the best method for funding it on a wide scale.

2. *Lighting*

According to some experts, lighting accounts for the largest single energy load in a large commercial building. It can represent 40-50 percent of the electric consumption which, in turn, makes up approximately 80 percent of total energy costs.[5] Relatively little progress, however, has been made in reducing consumption through better control; i.e., using the right amount of light, where needed and when needed. Therefore, the potential for energy savings in commercial lighting is substantial.

Public Works Canada conducted an energy analysis of the Atmospheric Environment Service (AES) Building in Downsview, Ontario, in 1977. The study concluded

"that heating is responsible for the largest energy consumption and energy cost in the building. Lighting and fans are second and third, respectively, in use of energy and corresponding cost. Cooling, miscellaneous block loads . . . pumps and accessories represent only 11 percent of the total energy consumption and 20 percent of the total annual energy cost . . . 89 percent of the total energy consumption in the building is due to heating, lighting and fan systems . . .".[6]

The study showed that while the AES building had an annual consumption of 79 kw.h per sq. ft. of equivalent energy (gas heating, electric cooling), a reasonable level of energy consumption for that building would be 32 kw.h per sq. ft. per year, representing a potential reduction of approximately 60 percent.

Another finding was that lighting accounted for 27 percent of the cost of energy at a time when electricity was relatively more expensive than oil and gas than is the case today. The relative importance of lighting may be expected to increase as heating and cooling systems become more efficient.

Ontario Hydro regards street lighting as an area having great potential for energy savings. It is developing an "Energy Conservation Street Lighting Retrofit Program for Ontario" to reduce consumption and kw demand. The potential savings on the Ontario Hydro system are 400 million kw.h annually; a reduction in power demand of 100,000 kw.h could be achieved by adopting efficient street lighting.[7] A variety of improved types of street lighting have been developed and are in production (incandescent, tungsten halogen, mercury vapour, metal halide, high and low pressure sodium).

In Ontario new subdivisions are usually lighted with systems using high-efficiency components (generally mercury lamps are used). A number of demonstration programs using high and low pressure sodium lights have been carried out to test public acceptance and increase awareness of these high-efficiency lighting systems.

The high initial cost of improved street lighting systems acts as a deterrent to their installation. Studies have shown, however, that the improved systems generally have payback periods of 5 to 7 years, which will decrease as prices drop because of economies associated with production of standardized assemblies. Due to the lack of development and dissemination of energy-efficient lighting systems in the past, a large market exists for this technology.

The studies quoted above suggest that, in the commercial sector, lighting is a very important element in energy consumption and therefore an area of significant opportunity for energy conservation.

**Federal Government Support Programs**

The major federal programs and measures now in place to encourage energy savings in the building sector are described below:

**1.** *The Canadian Home Insulation Program (CHIP)* provides taxable grants of up to $500 to accelerate and extend the energy conservation retrofit of Canadian residences.

**2.** *The Canada Oil Substitution Program* (Super-CHIP component) provides taxable grants of up to $800 to accelerate the energy conservation and renewable energy retrofit of residences in Newfoundland, Prince Edward Island and the Territories.

**3.** The government is encouraging the implementation of energy-efficient housing by assisting in the training costs, information transfer and construction of approximately 250 demonstration homes across Canada.

**4.** Through the *Small Projects Fund*, the government is encouraging the implementation of energy conservation measures in the area of buildings and urban energy use by supporting workshops and seminars, pilot demonstration projects, publications, studies, etc.

**5.** *Energuide - Energy Consumption Labelling of Appliances*. This program increases consumer awareness of energy efficiency of major household appliances thereby inducing manufacturers to accelerate the introduction of energy-efficient appliances.

**6.** *The Ener$ave Program* provides advice to householders on the potential savings from energy conservation retrofit programs through the use of a computerized mail-in/mail-out information package, and a telephone advisory service (Heatline).

**7.** The government is assisting in the implementation of energy conservation measures in the commercial buildings sector. Voluntary conservation task forces have been formed to monitor programs and set conservation targets, to exchange information among building owners, operators and tenants, and to hold discussions with governments on energy conservation issues.

**8.** By means of a *Building Technology Support Program*, the government is involved in the acceleration and extension of the implementation of energy conservation measures in buildings through the preparation and provision of detailed technical and economic information on a comprehensive range of energy conservation technologies.

**9.** The presentation of *Low Energy Building Design Awards* increases awareness of building designers (architects and engineers) to the opportunities for energy conservation in commercial buildings by recognizing these efforts nationally.

In its deliberations, the Task Force judged that many federal programs do not satisfy the need of the end-users. This is sometimes due to a lack of knowledge that the programs exist. Specific details concerning a program's objectives, criteria for eligibility, means of application, and potential savings are frequently not known. If more consumers knew what savings could be realized, they would more readily adopt energy conservation technologies. The best means of achieving this is through marketing programs operated by experts in the strategies and methods for prompting people to action.

**Impediments to Dissemination**

While technologies to realize energy savings in the building sector are well known, in practice only a small portion of the potential saving has been achieved. There are numerous financial and institutional constraints that impede the adoption of effective energy conservation technologies. Addressing this problem, Charles Ficner (Chief, Buildings and Urban Policy, Energy, Mines and Resources Canada) writes:

"Major efforts are required: to establish conservation goals in the building sector; to ensure that these goals are supported by all levels of government, by all who are involved in the building design and operating process and by the public at large; to put in place appropriate programs for achieving these goals, both internationally and within individual countries; and to provide a solid technical support infrastructure which would allow conservation activities to be identified and implemented."[8]

The Task Force believes that many of the barriers to the dissemination of technologies can be overcome by the implementation of proper strategies and support mechanisms and by the offering of suitable financial incentives to builders and buyers. The major barriers identified by the Task Force are described below.

1. *Inadequate Information*

A recent major study by the Solar Energy Research Institute (SERI) noted that information about the technical performance and cost effectiveness of many energy-efficient products is inadequate.[9] The Institute also noted that there are not enough mechanisms to disseminate information about retrofitting techniques to building owners. A similar idea emerged from a 1981 conference sponsored by the International Energy Agency on "New Energy Conservation Technologies and Their Commercialization".[10]

There is no comprehensive, up-to-date, and reliable data base on the technical performance and the costs of available energy conservation technologies. In the building sector, this is largely responsible for the reluctance of owners, builders and developers to commit themselves to the expense of conservation investments out of fear that they may be ineffective, unsafe, or, if neither, too dear for the savings they yield.

**2.** *Lack of training and knowledge in design and construction*

With the notable exception of those being demonstrated in Saskatoon, relatively few homes are being built to a high standard of energy efficiency. Builders and their tradespeople have had little experience or training in the new techniques required to build energy-efficient homes. Many of these, such as vapour barrier installation or the prevention of air infiltration, require considerable skill and care. Many tradespeople do not have the knowledge or the incentive to make the effort required for such jobs. Also, a well-sealed home requires controlled ventilation using heat exchangers, but this technology, although available, is not well known throughout the industry. Furthermore, there is currently no mechanism for training personnel in the proper techniques of retrofit. Most institutions, such as community colleges, are hampered by outmoded apprenticeship programs geared to current building standards which are behind the "state of the art".

**3.** *Lack of co-ordinated regulations and standards*

The only reference to insulation in the 1980 National Building Code states that sufficient insulation must be used to prevent condensation. Alberta, where the cost of energy to the home-owner is least, is the province which has recently adopted the highest insulation standard. The other provinces are either well behind in their standards or have no standard at all.

There is great resistance, on the part of builders, to the setting of standards for energy-efficient home construction because of the higher price which must be asked for such homes and the resulting difficulty in selling them. The federal and provincial governments have drawn back from standard setting as shown by the fact that the moderate levels proposed by the Associate Committee of the National Building Code in 1978 were never adopted. As the acceptance of mandatory standards is difficult to achieve, an alternative method of realizing higher levels of energy efficiency is through greater demand by purchasers of homes. One way of achieving this would be by the identification of energy-efficient buildings - residential and commercial - according to a national measure of energy efficiency, along the line of the "Medallion Homes" which were so labelled by the Canadian Electrical Association. The Canada Mortgage and Housing Corporation (CMHC) or some other appropriate national body could perform the same functions with new homes.

**4.** *Heavy initial capital outlays*

Many buyers of new buildings or owners of existing buildings hesitate to invest in conservation technologies which require large capital outlays. Buyers who expect their stay in a dwelling to be short, say two to four years, are reluctant to make investments when interest rates are high and pay-back periods seem long. In situations such as these, investment in energy-saving technologies could be encouraged by means of financial incentives.

**5.** *Extra building costs*

Builders are reluctant to improve the energy efficiency of new homes because the extra conservation features required will increase the price of individual houses. By a recent policy change, however, lending institutions now include the extra cost of installing energy-efficient features in mortgage valuations rather than in the up-front charge to the home-owner. Builders are thus no longer forced to erect homes that are less energy efficient than a modest additional expense would make them.

The Solar Energy Research Institute's recent study noted that, although most energy conservation measures are warranted on cost/benefit grounds, because of institutional and market barriers there was a justification for using "well-designed and carefully monitored financial incentives . . . to speed the adoption of such energy conservation measures".[11]

**6.** *Rental Units*
There is a reluctance on the part of owners of rental accommodations, and their tenants, to make retrofits because the former generally bear the capital costs of such retrofits, but see the benefits of reduced operating costs accruing to the latter. Tenants in turn hesitate to make an investment which does not alter their rent and which they see as being of benefit to the owner who will enjoy a better property at their expense.

**7.** *Absence of reliable energy audit firms*
The problems associated with urea formaldehyde foam insulation and the unethical business practices of some operators who have taken advantage of home-owners by using the prospect of CHIP grants to induce the purchase of unreliable products and/or services have generated serious suspicions toward companies which advise home-owners about what to do in order to reduce energy consumption. As a result, the cause of conservation has been set back.

A recent regulation in the CHIP program is a requirement that all installers be listed with the Canadian General Standards Board. This should provide the consumer with some protection. Further protection could be provided by independent inspection of work done.

**8.** *Public utilities*
In cases where the demand for natural gas is not high enough to amortize the distribution system out of expected revenues from home-owners at approved existing and future rates, some utility companies have required developers of energy-efficient dwellings to provide money "up-front" before they will agree to provide service. While such a levy may be justified to amortize the costs of the natural gas utility - this question has not been examined - it runs counter to conservation and, as a result, to the adoption of energy conservation measures by builders and home-owners. Indeed, where such up-front charges on natural gas are levied, the area might be better served by other means.

**Conclusions**
In reviewing actions which might be taken to accelerate the adoption of energy-efficient technologies in the residential and commercial market, whether at the time of building or through retrofit, the Task Force concludes that appropriate financial incentives are needed to overcome the present reluctance of builders and buyers to invest in such technologies.

Financial incentives for residential and commercial buildings should be in the form of interest-free or low interest loans to assist builders and developers (in the case of new buildings) and owners (in the case of existing buildings) to offset the cost of implementing energy conservation technologies.

An example of what can be done in this area is provided by the Government of Saskatchewan which, in co-operation with the Saskatchewan Power Corporation and the Saskatchewan Housing Corporation, offers interest-free loans for construction of energy-efficient homes. The Home Energy Loan Program provides a $3,000 interest-free loan, repayable over 10 years, to the first owner/occupier of a newly constructed home which meets all the minimum technical standards of the program. The standards are projected to reduce the space heating requirements of the home by approximately 75 percent over that of a similar conventional home. The objective of the program is to encourage the construction and purchase of energy-efficient homes by offering an incentive which significantly decreases the short-term incremental cost of constructing or purchasing such a house.

Financial incentives will have to be made available for a period sufficient to demonstrate the advantages of adopting energy conservation technologies on a broad scale, to train designers, tradespeople, inspectors and operational personnel and to determine satisfactory performance levels for these technologies. It should be left to a later time to determine whether these performance levels should be incorporated ultimately into mandatory standards, recognized through a performance labelling system or merely serve as guidelines. It is essential, however, that buyers be made aware of the technical performance of conservation devices, that a building's energy performance statistics be made available, and that the advertised level of performance be certified. There is also an ongoing need for energy conservation materials to be tested and certified for safety as well as for effectiveness.

Adopting, and recording the performance of, energy conservation technologies in new buildings would, with time, make it possible to effectively predict the financial return of such technologies to the user. Where such technologies can lead to significant savings, programs financially assisting the demonstration of their benefits would encourage their widespread adoption.

In general, the knowledge and skill exists to evaluate energy conservation proposals for new commercial buildings. The major investment barrier is that the person who makes the investment is not the one who receives the benefits (with the exception of owner-occupied buildings). Product differentiation is not generally made on the basis of energy cost by the tenant, particularly with net, net, net leases where the tenant pays all costs. (Current energy costs are substantial in total dollars but as a percentage of business expenses they fall to below one percent and as a percentage of lease cost they are likely to show as less than three percent.)

By and large, the buying public does not know how to recognize an energy-efficient dwelling, nor is it even aware of the economic justification for energy efficiency. Saskatchewan is one province where this generalization does not hold true. An analysis of the programs that have resulted in public awareness of energy efficiency in that province should be undertaken before establishing programs for the promotion of energy conservation technologies in homes in the rest of Canada.

As was mentioned previously, difficulties have arisen over the disreputable tactics of some firms providing equipment and services promising a reduction in energy consumption. The availability of reliable, reputable businesses offering energy audit and diagnostic services, unassociated with contracting firms specializing in conservation, would help correct this situation. A few such firms have now begun to emerge. This trend should be encouraged.

As well, to increase public awareness of the benefits of energy conservation technologies, governments should ensure the availability, or subsidize the costs of, energy audit and diagnostic services for residential housing. Quebec and Ontario are providing audit services through electric utilities and it would be desirable to have the information gathered during such audits made available in a data bank for analysis and planning.

There are, however, some questions and difficulties associated with measuring energy efficiency with thermographic techniques and detecting air infiltration. The following observation points out some of these:

"As energy consciousness rises new equipment and companies are springing up to fill the void of experience and knowledge. However, as in any new field, opinion varies on exactly what constitutes a satisfactory home energy audit. Answers vary from a full battery of tests with highly sophisticated equipment to a more modest evaluation of the heating system, house constructions, and utility bills."[12]

Energy audit techniques are well developed. There are over 100 commercially packaged energy audit computer programs available. These programs, however, require certain assumptions and interpolation of known facts relating to energy use to be made in order to suit their inputs. This causes confusion in interpretation and application of the program and outputs. Frequently, the same computer program run by two different operators will have widely differing results (as much as a 30 percent deviation). Differences between one program and another are even larger, making it difficult to compare the results.

Furthermore, some persons knowledgeable in the field such as Chris Milne of Scanada Consultants Ltd. of Ottawa and Dr. D.G. Stephenson, coordinator of the energy program of the Division of Building Research of the National Research Council, believe that:

"The highly detailed results available with infiltrometers, thermography and gas decay techniques are better suited to research projects than to the air tightness needs of the homeowners.

"As well ... the multitude of variables that have to be considered in a computer analysis of the energy performance and retrofit needs of a specific house have not yet been mastered and further research is necessary before these programs can be expected to reflect reality. It's at this information gathering stage that infiltrometers, etc. can play a crucial role."[13]

A number of energy conservation technologies, processes and procedures are available to reduce energy consumption in the building sector. The question of which are most suitable depends on the type of building and whether it is new construction or an older building requiring retrofit.

The most promising technology for conserving energy in residential buildings is minimising the heating, ventilation and cooling loads by building airtight, well-insulated shells, either at the time of construction or through retrofit. Much has been done in Canada to increase the level of insulation in homes, but this is not true for efforts aimed at reducing air infiltration. Simple methods to ensure airtightness and to solve the problems associated with disposing of odours, toxic contaminants and moisture, while rejecting as little heat as possible in the process, are known and the necessary equipment is available "off-the-shelf". The challenge involves the dissemination of such technologies. This can open up industrial opportunities for Canada.

As more existing residences are retrofitted and new ones built to very high energy-efficiency standards, smaller heating, ventilation and air conditioning systems will be required, not only to ensure that buildings are energy efficient, but also that they are healthy for the occupants. The development, manufacture and marketing of such systems offer another attractive technological and commercial opportunity for Canadian industry.

Existing small commercial buildings have the same opportunities to improve energy efficiency as domestic residences, but more emphasis should be placed on automatic and integrated control systems, on the heating of water and on commercial equipment. In existing large buildings, the first focus should be on lighting, where most energy can be saved. Next in importance are the systems for the scheduling of heating, ventilation and air conditioning equipment.

For new large, commercial buildings, primary emphasis should be placed on lighting. Next in importance are the airtightness of the shell, cooling systems and heat reclamation techniques.

## Footnotes

## Chapter Three

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[11] Solar Energy Research Institute, *op. cit.* p. 107.

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# 4

# Energy Conservation Technologies for Transportation

## Energy Use in Transportation

In terms of energy consumption, the transportation sector accounts for approximately 31 percent of all energy used in Canada. The relative importance of the various sources of energy used in this sector is as follows:

*Table 4:1*

| Source | Percentage |
|---|---|
| Oil Products & Liquefied Petroleum Gases | 95.7 |
| Natural Gas | 3.9 |
| Electricity | 0.4 |

*Source:* Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada, 1980: IV.* pp. 4-5

As the above figures show, the most significant fact about the transportation sector's use of energy is its overwhelming dependence on petroleum, which meets 95 percent of all Canadian transportation needs. In a world where oil is very costly, and where suppliers can no longer be relied upon with confidence, those who depend heavily on foreign supplies of oil are extremely vulnerable.

Another important fact is that, as Table 4:2 shows, the automobile is by far the largest user of oil in Canadian transportation. It can be argued that we would not have an energy problem if it were not for the importance of the automobile in the life style of Western nations.

*Table 4:2*
*Energy Consumption Within the Transportation Sector, 1979*

| Mode | Percentage | |
|---|---|---|
| Automobiles (gasoline) | 48.2 | |
| Trucks and Buses (gasoline) | 20.6 | |
| Automobiles, Trucks and Buses (diesel) | 10.7 | |
| Total Road | | 79.5 |
| Marine | 7.7 | |
| Air | 7.6 | |
| Rail | 5.2 | |

*Source: Canada's Automobile Fuel Consumption Policies and Programs.* Energy, Mines and Resources Canada, October, 1981.

**Relative Energy Intensities**

Energy intensity is not to be confused with energy efficiency. *Energy intensity,* which has greater relevance to the transport of people than to that of freight, is related to the "load factor" - the percentage of capacity actually utilized. Load factor is determined by dividing the number of passenger-miles actually carried by available seat-miles. *Energy efficiency* is determined by energy consumption per ton-mile or passenger-mile at a given load factor, for a given stage length.

The opportunities for conserving energy, therefore, lie in improving not only energy efficiency but also in improving load factor. An improvement in either, even more in both, would reduce the energy intensity of any given mode.

Given the present pattern of use for the various types of passenger transport, the relative energy efficiencies of the various inter-city transportation modes are illustrated in the following table.

*Table 4:3*
*Energy Use in Inter-City Transportation*

| Vehicle | BTUs per Passenger Mile |
|---|---|
| Train (fully loaded, 120 mph, bus seat spacing) | 432 |
| Bus (fully loaded) | 520 |
| Train (fully loaded, 120 mph, wide seat spacing) | 650 |
| Small car (46 mpg, fully loaded) | 805 |
| Small car (46 mpg, 2 passengers) | 1,610 |
| STOL DASH 7 (315 mile trip) | 2,690 |
| Boeing 767 jet (315 mile trip) | 3,200 |

*Source:* Rail consumption figures taken from *Strategic Planning and the Railway Passenger Mode*, Canadian Institute of Guided Ground Transport, Queen's University, Kingston, Ontario. Bus consumption figures taken from Ata Khan, et al. *Intercity Passenger Transport Energy Efficiency: Data Base & Case Study*, prepared for Strategic Studies Branch, Transport Canada, 1979. Car consumption figures are a straight calculation. Boeing 767 consumption from presentation by C.H. Glenn to Science Council of Canada's Intercity Passenger Transport Conference, May 17/18, 1979. STOL consumption from *STOL and Short Haul Air Transportation in Canada*, Transport Canada, 1978.

In recent years, conflicting data and statistics have been produced comparing the relative energy efficiencies of different transportation modes. Given the complexity of the issues involved, this report cannot offer a clear resolution of these contradictory figures. The Task Force has accepted the accuracy of the data presented in this report.

**Energy Conservation in Transportation**

There are two basic methods of conserving energy in the transportation sector. One involves increasing the energy efficiency of all transportation modes. The other aims at encouraging the public to switch to transportation modes (e.g., trains, buses) which, if used on a massive scale, consume less energy in serving their purpose than do other modes (e.g., airplanes, automobiles). The successful application of both types of measures can contribute significantly to the reduction of energy consumption in this country.

## Automobiles

1. *Greater Efficiency*

Major opportunities for the conservation of energy in automobiles lie with newer aerodynamic designs, the use of lighter components such as high-strength, light alloy steels or aluminum, and improved engines/drive trains. Examples of the latter include:

(a) small diesel engines;
(b) multi-speed and continuously variable transmissions;
(c) electronic engine/transmission controls;
(d) multi-fuel engines or kits;
(e) improved accessory load characteristics.

One study suggests that the automobiles sold in the United States in the mid-to-late 1990s may average more than 50 mpg if consumers are willing to accept some change in vehicle size and performance. Average efficiencies could exceed 70 mpg if the public chose to purchase significantly smaller vehicles or if any of several promising new technologies find their way into the marketplace.[1]

Another study reaches similar, if not more dramatic conclusions. It describes a hypothetical fleet of light vehicles that have been redesigned to achieve much higher fuel economy. In such a fleet more than half

"would be four-passenger vehicles and would include a significant fraction of two-passenger cars. The power required at the drive wheels would be less than half that of present vehicles because of reductions in weight, in aerodynamic drag and in the rolling resistance of the tires. The vehicles would be powered by significantly more efficient versions of today's internal-combustion engines, with the transmissions and the peak power of the engines being optimized for fuel economy. All the technology required for such a highly efficient fleet exists today in production vehicles or in near-commercial prototypes."[2]

There already has been a substantial reduction in the weight of American automobiles and in the average size and power of their engines without any significant loss of useful interior space. Further major weight reductions could be achieved by replacing steel with aluminum, fiber-reinforced plastics and foam-filled structures.

"The ultimate weights that can be achieved by such substitutions will probably be close to 40 percent less than those that are being achieved in today's newly redesigned cars. The concern has sometimes been expressed that the savings in fuel that can be realized with lightweight materials might be offset by increases in the energy needed for their fabrication. This is not the case. Very roughly, a reduction of 1 percent in the weight of a passenger car can yield a reduction of .7 percent in the car's lifetime energy consumption. Since passenger cars today consume about 10 times their weight in fuel over a lifetime of 100,000 miles, a one-pound reduction in weight implies a fuel saving of about seven pounds. This is several times the penalty in manufacturing energy resulting from the substitution of lightweight materials."[3]

With the methodical application of such technologies, the energy intensity for the average car can be reduced substantially. However, there do not appear to be many significant opportunities for developing, disseminating, or marketing energy conservation technologies for Canadian industry in the important field of automobile transportation. The design and manufacturing control in the automobile industry rest with multi-national companies with headquarters outside this country. Therefore, the industrial opportunities for Canada depend on negotiations on production-sharing and world product mandate agreements with foreign manufacturers. These companies may have marketing plans that are not necessarily responsive to Canadian concerns.

**2.** *Control of Excessive Emissions and Fuel Consumption*

The Task Force examined a proposal to reduce excessive emissions and fuel consumption in motor vehicles currently in use by the implementation of an emissions inspection/maintenance program.

The federal government has had mandatory emission standards for new motor vehicles since 1971 and manufacturers have met these standards. Unfortunately, as most automobiles are poorly maintained by their owners, their pollutant emission rates and fuel consumption soon become excessive.

A large number of studies of automobile fleets in the United States and Canada have demonstrated that carburetor adjustment to minimize engine emissions of carbon monoxide and hydrocarbons results in improved fuel economy. Data compiled by Environment Canada summarizing several studies of the fuel economy benefits resulting from emission inspection and maintenance indicate that the average fleet benefit is 5.5 percent for urban use and 1.8 percent for highway, with a combined fuel economy of 4.4 percent. Based on current gasoline consumption, this would translate into a saving of 18,000 barrels of oil per day.

Two inspection and maintenance programs were run by the Centre for Energy Studies of the Technical University of Nova Scotia, in co-operation with the Mobile Sources Division of the Air Pollution Control Directorate, Environment Canada, in Halifax, Nova Scotia in August, 1979 and in Charlottetown, Prince Edward Island in July, 1980. The Nova Scotia test resulted in an average improvement in fuel economy of 2.7 mpg or 16.6 percent. In Prince Edward Island, the average improvement was 13.8 percent.

The level of improvement in fuel economy indicated in these two tests is higher than the 3 to 5 percent savings found in controlled laboratory testing. It is likely that the difference reflects factors in addition to carburetor adjustment. Important aspects of driving, such as correct tire pressure and avoidance of high speeds, were emphasized by the test personnel to the drivers during the test period. These could well have had a significant effect on the fuel economy for the period immediately following the test. If this was the case, the longer term improvement may well decrease.

Surveys conducted in Canada show that some 70-75 percent of vehicles do not meet manufacturers' specifications (largely owing to carburetor maladjustments). If one were to use a 70 percent capture ratio standard, then a total fleet fuel saving of over 3 percent could be realized. It should be noted that this number is based on laboratory tests and does not include larger savings obtained in field test programs. This 3 percent benefit must then be considered conservative. There is a good probability that a well managed inspection/maintenance program, incorporating some checks specific to fuel consumption (e.g., tire pressure), could yield a larger improvement in fleet fuel consumption.

In 1979, a Technical Advisory Committee, representing federal and provincial agencies and industry and consumer groups, was convened to review current research data and the concept of a proposed inspection program. The Committee's research indicated that most in-use vehicles are poorly tuned and that excessive emissions and fuel consumption are due primarily to carburetor maladjustment.

The Committee concluded that "the dual problems of excessive emissions and fuel consumption can be attacked most efficiently by implementing a motor vehicle emission inspection program *in specific metropolitan areas* while exempting areas with low population densities".[4] This program would be carried out in government-controlled inspection stations, although these can be operated by contractors. In contrast with certain existing programs which attempt to relate directly to new vehicle emission standards, this program should have the simpler goal of holding each vehicle very close to its design specification.

In some 1979 and 1980 model cars in Canada, controls on adjustments to the idle mixture were introduced, making the access to the mixture screws very difficult and thus reducing the probability of carburetor maladjustment. However, data from surveys of in-use vehicles indicate that even these control features are being tampered with and carburetors again are being maladjusted.

Should regulations requiring limitations to carburetor adjustment and the use of tamper-proof systems prove to be effective, the eventual requirement for in-use emission inspection programs would disappear. However, for those areas where specific problems can be solved by an inspection/maintenance program, it may be cost effective to implement a fleet-wide program for a four to six year period, at which time the bulk of distance travelled would be on vehicles equipped with new technology.

A vehicle inspection/maintenance program would not only offer substantial savings in the consumption of gasoline, it would also provide an entrepreneurial opportunity for the provision of services and the development of technologies associated with it. For instance, in New Zealand, the promotion of a government-sponsored "Exhaust Emission Analysis Programme" was aimed not only at consumers, but also at those involved in automobile repair. Free emission analyses were provided to motorists on selected dates in order to highlight the importance of peak engine performance in saving fuel. Mechanics and dealers were encouraged to offer these free tests, as they would provide them with opportunities for carrying out the engine tuning and maintenance indicated as being necessary by the emission analyses. In addition, the need for vacuum gauges, to be sold and installed by local dealers, would be promoted by the government's program.

Since immediate reductions in energy consumption can be substantial, the federal government should promote a program of public education and technical assistance on the proper maintenance of motor vehicles. Furthermore, as supposedly "tamper-proof" carburetion systems of automobiles coming on to the market are being maladjusted, regulations should be instituted to ensure that tamper-proof carburetors remain so.

### 3. *Diesel Engines*

Today's most efficient engine for transportation purposes is the diesel. The increased use of diesel engines would provide significant energy conservation opportunities for Canada and would also lessen this country's dependence on costly and insecure supplies of imported oil. If one looks at the thermal efficiency of an engine, that is, the efficiency with which the engine converts fuel energy into mechanical energy, a diesel engine is 37 percent thermal efficient, whereas a standard gasoline engine has a thermal efficiency of only 25 percent.

In the diesel engine, fuel is injected directly into the cylinder. This results in higher efficiency than that of "carbureted" engines in which fuel and air are mixed before being drawn into the cylinder.

Table 4:4 provides a forecast of the future for gasoline and diesel fuels for highway use in Canada.

*Table 4:4*
*A Highway Fuel Demand Forecast 1980-2000*

| | petajoules per year | | |
|---|---|---|---|
| | 1980 | 1990 | 2000 |
| Gasoline | 1340 | 1215 | 1115 |
| Highway Diesel | 220 | 400 | 605 |
| Total | 1560 | 1615 | 1720 |

*Note:* Forecasts for 1990 and 2000 are given as the mid point of a range of possible demand.

Highway diesel use in 1980 is estimated at 20.8 percent of gasoline use on a volumetric basis and 16.5 percent on a thermal equivalent (BTU or joule) basis.

*Source:* Energy, Mines and Resources Canada, based upon data provided at the 1980-81 National Energy Board hearings and the 1981 NEB publication *Canadian Energy Supply and Demand 1980-2000.*

The demand for gasoline is expected to decline by about 17 percent over the period 1980-2000. This will reflect the use of energy-conserving vehicles (which are in response to higher gasoline prices and fuel economy standards set at the vehicle manufacturing level), the dieselization of the fleet, and a modest penetration of the light vehicle fuel market by propane and compressed natural gas (CNG). The increased use of highway diesel from 17 percent of the highway transport fuel market in 1980 to 43 percent by the year 2000 is placing severe constraints on the ability of Canadian oil refineries to meet this demand and at the same time maintain product quality. Canadian refineries are examining various possible solutions to these problems. It is expected that middle distillates from tar sands synthetic crude will fill the gap in diesel fuel supply.[5]

The federal government should take advantage of the industrial opportunities afforded by the trends to increased use of diesel fuel in the transportation sector in North America. The establishment of an automotive diesel engine manufacturing plant in this country would have significant industrial development, employment and export potential. Such a development would give Canada more of a lever in implementing an optimum transportation fuel strategy as well as for negotiating improvements in engines to be marketed in Canada by other suppliers. At the present time, foreign-based companies have not satisfactorily addressed the particular needs of the Canadian market.

**Air**

Before the OPEC embargo of 1973, fuel represented about 10 percent of total operating expenses in the Canadian air industry. By 1980, this had increased to about 20 percent. It is expected that by 1985 fuel will represent about 30 percent of total operating expenses, reaching about 35 percent or more by 1990. These developments take into consideration that the air industry has already implemented many efficiency improvements in its operations (flight altitudes, procedures around airports, high density seating, etc.), and assumes some improvement in the efficiency of new airplanes.

Over the past fifteen years, Canadian mainline and regional carriers have reduced their energy consumption, in terms of revenue passenger-miles per gallon, by over 50 percent, with 30 percent of the improvement taking place since the start of the oil crisis in 1973.

The largest energy efficiency improvements in the air industry have come by increasing seating densities and load factors, through the retirement of many fuel-inefficient planes, and through energy conservation in day-to-day operations. Cooperation from Transport Canada has permitted planes to fly at more efficient altitudes, to make more "straight-in" approaches to airports, and to operate at cruising speeds giving the best fuel economy consistent with good flying characteristics.

Further performance improvements of 20 to 30 percent will come, of course, from the next generation of fuel-efficient airplanes. However, overall improvement will not likely exceed 10 to 15 percent as the fleets are a mixture of several generations of technology.

The next generation of aircraft ordered by the major airlines, which will not be flying in significant numbers before 1983-84, do not introduce major changes in technology. Airframes and wings will look something like those of today's airplanes and, with one or two exceptions, the engines used will merely be refined versions of today's types. The cost of designing a completely new airplane and engine is at present prohibitive and given the unhealthy state of the world's airline industry, it will likely be several years before we see the emergence of an airplane utilizing new airframe and engine technology.

Some more energy-efficient types of air transports may emerge in the next decade. Lighter-than-air machines are likely to come into use in the next ten years, although they are not likely to represent more than a minuscule percentage of the total air transportation capacity. The medium-to-long-range, high-speed prop-fan airplane may emerge as a competitor to the turbo fan-powered plane in the next decade, and the use of hypersonic transport for specific long-range applications, by the turn of the century, should not be ruled out.

However, as in the automobile industry, there do not appear to be many significant opportunities for the development and marketing of energy conservation technologies in the field of air transport as the design and manufacturing control of this industry does not reside in Canada. One notable exception is in the area of small, specialized aircraft and airplane engines, a case where thinking small is good for Canada.

**Public Transit**
The public transit sector, in which the Task Force includes intra-urban transit and inter-city bus and rail transportation, offers very important technological opportunities for Canadian industry, as well as significant potential for energy conservation. Considerable energy savings could be achieved in Canada by a shift from the use of other modes of transportation (especially automobiles) to public transit. As Tables 4:3 and 4:5 show, public bus and rail offer greater energy efficiency per passenger mile that do automobiles or air transportation.

Road vehicles account for almost 80 percent of the energy used in the transportation sector in Canada, which in 1978 totalled 243 million barrels of oil. For each one percent shift from the automobile to the public transit mode, there could be a saving of approximately 1.2 million barrels of oil annually. It is envisaged that adequate inter-modal public transportation facilities could attract as much as 10 percent of automobile users, resulting in a potential annual energy saving of 12 million barrels of oil.[6] Therefore, the acquisition and installation of new ground transit equipment and the provision of related services are well justified on energy conservation grounds.



1. *Urban Transit*
The majority of journeys in Canada take place in urban areas. It is therefore important in terms of energy conservation to note the relative efficiency of the different modes used in intra-urban transportation. The following table shows clearly that urban transit is more energy efficient than the private automobile.

*Table 4:5*
*Energy Use in Urban Transportation*

| Vehicle | BTUs per Passenger Mile |
|---|---|
| Subway or Light Rail Vehicle (200 people at peak periods) | 280 |
| Transit Bus (67 people at peak periods) | 460 |
| Subway or Light Rail Vehicle (100 people) | 560 |
| Transit Bus (41 people) | 750 |
| Small Car (36 mpg, 4 people) | 1,030 |
| Small Car (36 mpg, 1 person) | 4,130 |

*Source:* Transport 2000 Canada: Energy consumption of light rail and subway is 5 Kwh per car mile with the electricity generated thermally at 30 percent efficiency. Bus consumption is 5.5 bus miles per gallon of diesel. Car consumption is a straight calculation.

According to the Canadian Urban Transit Association, over 40 percent of the transportation sector's petroleum consumption and, therefore, about 20 percent of Canada's total petroleum consumption is the result of automobiles travelling in municipalities. Since some three quarters of Canada's urban population is also served by public transit, it is clear that public transit offers a significant opportunity to reduce energy consumption in this country.

Urban transit systems are effective where enough travellers exist and can be attracted. The Toronto and Montreal systems are already becoming saturated and the Edmonton and Calgary systems are reaching ridership levels well above forecast demand. The evidence is that well developed urban transit can move people out of automobiles and in this way contribute significantly to energy conservation.

Perhaps as important as the direct energy savings which would result from the increased use of urban transit are the indirect benefits from reduced traffic congestion, faster transit times and diminished demand for wider urban streets and more parking facilities.

Further advantages to an increased development of urban transit systems and technologies in Canada are the industrial opportunities afforded, both domestically and for export. Canada has been effective in the development of such systems and technologies and this initiative should be encouraged.

**2.** *Inter-city Bus*
Inter-city buses are used for long distance regular route service, for medium distance service in high density corridors, for short distance commuter or suburban operation, for airport service to and from downtown areas, for tour and charter operations, and for executive limousine service.

The increase in the number of passengers recorded in the United States over the past few years is an indication that fuel shortages and higher prices will encourage more people to use buses as a means of transportation between cities. Industry spokesmen expect the same development to occur in Canada.[7] As was pointed out in Tables 4:3 and 4:5, the inter-city bus is a very efficient mode of transportation. The increased use of buses, therefore, will contribute to a reduction in transportation energy consumption in this country.

In general, the inter-city bus industry shares common suppliers with manufacturers of heavy-duty trucks. Most of these suppliers are based in the United States. Therefore, the choice and supply of components available for use on inter-city buses is limited to those components used by the trucking industry. The use of these components in many cases involves tradeoffs in bus design and performance. However, with the slowdown in the U.S. heavy-duty truck market and the upsurge in bus construction, more supplier emphasis is now being placed on the inter-city bus industry, particularly in Canada.

With the increasing costs of fuel, bus manufacturers are now offering computer-matched engine/transmission/axle ratio packages that provide optimum performance. Efforts are being made to reduce overall vehicle weights by redesigning bus structures and employing lighter, stronger materials. Some small aerodynamic gains have been made through restyling. Accessory drives are being thoroughly reviewed to provide optimum efficiency when loaded, and to minimize power consumption when not in use. The use of radial tires by the majority of inter-city bus operators has resulted in significant fuel savings.

One of the major factors in improving bus fuel economy is in the use of turbo-charged diesel engines. Such engines are generally more fuel efficient than naturally-aspirated diesel engines, and run cooler, quieter and cleaner. It is quite likely that these will be the engines of the immediate future for inter-city buses.[8]

Even with the developments noted above, some experts argue that the bus has the least potential for technological improvement, in relative terms, among the other inter-city transportation modes.[9] (It was noted that the articulated bus for inter-city service was an exception to this statement.) Furthermore, the United States controls most of the inter-city bus market in North America. One consequence of this is that Canadian bus manufacturers must meet U.S. regulations, in addition to those found in Canada. Therefore, as is the case with automotive and air transportation modes, there do not seem to be many significant opportunities for Canadian industry to develop or disseminate energy conservation technologies in the field of inter-city bus transportation.

### 3. *Inter-city Rail*

There is potential in Canada for a major reduction in energy consumption through the increased use of inter-city passenger rail services. According to the 1980 annual report of VIA Rail Canada, the number of revenue passengers travelling on VIA trains in 1980 was 6.8 million, which is an increase of 41 percent over the combined number of passengers carried on CN and CP trains in 1976. The declining trend of rail passenger traffic thus appears to have been broken. However, much of VIA Rail's equipment is antiquated and expensive to operate. Of 1,184 units of locomotive and passenger equipment held by VIA Rail in 1981, 1,126 are more than 21 years old.

The phasing out of traditional trains and the introduction of modern, rapid passenger rail would conserve energy, provide superior transportation and generate considerable industrial activity in Canada. (The prospects of electrified rail systems seem particularly encouraging in the long-term; however, as the Task Force's mandate concerned technological opportunities in the immediate future, the examination of railroad electrification was not pursued.)

A recent study by the Canadian Institute of Guided Ground Transport (CIGGT) indicated that a modern, rapid rail passenger system on the Montreal-Toronto run could substantially reduce unit cost and provide an attractive and efficient alternative to automobile and air travel, provided it can be operated at a sufficiently high load factor.[10]

With an average speed of 47 mph the Ottawa-Toronto run carries only 4 percent of all traffic (8 percent of public carrier traffic), whereas the 67 mph Montreal-Toronto run captures 14 percent of traffic (24 percent of public carrier traffic). For all inter-city corridors, the CIGGT study predicted that a 120 mph rail service would capture 25 percent of existing air traffic and 10 percent of existing automobile traffic, at 1980 fuel prices.[11]

The Task Force does not necessarily agree with the findings of the CIGGT study as stated above. With 80 percent of the local passengers on the Montreal-Ottawa-Toronto corridor stating "business" as their reason for travel, it is unlikely that more than 10 percent of total air traffic would be diverted to rail, although this itself is not an insignificant number.

Inter-city rail passenger transit offers Canada one of the most promising industrial opportunities in the field of energy conservation. Canadian technological capability in the rail passenger vehicle field is well recognized outside the country. In world markets, it is accepted that Canada now has some of the best rail passenger vehicle design and production technology available in either North or South America.

Canada has developed its expertise in this field in two ways: through imported technology, modified to meet North American requirements and improved upon to eventually yield a distinctively Canadian product; and through innovative technology designed and developed in Canada.

Examples of this technological capability include:

(a) the LRC (light, rapid, comfortable) train, the most advanced high speed banking train in the world;
(b) the first fully automated intermediate capacity transit system (UTDC);
(c) major improvements in rubber-tired metro systems originally developed in Europe; and
(d) a production system using the most advanced North American manufacturing techniques.

As a result of the vehicle and systems expertise developed in Canada, and in particular because Canadian industry has greatly expanded its transit product range, the technological capability of Canadian component manufacturers is advancing rapidly.

To ensure that the mass transit industry has enough depth to compete successfully in international markets, Canadian component suppliers have been developed at the secondary and tertiary levels. As a result, Canadian companies now produce almost all the materials and components required in the manufacture of modern rail transportation systems. This new expertise is already being used to good effect. The LRC trains produced for VIA Rail have a Canadian content of about 95 percent. The metro vehicles being manufactured for Mexico will have a Canadian content of 80 percent.

Thus, Canadian rail passenger technology is sufficiently advanced to meet domestic and foreign needs. This capability stands in contrast to other passenger transport modes. Neither the automotive nor aviation sectors in Canada are capable of gaining a supply position equal to that which this country now holds in the international market for rail passenger equipment.

In the rail passenger sector, Canadian companies possess the technology needed for all aspects of systems design, manufacture and implementation and can put in service components ranging from power supply to automated ticket printers, and from rails to electronic monitoring and control systems. In effect, Canada can now meet all requirements for complex rail passenger systems.

In the most recent year for which figures are available, Canada exported 300 million dollars worth of such vehicles representing employment for about 6,000 people. If Canada could capture only one-third of the North American market for rail passenger equipment, ten thousand continuing jobs would be created directly in the manufacturing sector and this, in turn, would have a significant multiplier effect on the economy as a whole.

The growing acceptance of rail transit as an efficient means of moving people with less energy is encouraging the establishment of new rail systems, and the enlargement and re-equipping of others. Recent increases in energy and labour operating costs, and perhaps more importantly, the inevitability of future increases in energy prices, prompt a demand for new and improved types of rail passenger vehicle. As an example, main line, self-propelled rail coaches capable of providing energy-efficient and attractive service as independent units on non-electrified lines will be needed for operation in medium density traffic corridors. The vehicles currently used in such service are energy-inefficient and unattractive to travellers, and the only vehicles of equal capability available to replace them are produced in the United States. These are known as rail diesel coaches (RDCs). The potential North American market is about one billion dollars.

As approximately one third of the North American market for this product is in Canada, it is important that it be developed and produced in Canada. The Task Force believes that if the federal government were to underwrite half of the industrial development cost of a new rail diesel coach, the private sector would fund the other half.

**Governmental Constraints**
Competing jurisdiction over various modes of transportation by different levels of government in Canada offers an excellent example of the type of institutional barrier that makes it difficult to achieve a co-ordinated system which can take advantage of existing energy conservation technologies. Most urban transit systems are under municipal jurisdiction. Suburban and inter-city systems and most highways are the responsibility of the provinces. Long distance passenger systems (rail and air), with their fixed facilities in right-of-way and airports, are under federal jurisdiction. The entire

transportation problem cries out for a co-ordinating body to minimize conflicting policies, to encourage the public to use more energy-efficient modes of transportation, and to promote the purchase of appropriate transit equipment from Canadian manufacturers.

As a desired objective is to provide the best personal transit system at lowest energy cost, an inter-governmental organization should be established, under federal government auspices, to ensure that policies and programs are co-ordinated to encourage the public to switch transportation modes from automobiles to more energy-efficient means and to ensure that Canadian industry is, to the extent possible, the beneficiary of any new equipment purchases.



## Footnotes

## Chapter Four

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3 *Ibid.* p. 51

4 Environment Canada (Mobile Sources Division, Air Pollution Control Directorate) in consultation with Technical Advisory Committee on In-Use Motor Vehicle Emissions, *Control of Excessive Emissions and Fuel Consumption By In-Use Motor Vehicles*. January, 1981, p. ii

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6 Bombardier Inc., *Submission to the Federal Task Force on Energy Conservation Technologies*. October 6, 1981.

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9 Khan, Ata M., *Intercity Passenger Transportation: Energy Consumption Characteristics*. Paper prepared for the Science Council Committee on Opportunities in Canadian Transportation. Ottawa, November, 1980, p. 10.

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# 5

# Energy Conservation Technologies for Industry

## Technological Opportunities

The industrial sector of the economy accounts for approximately 32 percent of national energy use. The relative importance of the various sources of energy used in the industrial sector is as follows:

*Table 5:1*

| Source | Percentage |
|---|---|
| Natural Gas | 32.4 |
| Oil Products & Liquefied Petroleum Gases | 26.9 |
| Electricity (hydro & nuclear) | 25.9 |
| Coal & Coal Products | 12.7 |
| Steam (primarily nuclear) | 2.2 |

*Source:* Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1980:IV, pp. 4-5

Since energy was quite inexpensive and its supply apparently secure until the Middle East oil embargo of 1973, there was no strong call for industry to adopt conservation measures or to install energy-efficient equipment. In fact, from 1962 to 1972, the annual growth rate of energy consumption in Canadian industry averaged 4.9 percent.

A recent study observes a similar development in the United States where there has been "historic under-investment in industrial energy productivity because of public policies that have led industrial investors to place a lower value on energy productivity than they would have in a market environment free of distortion".[1]

Even when energy prices did begin to rise, conservation through retrofit remained very expensive. As oil moves towards world prices, therefore, the attractiveness of conservation in the industrial sector will grow apace. This is true even though Canadian industry, compared with other sectors of the economy, has used energy more efficiently in recent years. Surveys of some key industries, analysis of industrial conservation opportunities by industry and government, and an examination of the performance of certain companies indicate that, during the period from 1972 to the year 2000, an average efficiency improvement of approximately 50 percent could be achieved by Canadian industry.

As was pointed out in a presentation to the Task Force by Graham Armstrong of Energy, Mines and Resources Canada, efficiency improvements in industry come from three major sources:

(a) Improved operating and maintenance procedures, including low cost, short payback (less than one year) changes to existing plants. Energy savings potential from this type of initiative is estimated to be almost 15 percent in Canada.

(b) Retrofit of existing processes and systems requiring capital investments characterised by high costs and longer paybacks (1-6 years). These characteristics however, compare favourably with the economics of expanding traditional sources of energy supply. Energy savings potential for the whole industrial sector from this type of initiative is estimated to be around 25 percent in Canada.

(c) Development and implementation of new processes and systems of improved energy efficiency. Energy savings potential for the whole sector from this source is estimated to be about 10 percent over the 1972-2000 period."[2]

Most large, energy-intensive Canadian companies have taken advantage of their housekeeping opportunities and are now into the retrofitting phase of their energy conservation programs.

**Voluntary Industry Program for Energy Conservation**

A few years ago, the federal government recognized the need for an intensive energy conservation effort in the industrial sector. As a result, in May, 1975, the ministers of Energy, Mines and Resources and of Industry, Trade and Commerce convened a meeting of heads of major Canadian industries. The government had decided to encourage and support voluntary action on the part of industry, and to use market mechanisms rather than mandated programs, to deal with the problems associated with the need for conservation.

Following the May, 1975, meeting, a voluntary task force program for industrial energy conservation was set up. The Chairman of its Co-ordinating Committee, Carl Wolf, Jr., described the government's approach, and industry's reaction to it, in the following terms:

"A challenge was laid at industry's doorstep. Could industry voluntarily encourage and implement energy conservation? Could this sector of Canadian society properly manage its own energy affairs and by doing so, obviate the need for legislated programmes to assure energy restraint? Could Canadian industry assume a leadership role to demonstrate the impact of energy conservation to other sectors of Canadian society?

"The challenge was not only accepted but was welcomed by the assembled industry leaders. This cooperative and consultative approach by government on a national imperative was refreshing. Thus, a unique industry/government relationship and programme for voluntary energy conservation had its beginning."[3]

Industry proceeded to establish ten sector task forces, which have since grown to sixteen, to promote the objectives of this voluntary program for industrial energy conservation. Goals were set (for completion by 1980) for the reduction of the average amount of energy required to produce a given product. The performances of all industries have been compiled and, overall, they exceeded the target of 12 percent improved energy efficiency a year ahead of schedule. By year-end 1980, the actual average efficiency gain was 15.4 percent. Current estimates indicate that an improvement of similar magnitude could be realized between 1980 and 1985 and progress can be expected to continue into 1990.

Officials at Energy, Mines and Resources Canada calculate that the cumulative result of industry's energy conservation measures would improve efficiency in the order of 40 percent and reduce the average annual energy use growth rate by industry to about 2 percent between 1980-90. The resulting oil equivalent saving in 1990 would be around 600,000 barrels per day, or the production of 6.7 Syncrude tarsands plants,[4] compared with what would have been consumed had pre-1973 trends continued. Another measure of the impact of conservation is the fact that the capital required to build the Syncrude tarsands plant was 2.2 billion dollars. (In considering this figure, it should be borne in mind that construction began in the spring of 1978 and that costs have escalated considerably since then.)

As well, conservation increases Canada's security of energy supply by preserving non-renewable forms of energy for future needs. It also contributes to easing pressure on the capital market by not calling for funds that can be used for other purposes, and to reducing competition for scarce, highly qualified manpower, at a time when it is in great demand for other needs. Other benefits anticipated from the implementation of energy efficiency measures by industry include lower product prices, improved competitiveness in domestic and international markets, and more jobs.

The motivation for industrial firms to voluntarily commit themselves to a program of energy conservation is essentially twofold. First, it is good business to do so and, second, it avoids the lengthy consultations and onerous paper work associated with government-mandated programs to enforce and monitor industrial energy conservation. This suggests that what is needed is *not* more programs, but more efficient and effective administration, planning and co-ordination.

**Energy Conservation Technologies for Industry**

The number and diversity of companies within the industrial sector make it extremely difficult for them to agree on which technologies would be the most promising in terms of overall energy savings. The appropriateness of each technology to a particular set of needs will depend on whether the industrial plant is already in place and can only be retrofitted, or is being newly built, and it will depend as well on considerations of a regional nature. The Canadian Industry Energy Conservation Task Forces have identified a number of energy conservation projects which are currently either in the feasibility, engineering, or implementation stages.[5] Furthermore, the following list points out a number of technologies which have been brought to the attention of this Task Force as being the types of technologies and processes which can result in a reduction of energy consumption in the industrial sector.

*List of Technologies*

1. *Diagnostic technologies*

(a) For the identification of energy wastes;

(b) For energy audits.

2. *Energy generation*

(a) Low excess air industrial burners (e.g. Vortometric®). Compared with conventional burners, fuel savings of at least five percent are typical. Vortometric burners are used worldwide for process heating in refineries and marine applications using a wide variety of fuels. The technology is fully developed for conventional fuels but certain design modifications are required for use with unconventional fuels.

(b) Wetox® industrial liquid waste system. This technology is economically applicable for the treatment of wastes that are too concentrated for biological treatment and too dilute for incineration. The oxidation is autothermal and no external energy is necessary to heat the reactor. Excess energy can be recovered in the form of steam, hot water or boiler feedwater preheating.

**3.** *Controls*

(a) Monitoring devices for:
- (i) improved/cheaper mass and thermal flow meters;
- (ii) mechanisms for the control and balance of heat flows.

**4.** *Recovery of energy from waste heat and combustible materials*

(a) Technologies for the reclamation of heat from ventilation exhaust air of underground mines;

(b) Technologies for the recovery of steam from thermomechanical pulping by vapour recompression;

(c) Technologies for improved stack gas heat recovery from small boilers;

(d) Technologies for recovering condensate contaminated during use;

(e) Technologies for preheating of coking coal;

(f) Technologies for dry coke quenching;

(g) Technologies for preheating scrap to increase melting efficiency in basic oxygen furnaces;

(h) Technologies for preheating wood chips using waste gases;

(i) Organic Rankine Cycle (to re-use furnace and kiln exhaust gases);

(j) Technologies for use in energy cascading (described in greater detail in following section);

(k) Industrial cogeneration (described in greater detail in following section);

(l) Solving problems related to the use of heat exchangers in connection with:
- (i) corrosive and/or contaminated heat streams;
- (ii) wider operating ranges;
- (iii) improved efficiencies;
- (iv) reduced flow rates in basic oxygen furnaces.

(m) Heat pipes. This device consists of a sealed pipe containing a working fluid under its own vapour pressure. When one end of the heat pipe is exposed to a higher temperature, fluid in contact with the heated wall absorbs heat and evaporates. The vapour then flows to the cooler end where it releases heat as it condenses. The heat pipe's effectiveness in heat transfer makes it attractive for heat recovery systems and energy conversion processes. Applications include the recovery of heat from restaurant kitchen exhausts for space heating or absorption air conditioning, in coal gasification, and in reducing exhaust emissions from gasoline engines.

(n) Heat pumps (described in greater detail in following section).

**5.** *Substitution of low energy processes*

(a) Filtration (for evaporation);

(b) Membrane technology employed in chlor-alkali processes;

(c) Reverse osmosis (described in greater detail in following section).

*Specific Technologies*

Among the technologies and processes examined by the Task Force, the following have been identified as having significant potential and are described in some detail: *energy cascading*, *industrial cogeneration*, *heat pumps* and *reverse osmosis*. It should be kept in mind, however, that they are described for illustrative purposes only, to show that a great deal can be done to reduce energy consumption using existing technologies, if they were methodically exploited and disseminated. (While energy cascading and industrial cogeneration have potential for application in the near term, further developmental work is required before heat pumps and reverse osmosis make substantial contributions in large-scale industrial plants.)

1. *Energy Cascading*
Energy cascading in the industrial sector can be described as organizing the flow of energy through the various thermal systems, production processes and equipment within a plant operation, in a sequence which will allow the achievement of maximum efficiency throughout the total process. Degraded heat from one operation becomes a useful input to the next, and so on to those operations which follow, until the residual energy is so degraded that it has become useless. The key to cascading is to match the form and quality of energy to the actual energy requirement to ensure that it is used in a sequence where the decreased quality is always sufficiently high to meet the needs of the operation to which it is applied.

Most industrial processes lose large amounts of heat to the environment as a by-product of plant operations. Lost heat can range in temperature from 30°C, for water used in general industrial cooling processes, to as high as 1100°C, for exhaust gases in some furnace and kiln operations.

Conventional practice often leads to high quality primary energy inputs being used to perform all tasks, even though most energy requirements are for heat at temperatures well below that of the flame of fossil fuels or of the maximum potential of electricity. This suggests that some of these tasks could be performed by lower quality energy, including heat recovered from waste heat streams.

The energy cascading technique is usually limited to heat which can be transmitted with relative ease from one place to another or stored at intermediate points. The proximity and sequence of industrial equipment and processes, as well as the method of transporting waste heat recovered from one task for use in another requiring lower grade heat, become key factors in the design of the industrial plant. As well, energy which can no longer be used within the industrial plant may still be useful beyond the plant: an obvious example is district heating for commercial buildings, housing developments, or greenhouses.

A number of such agriculture and aquaculture demonstration projects are either in place in Ontario or are being planned. A report issued by the Ontario Ministry of Energy says:

"For example, reject warm water from the Bruce Nuclear complex will be used for greenhouse heating and for improving the productivity of commercial fish-raising through aquaculture, a method in which water held at a selected temperature can increase the normal growth rates of certain species of fish by two or three times. In preparation, a demonstration greenhouse is now operating near Kincardine using a conventional heat source. A similar but smaller demonstration greenhouse is also being operated by Ontario Hydro at the Pickering Nuclear Station.

"In addition to the Bruce and Pickering AgriPark projects, Texaco Canada in cooperation with the University of Guelph has announced plans to develop a greenhouse complex adjacent to its Nanticoke refinery. TransCanada PipeLines, in cooperation with Northern College of Applied Arts and Technology, is experimenting with the use of exhaust gas from their compressor station at Ramore (near Kirkland Lake) for greenhouse vegetable production. And INCO is using heated mine exhaust air in an underground, artificially lighted greenhouse. Since 80 percent of salad greens, tomatoes, and cucumbers consumed are imported, these projects have obvious agricultural benefits beyond improving efficiency."[6]

It is estimated that the main energy-consuming Canadian industries - logging, mining, manufacturing, and baseload thermal-electric power - used 2,878 trillion BTU of energy in 1976, 45 percent or 1,257 trillion BTU of which were lost into the environment in the form of gaseous and liquid waste heat streams. Analysis of this lost waste heat shows that, technically, using existing energy cascading equipment and techniques, 355 trillion BTU, or the equivalent of approximately 60 million barrels of oil per year - the production of 1.8 Syncrude tarsands plants - were recoverable.

While various types of equipment and techniques - such as heat exchangers, cogeneration, and central heating systems - are fairly well developed and used by industry, almost no attempt has been made so far to develop the technique of energy cascading to its full potential. This applies not only to in-plant use, but to the transfer of heat beyond plant boundaries to other industrial operations, or for uses such as district heating, and for agriculture and aquaculture.

Institutional obstacles, such as legislation, regulations, standards, practices and attitudes, may have to be dealt with during the planning and implementation of energy cascading systems, particularly when inter-plant and inter-sector energy transfers are required. Legal questions, involving the entitlements and responsibilities of each participant, must be dealt with clearly.

The realization of the full potential of waste heat recovery depends in large part on the inter-sector transfer of industrial waste heat to district heating and similar systems, which together could absorb almost 70 percent of the total recovery potential. Such a level of recovery could be accomplished using currently available equipment. Temperature levels of 100°C and below can presently only be used extensively if large-scale district heating or similar systems are located near the waste heat source. Yet in many plants substantial amounts of water effluent streams exist in the 60°C to 80°C temperature range - far more than is required for the present in-house applications of space heating and boiler feed make-up.

The full implementation of the cascading concept would require the development of integrated energy systems, to be matched to the process and operating characteristics of a particular plant operation, or to other nearby industrial plants, or to users in other sectors. Such implementation can be achieved by retrofit, but is most effective and economical when planned into the plant design and location decisions of new operations at the very outset.

Industries have two choices in achieving more energy-efficient operations. They can either:

(a) invest in new, more energy-efficient processes and equipment, thus eliminating large waste heat flows; or
(b) develop or purchase equipment for the recovery of waste heat and other waste energy for their existing processes.

The choice depends on factors such as the type of industry, the age of the facility, the availability of capital, and the energy intensiveness of the production process. Where expansion or modernization of production facilities are involved, the primary objective will be to eliminate the production of unnecessary heat through the introduction of new technology. Only where the production of unnecessary heat cannot be avoided will waste heat recovery become a concern. For example, in the steel industry, the energy-intensive open-hearth furnace has been replaced by the Basic Oxygen Furnace (BOF) which requires no fossil fuels. Similarly, billet casting operations are being replaced by continuous casting methods. With continuous casting, inefficient soaking pits can be replaced with induction heating, requiring less energy and producing very little waste heat. Therefore, in the case of steel mills, it is preferable not to invest in soaking pit recuperators, if they can be replaced by the new BOF technology. In this situation, waste heat recovery projects are considered to be a transitional solution requiring a high rate of return on investment and are used pending the adoption of more energy-efficient equipment and processes.

**2.** *Industrial Cogeneration*
Cogeneration is the sequential use of energy to simultaneously produce (a) either electricity or shaft power and (b) usable process heat. The usable process heat can be in the form of hot gases for drying purposes, or in the form of steam.

Cogeneration (or, as it is called in Europe, combined heat and power) attempts to achieve maximum energy efficiency, usually in industrial processes, as compared with achieving maximum electrical efficiency. While the efficiency of the electricity (or shaft power) generation cycle is reduced, that of the overall thermal cycle is increased by about 10 percent. One megawatt (MW) of total power output from cogeneration operating with a typical load factor of 75 percent would save in excess of 6,000 barrels of oil, or its equivalent, a year.

A study prepared for Energy, Mines and Resources Canada[7], based on results obtained for 1977, estimated that the total technical potential for cogeneration in Canada was in the order of 4,200 MW, of which 1,200 MW had already been developed. Thus, that year, cogeneration saved the equivalent of 7,200,000 barrels of oil - the production of 0.2 Syncrude tarsands plants - and, potentially, the equivalent of an additional 18,000,000 barrels of oil was available for recovery - or 0.5 Syncrude tarsands plants.

The rank order of the total technical potential of the provinces and industries is as follows:

| | |
|---|---|
| Ontario | 1,447 MW |
| British Columbia | 891 MW |
| Alberta | 776 MW |
| Quebec | 694 MW |
| Nova Scotia | 174 MW |
| Others | 292 MW |

| | |
|---|---|
| Pulp & Paper | 1,902 MW |
| Refineries | 958 MW |
| Chemicals | 604 MW |
| Food & Beverages | 196 MW |
| Manufacturing | 192 MW |
| Others | 422 MW |

With present technologies and processes, however, not all of this waste heat can be recovered economically.

Energy for cogeneration can be supplied from virtually any source. This is particularly advantageous where it is available from wastes or by-products, e.g., forest or agriculture wastes, or municipal garbage. In fact, wood wastes are currently being utilized for cogeneration by the pulp and paper industry. In the steel industry, energy can be recaptured from by-product gases.

In Germany, which has direct access to coal and an active nuclear program, 28 percent of the country's total electrical generation is provided by industrial users through cogeneration. In Canada, by contrast, only 3 percent is provided by industrial users. Industrial cogeneration was in wide use in Germany well before the Second World War owing, it would appear, to a weak and unreliable central government between World War I and the takeover of the country by Hitler. During this period much of the country's vast industrial base was built up and individual companies had to plan for energy self-reliance. When World War II ended, the technology was known and continued to be used, or was enlarged as a matter of course. In Canada, by contrast, energy for industrial purposes was available since the beginning of the century in the form of cheap electricity from private or public utilities and, as a result, there did not appear to be a problem for which cogeneration was a solution.

With the enormous increase in the price of oil since 1973-74, combined with diminishing, as well as insecure, supplies, the importance of conservation by every means possible is now generally recognized and accepted. Accordingly, cogeneration has become a good deal more attractive as an energy conservation system whose economic and energy security benefits to Canada as a whole, were it to be widely adopted, would well exceed any financial advantages it might yield solely to private sector users. These benefits would arise from a decrease in the need for hydrocarbon fuels, a consideration of great importance in a country which is excessively dependent on costly offshore oil. Thus, cogeneration, which already benefits the nation to the extent that its potential has been exploited in some areas, could do so even more by increasing the security of oil supply, easing the burden of international payments and creating opportunities in the Canadian manufacturing sector for the production of the technologies needed. The opportunity here lies not so much in developing new technologies - those required are, by and large, already known - but in producing them on a larger scale, in getting them adopted domestically and, eventually, in exporting them. Since the country as a whole stands to benefit, stronger government involvement is fully justified to stimulate extensive use of industrial cogeneration.

The barriers to the widespread adoption of cogeneration are essentially institutional, i.e., non-technical, and they arise mostly from the regulatory and negotiated relationship between the industrial "cogenerator" and the electrical utility. These barriers will be examined below. Suffice it to note here that the potential for cogeneration is enhanced when electrical power can be exchanged unimpeded between cogenerator and utility. Typically, at maximum potential, a "cogenerator" will have excess electrical energy available for sale to a utility or other user. For this excess to be purchased and transmitted, firm prior agreements are needed. The interface between industry and utility is complicated not only by certain regulations but also by their different objectives.

Some provincial utilities, in particular those of Ontario, Manitoba, and British Columbia, have recently revised their policy for purchasing electricity. They have also dropped pricing policies under which plants with cogeneration capacity would have been required to offer the utility a premium price, or insurance, for standby electricity in case of excess demand or because of plant cogeneration failure.

Economics are still the major determining factor in the adoption of cogeneration. Of all the barriers to be removed, the major one, insofar as industry decision makers are concerned, is the rate of return of the cogeneration investment. As the generation of electricity is usually foreign to the main purpose of an industry, and since there are other ventures which compete with it for funds, industry will not develop cogeneration projects unless their rate of return is at least equal to that available from competing investment opportunities. As well, the private sector may be reluctant to make capital investments for cogeneration in plants where electricity demand has been reduced by the introduction of other methods of energy conservation.

Each industrial plant has its own specific requirements for steam and electricity. Because of variations in operating conditions, or because of low requirements for process energy, many plants are not suited for industrial cogeneration. Plants which are technically the best suited for cogeneration are those with a high load factor for both steam and electricity. These include plants for pulp and paper, smelting and petroleum refining. However, while excess electricity could always be sold to a public utility, there would normally be no point in cogeneration at times when process heat is not needed, since such heat would simply be wasted.

As an incentive to increase the application of cogeneration, the federal government now allows an accelerated tax write-off on a straight line basis over two years for cogeneration capital equipment (Class 34, Schedule II of the Income Tax Act). In addition, various grants are available from the federal and many provincial governments to encourage better utilization of wastes as an energy source and to encourage substitution of other fuels for oil.

Cogeneration equipment is well developed, produced in Canada, and easily available. Despite these facts, however, there remains a largely untapped domestic market for it, as the figures quoted earlier would suggest. High pressure steam boilers, which are used extensively throughout industry, and steam turbines, which are commonly used by electric utilities, are cases in point and they are manufactured in Canada. It is therefore clear that increasing the adoption and use of cogeneration is not held back by a lack of technological capability. Since that capability is not being fully exploited, however, there is an important industrial opportunity for the firms manufacturing cogeneration equipment. The challenge is in capitalizing on this opportunity.

As was mentioned above, when cogeneration is intended to supply a number of users, the major obstacle to its implementation arises from institutional problems. To illustrate, there are situations where an industry can have a source of fuel which is now considered waste, such as sawdust and shavings from a sawmill. Heat and electricity, which would not be considered "excess" from such "waste" fuel, could be supplied to adjacent industries or to nearby towns. However, it has happened that such an easy and economical method of using waste fuel was not adopted because of the reluctance of those involved to invest in, and operate, cogeneration systems.

Today, it is conceivable to view the establishment of cogeneration facilities, associated with an industrial or commercial complex, as an extension of the public utilities' recognized role of providing electrical power. If they were treated as such, these cogeneration facilities could be financed at the lower rates now enjoyed by the utilities. This would provide a strong stimulus to the increased production of cogeneration equipment by creating a market for its dissemination. However, most provinces do not at present have institutions (such as the Ontario Energy Corporation) which, if given the necessary authority and borrowing powers, could see to the establishment of cogeneration facilities, where appropriate. As for utilities, they have not, in general, been active in promoting cogeneration. Their mandate under the law does not always encourage or authorize them to do so, because of the difficulty of incorporating cogeneration opportunities into long-term planning of energy-generating capacity, current over-capacity in some cases, and because of their legal obligation to provide the most reliable and economic service to all customers. (It should, however, be noted that Hydro-Québec is seriously considering offering capital at low utility financing rates for, and perhaps to participate in, such cogeneration.)

### 3. *Heat Pumps*

A heat pump has been defined as

"A thermodynamic refrigeration cycle machine which moves heat from a low temperature source to a higher temperature sink by the addition of work. When low temperatures are desired, as in air-conditioning or refrigeration, the heat pump removes unwanted heat and expels it to a higher temperature sink (such as warm outside air or water). When high temperature heating applications are desired, the heat pump supplies this energy by drawing it from a low temperature source. Thus, there is little difference between a refrigerator and heat pump; the difference is entirely in the purpose of the process."[8]

The majority of the heat pumps currently in use are refrigeration cycle machines which typically use liquid-vapor refrigerant as the working fluid in a vapor-compression cycle driven by an electric motor.

The potential for heat pumps as energy-saving devices in the industrial, commercial and residential sectors is enormous. In heat pump applications, the heat output is the sum of that heat extracted from the lower temperature source plus the energy added to the heat pump system. Therefore, the total heat output will always be greater than the energy required to run the device and, thus, the coefficient of performance (COP), which is the ratio of heat output to the energy added, will always be greater than one.

Heat pumps provide the only means of upgrading stored thermal energy in a system. Possible applications are numerous and no attempt has yet been made to draw up an inventory of them. In many applications, including most residential and commercial uses, the same machine may at one time operate as an air conditioner and at another time as a heater. In some industrial applications, the heat pump may be used for cooling at one temperature level and simultaneously for heating at another temperature. For instance, in breweries, heat pumps could be used to remove heat from the fermentation vats and "pump" this heat to increase the temperature of water to be used elsewhere in the facility. In large commercial buildings heat pumps have been used to "pump" heat from the warm side of the building (sun load or internal heat generation) to the cooler side of the building.

Other examples of heat pump applications are: the drying of paper, one of the most energy-intensive processes in industry; boiling applications, where the exhaust steam can be recompressed and reinjected in the process at a higher temperature; recovering solvents by direct pumping of the vapour; drying hardwood lumber to reduce loss due to warpage, cracking, etc., and to reduce the length of time lumber remains at a process plant; the drying of brick and ceramics; as well as in food and milk evaporation and concentrating solution such as sugar and alcoholic beverages.

With the exception of some installations to dry hardwood, virtually no heat pumps are presently operating in the process industries in Canada. This is thought to be due to the poor economics traditionally associated with heat pump installations. Nearly all industrial production requires process heat, and about half of the energy used in Canadian industry is required at temperatures below 200°C. The use of heat pumps shows considerable promise for supplying process steam or hot water using a low temperature source of heat which is currently being lost, sometimes at considerable expense. In many plants, there are substantial amounts of water effluent in streams within the 60°C to 80°C temperature range, whose present in-house applications are space heating or, for limited use, as boiler feed make-up water.

The present line of industrial heat pumps on the market is designed to recover heat from, and transport it to, liquid streams only. The highest operating temperature that can be achieved with this type of heat pump is 104°C. This temperature limit is quite restricting as it is just below the temperature for raising low pressure process steam at 121°C and 15 psig. The development of an industrial-scale heat pump capable of raising the temperature of water beyond its boiling point (to 120°C or 130°C) could provide enormous benefits by upgrading this virtually wasted energy source to low pressure steam for process use with comparatively little additional energy.

Technical difficulties holding back the development of such heat pumps and associated equipment are: developing or finding a suitable refrigerant which will not have a chemically degrading effect over a long period of time at the proposed operating temperatures; developing bearing seals inert to the refrigerant; and designing the associated heat exchange steam-generating equipment. Also, the maximum size heat pump which is commercially available is 100 ton (approximately 1.2 million kj/h or 400 kw). This means that multiple units would be needed for many industrial applications. Provision of space for the required number of units makes the proposal uneconomical.

The greatest disadvantage of the system most widely used to operate a heat pump, the electric vapor-compression refrigeration system, is the expenditure of high quality energy/electricity. The elimination of this source of work is largely responsible for the perceived economic success of various chemical absorption and absorption-vapor refrigeration systems in commercial use. These systems can use, as a work source, any relatively low grade heat energy, such as waste steam.

As an energy conservation technique, absorption-type refrigeration is attractive where a source of waste heat is available and where there is a need for cooling or air conditioning. Examples would be in the food and meat processing industry or in commercial establishments where exhaust waste heat could be used as a source of space heat during the winter and an energy source for air conditioning during the summer.

In the United States, a variety of absorption-type processes which could be operated using low-grade heat are under study, principally by the U.S. Department of Energy and the Sandia Laboratories.

Apparently, the only research presently carried out in Canada on absorption technology is being performed on a limited scale by the National Research Council (NRC). A bench-scale demonstration of an ammonia-water process is planned which could provide refrigeration on-board fishing trawlers by using the ship's diesel exhaust as the heat source.

Apart from the development of these "second-generation" heat pumps capable of generating a higher temperature product, or those capable of using low-grade heat as the driving source, many problems associated with the existing technology have tended to discourage more extensive application. For example, air-to-air heat pumps for use in residential heating have a number of problems associated with them: one is that when the outdoor temperature falls below approximately 45°F, the outdoor coil temperature is generally below freezing and frost accumulates on it. Most heat pumps defrost the outdoor coil by reversing the cycle temporarily (2 to 10 minutes) to provide warm refrigerant to the outdoor coil to melt the frost. Depending on the outdoor temperature, reversing-cycle defrost may add between 5 and 10 percent to the annual energy cost of the heat pump.

In addition to the NRC's limited investigations into more advanced heat pump technology, a number of demonstrations are planned under their "Industrial Heat Pump Program". The objectives are to demonstrate the capabilities of currently available equipment and provide useful operating experience by having full scale equipment installed and operated on a number of typical industrial processes producing edible oils, pulp and paper, dairy products, lead and silver, and for use in poultry processing.

**4.** *Reverse Osmosis*

When two solutions at unequal concentrations but at equal pressure are separated by a semi-permeable membrane, solvent will pass from the more dilute to the more concentrated solution by osmosis. If sufficient pressure is applied to the more concentrated solution, the solvent flows in the opposite direction, giving rise to reverse osmosis. Using this process, it is possible to concentrate a desired product or to remove selected contaminants from a solution. While osmosis has been known for over a hundred years, the reverse flow was neglected because of the lack of semi-permeable membranes which are sufficiently strong to withstand the "reversing" pressures required.

Reverse osmosis emerged as a technology with practical applications as a result of the development, in the early 1960s, of a synthetic cellulose acetate membrane by S. Loeb and S. Sourirajan at the Los Angeles campus of the University of California. The characteristics of this membrane allowed it to be pressurized and to let water (as a solvent) pass much more readily than dissolved solutes. Dr. Sourirajan is now doing research on membrane technology, on a limited scale, at the National Research Council.

The standard methods for separating industrial and commercial products have been either distillation, multiple-stage evaporation, or freezing, all of which are capital- and energy-intensive processes. The thermal energy needed to distill water in the best multi-stage distillation plant (where process heat is re-used in up to 40 stages) is about ten times that of reverse osmosis. Since reverse osmosis technology is at a very early stage of development as compared with the standard mature methods of separation, this tenfold difference is likely to increase substantially. In avoiding distillation, a significant amount of energy is thereby saved, thus making reverse osmosis very attractive from a conservation viewpoint.

The first commercial application of this newly found technology was in the production of potable water from salt water and brackish water. Since then the application of reverse osmosis in water desalination has grown rapidly, as shown by estimates that, by 1985, the Middle East could have a total of 47.5 million gallons per day (g/d) actual reverse osmosis capacity. Industrial applications of reverse osmosis include the preparation of ultrapure water in the production of pharmaceuticals, semi-conductors and electric power. In the semi-conductor industry, high-purity washing is used, after etching and other processing steps, to remove contaminants which would otherwise shorten the life of manufactured components.

Under the present cost of operation, reverse osmosis is competitive with distillation for the production of high quality boiler feedwater used in thermal electric power generation. The penetration of reverse osmosis in this market has been proceeding rapidly in many countries, including the United States. In northern England, an installation provides one million g/d boiler feedwater for an oil refinery and a plant of 2.5 million g/d has been installed in a Dutch brewery. Other applications are plant water recovery in the automobile industry, recycling distillery waste water, recovery of soda liquids and sulphates, treating of pulp and paper effluent, producing purified cooling water for steel plants (4 million g/d in Japan) and in the tanning, pickling and fertilizer industries. One of the largest, single reverse osmosis plants is a Soviet one providing 3.3 million g/d of purified water for steam injection in oil wells near the Caspian Sea.

In addition to existing applications, a number of near commercial or experimental uses are being developed, such as in sewage treatment, various forms of pollution control, separation in food processing, and in the separation of products such as alcohol from water.

Since about 1965, cumulative investment in membranes for reverse osmosis has amounted to around $400 million, while investment in related system parts exceeds $2 billion. New annual investments are currently $200 million and $1 billion, respectively. It is expected that the present market growth rate will accelerate over the next decade. The driving force for this high growth rate in the use of reverse osmosis technology is energy conservation, although it has important pollution prevention applications as well.

A company in the United States has recently won the 1981 Kirkpatrick Chemical Engineering Achievement award for an effort related to reverse osmosis. According to an article in *Chemical Engineering*, this distinction was for "efforts in introducing an ingenious hollow-fibre system that, for the first time, allows the practical use of permeable membranes for large-scale gas separations".

The company claims that this new "Prism" separator is particularly suited to the splitting off of such fast-permeating gases as hydrogen and/or carbon dioxide and promises to have a major impact in diverse areas ranging from ammonia and petrochemical processes to tertiary oil-recovery operations. While other more conventional processes for gas separations such as cryogenic systems, pressure-swing absorption and absorption in liquids are relatively energy-intensive, the new reverse osmosis process uses very little energy. This technique is possible because the differential pressure which provides the driving force for the separation is almost always available since the feed gases are usually already under adequate pressure.

Apart from the commercial prospects for the process, its contribution as an energy conservation technology is enormous when one considers that in the U.S. alone it is expected that 500 billion standard cubic feet per year of hydrogen will be produced using this process. The low-energy production of carbon dioxide is even more staggering when we consider that some 15 to 30 billion barrels of potentially recoverable oil (appropriate for tertiary recovery using carbon dioxide) lie in U.S. fields. Injections of 5,000 to 12,000 standard cubic feet of carbon dioxide are required per barrel of oil recovered. It is interesting to note that the NRC has been separating hydrocarbon gases and liquids by reverse osmosis on a limited bench scale since the early sixties, yet no Canadian commercial process exists.

Suppliers of reverse osmosis equipment are mostly suppliers of components, especially membranes, or of systems, although some provide both. The component unique to reverse osmosis is the membrane, and membrane suppliers have been mainly responsible for promoting this technology. The systems suppliers tend to be engineering firms that assemble components to meet particular needs rather than mass produce them.

Most membrane suppliers are in the United States; in Europe, such firms are similar to those of the smaller American market share suppliers. However, the number of European companies supplying reverse osmosis installations has risen sharply within the past decade. With the assistance of NRC's technical developments, a Canadian firm is supplying reverse osmosis systems in Canada on a small scale.

On the other hand, Japanese companies seem to be aiming at a significant worldwide share of the membrane market rather than at supplying specialty items. They are currently developing membranes to compete directly with the largest American suppliers. One firm, for example, produces membranes that have achieved worldwide acceptance in direct competition. In Canada, there is virtually no technical development of the osmosis process and membrane technology by industry, and very little by government laboratories, despite the fact that Dr. Sourirajan, one of the world's foremost scientists in this field, has been with the NRC for many years. Mainly because of its restricted size, the only major impact of this unit at the National Research Council has been to train scientists of other nations, for example, Japan, China and the U.S., who then have been able to ensure investment and greater effort in this technology in their respective countries.

On a worldwide scale, Japan appears to be the only nation to have recognized the full potential of this technology as a low-energy process. In addition to its previously described industrial activities, Japan is currently establishing an institute with an annual budget of $10 million devoted exclusively to the study and further commercialization of reverse osmosis; this institute will be operated under the direction of specialists who have been trained under Dr. Sourirajan at the NRC. Worldwide technical advances to date have been to improve upon the discoveries made by Dr. Sourirajan when at U.C.L.A., such as increasing solvent flow rates in aqueous solutions while using a limited number of types of membranes mainly from cellulose acetate or a polyamide.

In practice, reverse osmosis has been applied commercially in the separation of aqueous and some gaseous solutions. In theory, the technique could be applied to the separation of any number of compounds whether they be in a liquid or gaseous state, provided the proper semi-permeable membranes can be found. As stated in a study by the SRI International Business Intelligence Program:

"Although the membrane technology for desalination is relatively mature, the technology for other reverse osmosis separation processes is not. The development of special application membranes is therefore a field with a future. The unique membrane will also guarantee freedom from competition. . . . Further development of membranes that are stable at high temperature and extreme pH levels will eventually open a great many specialty businesses such as for petrochemical separation."[9]

It is likely that many of the more energy-intensive industries, such as petroleum refining, the petrochemical industry and food processing, which presently use most of the energy required for the separation of compounds by distillation, evaporation and colloidal precipitation will be employing reverse osmosis techniques. The petroleum and chemical industries alone currently consume over 8 million barrels of oil equivalent yearly as process heat.

The use of ethanol as a gasoline extender, while still being seriously considered in Canada, suffers from poor economics because of the high cost of separating it from its aqueous solution and because of the poor energy balance (it takes nearly as much energy to produce the ethanol as is contained in the finished product). As was mentioned previously, Dr. Sourirajan and his associates have already carried out preliminary studies on the reverse osmosis separation of ethanol present in aqueous solutions. The development of a commercially viable process applicable worldwide would open the door to a revolution in the fuelling of automobiles by making possible far greater use of ethanol as an extender or a substitute for gasoline as well as for other petroleum-derived fuels. There could be very important technological and commercial opportunities for Canadian industry here if we could get a head-start. Since the development of the synthetic cellulose acetate membrane, the commercial application of reverse osmosis, with the exception of medical uses, has been mainly directed towards environmental applications, such as reducing the harmful contents of effluents in the pulp and paper industry and in the dairy and cheese industry.

With the rise in energy prices and the threat of energy shortages, it is surprising that so little R&D effort has been directed towards what is no doubt the most important characteristic of this technology, the ability to separate substances for a fraction of the energy required by other processes currently in use. The decision in Japan to establish an institute devoted to industrial applications of reverse osmosis and membrane technology, and some recent activity in the U.S. indicates that some governments and industries realize the enormous benefits which will accrue to both suppliers and users of any new technological developments. It is not too late for Canada to be among the leaders in this field and share in the rewards, provided the federal government makes a major commitment to take advantage and fully utilize the outstanding expertise which we now have and to direct its efforts in this area.

**Technical Impediments to Dissemination**

A number of technical problem areas can be identified in the field of energy conservation in the industrial sector. Some of these have been noted in the previous section of this chapter. Further equipment and process refinement and development should facilitate the effective dissemination of energy conservation technologies.

In a recent conference sponsored by the International Energy Agency[10], several papers were presented which dealt with this question of generic technical problems. Briefly summarizing, these areas include:

1. *Overall system analysis*. Energy conservation technologies should not be considered separately from the industrial plant in which they are used since the optimal efficiency of the whole system is important. This systems approach has proved particularly effective in designing energy cascading processes for chemical plants in the United Kingdom. The refinement and more systematic application of integrated energy systems offer great potential for energy savings.

2. *Development of thermodynamic media*. Many energy conservation technologies require special working fluids. For instance, there is an urgent need for heat pipe fluids operating at temperatures above 300°C which do not suffer from the disadvantages of liquid metals. As well, the development of a suitable refrigerant which will not have a chemically degrading effect over a long period of time is necessary for the effective use of industrial heat pumps.

3. *Mechanical and metallurgical problems*. The interaction of fluids and structures is poorly understood and this is seen in such problems as heat exchanger tube vibration. Noise generation and the related acoustic damage can create environment and maintenance problems.

4. *Fouling and deposition*. The correction of fouling problems has added great expense to heat recovery operations thereby dissuading many firms from taking advantage of heat recovery opportunities.

**Non-Technical Impediments to Dissemination**

There are numerous financial and institutional constraints that impede the effective exploitation and dissemination of energy conservation technologies in the industrial sector in Canada. One such barrier arises from the costs of pilot projects to demonstrate technologies which have significant potential for energy conservation. The infusion of government financial support in this area could be of significant assistance if it were oriented toward sharing the burden and risks taken by industry.

The investment criteria of some industrial firms also pose a significant barrier to the implementation of energy conservation technologies in this sector. Analyses by Energy, Mines and Resources Canada show that firms seek a rate of return of better than 25 percent (for a three-year payback) on conservation investments, compared with a 10-15 percent return on production expansion.[11] The Task Force expresses some doubts with regard to these figures. The rate of return in production expansion is approximately 25 percent unless there are assured long-term markets that will allow bond financing. Nevertheless, in times of high interest rates, industrial companies seem to prefer investments in production expansion rather than in processes and technologies aimed at reducing energy consumption.

Even though higher energy prices should result in more conservation investments, this in fact does not occur as much as theory would predict. Owing to the different criteria applied, a case can be made for special government incentives for industrial conservation, in the national interest.

In many cases, firms lack the technical personnel and expertise to identify and implement energy-saving projects. More programs to provide them with technical training and assistance are necessary. There is already an urgent need for engineers, designers, systems operators, maintenance personnel and other professionals who can install and operate energy conservation technologies and processes. The government should encourage and support the training of the full range of specialists needed in the energy conservation field.

The barriers to the widespread dissemination of some energy conservation technologies and processes, such as industrial cogeneration, are essentially institutional. They are mostly caused by the relationship between the industrial cogenerator and the electrical utility. The potential for cogeneration is enhanced when excess electrical power can be made available, without restriction or penalty, by the cogenerator to a utility or other user. Utilities, in general, have not been active in promoting cogeneration as their mandates usually do not encourage or authorize them to do so.

If cogeneration facilities could be financed at the lower interest rates now enjoyed by utilities, this would provide a strong incentive to the increased production and use of cogeneration equipment. A further incentive would be for power produced by cogeneration to be sold to electrical utilities at the utilities' cost of generating power.

Yet another significant barrier to the widespread adoption of energy conservation technologies is the lack of awareness by many industries of profitable conservation opportunities. This problem is shared by other sectors of the economy, as has been shown in previous chapters. Furthermore, current federal programs seldom satisfy industry's need for specific information upon which to base decisions as to whether or not to invest in energy conservation technologies, nor do they provide sufficient incentives for them to do so.

**Government Programs**

The federal government has developed a number of programs which provide information and offer financial and fiscal support measures to assist and encourage industries to adopt energy conservation measures. The major government programs are described in the following paragraphs.

**1.** *The National Energy Program* provides for substantially increased federal expenditures on energy research and development (R&D) in the following areas:

(a) alternatives to gasoline - to find the most promising fuel option and provide the necessary support for commercialization, so that oil dependence can be quickly reduced in the transportation sector;
(b) increased efficiency of energy use, in all sectors of the economy;
(c) new energy sources - ranging from coal (where technology must provide the key to environmentally safe use) to hydrogen, a promising option for future generations.

**2.** *National Energy Audit Program*: This provincially administered program assists industrial and commercial establishments to identify areas of energy waste and to plan and implement corrective measures. The federal government provides funds totalling $40 million over a three-year period (1981-1984), to be applied on the basis of an 80/20 cost-sharing ratio with the provinces. The program provides on-site energy audit and grants to assist firms to plan and implement projects offering significant energy savings. The amount will generally be 90 percent of the consultant's fee, to a specified limit based on the applicant's total energy bill.

**3.** *The National Energy Bus Program:* The federal government and participating provinces provide a free service to industry and commerce to identify energy waste and opportunities to reduce energy consumption and costs. By means of mobile, computer-equipped vehicles, on-site plant audits are conducted to analyse energy use patterns and recommendations are offered on possible corrective measures. The program is implemented by federal-provincial cost-sharing agreements. Program administration is the responsibility of the provinces.

**4.** *The District Heating Detailed Engineering Design Program:* District heating is the provision of hot water from a central boiler or a source of waste heat to heat family housing units or commercial buildings. The absence of a well-documented demonstration of district heating in Canada prevents municipalities or utilities from introducing systems of this nature, largely because of high design costs and the considerable risk that may be involved. This program is intended to encourage the development of district heating.

**5.** *The New Technology Employment Program* is intended to create employment for scientifically and technically qualified post-secondary graduates who are recent labour force entrants and who are unable to find employment in their discipline. Additionally, this employment is to result from activities in research and development and its application in technological innovations in manufacturing, product and process development and the development and application of small-scale energy conservation programs and alternative energy technologies. The federal government will contribute up to 75 percent of the wages paid to an eligible individual to a maximum contribution of $290 per week per job.

**6.** *The Atlantic Capital Retrofit Program*, operating in conjunction with the National Energy Audit Program, provides grants to industrial and commercial firms in the Atlantic Provinces to finance a portion of their energy conservation investments (such as industrial process changes, retrofitting, waste heat recovery and co-generation). The federal government provides funds totalling $45 million over the period 1981-1986.

**7.** An *Industrial Energy Research and Development (IERD) Program* assists industry to develop new or modified energy-efficient processes and technologies. The results of R&D under the program should have the potential to be widely applied across Canada, and the recipient of the grant must make the technology available to interested companies in Canada. The program provides cost-sharing grants of up to 50 percent for approved projects.

**8.** *The Development and Demonstration of Resource and Energy Conservation Technology (DRECT) Program* helps the private sector, in co-operation with municipalities and provinces, to develop and demonstrate equipment, systems or products designed to recover or otherwise save energy. DRECT supports development and construction of demonstration or prototype installations. Criteria for funding assistance primarily include environmental protection benefits and energy conservation.

**9.** *The Federal-Provincial Conservation and Renewable Energy Demonstration Program* is designed to share the costs with the provinces for the demonstration of renewable and conservation technologies by reducing the technical and financial risks of the first application of the technology. In those provinces which have not signed a bilateral agreement, the federal government will fully fund demonstration projects.

**10.** *The Industrial Energy Management Program* increases awareness and transfers information to energy managers and technicians through energy management workshops and seminars.

**11.** Under *Schedule II (Capital Cost Allowances) of the Federal Income Tax Regulations*, energy conservation equipment included in Tax Class 34 may be written off in two years. Eligible equipment would use municipal, industrial or wood waste to produce heat or generate electricity. This measure supplements Tax Class 29 which provides the same incentive and under which most manufacturing and processing equipment is covered.

**12.** The *federal sales tax* has been removed from a range of energy conservation equipment and materials, such as heat pumps; thermal insulation material for buildings, ducts and pipes; heat recovery units for extracting heat from exhaust air or waste water; wood burning stoves and furnaces; and solar panels, cells and tubes.

**13.** *Canertech*, a Crown corporation, has been established to support the development of companies in the renewable energy and conservation areas, by means of joint ventures, share purchase and other support.

In discussing government programs designed to encourage energy conservation in the industrial sector, the Task Force received information concerning a number of anomalies and difficulties which companies have encouraged in their attempts to take advantage of such programs. Many companies were critical of government programs and stated that they do not offer a great inducement to industry to work with government to achieve such mutually beneficial objectives as increased energy efficiency.

A number of industrial firms do not take advantage of current government programs which are designed to encourage the development and dissemination of energy conservation technologies. This is due to a lack of awareness of programs in general or specific details concerning a program's objectives, criteria for eligibility, means of application, and potential savings. As well, the administration of these programs is such that obtaining financial support through them is a difficult and time-consuming undertaking, so much so that many companies have withdrawn their participation. The Task Force has received criticisms that many programs suffer from excessive regulation, overly-strict controls and a lack of co-ordination with other government programs.

Although the focus of decision making concerning the development and adoption of energy conservation technologies should be the industrial energy user, the federal government should streamline and strengthen its programs in order to assist industry with the financial burdens involved in this area.

As industries are more inclined, on the whole, to make investments to increase production rather than to implement energy conservation technologies, the government should provide fiscal measures and tax incentives to encourage the adoption of such technologies and processes, as these would be much more effective than existing federal grant programs. If the federal government is serious in its efforts to reduce Canada's consumption of energy in general and of oil in particular, it should consider as eligible any project that will permit reduced consumption and allow industry to determine the most economic means of achieving that goal.

The government should provide industry with alternative means of assistance. It should retain the accelerated write-off for capital expenditures on specified energy conservation technologies listed under Class 34 of the Income Tax Regulations. It should also provide a one-time refundable tax credit for capital expenditures directed towards energy conservation, subject to their conforming to previously established performance standards. Another incentive for industry to invest in energy conservation technologies would be for the government to subsidize low-interest loans through existing financial institutions for conservation projects meeting specified criteria. We believe banks should be willing to fund such loans from their resources, providing the difference between the rates at which they are offered and the going rates for other loans is made up by a government subsidy.

The question of the substitution of one type of energy (such as gas) for another (such as oil) is a most important consideration to industry in terms of energy conservation. However, this area was not explored as it was regarded as beyond the mandate of the Task Force. It should be noted, however, that in some cases the substitution of a more efficient fuel leads to an opportunity for energy conservation.

## Footnotes

### Chapter Five

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# Annex I

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