ENERGY ALTERNATIVES

HOUSE OF COMMONS
CANADA

A REPORT BY

THE SPECIAL COMMITTEE
ON ALTERNATIVE ENERGY

Members of the Special Committee on Alternative Energy and Oil Substitution

Chairman: **Thomas H. Lefebvre, M.P.** — Pontiac-Gatineau-Labelle

Robert A. Corbett, M.P. — Fundy-Royal
Gary M. Gurbin, M.P. — Bruce-Grey
A. Allister MacBain, M.P. — Niagara Falls
Gary F. McCauley, M.P. — Moncton
Arthur Portelance, M.P. — Gamelin
Mark W. Rose, M.P. — Mission-Port Moody

Clerk of the Special Committee

J. M. Robert Normand

Research Staff

Project Manager: **Dean N. Clay**

Peter T. Alward
Judith E. Beange
John R. DeGrace
Brenda J. Dyack
James F. Follwell
John E.S. Graham
Lynne C. Myers

First Session of the
Thirty-second Parliament, 1980-1981

Available in Canada through

Authorized Bookstore Agents
and other bookstores

or by mail from

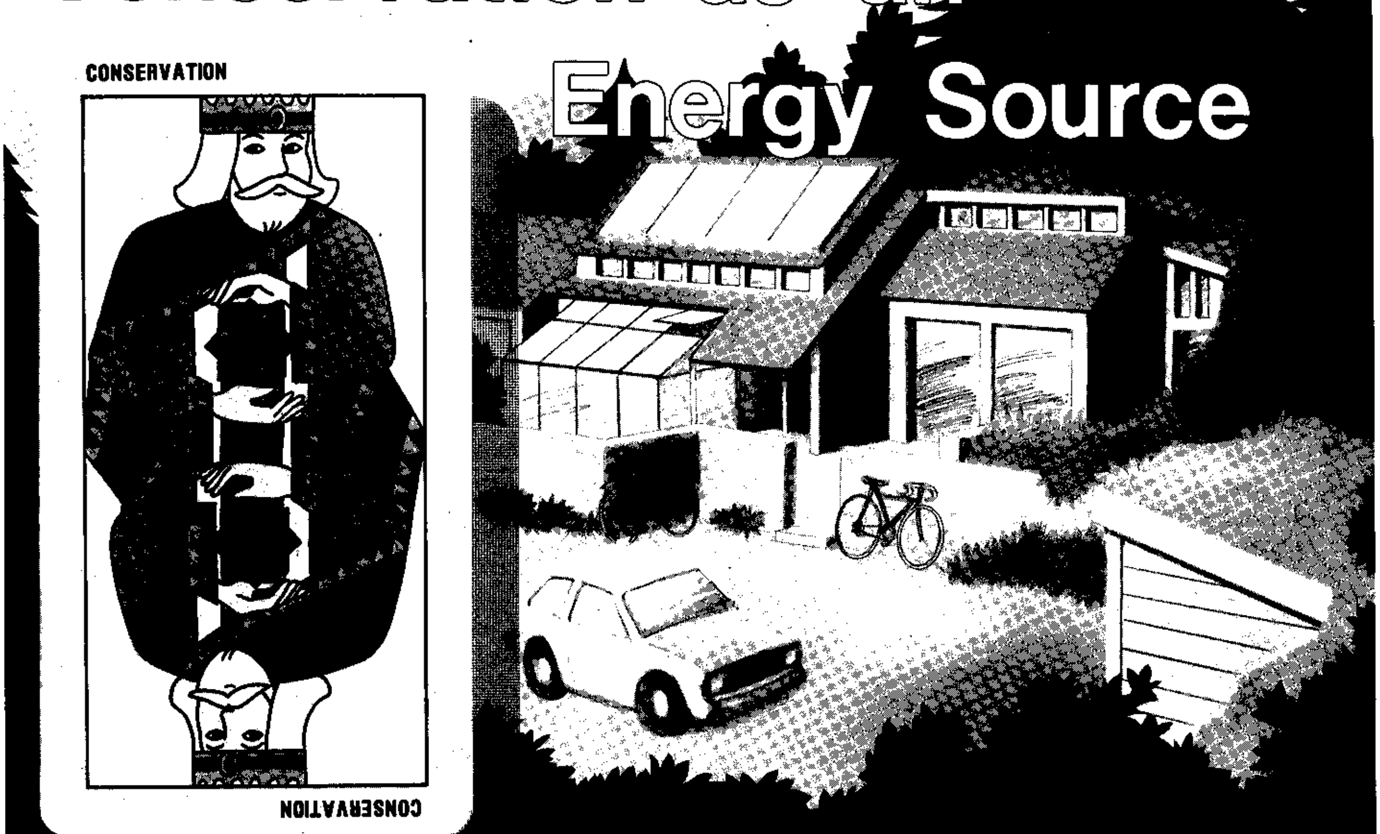
Canadian Government Publishing Centre
Supply and Services Canada
Ottawa, Canada, K1A 0S9

Catalogue No. XC 2-321/2-01E — Canada: $4.95
ISBN 0-660-10912-3 — Other Countries: $5.95

Price subject to change without notice

TABLE OF CONTENTS

Conservation as an Energy Source



It may seem unusual at first glance to include conservation in a section entitled Alternative Energy Sources, Currencies and Technologies, but the Committee has come to view conservation as an energy source. We feel that the conservation resource is large in Canada, principally because energy efficiency was not a prime consideration in the past. Energy has traditionally been inexpensive and for this reason our economy has evolved in a way which results in Canada spending more energy per dollar of gross domestic product generated than other countries. Paradoxically, this means that although our former wasteful practices may be regrettable, they do provide a substantial conservation energy resource which can generally be exploited more easily and more economically than any other energy source today. By reducing demand, the value of existing energy supplies is increased in relative terms.

Many witnesses told the Committee that conservation must be the cornerstone of any alternative energy

Conservation and the Energy Supply Gap

Suppose a country can only supply 60% of its energy needs; that is, the ratio of supply to demand is 60/100. If that country reduced its demand to 80% of its former level, then the supply-to-demand ratio would become 60/80 or 75%. In other words, by tapping the conservation energy resource, this country could improve its supply-to-demand ratio from 60% to 75%, an improvement of $\frac{75-60}{60} \times 100$ or 25%, without investing in the supply of one additional unit of energy.

strategy and we agree wholeheartedly with this conclusion. It is, in fact, this conviction which has led us to give conservation a prominent position in our Report, even though it was not specifically mentioned in our terms of reference.

It is one thing to recognize and accept that conservation is of uppermost importance but it is quite another to suggest what specific steps should be taken to ensure that we exploit this resource. To undertake to do this in the context of this Committee's already complex report on alternative energy would, we feel, greatly understate the importance which this subject carries. Because conservation is not a concern of the Federal Government alone, it deserves and requires a detailed study which looks at this subject at all levels of jurisdiction.

RECOMMENDATION

The Committee recommends that a detailed study into all aspects of energy conservation, in all sectors of the economy, be undertaken immediately.

There have been many studies dealing with individual conservation technologies and studies of industrial, residential or commercial energy conservation. This wealth of information needs to be pulled together and the study we propose could well carry out this function. The study should be aimed at the needs of policymakers and should offer recommendations on specific policies and standards which could be implemented. Regional variations in the supply and demand for energy must also be accounted for as no single policy will be suitable for all regions of the country nor for all sectors of the economy. The study should also differentiate in some detail between capital and operational costs so that a clear picture of the payback from conservation initiatives is obtained.

While we have not undertaken a detailed examination of conservation, we have been exposed to a wide variety of concepts, proposals and opinions on this subject. We therefore present the following observations and comments as examples of the information we have received and the opinions we have formed, knowing full well that we have only touched briefly upon the subject.

To take complete advantage of the conservation resource, two approaches must be taken: wastefulness must be discouraged and the efficiency of all our energy-consuming activities must be improved. The first approach needs no explanation; the second requires us to begin thinking of our daily activities in terms of the amount of energy they consume. In short, we must build energy efficiency into products, processes and lifestyles. We have to develop a sense of energy responsibility.

Initially, progress in conservation may be slow because the market for energy and energy technologies is ineffective at signalling appropriate levels of investment in conservation — people do not have a feeling for the real costs of foregoing conservation measures. Homeowners, for example, may react negatively to the initial price of insulating their homes and fail to take into account the real savings such an investment could generate over a period of years. Programs are needed to prompt people to make the correct energy decisions. For instance, Hydro-Québec has recently introduced an innovative program to promote home insulation. It is designed to make the initial capital cost — a barrier in many cases — disappear. Under its terms, a homeowner obtains a loan from Hydro-Québec to insulate his home and repays the loan over five years by paying the difference between pre- and post-insulation heating bills. The customer is not faced with a large capital outlay and for five years simply continues to pay his heating bill as he would have otherwise without the added insulation. Thereafter, his billing drops to the new level reflecting his energy saving. We see no evident reason why a similar program could not be extended by the Federal Government to small businesses and industries with limited capital resources.

Unfortunately, there is not a well-organized conservation lobby in Canada and, as advertising is overwhelmingly directed towards convincing people to buy and consume most products, this message is reflected in our attitude towards energy. Thus leadership in promoting the conservation ethic must come from Governments, which have only recently begun funding and encouraging energy conservation efforts. The Federal initiative has begun well and the Committee recognizes that Canada's public education program in energy conservation has been widely applauded. Despite this, there remains room for improvement and greater public and governmental commitment to conservation is imperative. With these concepts in mind we now consider some of the conservation suggestions which the Committee received from various sources.

Electricity will contribute a larger share of end-use energy in Canada in the future, and this energy currency should be wisely managed and spent. Two measures which would help ensure that this is accomplished are listed here.

- The current practice of charging less for higher levels of electrical use should be discontinued.
- Utilities should consider rate structures which encourage the use of off-peak electricity.

The transportation sector is one of the largest consumers of energy in our economy and Canadian drivers seem as reluctant as ever to abandon the convenience of private automobiles. This is not surprising as our cities, towns and villages are built around personal transportation. A large potential exists, however, for energy economizing in moving goods and people. Automobiles are becoming lighter, engines are becoming more efficient in their use of fuel, auto bodies are being made with improved aerodynamic efficiency, tires with less rolling resistance are being developed — these are some of the design approaches already generating energy savings and much more can be accomplished along these lines. More innovative changes, such as incorporating flywheels into vehicles, may produce similar benefits in the future. Energy savings can also be realized through improved management of vehicular flows, as the following examples suggest.

- Although existing speed limits are acceptable and practical for this country, they must be *enforced* so that vehicles are driven at speeds which make efficient use of fuels.
- Stop signs should be replaced by yield signs wherever safety permits to reduce energy-wasting stops and starts. Similarly, whenever possible, traffic lights should switch to flashing amber, instead of continuing through a full amber, red, green cycle when traffic volume does not warrant it.

There are significant savings to be realized by manufacturing industries as well. This sector was built predominantly in an era of low-priced energy and, as a result, it was often inefficient in its use of energy. In response to a call by the Federal Government in 1974 for an aggressive and voluntary program to cut energy demand, the industrial sector established 15 conservation task forces. Each task force represented one segment of the industrial sector (pulp and paper, chemicals, food and beverage, industrial minerals and so on) and each set its own goals. Industries responded very favourably since conservation quickly paid off for them and results have been encouraging. Some sectors met their 1980 targets ahead of schedule and are formulating new goals for even greater savings. Although this is only a start and a sustained effort will be necessary, the Committee is encouraged by the early success of these voluntary activities. We would like to see this initiative continue to ensure that:

- Industrial processes are redesigned, changed or retrofitted when and wherever feasible to reduce the amount of energy they consume.
- Industries place added emphasis on maintaining machinery at levels of maximum energy efficiency and replace "extravagant" energy users with new and energy-efficient equipment.
- Every effort is made to utilize what is now considered waste heat generated in industrial processes.

Since a large amount of Canada's energy is used in heating and lighting buildings, there is significant potential for energy savings here as well. In this sector, however, the message of conservation should be accompanied by information concerning the concept of passive solar design.

RECOMMENDATION

All levels of government should cooperate in ensuring that architects, builders and contractors learn and practice energy-efficient design and construction. In particular, these people should be made aware of the energy-saving benefits which result from the passive use of solar energy.

Passive solar design incorporates a number of energy-saving features such as insulated night shutters, double or triple glazing, removal of most north- and west-facing windows, the use of windbreaks and/or earth berms (embankments) to the north and west of buildings, or building into the south face of a hill.

Other measures to reduce heat loss, which apply to both ordinary and passive solar buildings, include adding extra insulation and improving airtightness. It has been demonstrated in Canada that these two measures, plus using a larger area than usual of south-facing windows, make it possible to construct houses in which energy consumption is reduced by 80 to 90% compared with similar houses built to existing standards. The Committee had the opportunity to visit the most well-known of these energy-efficient homes, Saskatchewan Conservation House, during the course of its cross-country hearings.

Demonstrating that these levels of energy saving are possible was an important first step, but what people really want to know is, "Can it be done cost-effectively?" Unfortunately there is not yet a great deal of data on the costs and benefits of energy-efficient passive solar design due to the limited number of passive solar homes and the minimal amount of monitoring which has been done on those which are in place. Nonetheless, there seems to be sufficient information available to make at least preliminary estimates.

A recent study done for the Department of Energy, Mines and Resources (Gough, 1980) performed such an analysis. It concluded that in new construction the most cost-effective strategies, in order of priority, were to (1) relocate as much as possible the normal window area of a house on the south wall; (2) increase the insulation in buildings by about 50% beyond the 1978 NRC standards; and (3) either further increase thermal specifications or further increase the south-wall window area beyond redistribution.

The conclusions of this study agree with testimony heard by the Committee. Energy-efficient housing can use standard building materials and techniques, so the technology is available now. Furthermore, it appears that substantial energy savings can be achieved within a reasonable payback period for the added investment. If all of these conclusions are correct — and we have no reason to believe that they are not — then why is such housing not being constructed on a much broader scale in Canada today? Several Committee witnesses described barriers to the construction of energy-efficient housing and certain factors were identified time and time again. The proposed energy conservation study will perhaps identify other obstacles which are not now apparent.

Economics play a very large role in determining the adoption of energy-conserving construction practices and the inclusion of passive solar features. The initial capital investment can be justified by savings in energy costs over time; however, the consumer faces the problem that the return on his investment may not be realized for as much as 10 or 15 years. Certainly the current high rates of interest for loans and mortgages deter many would-be "conservers" from making such an investment. Moreover, the uncertainty of future energy prices clouds the issue of the length of the payback period.

A person's eligibility for a mortgage is based on a calculation of the proportion of his or her monthly salary available to make payments. With an energy-efficient house and the resultant lower energy costs, a person would have more money available each month — perhaps enough to cover the increased mortgage charges occasioned by adding the cost of the conservation measures to the mortgage. This suggests that the method of calculating mortgage limits should be changed to take energy saving into account. This would seem to be a particularly appropriate measure for the Canada Mortgage and Housing Corporation (CMHC) to consider when funding non-profit housing.

CONCLUSION

Federally-financed housing provides an excellent opportunity for the Government to demonstrate the benefits of conservation and passive solar design.

RECOMMENDATION

The Committee urges that Federally-financed housing incorporate energy-conserving and passive solar design in order to demonstrate its benefits.

In this regard, the Committee welcomes the announcement in the 1980 National Energy Program of a $6 million measure to promote energy-efficient housing through workshops, training programs, and the design and construction of 1,000 energy-conserving homes across Canada. If this program were extended to social housing, it would provide the added benefit of shielding those in need of such homes from increasing energy costs.

The NEP initiative provides a chance to gain much-needed practical experience in the operation of passive solar heating systems. Such systems are by no means simple and there is a complex relationship between energy collection, storage and conservation in these buildings. Unless these elements are properly balanced, a passive solar house can be a very uncomfortable place to live in.

Another barrier to the widespread use of energy conservation measures and passive solar systems is the lack of suitable building standards. In October 1980 the ten provincial Energy Ministers called on the Federal Government for improvements in the National Building Code (NBC) to ensure that energy conservation features were included. This call for action followed the publication of a set of building standards known as *Measures for Energy Conservation in New Buildings* (1978). As with the NBC however, adoption of these measures by the provinces is voluntary and, as of the end of 1980, not one province had adopted the new standards. The Division of Building Research at the National Research Council carried out a study to determine why none of the measures has been adopted and the major reason was found to be the lack of inspectors qualified to oversee the new measures. The cost involved in retraining building inspectors would have to be borne by the provinces and this illustrates the type of jurisdictional problem facing the Federal Government in its attempts to promote energy conservation through the building code.

Several witnesses suggested to the Committee that the Federal Government ought to develop a new building code based on energy performance standards. They believe that such standards are an important signal to the construction industry and to consumers that conservation is an important priority with the Government. The Division of Building Research (DBR) is in fact developing guidelines for energy budgets in four types of buildings: office buildings, shopping centres and retail stores, apartment buildings, and schools. DBR hopes to publish these guidelines in 1983 as a first step towards a comprehensive set of building energy performance standards. As the standards develop, DBR is also assessing how compliance with the guidelines can be assured as this is seen as one of the main problem areas. All levels of government will have to work together if progress is to be made.

RECOMMENDATION

Energy performance standards for buildings should be incorporated in the National Building Code so that conservation and innovative design and construction are promoted.

RECOMMENDATION

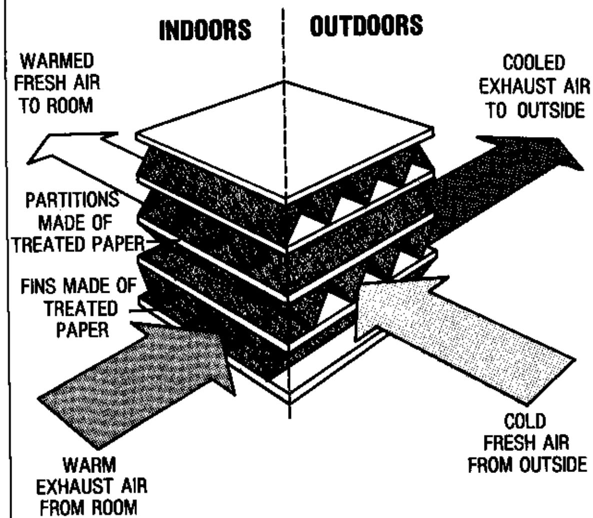
Standard tests for the energy performance of buildings should be established by the Federal Government so that energy-efficiency ratings can be assigned.

The Committee has concluded that performance standards are preferable to prescriptive standards since they do not stifle innovation and thus allow architects and builders freedom of choice in developing energy-efficient housing. Nonetheless, prescriptive examples must still be provided to assist the building trades in adapting to the new standards. The Committee recognizes that building performance is more difficult to assess, but feels that the extra effort is worthwhile. We also recognize that in developing a performance code, regional standards will be required to take account of climatic variations across Canada. The proposed development of such standards for the Canadian Arctic (Canada, EMR, 1980e) is an appropriate beginning to this process.

Another interesting suggestion put before the Committee recommended conducting a voluntary performance test on new housing. A 24-hour airtightness test, similar to a mandatory test done on all new homes in Sweden, would provide a fuel economy rating which consumers could use as a basis for comparing homes. That is to say, like the miles per gallon ratings on cars, such a system would not provide a guaranteed fuel consumption figure but rather a means of comparison. Once homebuyers are made aware of the potential energy savings which can be realized in energy-efficient housing, it is felt that they will begin to demand this sort of home in the marketplace. As a first step, the Federal Government should subject its own buildings and those which it helps finance to such tests. Private contractors should then be encouraged to assign an energy performance rating to their buildings as well.

Airtightness does conserve energy but it may also lead to the accumulation of unacceptable levels of indoor pollutants and to excess humidity if proper precautions are not taken. This problem can be overcome by providing adequate and controlled ventilation in the otherwise airtight building. By passing incoming cold air and outgoing warm air through an air-to-air heat exchanger (Figure 6-1), proper ventilation can be achieved without losing excessive amounts of heat to the outdoors. A number of air-to-air heat exchangers are on the market at prices ranging from $100 to $500, and plans are also available for inexpensive do-it-yourself units.

Figure 6-1: A SIMPLE AIR-TO-AIR HEAT EXCHANGER



As warm and cold air pass each other in separate and alternating layers of the heat exchanger, heat is transferred from the outgoing stale air to the incoming fresh air. This ensures air exchange but recovers most of the heat which would normally escape with the vented air.

Source: After Hand, 1980, p.77.

RECOMMENDATION

The Committee recommends that the Federal Government establish a standard procedure for testing the airtightness of buildings. The Committee further recommends that, once established, the test be applied to Federal buildings and to all new homes financed through the Canada Mortgage and Housing Corporation.

Further energy savings in buildings can be achieved by reducing lighting levels (provided that the lighting is not already serving to handle part of the heating requirement of the structure).

RECOMMENDATION

Lighting regimes in business and homes should be designed to ensure that electric energy is not wasted.

In a greater departure from typical building design, one witness advocated underground construction as a means of lowering the energy requirement for space heating and cooling. This saving can be realized because temperature fluctuations within the soil or bedrock are much smaller than in the air. For example, an estimated 10% of all cold storage in the United States is underground in Kansas City. In Scandinavia more than 200 underground units are now in operation for storing petroleum products. Experience here has shown that the construction and operating costs of such facilities are 30 to 50% less than for surface storage and that the energy required to keep the oil warmed to 50 to 70°C (to avoid coagulation and other problems with product quality) is reduced by 60 to 80% (Jansson *et al,* 1980). Cold storage and frozen storage facilities similarly demonstrate impressive energy savings when located underground.

The Swedes are also considering transporting hot water up to 120 km from a nuclear power station to serve district heating systems in Stockholm and Uppsala. The water would be moved through unlined rock tunnels because heat conduction in rocks is so low that the loss of thermal energy would be minimal.

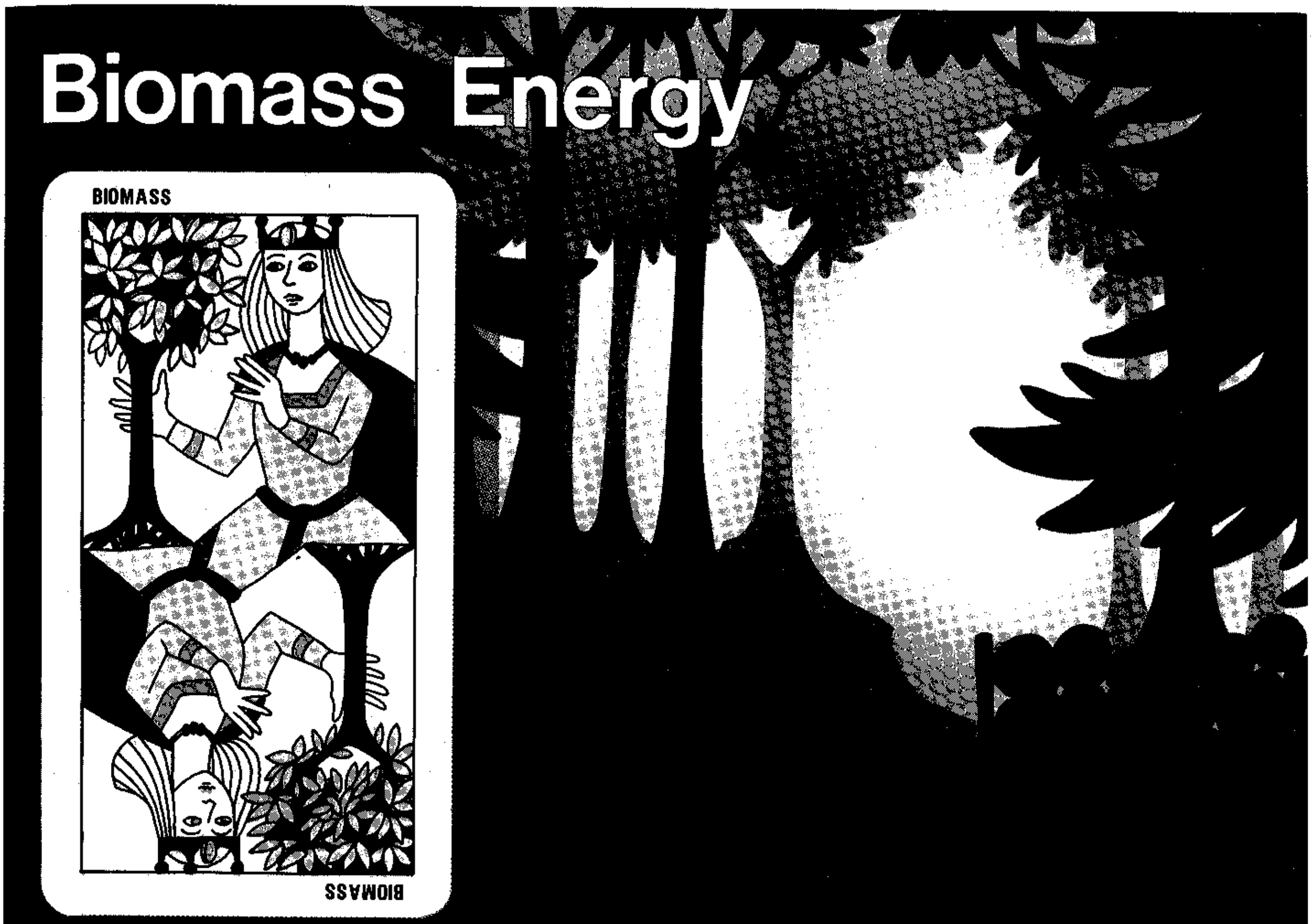
While the groundwater regime and other subsurface conditions will prevent underground construction from being practiced in some locales, this approach should be receiving more serious consideration in Canada.

RECOMMENDATION

Underground construction should be encouraged in appropriate circumstances as an energy-conserving building technology.

As we noted at the beginning of this section, we have done little more than give examples of some energy-conserving suggestions made to the Committee. Nevertheless, the breadth of these suggestions has reinforced our conclusion that the conservation resource is rich indeed and worthy of much more attention than it has thus far received.

Biomass Energy

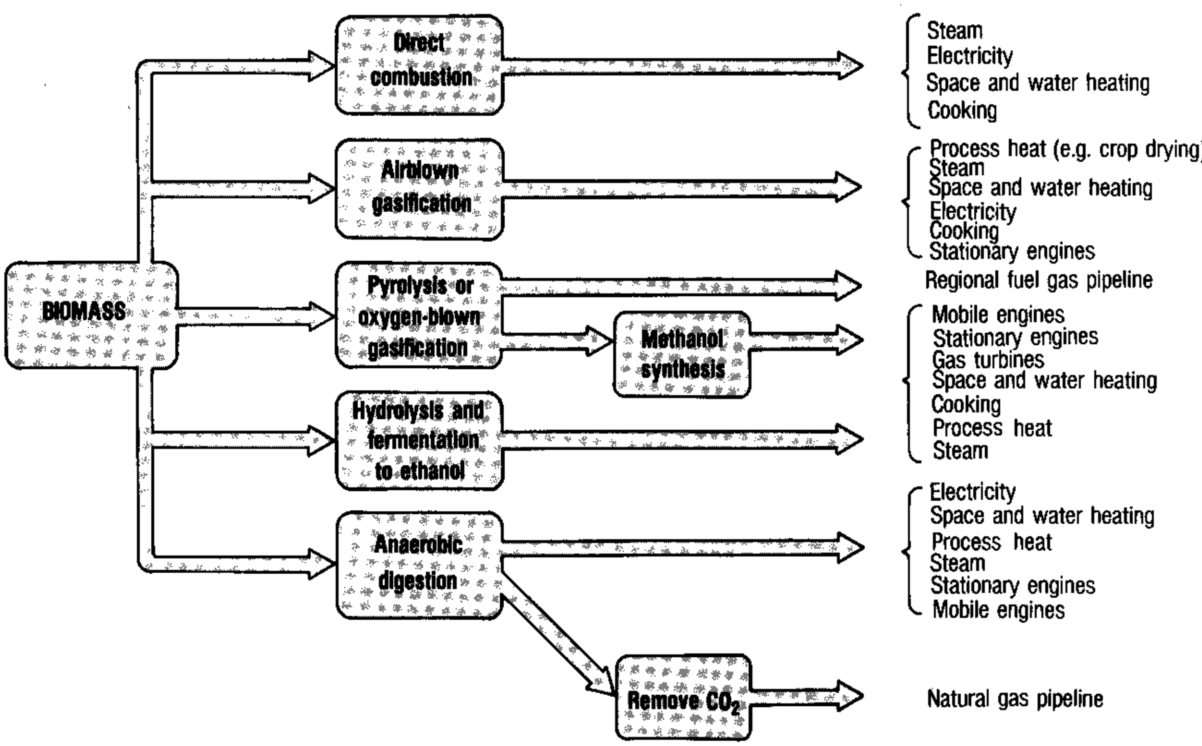


The term biomass refers to all matter of plant and animal origin excluding fossil fuels. This organic material is an exploitable energy resource because the carbon contained in the large molecules of biological organisms can be made to undergo a variety of chemical reactions which either release energy directly, or convert the original substance into new forms which can be reacted later to release energy.

The abundance and variety of organic matter which makes up the biosphere contains a large amount of energy. With petroleum destined to lose its preeminent position in our energy affairs, biomass has become more attractive as an alternative source. Originally biomass supplied most of this country's energy needs but when inexpensive fossil fuels became available to consumers, first coal then petroleum supplanted biomass as Canada's most important energy source. Today biomass meets only 3 to 4% of Canada's primary energy requirements.

Strictly speaking, biomass energy can be classified as a form of solar energy because plants are really organic solar receptors which intercept, transform and store the energy of the sun's radiation in the chemical bonds of large, complex, organic molecules. The chemical energy contained in such macromolecules can be released in a variety of ways (Figure 6-2): it can be burned directly; it can be gasified under anaerobic, aerobic or oxygenated conditions to produce synthesis gas; it can be hydrolyzed and fermented to alcohols; or, it can be anaerobically digested to produce biogas (methane). Thus biomass is a flexible energy source which can produce a variety of products, all of which are eventually combined with oxygen to release energy and do useful work.

Figure 6-2: FUEL USES FOR BIOMASS



Source: United States, Office of Technology Assessment, 1980a, p. 24.

There are a number of advantages which accrue from exploiting biomass as a source of energy.

- It is an abundant resource.
- It is available in many different forms and can be adapted to a variety of uses.
- Biomass is continuously renewable provided adequate resource management practices are carried out.
- Its combustion can not only provide energy but it can also help reduce the waste disposal and/or pollution problems associated with the forest, pulp and paper, and food processing industries, and with the municipal and agricultural sectors.
- The combustion of recently living organic matter does not significantly alter the concentration of carbon dioxide in the atmosphere as does the combustion of fossil fuels. (This presumes proper management of the biomass resource.)
- Biomass is a widely dispersed resource which can often be well matched to regional requirements and small decentralized sites for energy production.
- Biomass can replace high-sulphur-content fossil fuels and, in so doing, can reduce sulphur dioxide emissions, one of the prime causes of acid rain.

There are, however, a number of difficulties associated with using biomass for energy production on a large scale.

- The harvesting of vast amounts of biomass could radically modify natural ecosystems and irreversibly damage them or, even worse, completely displace them. (This impact could be reduced with proper resource management; however, if very large amounts of energy were to be derived from biomass, the amount of growing space required would be correspondingly extensive.)
- There is a great deal of controversy over whether large tracts of land should be used for food or energy production.
- The resource is often remote in location.
- It typically has a low energy density (contains a low amount of energy per unit weight).
- It is often difficult to ship and store because of its wide variety of forms, which means that much of this resource is not economically exploitable with prevailing energy costs.
- Biomass usually has a high moisture content, meaning it must be dried before burning because energy con-

tent is inversely proportional to water content and combustion efficiency increases with fuel dryness.

- If biomass is burned in numerous, small, widely-dispersed combustion units, it is difficult to control or contain emissions.
- Biomass has a relatively high ash content.
- The incomplete combustion of biomass, such as occurs in most wood stoves and fireplaces, releases polycyclic organic matter (including benzo [a] pyrene and several other known or suspected cancer-producing agents) to the atmosphere.

1. ALCOHOL FUELS

There are two types of alcohol which have recently received attention as possible transportation fuels. These alcohols are methanol, characterized by the chemical formula CH_3OH, and ethanol, C_2H_5OH. Although the former is usually associated with the feedstock wood (methanol has long been referred to as wood alcohol), it can also be synthesized from other biomass feedstocks, as well as from natural gas and coal. Ethanol can similarly be derived from wood but the process has not yet reached the commercial stage and nearly all ethanol is produced from the fermentation of sugar- or starch-containing biomass.

Alcohols have long been considered attractive as liquid fuels. Henry Ford originally designed the Model T to run on alcohol and later modified the design to accommodate alcohol, gasohol or gasoline when petroleum-derived fuels became cheap and plentiful. Alcohols are well suited for use as fuels because they are completely biodegradable, are easily portable, have a relatively high Btu content per unit weight (Table 6-1), burn cleaner than petroleum-derived fuels, and have a higher octane rating than pure gasoline with no additives (octane number is a measure of a fuel's resistance to self-ignition). The combustion products of ethanol are discussed in the section on Nonconventional Propulsion.

Table 6-1: ENERGY CONTENT OF METHANOL, ETHANOL AND GASOLINE

	Btu/lb	MJ/kg
Methanol	8,570	20
Ethanol	11,500	27
Gasoline	18,900	44

Source: After Mathers, 1980, p. XXII-11.

A. ETHANOL

Ethanol (C_2H_5OH) is produced almost exclusively by fermentation and all such processes consist of four basic steps: (1) the feedstock is processed and/or treated to produce a sugar solution; (2) yeasts or bacteria convert the sugar to ethanol and carbon dioxide; (3) distillation is used to remove the ethanol from the fermentation solution, yielding an ethanol/water solution which is at best 95.6% ethanol at normal pressures; and (4) any remaining water is removed to produce "dry" or anhydrous ethanol. This latter step is usually accomplished by a second distillation in the presence of another chemical.

Distillation

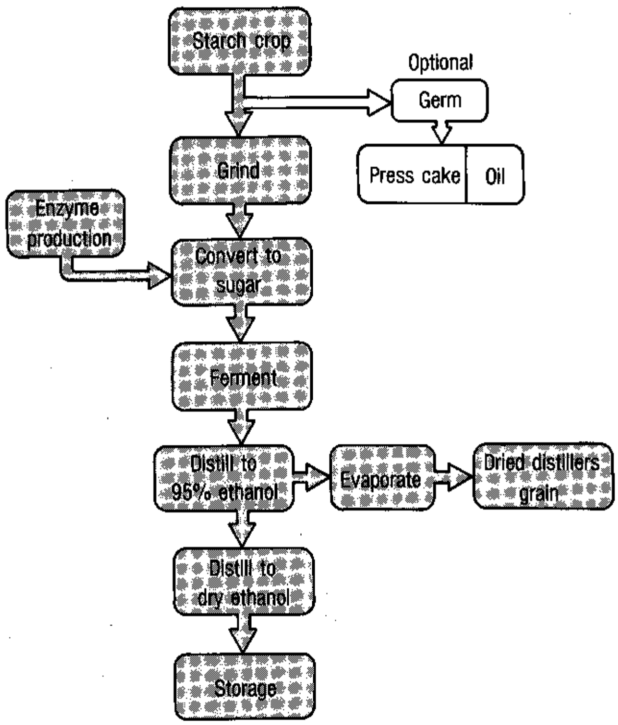
Distillation is a physical process which consists in this application of heating an ethanol-water solution and passing the resultant vapour through a cooling column in which the vapour condenses and revapourizes numerous times — a process that concentrates the ethanol and removes the water.

Because the boiling points of ethanol and water are very close, however, a certain amount of water is entrained with the ethanol as it vapourizes and condenses; thus the ethanol cannot be made more pure than 95.6% by this process alone.

The main distinctions among fermentation processes utilizing different feedstocks arise primarily out of differences in the *pretreatment* steps to which the feedstock is subjected. Sugar-containing crops such as sugarcane, sweet sorghum, sugar beets and sugar mangels yield sugar directly upon processing, but the sugar must be concentrated or treated in some other fashion for storage to prevent it from being broken down by bacteria. Starch-containing feedstocks such as corn and other grains need to be broken down (hydrolyzed) with enzymes (biological catalysts) or acids to reduce or convert the starch to sugar. Similarly, cellulosic (woody or cellulose-containing) feedstocks such as crop residues, grasses, wood and municipal wastepaper require extensive hydrolysis (either acidic or enzymatic) to reduce their more inert, long-chain, cellulose molecules to sugar subunits. No commercial cellulose-to-ethanol installations exist at the present time but pilot plants have been established in Brazil using eucalyptus wood. Small-scale experiments are being carried out in Canada as well.

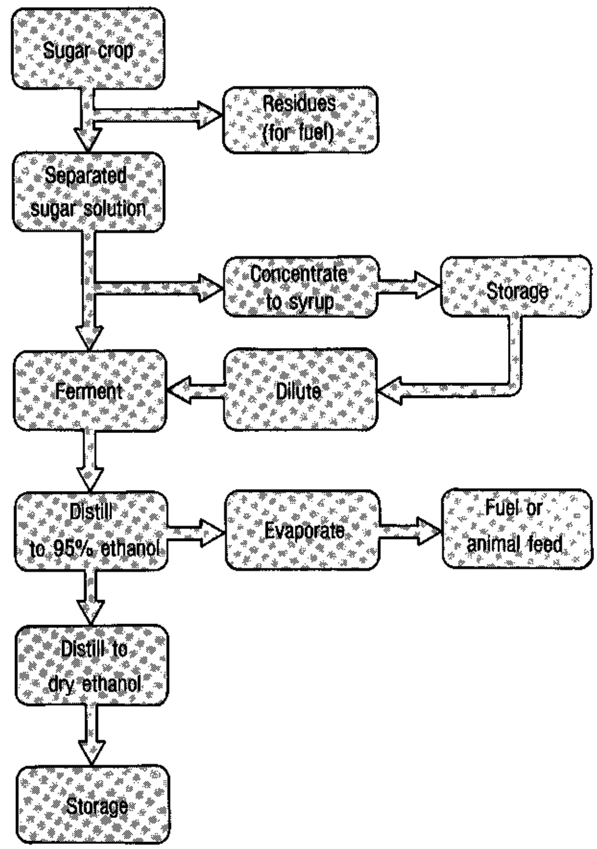
Ethanol can of course be produced from starch and sugar feedstocks with commercially available technology. Starch feedstocks are primarily grain crops such as corn, wheat and oats, but also include various root plants such as potatoes. The sugar feedstocks are

Figure 6-3: PROCESS DIAGRAM FOR THE PRODUCTION OF FUEL ETHANOL FROM STARCH-CONTAINING CROPS



Source: United States, Office of Technology Assessment, 1980b, p. 160.

Figure 6-4: PROCESS DIAGRAM FOR THE PRODUCTION OF FUEL ETHANOL FROM SUGAR-CONTAINING CROPS



Source: United States, Office of Technology Assessment, 1980b, p. 160.

plants such as sugarcane, sweet sorghum, sugar beets, mangels and Jerusalem artichokes. The two processes for producing ethanol from starch and sugar feedstocks are shown schematically in Figures 6-3 and 6-4.

The attractiveness of ethanol derives from the fact that it can be used directly as a portable liquid transportation fuel or it can be mixed with gasoline to produce gasohol. In either case, it reduces demand for gasoline.

Mohawk Oil is the first company in Canada to produce gasoline-ethanol fuels. This company will be using ethanol, manufactured from damaged or surplus agricultural crops at the rate of approximately two million gallons per year (roughly 155 barrels per day) in a revamped distillery, to produce gasohol for sale in retail outlets in Manitoba.

The proposal to make ethanol from *cellulose* is very appealing as it would allow exploitation of Canada's substantial cellulosic biomass resource, including wood wastes, spruce-budworm and fire-damaged wood, for feedstock. This resource is much larger than that represented by our starch and sugar crops and our food processing wastes combined, and its exploitation would avoid using food crops for energy production. Unfortunately, there are problems in breaking down cellulose to sugars which can be fermented to ethanol.

Wood

Wood is composed primarily of cellulose, hemicellulose and lignin. Cellulose can be broken down to sugar and then fermented to alcohol. Hemicellulose, on the other hand, is composed of 5-carbon sugar (pentose) subunits and is more difficult to convert to ethanol. Researchers at the NRC have, however, made good progress in developing organisms capable of pentose fermentation. Lignin binds the woody material together, makes the cellulose difficult to hydrolyze and is itself not fermentable to alcohol.

A new process has been developed in Canada whereby cellulosic material is steam exploded to open the wood structure and make the cellulose accessible for hydrolysis. This technique, together with the development of new hydrolytic enzymes, new genetically-engineered fermenting organisms and new ways of separating and utilizing the lignin by-product of the process, promises to make the production of ethanol from cellulosic feedstocks much more attractive in the future. If biotechnological research produces new organisms which can improve the efficiency of the overall process, ethanol from biomass may become a much more attractive alternative energy option in the future.

CONCLUSION

Canada could become a world leader in cellulose-to-ethanol technology by encouraging the research, development and demonstration of novel processes already being developed in this country.

RECOMMENDATION

The Committee recommends that the Federal Government, through Canertech, encourage the research, development and commercialization of cellulose-to-ethanol technology.

The controversy over whether or not ethanol production from agricultural crops results in a net energy gain remains to be resolved. If there is a net energy gain, it is certainly small. Similarly, the controversy over whether agricultural crops should be used for food or for fuel rages on. Many observers now agree, however, that two competing end uses for the same product will inevitably lead to increased food prices and perhaps, in some instances, to food shortages in the future.

CONCLUSION

The Committee believes that fuel ethanol should be produced from spoiled and/or surplus crops and from crops grown on marginal land. Only in special circumstances should prime agricultural land or crops be exploited.

CONCLUSION

The Committee believes that exploitable ethanol feedstock resources (not counting cellulose) cannot provide enough ethanol to power the whole transportation sector.

RECOMMENDATION

Ethanol should be used as a gasoline extender only and not as a substitute transportation fuel in pure form, except perhaps on farms.

Individuals and members of farm co-operatives may wish to proceed with alcohol production using surplus or damaged crops or biomass grown on marginal land. To date, experience with the on-farm production of alcohol in the United States has shown that this can be an expensive and frustrating venture. Nevertheless, some farmers feel such production could be profitable and provide a measure of energy self-sufficiency on the farm. There is no single recommended method for ethanol distillation and each operation must consider the availability of conventional fuels for the distillation process as well as the kind of ethanol feedstock available. For example, the amount of ethanol which can be derived from different crops varies widely (Table 6-2). Furthermore, farmers must take into account the capital investment required for stills and the use to which the alcohol and by-products of distillation will be put.

Table 6-2: POTENTIAL ALCOHOL YIELD FROM SELECTED STARCH- AND SUGAR-CONTAINING CROPS

Crop	Yield[a] (litres/tonne)
Corn	430
Winter wheat	410
Barley	390
Rye	390
Spring wheat	380
Mixed grains (West)	350
Buckwheat	350
Peas, beans	350
Mixed grains (East)	330
Oats	270
Potatoes	110
Jerusalem artichokes	87-100[b]
Fodder beets	70-77[b]
Sugar beets	70
Field roots	30

[a] Yield assumes a maximum theoretical conversion to alcohol of 95%. The efficiency on farms would more likely be 50 to 85%.
[b] Preliminary values.

Source: Canada, Department of Agriculture, 1980, p. 4; and personal communication, Department of Agriculture, 1981.

The on-farm distillation of ethanol can give a measure of independence from conventional fuels because gasoline engines can burn gasohol containing between 10 and 20% ethanol without modification and apparently without causing damage. Kits are being developed to allow gasoline and diesel engines to burn mixtures of gasoline (or diesel), alcohol and water, and engines which run on pure alcohol have been developed although they are not commercially available in Canada.

The economic risk of farm-scale alcohol production is not well defined. Farmers may find this activity worthwhile if they are good handymen and can build a still rather than buy a commercial set-up. They may also not count their own labour in overall costs. In any event there will be some capital outlay and interest to be paid on the capital. In addition, the farmer must consider the loss in revenue from not selling that portion of a crop which is used as ethanol feedstock, plus the costs of depreciation, operation, energy inputs, chemicals, enzymes, insurance, licensing and bonding. (Feeding the mash or residue from ethanol production to livestock could help offset some of these expenses.)

CONCLUSION

Evidence suggests that on-farm alcohol production can be a risky business. Some knowledge of chemistry, engineering, microbiology and plumbing is required and careful economic planning must be carried out before any such operation is attempted.

One way in which Canada is attempting to make it easier for interested and enterprising individuals or groups to begin alcohol fuel production is to ease regulations set out in the Excise Act. Under existing legislation, alcohol must be collected in a "locked receiver" which can only be opened by a customs and excise inspector. The alcohol must also be rendered undrinkable (denatured) by adding a prescribed chemical if the alcohol produced is to be free of excise duty. Furthermore, a distiller's license ($250 per year) is required as well as a surety bond of $200,000 which costs $500 per year. These restrictions inhibit would-be distillers from making alcohol fuel.

CONCLUSION

The Committee welcomes the Government action to amend the Excise Act, making it easier for interested people to begin distilling alcohol fuel.

RECOMMENDATION

The Committee recommends that the Government ensure, in its amendments to the Excise Act, that production of ethanol in excess of individual requirements may be sold to retail suppliers of alcohol fuel or gasohol.

RECOMMENDATION

The Committee does not endorse pure ethanol from starch or sugar feedstocks as a major alternative liquid transportation fuel for Canada. It does, however, recommend that fuel ethanol be permitted for personal use or for the production of gasohol.

B. METHANOL

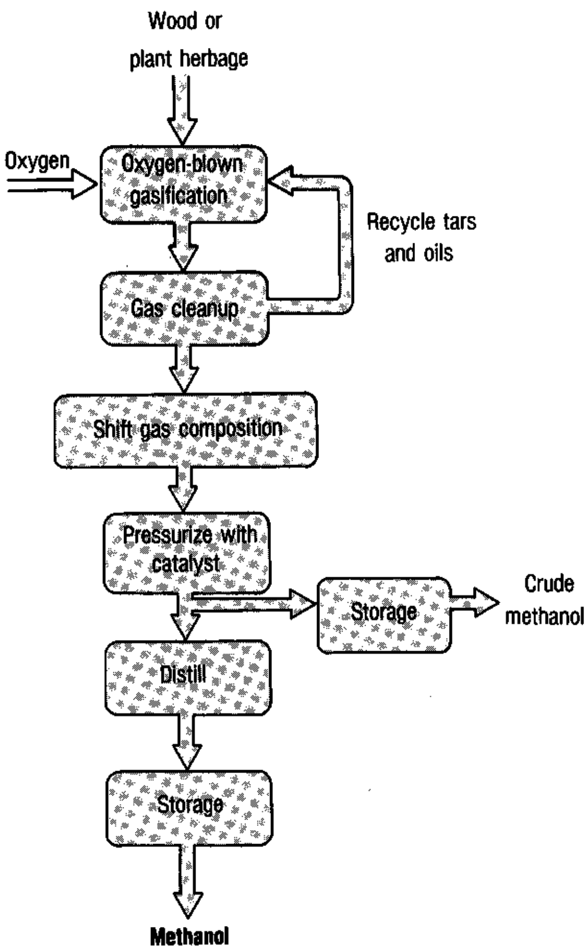
Methanol (CH_3OH) can be synthesized from a variety of sources including biomass, natural gas and coal. In the cases of biomass and coal, the raw feedstock must first be gasified before synthesis.

In the production of methanol from wood biomass, three basic steps are involved: gasification of the wood, cleanup and modification of the gas produced, and liquefaction of the gas. Generally, gasification occurs when the wood is heated in an atmosphere deficient in oxygen. This prevents complete combustion of the wood and produces a gas containing principally hydrogen, carbon monoxide, carbon dioxide and hydrocarbons. These gaseous compounds are not produced in concentrations ideal for the synthesis of methanol; therefore, their relative proportions are altered to obtain a hydrogen to carbon ratio which will provide good yields of methanol. In the final step, methanol is produced by subjecting the modified synthesis gas to from 50 to 150 atmospheres of pressure at 230 to 270°C in the presence of a catalyst. A flow diagram for methanol synthesis is given in Figure 6-5.

Initially, a methanol industry could be fueled by unusued mill wastes, forest residues, and other recoverable biomass not currently utilized. In the long-term, however, significant potential exists for tree farming (energy plantations) to provide the cellulose required to feed methanol plants. These plantations would allow abandoned farms and marginal lands to provide high yields of forest biomass with rotation times of from two to five years.

Since the quantities of cellulosic feedstocks are so much greater than those of sugar or starch crops, it would seem there is greater potential for alcohol production via the methanol route than via the ethanol route (although production of both alcohols can be encouraged). The provision of cellulosic feedstocks for methanol production requires less energy than does raising agricultural starch or sugar crops. In other words, the chances of achieving net energy gains from methanol may be greater than from ethanol. Fewer land-use arguments should arise in producing feedstock for a methanol industry than for an ethanol industry as trees can be grown on land which ranges widely in quality and topography. Indeed, there is unlikely to be

Figure 6-5: PROCESS DIAGRAM FOR METHANOL SYNTHESIS



Source: United States, Office of Technology Assessment, 1980a, p. 95.

severe competition between crops for energy and crops for food if methanol is produced, thus resolving the "food versus fuel" controversy to some extent.

Witnesses before the Committee described a unique Canadian opportunity for development of a methanol industry, incorporating a combined natural gas/biomass primary feedstock. Since the carbon/hydrogen ratio in biomass is higher than ideal for methanol synthesis, significant gains in yield can be made by spiking the synthesis gas with hydrogen. Canada has abundant supplies of natural gas which is a hydrogen carrier, as CH_4 has a high hydrogen to carbon ratio. Therefore combining natural gas with the biomass synthesis gas is essentially spiking it with hydrogen and high yields of methanol can thereby be achieved. High yields translate into reduced production costs and mean that the methanol industry can produce methanol at costs competitive with gasoline at present world prices for oil.

This technology would allow Canada to use natural gas in the short term to produce some liquid transportation fuel. It would also allow us to exploit biomass for methanol production faster and on a larger scale than by any other route. Methanol could be produced via this hybrid technology within two years, whereas developing a pure biomass-to-methanol technology would require an estimated seven years before commercial production could begin. Not only would yields be high using this hybrid approach, but experimentation with biomass gasification (the last untried step in methanol-from-biomass technology) would allow Canada to develop an expertise which could later be applied in methanol plants based completely on biomass as a carbon source and using pure hydrogen to spike the synthesis gas. This would give Canada a lead in the research, development and commercialization of methanol production from biomass and, when perfected, the expertise and technology could be profitably exported.

CONCLUSION

The Committee concludes there is a great potential for developing a methanol-from-biomass industry in Canada and that this country could become a world leader in methanol technology.

RECOMMENDATION

The Committee recommends that the construction of a hybrid natural gas/biomass methanol plant be encouraged to demonstrate this technology of methanol production as soon as possible.

RECOMMENDATION

Since hybrid natural gas/biomass methanol plants are a transitional step in establishing a fuel methanol industry, the Committee further recommends that such plants be converted when feasible to operation using biomass alone or biomass spiked with electrolytic hydrogen.

It has been suggested to the Committee that one of the major stumbling blocks to the introduction of methanol as an alternative fuel is the fact that Canadian consumers presently have to pay world-level prices for this commodity as a petrochemical feedstock.

RECOMMENDATION

In the short term, Canada should allow fuel methanol to be sold at prices lower than gasoline in order to make it attractive as an alternative transportation fuel.

2. BIOGAS

Biogas is produced by the anaerobic digestion of biomass. In this process various types of bacteria degrade organic material in the absence of air to produce a gaseous mixture composed predominantly of methane (CH_4 or natural gas) and carbon dioxide in varying proportions. The organisms which cause the breakdown may already be present in the feedstock or may be added to it as an inoculum (a small volume of a bacterial culture).

The energy value of biogas derives almost completely from its methane content which may range from 50 to 70% of the evolved gas. The carbon dioxide can be removed if the biogas is to be mixed with natural gas in pipelines but this involves treating the gas with a complex and expensive technology. Other gases such as ammonia may also be produced in varying proportions during the digestion process, but the main contaminant is usually hydrogen sulphide (H_2S). This compound can cause corrosion in engines using biogas fuel and it may cause irritation and nausea in people exposed to it. H_2S can be removed with simple, inexpensive technology.

Digestion usually takes place at temperatures ranging from 35 to 65°C, depending upon the feedstock used and upon which kinds of bacteria one wishes to favour for growth. The digestion process is well suited for treating wastes which are found in, or can be converted to, a wet slurry. Thus, in addition to producing a valuable energy commodity, anaerobic digestion can reduce the toxicity of waste materials, and hence their pollution hazards, and can reduce the odour problems usually associated with animal wastes.

Digestion is carried out by a mixed assortment of bacteria not all of which have been identified. The breakdown processes are complicated and the biochemistry of degradation is not completely understood; however, degradation generally takes place in three steps. First, decomposition of large organic molecules yields smaller molecules such as sugars and amino acids. Second, these smaller compounds are converted to organic acids, and third, the organic acids are transformed into the gas methane.

Cellulosic materials digest slowly, particularly those with a high lignin (complex cementing substance found in wood) content because this material makes the cellulose less susceptible to attack. Treatments such as hydrolysis can improve the susceptibility to attack but efficiencies of conversion to biogas are not expected to exceed 40 to 50%. It may therefore make better sense to burn cellulosic feedstocks directly to release energy rather than try to gasify them.

The best feedstock for biogas production is wet biomass such as animal manures, some aquatic plants, sewage sludges, or food-processing wastes from cheesemaking or potato, tomato or fruit processing. The digestion process must be monitored frequently because changes in temperature, feedstocks or toxin concentrations can generate an increase in the quantity of certain acids which can in turn inhibit the methane-producing bacteria.

During digestion a bacterial population evolves which is particularly adapted to the operating conditions of the reactor. For this reason, feedstock composition and operating conditions should be kept as constant as possible to ensure the process operates with maximum efficiency and produces optimal yields. Biogas production usually begins within a day of charging the digester but, without proper management, stabilization of the fermenting population may take months.

In addition to producing gas, anaerobic biodigestion generates other materials which are useful — the effluent from a digester may contain bacteria, lignocellulosic (containing lignin and cellulose) material, undigested feedstock and nutrients. Since most pathogenic (disease-causing) bacteria are destroyed during the process, wastes can be rendered less hazardous and the effluent or sludge used as a soil fertilizer or, under some circumstances, as a water fertilizer to enhance aquatic plant growth. Dewatered digester wastes also hold the promise of providing animal feed, a possibility under active investigation. Certainly, the economics of biogas production from animal manure and other feedstocks would be improved if digester wastes could be used for feed.

Despite the reduction in pathogenicity, the major potential problem associated with biogas production concerns treatment of waste waters which may contain heavy metals, pesticides and high levels of nutrients. This, however, is only a design and operational problem as the technology exists for treating such waters to render them environmentally harmless.

There are many designs for anaerobic digesters and these reactors are found in many forms and sizes around the world. They range from primitive structures to technologically-advanced units and R&D in this technology is advancing so rapidly that any list of digesters quickly becomes outdated. However several basic reactor types are described in the following paragraphs.

The single-tank plug flow system is a simple adaptation of the digester type which has long been used in Asia (Figure 6-6). The feedstock is loaded through the inlet, digested material is removed from the outlet and biogas is taken from the top of the fermentation tank where it collects.

Multitank batch systems consist of a series of tanks which are sealed after being charged with feedstock. When the digestion process is complete the biogas is drawn off and the effluent is emptied. Such systems are well adapted to operations which produce feedstock in batches rather than steadily.

A single-tank complete mix system consists of a fermentation tank which is heated and mixed several times daily. This system may be coupled with a second unmixed, unheated storage tank to form a two-stage digester in which additional degradation takes place and solid wastes are allowed to precipitate. The second tank allows yields of biogas to be improved. This type of reactor is used primarily for sewage treatment.

Experiments are now being carried out with multiphase digester systems in which successive tanks are regulated to optimize the various steps in the fermentation process. These are complex systems which must be carefully managed and are presently being studied utilizing sewage sludge as the primary feedstock. They may be adaptable to other feedstocks as well and theoretically could achieve high overall efficiencies in biogas generation.

Another variation in reactor design utilizes different types of "beds" to act as a material support for the bacterial populations which bring about the digestion of the raw organic matter. In this design the feedstock slurry is fed upwards through a vertical column packed with small stones, plastic balls, ceramic chips or other inert materials. The bacteria attach to this column material and degrade the organic matter as it flows past them. The design allows large quantities of slurry to pass through the digester while maintaining a high concentration of bacteria on the support material. This system is best suited to dilute municipal sewage as thicker feedstocks rapidly clog the column.

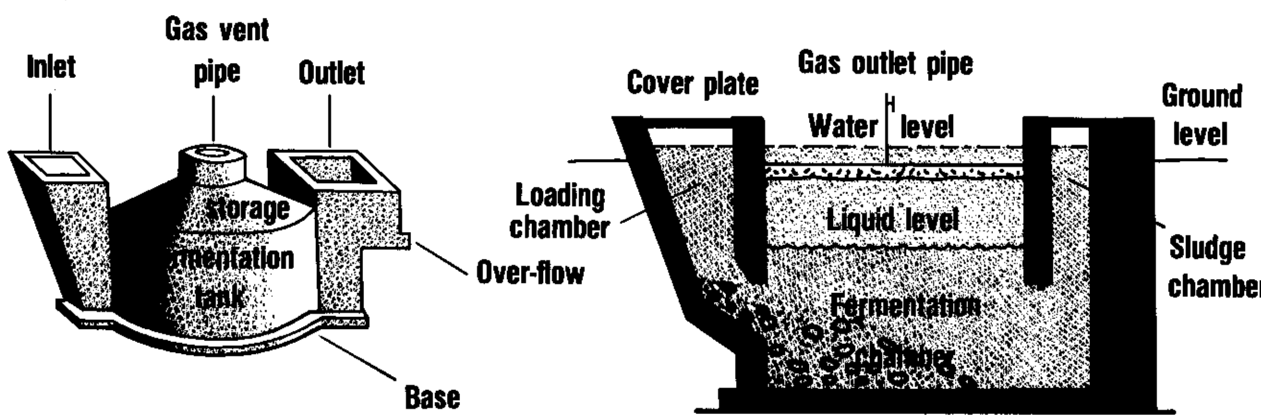
CONCLUSION

A wide variety of digesters has been described in the literature and a number are available from manufacturers. This type of system can help farmers attain energy self-sufficiency on their farms, and for operators of large feedlots and stockyards it offers the added bonus of reducing pollution problems by treating hazardous wastes. There are other advantages to be gained from anaerobic digestion, including the production of fertilizer and, possibly, animal feed.

RECOMMENDATION

The Committee recommends that the technology of anaerobic digestion should be actively pursued in Canada and that additional biogas reactors should be installed to demonstrate their effectiveness in the Canadian environment.

Figure 6-6: CHINESE DESIGN OF A BIOGAS DIGESTER



Source: United States, Office of Technology Assessment, 1980b, p. 185.

3. WOOD

Wood has been used as a fuel in this country since it was first inhabited. In fact, the burning of fuel wood is probably as old as civilization and continues to a greater or lesser extent throughout the world today. Wood is certainly Canada's most abundant biomass resource. It is available in most parts of the country either as waste material produced by the forest products industry or as standing, living biomass. In the future, with proper management of Canada's existing forests (which has not traditionally been the case) and with the development of energy plantations on marginal or abandoned farmland, this country's biomass resource could significantly increase in size.

At the present time biomass supplies about 3.5% of Canada's energy requirements (somewhat more than that contributed by nuclear fission), most of which is derived from our forests. Its main use is for the production of process heat and steam and, to a lesser extent, electricity. Virtually all of it is utilized by the forest industries.

The $104 million Forest Industry Renewable Energy (FIRE) program was designed to replace fossil fuels used in the forest industry by unutilized combustible biomass residues. Its goal is to save the equivalent of 23 million barrels of oil per year by 1985. FIRE provides financial incentives to the forest industry for the installation of proven biomass energy equipment and the companies involved receive progress payments of up to 20% of the eligible costs of approved projects. The program was initiated in 1978 and to date some 45 applications for assistance have been approved at a total commitment of $21 million. The type and distribution of fuels replaced through the FIRE program are shown in Table 6-3.

Table 6-3: CONVENTIONAL FUELS REPLACED PER ANNUM BY "FIRE" PROJECTS APPROVED TO 22 JUNE 1980

Type of Fuel Replaced	Per Cent of Total
Oil	70.0
Natural Gas	23.4
Coal	3.8
Electricity	2.7
Propane and Butane	0.1
	100.0[a]

[a] So far the equivalent of 2.5 million barrels of oil per annum has been replaced.

Source: Canada, Department of Energy, Mines and Resources, 1980f, p. 12.

Most FIRE funds have gone to pulp and paper mills rather than to the wood industry as the former generally have a higher energy consumption per unit of product output than the latter. Energy consumption for pulp and paper manufacture amounts to about 20% of the value added compared to less than 5% for wood products. Pulp mills require larger, more expensive and more complex energy systems, and it is easier to promote the program among 150 pulp mills than among the approximately 8,000 wood operations.

The Federal Government has also provided $30 million for the period 1978 to 1984 through the Energy from the Forest (ENFOR) program to help fund research projects and demonstrations of innovative techniques in biomass resource production and conversion. ENFOR is administered by the Canadian Forest Service of Environment Canada and evaluates proposals for biomass plantations, wood combustion and gasification, and liquid fuels production from biomass, to name some of the most important. As of early 1980, the Government had funded some 46 projects worth around $3.7 million.

CONCLUSION

The Committee concludes that the ENFOR and FIRE programs have been largely successful and applauds the recent announcement in the National Energy Program of a near tripling of the budget for FIRE.

Some say the amount of energy derived from biomass (primarily wood) could be trebled by the year 2000, an optimistic view which is shared by the Committee. The main problems to be overcome are those inherent in the resource itself: the size of the capital investment required to allow exploitation of the resource, and the lack of a well-developed commercial and industrial infrastructure geared to the harvesting, distribution and utilization of biomass in its many forms.

Many of the disadvantages involved in exploiting all forms of biomass, such as its low energy density, its variety in form and the attendant difficulties in its transportation, can be mitigated to a large extent by upgrading. This can be achieved by such means as pulverization, drying and densification, or chemical conversion. In fact, a variety and combination of steps can transform the organic matter of biomass into standard commodity fuels which are both convenient and economic to ship, store and burn.

There are many ways wood can be used to provide energy (Figure 6-7). It can be burned directly to provide heat, process steam and, via co-generation, electricity as well. It can be gasified to provide a fuel gas to replace oil and natural gas. It can be converted to methanol via synthesis after gasification, or to ethanol via fermentation. Finally, by means of slow heating under pressure, it can be converted to oil.

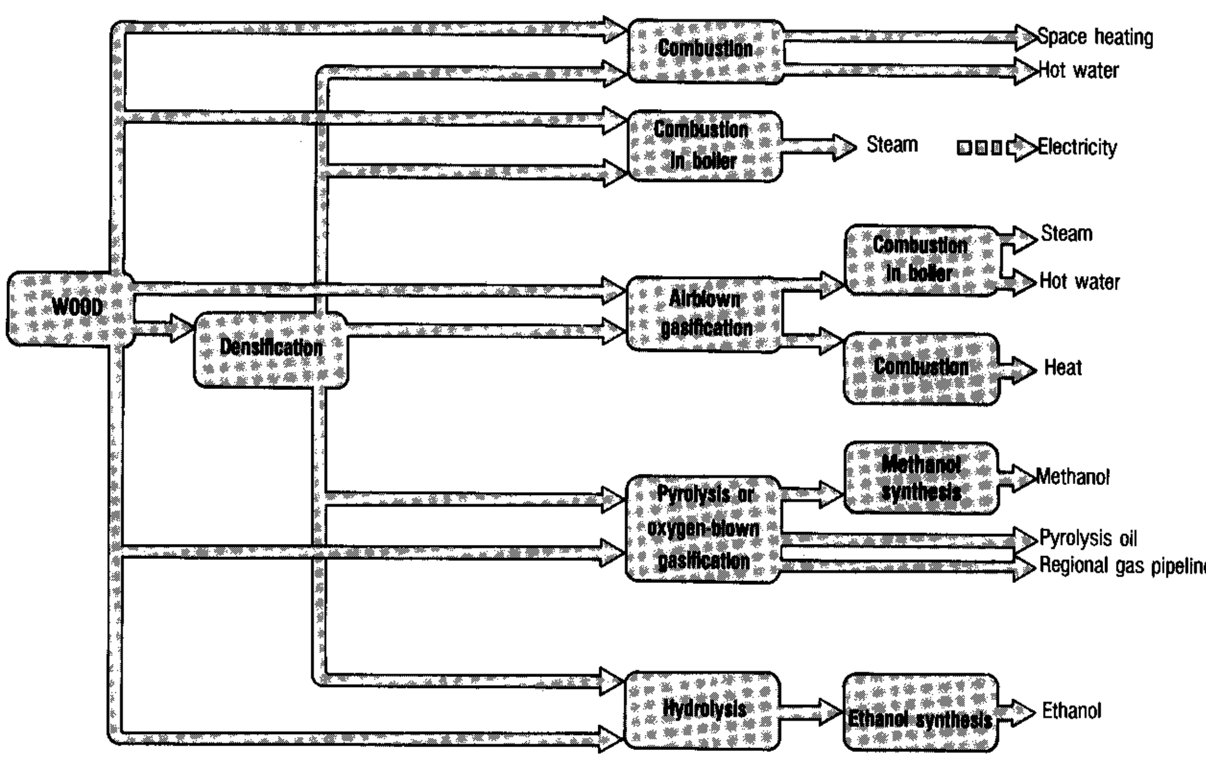
A. DIRECT COMBUSTION OF WOOD AND DENSIFIED BIOMASS FUEL (DBF)

Wood can be burned directly for residential use or for industrial purposes but certain conditions have to be met to maintain a positive net energy balance in exploiting this resource. The energy contained in wood justifies its cutting, handling and transportation for up to 40 to 60 miles depending on the region; however, further processing or transportation means that more energy may be spent in delivering the fuel to the user than is provided during combustion. It does not make good *energy* sense to spend more energy in providing a fuel than is contained in the fuel itself (although such use may be justified in the short term if the wood substitutes for oil). The use of unprocessed wood should remain local then and, fortunately, the wide dispersion of the wood resource very often allows this condition to be met.

Wood tissue is comprised primarily of cellulose, hemicellulose, lignin and water in varying concentrations. Biomass typically has a low *mass* energy density (MED) or low amount of energy which can be delivered per unit of mass. Similarly, biomass has a low *volume* energy density (VED). This is unfortunate as fuels with a high MED (or VED) are preferable to those with a low MED (or VED) because the former type is more efficient to store, ship and burn. Thus the large resources of wood in areas far from population centres or resource utilization locations are not economically exploitable unless they are upgraded or converted to fuels which have a high MED (or VED) before shipping. The prime energy commodities which can be derived from wood and wood waste are densified wood and, as described elsewhere, the alcohols methanol and ethanol. An increase in MED and VED is most desirable because combustion efficiency increases with increasing energy density and low moisture content; the efficiency of boiler heat exchange is a function of the quantity of gas produced from a given volume or mass of wood and the water content of the fuel.

Mass energy density and volume energy density values for raw wood and densified wood are shown in

Figure 6-7: CONVERSION PROCESSES FOR WOOD



Source: United States, Office of Technology Assessment, 1980a, p. 64.

Table 6-4. These data show that the densification of wood converts this resource into a substance which is superior to the raw feedstock in terms of fuel value per unit of volume. Figure 6-8 shows the typical energy content of biomass versus moisture content.

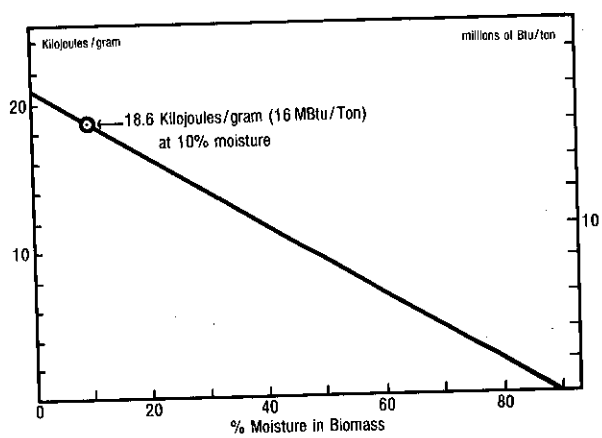
Table 6-4: ENERGY DENSITIES OF WOOD BY MASS AND VOLUME

Fuel	Water Content (%)	Density (gams/ cm^3)	Heat of Combustion[a] Mass (MED) (kilojoules/gram)	Heat of Combustion[a] Volume (VED) (kilojoules/ cm^3)
Wood	10	0.6	18.6	11.2
Densified Wood	10	1.0	18.6	18.6

[a] Values shown are representative of a range for each fuel.

Source: After Reed and Bryant, 1978, p. B-2.

Figure 6-8: SENSITIVITY OF ENERGY CONTENT TO MOISTURE CONTENT IN WOOD



Source: After Reed and Bryant, 1978, p. B-5.

The first patent for densification was issued in 1880 and described a process in which sawdust or other wood residues were heated to 150°F and compacted to the "density of bituminous coal" with a steam hammer. Since then a number of patents have been issued for similar processes but, in general, five forms of biomass densification are now practiced commercially: pelleting, cubing, extrusion, briquetting and rolling-compressing.

Depending on the feedstock and the degree of compaction, densified biomass may have a water-repellent skin. However, exposure to water should be avoided during storage, particularly if the DBF has a high paper content. Because compacted fuels have a low moisture content, they biodegrade slowly and can be stored for long periods but only if kept dry. Biomass pellets make a satisfactory fuel for fixed-grate boilers, either supplementing or replacing coal.

While DBF does not share two advantages of coal — concentrated sources of supply and an established industrial infrastructure — neither does it share many of its liabilities, such as sulphur emissions, environmental disruption by strip-mining and black lung disease in coal workers. Although any economic analysis of DBF versus coal is highly site- and time-sensitive, it appears that DBF may have an economic advantage in regions with abundant biomass but no coal. DBF may also be preferable to coal for industrial or utility processes where sulphur abatement is required.

The technology for burning DBF in supplement to or in replacement of coal is well developed. Suspension and spreader stoker coal-firing systems can burn DBF with little or no modification. Boilers specifically designed to burn wood — fluidized bed combustors, small firetube boilers, bark burning boilers, and vortex combustors — will also burn DBF and are commercially available today in a wide range of capacities.

It is neither practical nor economical to substitute DBF in existing gas and oil boilers. DBF is, however, an attractive feedstock for low- to medium-Btu gasification. The product gas can be used to produce process heat and to fuel existing gas and oil installations with only minor engineering modifications. Because gasifiers perform best on a uniform, dense and clean feedstock, DBF may be preferable to coal or green biomass.

Other potential uses of DBF include fueling residential, commercial or industrial central heating systems; fueling airtight wood stoves; firing external combustion engines; fueling fireplaces and outdoor grills; and producing pyrolysis oil and high-density charcoal. In summary, the process of densifying biomass holds the promise of providing a dry, uniform, easily stored and conveniently shipped fuel from the wide variety of residues produced by forest, agriculture and food processing industries.

CONCLUSION

The Committee feels that there are definite advantages to be gained from increased exploitation of Canada's wood resources and that one of the ways of making wood a more attractive and versatile fuel is by densification.

RECOMMENDATION

As the technology for biomass densification is available now and is being used in some loca-

tions, the Committee recommends that development of the wood densification industry should be encouraged in Canada. This means that increased emphasis in R&D should be placed on improving combustion technologies for densified biomass fuels and on developing end uses and markets for the densified biomass product.

Some environmentalists are expressing concern about the growing popularity of residential, as opposed to industrial, wood burning. Carbon monoxide, particulate matter and polycyclic organic matter (POM) are all emitted from wood stoves and fireplaces, and a draft paper prepared by Battelle for the Environmental Protection Agency in the United States concerning industrial and commercial wood combustion, stated that

> ...low-temperature wood-burning units tend to produce more undesirable atmospheric emissions than do the larger units which operate at higher temperatures and with greater turbulence ... it may be that the small residential wood-burning units are capable of producing larger quantities of POM emissions than the commercial/industrial-size wood-burning boilers... (Budiansky, 1980, p. 770)

Thus there is a danger that increased residential use of firewood may have detrimental effects on the environment. The POM emitted by wood stoves and fireplaces contains benzo [a] pyrene and other known or suspected carcinogens and may represent a significant health hazard and cancer risk in certain locations.

> Wood is now recognized as a serious source of air pollution. Vail, Colorado, and many communities in New Hampshire and Vermont (particularly in valleys susceptible to particulate haze) have already been forced into coming to grips with the smoke and haze resulting from the residential wood-stove boom. (Budiansky, 1980, p. 769)

CONCLUSION

The Committee sees increased use of firewood for home heating as a means of substituting a renewable energy source for oil and as a good way of making people aware of how they use energy in their lives. This may help Canadians develop a personal feeling for the importance of conservation. Nonetheless, the Committee is concerned about the increased use of firewood in homes, particularly in urban areas.

RECOMMENDATION

The Committee recommends that a study of how the increasing combustion of wood in urban areas will affect air quality should begin immediately. Such a study should be completed before expanded use of firewood is recommended for urban centres.

RECOMMENDATION

Fire safety regulations should be reviewed and strengthened so that the installation and use of wood stoves and fireplaces does not lead to a tragic increase in the incidence of fires in homes using fuel wood.

B. GASIFICATION

When wood is exposed to heat it first begins to lose moisture then decomposes (pyrolyzes) into a variety of compounds depending upon temperature, the rate of heating and the presence or absence of oxygen. The wood itself does not burn, rather it is the products of pyrolysis which do. In the presence of ample supplies of oxygen, these products combust completely to form predominantly carbon dioxide (CO_2), water and ash. In the absence of oxygen, the main gaseous pyrolysis products are carbon monoxide (CO), hydrogen (H_2) and some CO_2, collectively known as synthesis gas.

Gasification of wood under pyrolytic conditions is a highly useful process because it converts a bulky and difficult to handle raw material into a flexible fuel. The synthesis gas produced can be piped easily; it can be used to fire fossil-fueled systems; or it can be combusted to generate electricity. In addition, the chemical composition of this gas can be adjusted by adding hydrogen to give the proper ratio of carbon to hydrogen to allow efficient synthesis of methanol.

RECOMMENDATION

The Committee believes that the technology of biomass gasification should be funded on a priority basis in biomass R&D. It has the potential of allowing greater use of wood (and other biomass feedstocks) to fire systems which traditionally have used fossil fuels. It is perhaps the last part of the technology of methanol synthesis from biomass which must be improved upon to assure commercialization of this alcohol fuel option.

4. PEAT

A. THE NATURE OF PEAT

Peat is partially decomposed organic matter which is made up principally of decayed *Sphagnum* moss, although a minor component may be contributed by other aquatic plants, grasses or sedges. It is formed very slowly by the decay of this dead vegetation under anaerobic (oxygen deficient) conditions. All Canada's peat bogs have developed since the last glacial epoch, some 10,000 years ago.

Peat bogs differ from other types of wetlands in that they are nourished almost entirely from rainwater. Their surface is a continuous carpet of *Sphagnum* moss which supports a layer of grass and shrubs and, occasionally, trees. In Canada peat bogs may be as large as tens of kilometres across but are generally much smaller.

A peat bog is made up of a number of layers. The top level is living bog vegetation. The second consists of very young peat which is characterized by a loose open structure that clearly shows the form of the dead vegetation from which it is derived. The third layer is of varying thickness but becomes darker and denser with depth until the black colour and putty-like consistency of mature peat is encountered.

At all its different stages in development, peat contains a very high proportion of water, usually averaging around 95% by weight. This means that, perhaps surprisingly, there is less solid matter in peat than there is in milk. This high water content has always been the main barrier to the extensive exploitation of peat as an energy source.

Because peat occurs on the Earth's surface and extends only to relatively shallow depths, its removal is unlikely to cause environmental problems as severe as those associated with strip-mining. However, great care should be exercised during and after peat excavation to ensure that harvested bogs do not turn into muddy wastelands. Fortunately, peat has been mined for years in other countries and there is a wealth of experience in reclaiming bogs. In fact, with proper management, depleted bogs can be used for agricultural land or for energy plantations (Figure 6-9). It is essential then that peat harvesting only be permitted with the assurance of proper reclamation after excavation.

Harvested peat can be marketed in three different forms. Sod peat is made by a large cutting machine which dredges peat from all depths of the bog, mixes it and forms it into sods. They are therefore all of similar quality and can compete in the marketplace with other industrial fuels. Milled peat is scraped from the surface of the bog in the form of a coarse powder. After drying this material can be either burned in power stations or processed into briquettes. Briquettes are small tightly-packed blocks of milled peat, the quality of which is carefully monitored because the briquetting process can tolerate only small variations in density, moisture and ash content. About one-fifth of the energy in the peat is used to produce the briquettes and this product is used primarily for home heating.

Development of a Peat Bog for Energy Production

Peatlands have to be developed before they can produce utilizable peat and a great deal of preparation, usually taking several years, is required before production can proceed. First, the bog must be surveyed to determine how much peat there is, what its quality is, how it can best be drained and how access routes to the resource can be set up by rail and road.

The second step is drainage. Since peat is approximately 95% water, it cannot support heavy machinery and removal of as much moisture as possible is essential. A network of drainage ditches is dug to begin the process of dewatering and, as the bog consolidates, these drains are deepened to facilitate further water removal. This stage normally takes five to seven years to complete and reduces the bog's moisture content to approximately 90%. This may seem a trivial improvement but, in fact, it is very significant as it represents removing more than half the water contained in the peat. At 95% water content the ratio is 1 part solid to 19 parts water; at 90% the ratio is 1 part solid to only 9 parts water.

After draining the bog is levelled. This is done to facilitate drying of the peat and to allow mechanical handling to take place with maximum efficiency.

The final step involves establishing a network of light railways over the surface of the bog for the handling and transportation of the peat. All these steps plus the fact that only a few inches of peat are harvested annually mean that a bog may be commercially exploited for several decades.

B. INTERNATIONAL AND CANADIAN DEVELOPMENT

World peat resources over 50 cm thick are estimated to total some 145 billion tonnes dry weight, having an energy equivalent to about 63.5 billion tonnes of oil. Much of this total is located in the U.S.S.R. but large quantities are found in other countries as well, with Canada ranking second in terms of resource size (Table 6-5).

Finland has a number of power stations which utilize peat to produce electricity, and steam and hot water for district heating. The Finns expect to derive from 5 to 10% of their total energy requirements from peat in the future.

Figure 6-9: BOGS OF TODAY ARE FARMLANDS AND ENERGY PLANTATIONS OF THE FUTURE

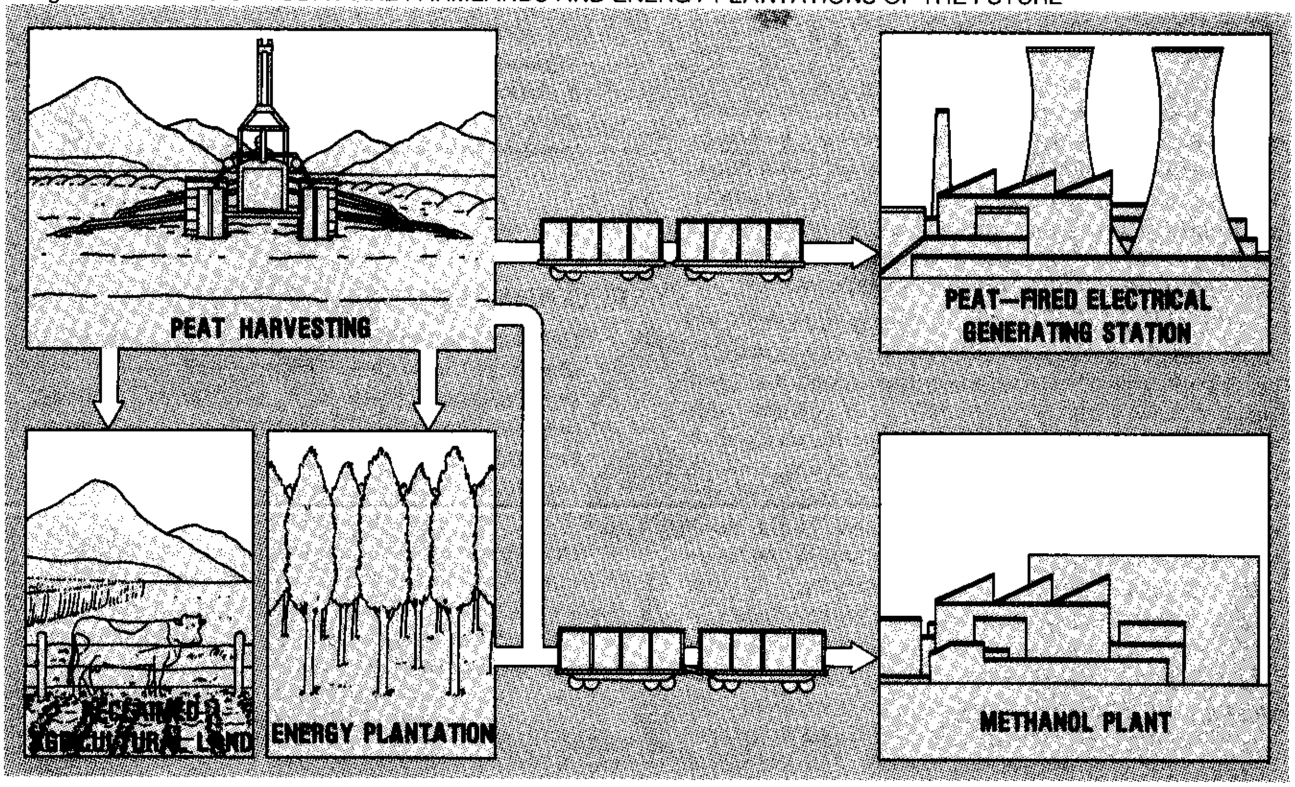


Table 6-5: WORLD PEAT RESOURCES

Country	Billions of Tonnes at 40% Moisture Content
U.S.S.R.[a]	147.4
Canada[b]	22.7
Finland	16.3
United States	12.7
Sweden	8.2
Poland	5.4
West Germany	5.4
Ireland	4.5

[a] Investigated resources; probable resources are about 200 billion tonnes.
[b] Now regarded as underestimated.

Source: "Peat Facts", 1977.

In the U.S.S.R. it is estimated that an electrical generating capacity in excess of 6,000 MW is peat-fired. (By comparison, Churchill Falls generates 5,225 MW and supplies about 6% of Canada's electrical power.) In addition, perhaps 4.5 million tonnes of peat are produced annually for home heating.

Ireland presently operates seven peat-fired electrical generating stations. These installations consume approximately 56% of Ireland's harvested peat (about 5 million tonnes annually) and produce about one-third of the country's thermally-generated electricity. If peat were not used as an energy source, the cost of supplying that electricity with imported oil would be some £60 million. Moreover, exports of peat (predominantly horticultural peat) currently pump £70 million a year into the Irish economy.

Irish research is currently directed towards studying the conversion of depleted bogs into energy plantations and experiments with fast-growing hybrid clones of several tree species are being actively pursued. The most promising species so far examined are willows, poplars and alders. It is estimated that the energy output per unit area from a biomass plantation will only be some 1/7th or 1/8th of that derived from milled peat production.

Peatlands cover approximately 12% of Canada's land surface, an area 12 times that of the Island of

Newfoundland. Much of the resource is located in inaccessible northern areas but significant deposits occur in the Atlantic Provinces and in southern Quebec and Ontario. Attempts to inventory the peat resource have been made in a number of parts of Canada, particularly in New Brunswick and Newfoundland, but a full characterization of the Canadian resource has yet to be done. The use of peat for energy production is attractive, particularly in areas that are deficient in other energy resources, but at the present time Canadian peat is recovered exclusively for horticultural purposes.

Recently there has been increasing interest shown in fuel peat by Canadians and one study on the feasibility of peat-fired power generation concluded that peat was economic compared with oil-fired or coal-fired stations of the same size in New Brunswick. Hydro-Québec has studied the feasibility of peat-fired power stations and has been considering peat gasification as a means of replacing diesel generation on Anticosti Island. Newfoundland is developing a peat bog to assess the feasibility and cost of harvesting and transporting fuel peat on the Island. Peat burning tests will be conducted at the Grand Falls pulp and paper mill of Price (Newfoundland) Limited. The Province is also interested in the potential for displacing diesel-electric generation with small peat-fired generating units in isolated communities.

Perhaps one reason peat development has been slow in Canada derives from the fact that very little peat expertise exists in this country. This is in contrast to many European nations where much peat R&D and the teaching of peat-related studies at the university level takes place. The technology of harvesting and utilizing peat is well developed elsewhere although it is strange to Canada.

CONCLUSION

As peat deposits often occur in less developed regions of Canada and since peat production is a labour-intensive activity, development of Canada's peat resources could provide employment as well as produce energy.

RECOMMENDATION

Canada's extensive peat deposits represent a significant alternative energy opportunity, but our resource base has been only partially outlined. An accurate assessment of its quantity, quality and location should be completed.

One option for peat use which may be particularly attractive from the point of view of helping Canada develop methanol as a portable liquid power fuel would be to develop an expertise in methanol production from peat-derived synthesis gas.

RECOMMENDATION

The Committee recommends that peat R&D encompass the development of an efficient technology for the gasification of peat. This would allow Canada to broaden its resource base for the production of the alternative liquid transportation fuel methanol.