PROGRESS REPORT TO

MINISTRY OF STATE FOR SCIENCE AND TECHNOLOGY

STUDY OF SOLAR AND WIND ENERGY SYSTEMS AND RECOMMENDATIONS FOR RESEARCH AND DEVELOPMENT TO BE UNDERTAKEN IN CANADA.

PRINCIPAL INVESTIGATOR: Mr. T.A. Lawand,
Director, Field Operations

July 1974

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Report:

In accord with the above contract, the following activities have been undertaken:

a) a historical review has been undertaken of different solar and wind energy applications. Special emphasis has been placed on:

1) wind energy applications
2) methane generation through anerobic decomposition of waste matter
3) solar cooking
4) purification of water
5) space heating and cooling
6) refrigeration
7) energy storage

These applications have not been given priority because of their order of importance. Much remains to be done with regards to this project; and every effort is being made to include the latest developments in the field.

It must be stressed that the field of solar energy research and development as well as its commercial and industrial component, is in a

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rapidly changing state of flux. For example, the United States, section of the Solar Energy Society, the professional society dealing with this field, encompassing Canadian members as well, rose in membership as follows:

	Number of Members
June 1971	240
June 1972	309
June 1973	411
June 1974	1,201

The degree of professional interest and involvement in particular in the United States of America has been phenomenal. It has not solely been restricted to the U.S.A.. The Japanese Government has invested in the "Sunshine Project", which is a stimulus to Japanese industry. Similar solar energy Research and Development schemes are underway in a number of other countries.

The greatest attention is being given to solar energy in the United States of America. A bill is currently before the U.S. Senate proposing the setting up of an Office of Solar Energy Research, with an initial budget of $600,000,000 for the first four years.

As part of this contract, this Institute prepared and submitted a brief to a U.S. Senate investigating committee outlining conditions in this field in Canada and proposing a course of action compatible to our needs. This statement is included in Appendix A of this report. It outlines the two principal areas where solar energy is currently utilized in Canada, i.e. in the climatization of buildings and in agriculture.

In preparing this progress report, the Institute surveyed the latest conferences dealing with Solar Energy Research and Development. This included some solar energy meetings in the United States of America, France, Russia and India as well as several windpower conferences in North America.

Through the bilingual abilities of its staff, literature is being reviewed in a number of different languages. Contact is being maintained and strengthened with overseas agencies looking into the question of solar energy utilization. Contact has been established with groups working in the oil-producing nations of the Middle East, where they are now turning their attention towards utilizing the vast potential of solar energy in their desert regions.

Finally it must be stressed that more attention should be paid to interesting the youth of this country in alternative energy sources. In hiring summer students this year, particular attention was paid to involving those interested in alternative energy utilization in the preparation of this report. We are grateful for their efforts, and hope that this opportunity will serve as a base for their formation and increased awareness of the potential of this national resource.

THE NATURE OF THE PROBLEM

It makes little sense to consider the field of alternative energy sources, and their potential application in this country without siting the whole question of energy consumption to the patterns of functioning of society today. We live in a world of high and often wasteful consumption of resources - and this is not strictly limited to energy resources alone. The entire pattern of operation of our industrial complexes needs to be thoroughly re-examined, with regards to inputs of capital, labour, material and energy resources in planning the world of tomorrow. To superimpose alternative energy sources such as solar energy onto our existing supply-demand system of operation, without modifying our philosophy of approach would effectively be futile. Surely the use of these more diffuse, and often more difficult to harness energy sources must be accompanied by some form of resource conservation, materials and energy recycling, reduced demand and more efficient designs of existing systems, etc. It is senseless to opt for alternative energy resources and continue with our present modes of operation - frankly it will simply not prove feasible.

A number of different countries have already made efforts to initiate solar energy research legislation.

The list of Bills and Resolutions introduced in the 93rd Congress of the United States of America is certainly impressive. All of these Bills deal with solar energy.

Bill No. Date Title & Objective

- S. 357. 12 Jan/73 Establishes a Federal Power Research & Development Board.

- S. 454 18 Jan/73 Declares that it is the policy of the Federal Government to bring into being the technology for commercial development of new energy sources as quickly as possible. Establishes a New Energy Source Corporation which shall have a Board of nine directors.

- S. 1283 19 Mar/73 National Energy Research and Development Policy Act - Title I: Coordination and Augmentation of Federal Support for Research and Development of Fuels and Energy.

  Title II: Geothermal Energy.

- S. 2167 13 Jul/73 Authorizes the Secretary of the Interior to conduct research, development, and demonstration projects in the fields of energy sources and technologies. Empowers the Secretary to make grants and enter into contracts to carry out the purposes of this Act.

- S. 2182 14 Jul/73 Banking Housing and Urban Affairs. Housing Act - Chapter I: Mortgage Credit Assistance - Revised National Housing Act - Title I: General Authority - Sets forth the definitions of terms used in this Act.

Bill No.	Date	Title & Objective

- S.2182 14 Jul/73 (cont'd)
  Title II: Insurance Funds, Premiums and Charges.

  Title III: Insurance for Property Improvement, Historic Structure Preservation, and Mobile Home Loans.

  Title IV: Home Mortgage Insurance.

  Title V: Project Mortgage Insurance.

  Title VI: Insurance Claims.

  Title VII: Miscellaneous.

  Chapter II: Public Housing Assistance Program.

  Chapter III: Special Housing Needs.

- S. 2636 30 Oct/73 Solar, Hydrogen, and Geothermal Energy Act.

- S. 2650 2 Nov/73 Banking, Housing and Urban Affairs.
  Solar Home Heating and Cooling Demonstration Act.

- S. 2658 5 Nov/73 Aeronautical and Space Sciences.
  Solar Heating and Cooling Demonstration Act.

- S. 2744 27 Nov/73 Energy Reorganization Act.
  Title I: Energy Research and Development Administration.

  Title II: Nuclear Energy Commission.

  Title III: Miscellaneous and Transitional Provisions.

- S. 2755 29 Nov/73 Aeronautical and Space Sciences.
  Directs the Administrator of the National Aeronautics and Space Administration, with the Secretary of State, the Secretary of Defense, and the Director of the National Science Foundation, to make a study of the possibilities for international cooperation and cost sharing in the development of a system for the collection and conversion of solar energy.

- S. 2819 17 Dec/73 Solar Energy Research Act -
  Declares that it is the policy of the Federal Government to pursue a program of research and development into the utilization of solar energy as a major source for our national energy needs.

- S. 3066 27 Feb/74 Housing and Community Development Act - (Revision of S. 2182)
  Chapter I: Housing Loan Insurance and Mortgage Credit Assistance -
  Title I: General Authority.

Bill No.	Date	Title & Objective

- S. 3066 27 Feb./74 (Revision of S. 2182) (cont'd)
  Title II: Insurance Funds, Premiums, and Charges.

  Title III: Insurance for Property Improvement, Historic Structure Preservation, and Mobile Home Loans and for Rehabilitation Loan Funds.

  Title IV: Home Mortgage Credit Assistance.

  Title V: Project Mortgage Credit Assistance.

  Title VI: Guarantee of State Housing Bonds.

  Title VII: Insurance Claims.

  Title VIII: Miscellaneous.

  Chapter II: Low-Income Housing Assistance.

  Chapter III: Community Development.

  Chapter IV: Comprehensive Planning.

  Chapter V: Rural Housing Assistance.

  Chapter VI: Mobile Home Construction and Safety Standards.

  Chapter VII: Housing Cooperative Financing Association.

  Chapter VIII: Miscellaneous.

- S. 3084 28 Feb/74 Department of Agriculture Solar Energy Research and Development Supplemental Appropriations Authorization Act.

- S. 3234 26 Mar/74 Solar Energy Research Act.

Bill No.	Date	Title & Objective

- H. R. 921 3 Jan/73 Creates in the Executive Office of the President a Council on Energy Policy.

- H. R. 1894 11 Jan/73 Suggests the establishment of a National Commission on Fuels and Energy.

- H. R. 6194 27 Mar/73 Establishes the Energy Development and Supply Commission.

- H. R. 6313 29 Mar/73 Suggests the establishment of a Joint Committee on Energy.

- H. R. 9696 30 Jul/73 Establishes an Office of Solar Energy Research.

- H. R. 10479 24 Jul/73 Authorizes and directs the Secretary of Commerce to study applications of solar energy.

- H. R. 10952 16 Oct/73 Solar Heating and Cooling Demonstration Act.

- H. R. 11299 6 Nov/73 Directs the Administrator of General Services to insure that design criteria for new Federally funded buildings provide for the best practicable use and conservation of energy. Provides that the Administrator shall consider: (1) features that make use of sunlight; (2) insulation and elimination of excessive fenestration; (3) energy expended in the manufacture and transportation of building materials; and (4) new techniques for energy supply, generation, and transmission.

  Provides that the Administrator of General Services shall examine existing buildings to determine what improvements can be made to insure the conservation of energy.

- H. R. 11510 15 Nov/73 Energy Reorganization Act -

  Title I: Energy Research and Development Administration.

  Title II: Nuclear Energy Commission.

  Title III: Miscellaneous and Transitional Provisions.

  Title IV: Sex Discrimination.

- H. R. 11542 15 Nov/73 Directs the Committee on Public Works of the Senate and of the House of Representatives, respectively, to not approve any project for construction of any public building under this Act unless such project provides for the use of solar energy to meet the heating and cooling requirements of such building, to any extent to which the use of solar energy is economical and efficient.

Bill No.	Date	Title & Objective
- H. R. 11543	15 Nov/73	Allows an income tax credit under the Internal Revenue Code for repaire or improvements of the residence of a taxpayer which improve the thermal design of such residence. Places limitations on the amount of such credit.
- H. R. 11566	26 Nov/73	Solar Energy Act.
- H. R. 11728	30 Nov/73	National Energy Research and Development Policy Act.
- H. R. 11781	4 Dec/73	Establishes the Energy Development and Supply Commission.
- H. R. 11857	10 Dec/73	Federal Non-nuclear Research and Development Act.
- H. R. 11864	10 Dec/73	Solar Heating and Cooling Demonstration Act.
- H. R. 11882	11 Dec/73	Energy Emergency Act. Title I: Energy Emergency Authorities. Title II: Coordination with Environmental Protection Requirements.
- H. R. 11933	12 Dec/73	Allows an income tax deduction with respect to the amortization of the amortizable basis of any certified solar heating and cooling equipment manufacturing facility, based on a period of 60 months.
- H. R. 12064	20 Dec/73	Solar Energy Act.
- H. R. 12069	20 Dec/73	Energy Conservation and Development Trust Fund Act - Title I: Energy Conservation and Development. Title II: Internal Revenue Amendments.
- H. R. 12118	21 Dec/73	Allows as a tax deduction from income tax, under the Internal Revenue Code, any expenditures made by a taxpayer during the taxable year for the purchase and installation, in any residential structure owned by him and expected to be occupied for at least one hundred and eighty-three days per year, of qualified insulative materials or qualified environmental conditioning equipment, including, but not limited to, solar energy environmental conditioning apparatus.
- H. R. 12248	23 Jan/74	Solar Heating and Cooling Demonstration Act.

Bill No.	Date	Title & Objective

- H. R. 12265 23 Jan/74 Energy Independence Act -
  Title I: Energy Research and Development Administration.

  Title II: Nuclear Energy Commission.

  Title III: Miscellaneous and Transitional Provisions.

- H. R. 12659 6 Feb/74 Solar Heating and Cooling Demonstration Act.

- H. R. 12718 7 Feb/74 Energy Research, Development, and Demonstration Administration Act -
  Title I: Statement of Findings and Declaration of Purpose.

  Title II: Establishment and Organization of Energy Research, Development and Demonstration Administration.

  Title III: Functions.

  Title IV: Transfers.

  Title V: Savings Provisions.

  Title VI: Funding.

  Title VII: Nuclear Energy Commission.

  Title VIII: Effective Date and Interim Appointment.

  Title IX: Definitions and Administrative Provisions.

  Title X: Separability.

- H. R. 12902 20 Feb/74 Interfuel Competition Act.

- H.R. 12904 20 Feb/74 Establishes the Energy Development and Supply Commission.

- H. R. 13089 27 Feb/74 Interfuel Competition Act.

- H. R. 13203 4 Mar/74 Authorizes an income tax deduction under the Internal Revenue Code for up to 50 percent of the cost of purchasing and installing solar heating and cooling equipment in any building owned, leased, or rented by a taxpayer.

Bill No.	Date	Title & Objective
- H. R. 14434	25 Apr/74	Special Energy Research and Development Appropriation Act.

Not all of these bills have been approved, and there is some repetition. It does, nonetheless, stress the degree of interest to which our American neighbours have become aware of the need to be independent in their energy requirements. A statement was presented to the U.S. Senate Committee on Insular & Interior Affairs, dealing with Bill 3234. This is included in Appendix A of this report.

A somewhat more comprehensive approach has been taken in Japan where the authorities have been turning their attention to the development of new sources of energy. To this end the government had initiated the Sunshine Project to study methods of utilising solar energy. By the end of the century it was hoped that new sources would substitute almost entirely for oil by (a) an unlimited supply of clean solar energy; (b) nuclear energy; (c) petroleum type products synthesised from coal; (d) geothermal and hydrogen energy. In addition, the whole Japanese industrial complex was being intensively examined in order to achieve a greater integration of technology and knowledge with available resources and energy. The aim was restriction of demand and the stabilisation of the growth of production. This would partly be achieved by the transfer from heavy industries, such as the chemical industry, coal and steel which are energy intensive industries, and the latter two of which consume about 20% of total demand, to lighter industries offering an incentive to new technological development.

INTERFACE WITH INDUSTRY AND THE SCIENTIFIC COMMUNITY

Since the granting of this contract by the Ministry of State for Science and Technology to the Brace Research Institute, it is interesting to note that a significant number of Canadian industrialists have written mentioning the availability of their products for any future activities involving solar and wind energies. Some of these companies are subsidiaries of American organizations already actively involved in solar energy development. Furthermore, the creation of a sense of national need to conserve energy and become independent in their energy supplies has stimulated their manufacturers to apply the potential of their industrial base to meeting their requirements.

This atmosphere does not as yet exist here, although it is significant that increasingly manufacturers contact this Institute, expressing the desire to fabricate and market windmills. This is far greater than the general interest in solar energy, although it is worth noting that a leading fuel oil distributor in the Montreal area, is seriously considering the manufacture of solar collectors which they can market in conjunction with petroleum fuels. They have already fabricated several working prototypes.

The awarding of the contract has also encouraged several scientists at differant universities throughout the country into exploring the possibility of doing research in these fields. Others who had been active in their own areas, have written indicating their interests and their desires to form part of larger overall teams in this effort.

It is interesting that three years ago when this author, as International Secretary for Canada of the Solar Energy Society, canvassed the Canadian membership with a view to determining the feasibility of establishing a Canadian section, the response was entirely negative. Today, several strong requests have been received suggesting that this be done.

Many other Canadian organizations have written lauding the granting of the contract and offering moral support. It would appear that Canadians are becoming increasingly disposed towards considering alternative energy sources as a national resource.

BIOMASS SYSTEMS

This is a vast field dealing with the byproducts of photosynthesis. In view of the tremendous land mass of Canada, the amount of potential biomass energy is significant.

Although work is progressing on all fronts, i.e. Methane production via Anaerobic digestion, the pyrolysis of Agricultural produce and Algae production, for the purposes of this report only work on the methane production has been discussed.

Methane Production - Using Anaerobic Digestion

Fuels for the production of methane range from sewage and manure to organic garbage. One of the most likely candidates for profitable and convenient utilization of methane are farms with large animal populations especially those with confinement housing managements. Relegation of animal wastes to a profitable product, i.e. methane, rather than a potentially soil and water polluting material, i.e. fertilizers, is not only ecologically sound but contributes to energy conservation. (Methane, or natural gas, is a clean burning fuel. It potentially has a wide range of uses such as heating purposes & as an energy source for generating mechanical and electrical power).

It is estimated that one ton of farm animal wastes would produce 50 to 60 cubic metres of gas, 52 to 58 percent of which is methane. With a calorific value of 5500 to 6000 calories per cubic metre, the gas would contain the heat energy equivalent to 10 Imperial gallons of gasoline.(1)

Anaerobic digestion as a method of treating farm wastes has several advantages. The main advantages are:

a) the organic content of the wastes is reduced by 50-70%.
b) the wastes are well stabilized and thus need no further treatment before final disposal on the fields.
c) the digested waste is a thick free-flowing liquid with no objectionable odors.
d) rodents and flies are not attracted to the end product of digestion.
e) the fertilizing constituents of the raw wastes are conserved and the fertilizer value of the digested solids is higher than that of raw wastes.
f) combustible gases which have commercial value are produced during the process.

It also has several limitations(2):

a) high initial investment for a completely equipped digester.
b) some means of disposal must still be provided for the remaining wastes.
c) daily supervision of the feeding of the digestor is required.
d) care must be taken to avoid gas explosion as well as inhalation of the gas.

The Agricultural Engineering Department of the University of Manitoba has been involved in methane production research. They have produced an informative article entitled, "Methane Gas Production from Farm Animal Wastes", which was published by the Canada Department of Agriculture, (Publication 1528, 1974). The University of Manitoba is now operating an experimental digestor system at their Glenlea Research Station.

The University of Waterloo has published a paper (March 1972) detailing a proposed digestor unit for a one-hundred cow dairy farm.

The New Alchemy Institute has published a booklet entitled, "Methane Digestors - for Fuel Gas and Fertilizers". This article describes the construction and operation of two working digestors, suitable for farm use. (4)

Sewage Treatment

The Mogden sewage plant in London, England, has been producing a methane-rich 600-700 Btu/ft.^{3} gas since 1935; total production there is now almost 8 million ft.^{3}/day. In addition, in Germany, most major cities have been generating methane from sewage using a similar approach since the turn of the century.

Pacific Gas and Electric Co., San Francisco, is currently negotiating with the East Bay Municipal Utilities District (Ebmud) in Oakland for purchase of digestor gas made at Ebmud's 85,000 gal./day sewage treatment plants. Ebmud is currently burning off 500,000 ft.^{3}/day in four giant flares. The Hyperion sewage treatment plant in Los Angeles produces 4 million cubic feet of methane-rich gas daily. The plant uses half of this fuel to feed several 1,688 Hp gas-diesel engines, the remainder is used by the city's Scattergood treatment plant.

Recently, Allis-Chalmers, Inc. and Waste Management, Inc. proposed a pilot plant project to the city of Milwaukee that would generate 1,500 ft.^{3}/day of methane from one-half ton of municipal solid waste. John T. Pfeffer, professor of Civil Engineering at the University of Illinois, developed this system which gives an offgass production containing 50-60% methane.(3)

Resource Sciences, Inc. (Santa Ava, California) is pushing an energy-recovery system based on pyrolysis of municipal refuse. From laboratory data, the company claims that the system produces about 16,000 ft.^{3} of 375 Btu/ft.^{3} gas for each ton of typical refuse. Since the pyrolytic reactor requires about one-third of this energy, the net available energy is approximately 4 million Btu/ton of typical refuse. Wallace-Atkins Oil Corp. (Houston, Texas) uses a bacterial fuel cell to both produce electricity from organic waste and to decompose the waste and generate methane. Then the electricity ionizes water into hydrogen and oxygen, and the hydrogen, garbage and methane are fed into a pyrolytic converter to produce a "crude oil", a 500 Btu/ft.^{3} fuel gas, charcoal and tar. Laboratory data indicate that 10,000-15,000 ft.^{3} of gas (containing about 50% methane) are produced per ton of garbage. Of this amount approximately 6,000 ft.^{3} would be used in the process. Also 2 barrels of crude oil, 400 lbs. of charcoal and 50 lbs. of tar are made.

Sanitary landfills offer another, relatively small source of substitute natural gas. Several public agencies and utility companies are using or considering landfill gases as a fuel supplement. As a joint venture between Los Angeles' Department of Water and Power, and of Public Works and the City's Bureau of Santitation, three hundred and fifty Los Angeles homes are having their electricity supplied from garbage. Methane-containing gas is drawn from the city's Sheldon-Arleta landfill. The gaseous mixture, containing 40-50% methane, fuels a 300 Hp internal combustion engine that drives a 200 Kw electric generator.

In India, Gobar gas plants are widespread and are used in other parts of the world as well. These utilize most forms of organic wastes.

Dr. Chung Po, of the Joint Commission on Rural Reconstruction, Taipei, Taiwan, has been actively engaged in research and design of anaerobic digestors, and has prepared in March 1974, "A Study on the Feasibility of the Production of Methane from Animal Wastes".

In Canada, the Biomass Institute in Winnipeg, Manitoba, continues to collect and publish excellent information in this field. Their Renewable Biomass Energy Guidebook, March 1974, resumés quite effectively the entire field of Biomass Conversion.

Finally, Macdonald College (Department of Agricultural Engineering) of McGill University has been actively involved with anaerobic digestion of animal wastes and have prepared in March 1974, "A Study on the Feasibility of the Production of Methane from Animal Wastes".

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2. Taiganides, E.P.,E.R.Bauman, H.P. Johnson and T.E. Hagen, 1962, Anaerobic Digestion of Hog Wastes, Journal of Agricultural Engineering Research, p. 237.

3. Ricci, Larry, Garbage Routes to Methane, Chemical Engineering, Vol. 81, No. II, May 27, 1974.

4. New Alchemy Institute (NAI) West, 3 15 W. Anapamu, Santa Barbara, California, 93101, Newsletter /3, Spring 1973.

SOLAR REFRIGERATION

Solar energy can be used to power a refrigeration system in two ways. On the one hand, solar energy can be converted to electricity or used to operate a heat engine, and thence operate a conventional vapour compression refrigerator. On the other hand, solar energy can be used to heat the working fluid in a vapour absorption refrigerator. The first type, solar-powered vapour compression refrigeration has a low efficiency and high cost of fabrication. As a result most work on solar refrigeration past and present has been done on absorption refrigeration.

Canadian involvement with solar refrigeration is centered at the University of Western Ontario (Faculty of Engineering Science), where R.K. Swartman has been active in research with intermittent absorption systems. In the U.S. there are currently two institutions researching the solar refrigeration potential. They are: the University of Wisconsin and the University of Florida, where E.A. Farber has constructed and successfully tested an electrically assisted absorption refrigeration system.

There is currently less involvement with solar-powered refrigeration than in other areas of solar energy use. In 1973, Professor Swartman carried out a State-of-the-art survey on Solar Refrigeration on a contract provided by the Brace Research Institute. This report is appended as it describes work undertaken to date in this field.

SOLAR COOKING

The principles and techniques of cooking with solar energy are well known. It does not seem likely that these processes will ever by utilized in Canada except for recreational purposes during the summer. It is interesting to note that several new elements have been developed which might enhance the improvement of existing cooker designs.

a) The Dornier Systems Group, Friedrichshafen, West Germany, have developed some solar heat pipes, as a spin-off from their space programs. Very high operating temperatures are claimed. These heat pipes are currently being tested by the Brace Research Institute.

b) Plastic acrylic mirrors which have a long life outdoors, high reflectivities and which can be cast into any shape are available from Ram Products, Michigan, U.S.A. Some of these reflector mirrors are undergoing testing at the Brace Research Institute and elsewhere.

It is with the development of these and other new materials that a change may very well occur in the economics and technical feasibility of solar devices. It is essential that our manufacturers be kept fully informed of the latest technological developments in this field as export markets may one day prove lucrative.

SOLAR DISTILLATION

The practical use of solar energy for the provision of fresh water in arid areas is well known and a well-accepted facet of this technology. The very essence of solar distillation plants dictates that they should be extremely simple in construction and operation. The problem, therefore, reduces to one of materials engineering. Again, this is not a process which will probably find significant application in Canada. However, it is interesting that its use is being considered for the small scale production of fresh water in certain more arid regions of our Prairie provinces. There are a number of new materials and processes which could be utilized by our manufacturers for the manufacture of prefabricated solar still components for the export trade. The Brace Research Institute for example, has developed, using a Canadian International Development Agency grant, several designs of prefabricated components which are available to Canadian manufacturers as a potential product line.

SOLAR HOUSE HEATING

This aspect of solar energy application should be of utmost importance to most Canadians. It is currently the fastest growing field of solar interest both in the research and application areas. Commercial buildings, schools and private residences heated partially by solar energy are being constructed at an increasing rate across the United States and in Europe. Solar collectors, the heart of heating systems have been developed to the point of required efficiency even for our climate. Increasing designs are becoming economically viable. A variety of heat storage systems are available and in conjunction with conventional, auxiliary heating devices for those periods of extreme cold or extended lack of sunshine will reduce the overall heating fuel bill. As conventional fuel prices continue to rise, whether gas, oil or electricity, the prospect of achieving lower overall heating costs through the use of solar energy becomes of major interest to home owners and builders. The location and number of all structures now employing some use of solar heating are too numerous to list here but a few examples follow showing a variety of possible applications.

1. The largest solar heated building planned anywhere in the world is a 278,800 square foot project for Denver Community College, Westminister, Colorado. Due to be completed in the fall of 1976, the building is to have 50,000 square feet of solar collectors (the type not yet selected), a 400,000 gallon reservoir for water circulating through the system, and heat pumps for summertime air conditioning and for accessory use in winter heating. A small boiler will back up the solar equipment, but the solar designers, Bridgers and Paxton Consulting Engineers, Inc. (Albuquerque, New Mexico), believe the boiler will not be needed in practice.(1)

2. The Centre Nationale de la Recherche Scientifique (C.N.R.S.) laboratory in Odeillo, France, has built three solar heated houses, two single units, and one three unit. A one unit structure built in 1967 employs 860 square feet of collector area for the house volume of about 10,000 cubic feet and incorporated provision for supplementary electric heating. The south facing concrete wall is fronted with glass paneling and an air space between the two allows heated air to rise and enter the house near the roof. Total cost of the heat provided by this system was on the order of 0.8¢/Kw.hr.. During the past five years about two-thirds of the heat used in these houses was provided by solar energy.

3. The Thomason Solaris System of Harry E. Thomason has been built into several houses in the Washington D.C. area. The first system has a record of fourteen years of continuous operation, with the sun supplying the major part of the heat load every year. The Federal Housing Administration (United States) has made a thorough investigation of the Thomason Solaris system and has made a report which was very favourable. The third Thomason house employs a solar collector covering the entire south side of the roof, 15ft x 60ft. Heated water from the roof area flows to a basement storage apparatus consisting of a 1600 gallon (U.S.) tank surrounded by a bin of 50 tons of low-cost fist-sized stones. Heat from the tank passes to the surrounding stones and a blower draws cool air from the house into the storage bin where the air circulating around the warm stones is heated and returned to the house, usually maintained at 70°F. This system allows for five cloudy, moderately cold days and supplies from 65-75 percent of year-round heating, domestic water supply included.

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(1) Chemical Engineering, Vol.81, No. 13, June 24, 1974

4. The National Science Foundation has been involved in several projects which provide solar heating of schools in various locations across the United States.

5. The University of Delaware has built a 1500 square foot solar house employing Cadmium Sulphide solar cells as collectors and lead-acid batteries for storage (2x110 volt 15Kwh) and uses DC predominently for fixed installation loads. The thermal system makes extensive use of heat storage in conjunction with a heat pump to maximize the use of solar energy. Harvested heat will be stored in a reservoir and hot water is produced via air heating using a heat exchanger in the main air duct. The main purpose of the solar house is to show feasibility for a major contribution of solar energy to the energy balance of the house and to shift its main use of auxiliary electric energy into off-peak hours.
As one of the earlier efforts in applying solar energy to house heating in Canada, F.C. Hooper (1), of the University of Toronto, in 1955 proposed the design for a two story, five-room house employing a basement water reservoir of 38,800 Imperial gallons heated by 600 square feet of solar collector area covering the entire inclined south facing wall.

The Brace Research Institute with engineering students of McGill University, has recently completed a review of the problems associated with solar house heating in Canada. Considering Montreal as the location, a two-story solar house design was evolved of 1100 square feet floor area. Solar collector area deployed on a 60^{o} inclined south sloping roof is 600 square feet. Assuming a 40 gallon per day requirement of hot water for domestic use as well as the house heating load and also assuming a 30% collector efficiency, the storage capacity was set at 5275 U.S. gallons with a tank 6 feet in diameter and 25 feet long.

This could heat the house for approximately three days without the need for auxiliary heat. However, given Montreal's climatic character, auxiliary heating would most probably be needed from November to April inclusive. It is estimated that for this particular design of house, forty to fifty percent of annual requirements could be supplied by the sun.

J. Wadsworth (CMHC) Development Group, has prepared an article (May 1974) entitled, "Can the Sun be Utilized to Heat Canadian Residences in the Winter?" They suggest that, "Typical for Ottawa some 800 square feet of solar panel and some 2000 gallons of water storage would be required for the average single family residence. The heat would be recovered from storage for space heating via a forced hot-air system. The auxiliary heating system would be far less than the normal furnace. There would be little difference between a solar heated house and that heated via a forced air fossil fired furnace so far as the final effect was concerned.

Recent computations performed at the Universities of Western Ontario and Waterloo would suggest that annual savings of 70 percent of space heating fuel consumption would be achieved using solar heating, at angles of latitude similar to Ottawa".

It should be remembered that a water heating unit may be incorporated into the solar heating system, thereby providing a further savings in fuel costs, particularly since hot water for washing, etc. is required on a year-round basis.

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(1) Hooper, F.C. "The Possibility of Complete Solar Heating of Canadian Buildings", The Engineering Journal, November 1955.

ENERGY AND HEAT STORAGE

In the broadest aspects there are three modes of storing energy: mechanical, electrical and chemical.

The simplest and most efficient way of storing energy mechanically is to pump water to a higher reservoir and let it flow back through a water turbine when the power is needed. For large pumps and turbines, the efficiency is high, but turbines of a fraction of a kilowatt have very low efficiencies. This implies that large installations are needed for mechanical storage of energy. One kilowatt-hour of stored energy is equivalent to 96,900 gallons or 12,900 cubic feet of water falling one metre or 3.28 feet. It would take 132.5 tons falling through 10 feet to store one kilowatt-hour of energy. This weight can be raised in elevation using a solar or wind-driven motor, which later operates as a dynamo when the weight returns to its lower level. A falling weight can also be used to unwind a rope on an axle and turn the wheel of a pump or other machines. Solar-generated power can be used to compress air in a pressure tank which expands at a later time, through an air-driven turbine or engine. Recent speculation has been shown on the prospect of large scale compressed air storage underground, perhaps in non-operative mines. Johns Hopkins University Applied Physics Laboratory sees a large potential for energy storage in their new multi-element flywheel design. They propose to achieve an energy density of 30 watt-hours per pound.

ELECTRICAL ENERGY STORAGE

The most familair method is storing D.C. in lead-acid storage batteries. It is efficient and considerably cheaper per kilowatt-hour than any other type. In ordinary automotive usage they last about two or three years. For the storage of solar or wind generated electricity it should be possible to simplify the structure and lower the costs, because the battery can be large, non-portable and would not be designed for heavy drains. Reserve lead storage batteries for power stations have a much longer life of 10-20 years. The serious handicap is using this type of battery for solar or wind energy storage is that the batteries are to be nearly completely discharged every day. Under these conditions, their life is much shorter. To assure long life, it is necessary to discharge the battery only half-way, which implies the storage capacity and the capital cost must be doubled. One of the advantages of the use of storage batteries is the ability to charge them in parallel at low voltages of perhaps 2 volts from a solar generator and then discharge them in series to give a high voltage and better efficiency in the operation of electrical equipment. (2)

Considerable effort is presently being displayed in the development of fuel cells encouraged by the efficiency of operation; 60-70 percent of the chemical energy being converted directly into electricity. This system also eliminates the temperature limitation effect of the Carnot cycle; also no moving parts are involved. Solar produced electricity can be used to electrolyse water producing hydrogen and oxygen which are stored and later fed into a fuel cell to produce electricity while reforming water.

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(2) Daniels, F. (Rapporteur), Energy Storage Problems, Proceedings of the Conference on New Sources of Energy, Rome, August 1961, UN Publication Sales No. 63.1.2.

Fuel cell costs are presently high and much more work needs to be done in improving their life span. Investigation is also underway with zinc and aluminum fuel cells.

CHEMICAL STORAGE OF ENERGY

The electrolysis of water to produce hydrogen fuel is one of the simplest ways of storing energy from the sun. Capital investment for the electrolytic cells is low, the cells have a very long life and over 70 percent of the theoretical amount of hydrogen is produced without moving parts or the need for skilled operators. The most efficient way to use the hydrogen is in fuel cells(previously discussed), but these have yet to be fully developed. Hydrogen can also be used in the operation of internal combustion engines, but further research is needed in this area. Hydrogen can also be used with air to produce steam and heat for operating a steam engine or turbine. Hydrogen storage for whatever purpose is a problem. Storage in the form of a liquid or solid chemical is attractive because of the much smaller space involved. Hydrogen can be transported over long distances in pipelines as is now done with natural gas. It can be transported in tanks or in the form of chemicals. Hydrogen, combined with carbon dioxide, under pressure in the presence of a catalyst, produces methyl alcohol which can be used for fuel.

Photolysis of Water: Production of Hydrogen

Several methods are known:

Photo reduction of a photo catalyst - this might be the photo reduction of the ceric ion.

Photoreduction

$$2Ce^{+4} + H_2O \xrightarrow{hv} 2Ce^{+3} + \tfrac{1}{2}O_2 + 2H^+$$

Photo-oxidation

$$2Ce^{+3} + 2H_2O \xrightarrow{hv} 2Ce^{+4} + H_2\uparrow + 2OH^-$$

Net Reaction $$H_2O \longrightarrow H_2 + \tfrac{1}{2}O_2$$

Recently, Nobel Prize winner, Sir George Porter, of the Royal Institution, London, gave a lecture at McGill University on the future role of solar energy in society.

He stressed the need for serious and concentrated investigations in this field. He stressed the photo voltaic and photo chemical conversion processes as having much potential and indicated that parts of the Arizona desert could conceivably meet the United States' energy needs in the future. He particularly was intrigued by the prospect of producing fuels such as hydrogen and methanol as from solar energy as substitutes for natural gas, gasoline and fuel oils.

SENSIBLE HEAT METHODS

Rockpile and Water Storage

A common method of storing heat as used by Harry E. Thomason (Maryland) and George Lof (Colorado) in their solar houses is the rockpiles. Depending on the heat load, several tons of stones (10cm across) are heated directly or indirectly by the sun. These are contained in a well insulated container to prevent excessive heat loss and air is blown through the warm stone bin into heating ducts. (Cooler house air being recycled to the heat source.) Stones may be used as the heat retention medium by themselves or serve as an intermediary surrounding a solar heated water tank. In either case, a high level insulation is necessary to insure that the collected heat is maintained.

The rockpile lends itself to heating uses other than house heating. In Australia and India, rockpiles are being used as a heat source in the drying of timber. In Australia, the Commonwealth Scientific and Industrial Research Organization's Division of Mechanical Engineering, have installed a test facility at Griffith, New South Wales, where a rockpile is the major system component in a solar drying unit. As well, the CSIRO utilize a rockpile storage system which is alternatively heated or cooled, incorporated into a year-round climatization system.

Water will retain acquired heat for a considerable period of time. Naturally, the greater its volume and initial temperature, the longer it will serve as a heat source. Again, insulation around the water temperature tank is a prime factor. Heat may be withdrawn from the tank with or without a heat sink (eg. aluminum-finned area) by simply blowing house air past the tank through a ventilating system.

Normally the tank is located in the basement. Due to Canadian winter extremes, the large tanks necessary to store heat would considerably reduce basement space. It is envisaged that a tank of not much less than 2000 Imperial gallons capacity would be required to provide at least three days heat reserve for a single unit dwelling. This, however, could only be verified by further design considerations and research under normal winter conditions.

HEAT OF FUSION MATERIALS

The Brace Research Institute has commissioned in 1974 a State of the Art Position paper on the storage of energy from solar and wind-powered systems. All of the possibilities are being carefully considered. Particular attention is being paid to heat of fusion materials. This is a domaine to which Dr. M. Telkes of the University of Delaware has paid much attention. Her developments in the field of energy storage in hydrates of Glauber's Salts, a commonly available material,are very significant and require further investigation. One of the principle problems is that of encapsulation. Recently, a paper by Dr. Telkes was presented (23 June, 1974) at the ASHRAE Meeting, Montreal, in which particular reference was made to recent experiments with these materials in the solar heated house in Delaware.

WINDPOWER

Winds are generated and sustained by solar energy. They are remarkably repeatable and predictable. Generally one attempts to extract power from the momentum of the wind. We are grateful for the collaboration of the Advanced Concepts Centre, Environment Canada, who have allowed Mr. Bruce McCallum to work with the Institute in the preparation of this section.

1. Letters have been sent out to windmill manufacturers to determine what companies are still in the field and to collect technical data on their equipment.
   Information about companies and organizations working in the field of windpower is also being collected by telephone and by word of mouth. There are undoubtedly other Canadian companies and organizations in the field who are considering entry that we do not know about. We suggest that a Canadian Windpower Newsletter be established to perform a liaison and communications function in this field. This might be something the Ministry of Trade and Commerce might eventually handle.

2. Information sheets are being prepared on research groups, manufacturers, distributors and their equipment.

3. A card index system has also been started, primarily for manufacturers, but this will be expanded as more data becomes available.

4. A comparative data sheet will be included in the final report. It will have technical and economic information on each available system.

5. Maps illustrating Canada's wind regime will be included in the final report.

6. A bibliography of the most relevant literature from recent conferences, symposiums and other sources is being compiled.

7. The final report will include a review of recent research grants that have been awarded in the field of windpower (particularly those in the United States of America).

8. In order to avoid undue repetition of windpower research going on elsewhere, a possible recommendation is that Canada select areas for research and development that are not being emphasized in other countries. Possible criteria might be the development of windmills that suit unique climatic conditions found in Canada or windmills that are appropriate for Third World nations.

9. Recommendations for research and development should be made on the premise that possible areas in which windpower could be used in Canada should be thoroughly studied to determine the nature of the problems before recommendations are made regarding the development of application of specific windmill systems. For example, broad areas of study might be: Windpower in Canadian agriculture; Windpower in isolated locations in Canada; Windpower in coastal areas of Canada.

10. A second premise is that windpower should be considered initially in areas where it has been used in the past, where it is being used, or where it might easily be applied. For example, water pumping windmills have been and continue to be used in agriculture. The expansion of their use in that field would not present serious problems. Likewise existing commercial electricity generating windmills could easily be applied in isolated communities and they may very well be competitive with diesel electricity generators. Experience gained with windpower in areas like these would be invaluable in attempting to harness it in other areas such as large scale windmills,

11. In discussions with numerous companies in Canada, it has become evident that many manufacturers and distributors are considering entering the field, but they are uncertain as to what the market will be and for this reason they are holding off for the present. This would suggest that a possible role for the government might be to conduct background studies to determine the potential for the utilization of windpower in different regions of Canada and what the market is likely to be. The government might also consider funding initial windpower research and developments. In this way, industry will no doubt be stimulated to make a more positive commitment in this field.

12. It is recommended that the government consider studying the possible uses of windpower in urban areas. This could involve designing buildings so that they facilitate the production of windpower or alternatively utilizing windmills to reduce wind velocity in urban areas such as downtown Winnipeg. Developments on shrouded windmills or windmills using the ejector principle as currently being undertaken at the University of Sherbrooke might prove useful in this regard.
The wind distribution patterns in large urban centres, in particular in the vicinity of skyscrapers are such that one might very well find research and development programs to study methods of best utilizing this service of energy.

One of the conferences whose papers were studied is the following. Only highlights have been commented on.

Wind Energy Conversion Systems Workshop Proceedings (NSF/RA/W-73-006 1973)
Washington, D.C., June 1973

a) R.A. Oman and K.M. Foreman, (Advantages of the Diffuser-Augmented Wind Turbine), pp.103-106. Allows practical rotor designs to operate even at very low windspeeds.

b) D.K. Reitan, (Wind Powered Asynchronous AC/DC/AC Converter System), pp.109-114. Non-synchronous AC/DC/AC - pumped storage. Wind Energy System for electrically isolated rural residence.

c) Joseph Tompkin, (Voight Variable Speed Drive), pp.121-122. Any desired speed range is available, applications possible from 5-10,000 HP. Simple in design, manufacture, operation and maintenance.

d) Walter Hausz, (Use of Hydrogen Rich Components as a Means of Storing and Transporting Energy), pp.130-134. Comparison of conventional and hydrogen fuel storage investment costs. Cost review of wind-electric-hydrogen storage systems.

e) George C. Szego, (Energy Storage by Compressed Air), pp.152-154. Examines pumped hydro vs. compressed air energy storage. Optimum wind machine output for this systems seen as from 50-100 MW(e).

f) Henry M. Clews, (Wind Power Systems for Individual Applications), pp.165-169. Describes an electrically self-sufficient home in Maine using a 2Kw Quirks generator and lead acid storage batteries. This system gives 15 Kw hours or 4 days reserve at 115 volts. Uses standby gasoline generator for emergency.

g) James H. Van Sant, (Wind Utilization in Remote Regions - an Economic Study), pp.174-176. Examines fuel costs to be saved by incorporating a 10 Kw aerogenerator with a 250 Kw diesel engine. Theoretical location is Povognituk, Québec.

h) Ralph E. Powe, (Technical Feasibility Study for the Development of a Large Capacity Wind-Powered Electrical Generating System), pp. 177-179. Proposal to have the wind push an airfoil equipped car around a 5-10 mile track and thus produce a 10 MW(e) electrical output.

i) John M. Noel, (French Wind Generator Systems), pp.186-196. Lists prices and data on several Aerowatt Corp. wind generators from 24 watt to 100 Kw. Discusses principle of designing and operating units for specific local wind conditions.

j) William Heronemus, (A Proposed National Wind Power R&D Program), pp.197-203. Discusses potential and methods for realization of large scale wind/electric power projects in the U.S.

k) Committee Report on Wind Characteristics and Siting. pp.209-212. Submission of proposals on methods of assembling and correlating accurate and standard wind data on a regional scale.

l) Report of the Committee on Applications, pp.222-224. Suggested ways and means of getting a wind power program accepted, supported and operated on a national scale.

RESEARCH AND DEVELOPMENT PROGRAMS

Research and development programmes in the field of solar energy are varied and in a state of flux. In the past, Governmental authorities have not offered much technical assistance; now in many countries, they have currently greatly increased their funding in this area. A typical example is set out in the case of the United States program sponsored by the National Science Foundation/Research Applied to National Needs.

The following list indicates the research grants awarded in FY '73. The entries show project title, principal investigator, affiliation, duration, and funding. The total NSF/RANN funding for the year was $4,200.00

Solar Thermal Power Generation

1. Chemical vapor deposition research for fabrication of solar energy conversion.
   H. Seraphin, University of Arizona
   12 months — $ 171,200

2. Analysis of solar-thermal electric power systems.
   G. Lof, Colorado State University with Westinghouse
   18 months — $ 491,800

3. Solar thermal conversion mission analysis.
   A. Greenberg, Aerospace Corporation
   6 months — $ 125,000

4. Research applied to solar-thermal power systems.
   R. Jordan, University of Minnesota, with Honeywell
   12 months — $ 494,700

5. Feasibility study of a solar thermal power system based upon optical transmission.
   L. Vant-Hull, University of Houston, with McDonnell-Douglas Astronautics Co.
   12 months — $ 130,900

6. Research on cadmium stannate selective optical films for solar energy applications.
   G. Haacke, University of Pennsylvania & University of Delaware
   18 months — $ 151,500

$1,565,100

Wind Energy Conversion

7. Development of an electrical generator and electronics cell for a wind energy conversion system.
   W. Hughes, Oklahoma State University
   18 months — $ 141,600

8. Technical feasibility study of a wind energy conversion system based on the tracked-vehicle airfoil concept.
   R. Powe, Montana State University
   12 Months — $ 49,900

9. Wind energy Conversion workshop.
J. Savino, NASA/Lewis Research Center
6 months $ 11,700

$ 203,200

Ocean Thermal Conversion.

10. Ocean-sited power plants.
W. Heronemous, University of Massachusetts, with J. Hilbert Anderson, Inc., and United Aircraft Res. Labs.
18 months $ 25,200

11. Solar power ocean-based plants.
C. Zener, Carnagie-Mellon University
18 months $ 190,000

12. Conference on power generation for ocean temperature difference.
A. Lavi, Carnagie-Mellon University
12 months $ 14,000

$ 229,200

Bio-Conversion to Fuels

13. Workshop on energy conversion sources.
A. Hollaender, University of Tennessee
6 months $ 18,500

14. Effective utilization of solar energy to produce clean fuel.
J. Henry, Stanford Research Institute
9 months $ 49,000

15. Bioconversion energy research conference.
W. Short, University of Massachusetts
6 months $ 17,800

16. Solar energy fixation and conversion with algalbacterial systems to produce methane.
W. Oswald, University of California, Berkeley
18 months $ 51,800

17. Research on a program for economic fuel gas production from solid waste.
D. Wise, Dynatech Corporation with University of Massachusetts and MIT.
13 months $ 427,000

18. Biological conversion of organic refuse to methane.
J. Pfeffer, University of Illinois
12 months $ 83,000

$ 674,100

Heating and Cooling of Buildings

1. Preparation and publication of a chapter for the ASHRAE Guide on the Application of Solar Energy for Heating and Cooling of Buildings.
C. MacPhee, American Society of Heating, Refrigeration, & Air Conditioning
12 months $ 5,000

2. Optimization Studies of Solar Absorption Air Conditioning Systems.
W. Short, University of Massachusetts
5 months $ 17,800

3. Computer Modelling and Simulation of Solar Heating and Cooling Systems.
J. Duffie, University of Wisconsin
12 months $ 65,300

4. Design, Construction, and Testing of Residential Solar Heating and Cooling Systems.
G.O.G. Lof, Colorado State University
24 months $ 210,000

5. Further Development of the Compressed-Film Floating-Deck Solar Water Heater.
R. Davison, Texas A & M University
12 months $ 36,900

6. Formulation of a Data Base for the Analysis, Evaluation and Selection of a Low Temperature Solar Powered Air Conditioning System.
E. Farber, University of Florida
9 months $ 49,400

$ 384,400

Photovoltaics

7. Photochemical Conversion of Solar Energy.
N. Lichtin, Boston University (Exxon Research)
12 months $ 115,000

8. Low-Cost Continuous Fabrication of Silicon Solar Cells.
B. Chalmers, Harvard University (Tyco Labs.)
12 months $ 150,000

9. Investigation of Thin Film Solar Cells Based Upon CU_2S and Ternary Compounds.
J. Loferski, Brown University
12 months $ 76,900

10. Applied Research on II-VI Compound Materials for Heterojunction Solar Cells.
R. Bube, Stanford University
12 months $ 48,300

11. Low-Cost Polycrystalline Silicon Photovoltaic Cells for Large Solar Power Systems.
P. Fang, Boston College
9 months $ 67,100

12. Development of Low-Cost Thin Film Polycrystalline Silicon Solar Cells for Terrestrial Applications
T. Chou, Southern Methodist University (Texas Instruments Corporation)
18 months $ 149,400

13. Studies of Surface Structure and Electronic Properties of Polycrystalline Photovoltaic Materials and Devices.
R. Davison, University of California
18 months $ 187,400

$ 194,100

It is evident that they are laying great stress on the heating and cooling of buildings which accounts for nearly one-third of the energy budget. However, a closer examination of the figures indicate that far more expenditures are being made on the large scale systems such as solar thermal power generation and photovoltaics. It must be recalled that each country will make investments in these fields in accordance with their own objectives and priorities. In this case, it should be stressed that the American Government has also made available a considerable amount of funding to heat four schools using solar energy. These are located in different areas of the country and provide a small amount of the heating required for these schools. Nonetheless, this action has permitted the design and construction of organizations to gather some first-hand knowledge of this technology. One school which the author visited this month in Boston uses its roof to collect solar energy for partially heating the building. It is obvious that the initial results are successful even through the decision to install solar collectors was very hurridly undertaken.

It is apparent that a major portion of the United States' effort will be directed into stimulating the efforts of industrial organizations into taking up the challenge. A survey of many of the contracts awarded indicate that by and large these have been made to industrial corporations employing university based consultants in this field. In three recent contracts awarded this year - the following teams secured the grants:-

1) Westinghouse - University of Colorado
2) General Electric - University of Pennsylvania
3) TRW Systems - University of Arizona

This stimulation to industry through the use of seed money to cover the proof of concept of viable systems and through financing of investigations into the development of technologies designed to acquire greater knowledge in certain fields such as ocean thermal conversion, photovoltaics, etc. have demonstrated the degree of flexibility to which the National Science Foundation have organized their programmes.

Canadian Problems regarding Solar Energy Research and Development

The question remains as to where a country like ours might allocate resources in R&D funding in these fields. As we have yet to make a committment to the utilization of alternative energy sources, it would be premature to detail suggestions as to what areas required funding. It is nonetheless, significant to note that the NSF/RANN program diverted some funds to support conferences, both in Paris, 1973, and others in the United States. Also they supported academic texts for including sections on solar energy. Dealing with a less aggressive private sector in Canada, the role of the Federal authorities would have to be substantially greater. Also the fact that we do not face potential crisis situation, makes the job of convincing the public all the more difficult. In Appendix A, a method is outlined on ways of providing "animation sociale" - even perhaps to an apathetic populace.

The next problem to be addressed in formulating an R&D program is objectives - in Appendix A, it is proposed that Canada concentrate on those areas of R&D dealing with the direct use of solar energy today - i.e.

in the climatization of buildings and in the field of agriculture. On what research areas should efforts be concentrated? The following list is only partial, and this will be discussed more fully in the final report.

Heating and Cooling of Buildings

If an organization were to undertake the design of a building, or series of buildings, involving the use of alternative energy sources - i.e. solar, wind or geothermal energies, the following would have to be done. These phases would not necessarily be undertaken concurrently but would follow logically from a total investigation of this support.

Details of this study would consist of the following:

Component No. 1: A review of building structures relevant to the Canadian climate.

2: A review of the available information on building heating and cooling requirements as related to Canada.

3: A review of the existing literature on solar space heating and cooling. (State-of-the-art survey)

4: A review of the existing literature on wind energy utilization as related to both mechanical and electrical energy production for use in buildings.

5: A review of the existing literature on geothermal energy availability and the use of heat pumps for heating buildings.

6: A review of the energy storage systems required for use with alternative energy supplies.

7: An investigation into dual function operation which in the same unit would combine winter heating and summer cooling systems.

8: A critical review of all the above facets with particular emphasis on the relevance to Canadian conditions.

9: An examination on a natural basis of meteorological conditions in order to specify zones of varying degrees of favourability to the use of solar, wind and geothermal energies. These zones would be specified in terms of potential for these natural energy sources to contribute to the heating and cooling requirements of buildings. Solar intensity, wind speed, temperature and other meteorological data would be combined to indicate the potential supply of natural energy sources in each area.

This would be compared on a monthly basis, with the existing demand for energy for heating, cooling and power illumination requirements of buildings in each area.

It should be noted that the type of energy utilized in various regions of the country vary substantially depending on the availability of alternative energy supplies

10: Economic feasibility study of adapting solar heating for Canada during the winter months. For this purpose, information from all existing solar heated houses would be used in mathematical models in conjunction with climatological data for Canada. This would indicate the percentage of the heating load that existing experimental solar houses can provide using solar energy alone. The cost of installing the "solar system" would be determined and the pay-off period calculated; particular reference being paid to the energy storage systems.

11: A similar economic feasibility study incorporating wind and geothermal energies in addition to solar energy would be undertaken.

12: If the mathematical models based on existing experimental houses appear to be economically feasible for Canada, then a detailed analysis would be undertaken in order to arrive at optimized designs incorporating the three natural energy forms mentioned above.

13: Recommendations would then be made with regard to further research and development efforts in the utilization of natural energy sources for the heating and cooling of buildings in Canada.

14: Once the situation were understood for existing structures, the procedure could be repeated, with specific emphasis being placed on the existing supply-demand characteristics of Canadian housing. It would then be possible to develop environmentally adapted structures which would greatly reduce the heating and cooling loads on the buildings. In this manner, solar and wind power would become far more feasible as their diffuse energies would not be inefficiently used.

15: The designer would then be ready to offer a proper design of a solar/wind powered house for testing. The degree of hybridity for each section of the country - i.e. in the initial instances, to what extent should the alternative energy sources handle the loads - i.e. 50%, 60%, 70% or even 100%. These questions cannot be arrived at by guesswork.

This procedure would have to be followed to undertake an indepth study of the design of solar/wind heated housing, etc. In addition, work would have to be coordinated with materials companies to insure the utilization of proper components, etc. Eventually, it would be advisable to discuss with municipal officials the ramifications of introducing such designs into the society.

The technology of solar heating systems as applied to housing is known. Systems must be studied for Canadian conditions - the proof of concept approach is necessary, under qualified technical supervision. It is, nonetheless, essential that every effort be made to undertake research into optimizing;-

a) solar collectors
b) storage systems - investigating the use of different materials as discussed earlier
c) total systems, with a view to developing adequate controls which can be incorporated into existing housing structures

Clearly, the extent that R&D is required for this project, must be repeated in other areas requiring immediate attention in Canada. These include:-

a) greenhouse heating and cooling
b) the development of low-powered windmill, drainage and/or irrigation, pumps
c) heating and cooling of farm buildings
d) the generation of methane from the anaerobic decomposition of organic farm wastes.

These are only a few of the problems which require immediate attention. They are given as examples only - and need not necessarily constitute priorities.

Timing: The question is often asked - how long will it take for research in the field of alternative energy sources to pay off. The above five projects, if funding were available should produce realistic results as follows.

Solar House Heating - within 10 years, systems could easily be evolved which could find application within Canada. Obviously, items such as solar water heaters, which need adaptation for freezing conditions, could be adapted here in the next five years following some R&D, allowing for Canadian climatic conditions. It is not infeasible that some progress could be made before, provided the R&D is undertaken. The acceptability by the public will depend on a number of factors, not the least of which is economics. Incentives for applying solar heating systems would help in getting the public to accept this technology more readily.

APPENDIX A

STATEMENT MADE TO UNITED STATES
SENATE COMMITTEE ON INTERIOR AND INSULAR AFFAIRS

by

T.A. Lawand

Brace Research Institute
Macdonald College of McGill University
Ste. Anne de Bellevue
Québec, Canada
H9X 3M1

Re: SENATE RESOLUTION 45, A NATIONAL FUELS AND ENERGY POLICY STUDY, CONSIDERATION OF BILL S3234 - TO PROMOTE THE DEVELOPMENT AND COMMERCIAL VIABILITY OF SOLAR ENERGY.

Location: Dirksen Senate Office Building, Room 3110
Washington D.C.

Time: 27 June, 1974, 10:00 hours

Forward: As a prelude to this statement, it is important that it be understood that these views represent those of myself and my Institute and are not the official thinking of the Government of Canada. We are very grateful to the encouragement and support given by Mr. H. Flynn, Policy Advisor, of the Canadian Ministry of State, for Science and Technology, Ottawa, and by Dr. D. Bennett, Science Counsellor, at the Embassy of Canada, Washington. It is through the efforts of these men that I am here today. While these opinions are based primarily on the experience developed over an active period of 15 years in this field, this statement, will in its greater part, be related to those areas of solar energy conversion which seemingly have the most potential for application in Canada.

The Brace Research Institute is a privately funded organization which was set up in 1961 on the bequest of Major James Brace to investigate methods of rendering arid zones more productive. Since its inception, we have applied ourselves to the task of finding solutions to the problem of water and power scarcity facing poor communities in developing regions of the world. This has led us into a field of development generally known as Appropriate Technology, one facet of which is the utilization of natural, renewable, non-polluting energy resources, available to these communities such as solar energy.

In our later review of the present state of the art in the solar areas in which our Institute is actively involved, I will also mention those facets of the field which have application in areas of the Third World. In recent years, we have applied some of this expertise towards the solution of similar problems in Canada. Our country possesses a somewhat severe climate, hence the application of certain aspects of solar energy conversion is restrictive, limiting the overall role that it can play in meeting our energy needs.

STATEMENT

I - Overall Picture:

In Canada, investigations into the utilization of alternative energy sources - generally classified under the overall heading of solar energy - i.e. solar, wind, wave, tidal, ocean temperature difference, biomass energies, etc. are receiving renewed attention, in particular within the last year. Traditionally, this field has been investigated by a number of organizations, the Brace Research Institute, of McGill University, The Building Research Division, of the National Research Council, individual researchers at the University of Western Ontario and the University of British Columbia, and others. More recently, the Biomass Institute has been established in Winnipeg. Also at this time a significant number of government departments, individual researchers and industrial organizations have begun to direct their efforts towards a better understanding of the potentials of solar energy, in order to assess what role it might play in meeting our future energy needs.

We enter this era, like many other nations, with a base of expertise, and a fund of knowledge of the availability of solar radiation, ably monitored over the past few decades by the Department of the Environment. Whereas only a few years ago, solar energy was not regarded in significant terms in our total energy picture, today it is viewed as a component part of our national resource scene. This was made possible to a large extent by the heightened interest in research and development in this field in Australia, Japan, Europe, and especially that in the United States of America. These records indicate that for our populated regions, the average annual solar intensity is of the order of eighty percent (80%) of the average for the United States of America.[(1)]

The so-called "energy crisis" of last winter resulted in an effective doubling of the price of our fuel oils and transportation fuels. As a result, increased attention has been focused on alternative energy sources - even in a country so well endowed with natural resources as ours. The reasons are complex and obvious. Our petroleum and natural gas supplies are by no means inexhaustible. While several hydro electric sites remain for development, an increasingly informed and concerned public has raised such an outcry on the environmental effects of one of the most massive of these projects currently underway, that future developments will no doubt be planned with much more exactitude. As with the United States of America, we have vast reserves of coal - and perhaps as is the case there, both oil and coal are found in the lesser populated regions and need transportation to areas of high demand. One day as well, new generations will be asked to account for the destruction by simple combustion of these valuable chemical stocks. In both Canada and the United States of America, great expenditures have been placed on the development of nuclear reactors. It is to be lamented that so much effort, and capital has been invested into this energy source of the future which depends on a non-renewable resource as fuel for the system. While this might bring some short-term advantages, the non-renewability of nuclear fuels, plus some disquieting features as to the safety of these installations in times of catastrophy, whether natural or man-made, tend to cast doubt in the validity of this option for the long term. The environmental effects of the disposal of the residues leaves much to be desired.

In Canada, we have not invested as yet in studies similar to that undertaken by the NSF/NASA Solar Energy Panel which published its report in December 1972, entitled, "Solar Energy as a National Energy Resource". The Science Council of Canada has undertaken a survey of different energy sources, including solar and wind energy, as a background study for the development of an Energy Policy for Canada. The Ministry of State, Science and Technology has commissioned a small state of the art review of solar and wind energy, with a recommended research and development program that the country might consider. This will not be ready till mid-September, 1974.

Nonetheless, we have institutions within the country who have been actively involved in this field for over 15 years - both on the Canadian scene and in the international arena, in particular with regards the developing countries.

The main reasons why one is disposed to recommending further investigations into the utilization of solar energy are the following:

1). Solar energy is renewable.
2). Solar energy is available in situ, and does not require transportation from one site to another.
3). Solar energy is clean, noiseless and if carefully planned, the installations can be made to be adaptable to the environment.
4). Solar energy can be harnessed in a variety of installations from small to large scale.

5). Solar energy is an Appropriate Technology in that it can be harnessed and utilized by ordinary people giving them partial or total independence in their energy supplies.

It must be stressed that the underlying principles which govern the formulation of future energy policies also establish the pattern and quality of the life which our country will have. Consequently, the decisions that must be taken are not solely the prerogative of politicians and their advisors, or lobbies of interested industry, but that of the collectivity of society. People in our countries are becoming better and better educated and so more and more demanding that the quality of life be improved for all its citizens. It is in this aspect that solar energy has its greatest chance of success and its most avid champions. For it is truly an Appropriate Technology, for it can be utilized within the structure of a community without necessarily dominating it in order to enable its citizens to realize their real needs.

Eventually, it is hoped that rational societies will start eradicating the many "inappropriate technologies" which have been allowed to grow within our midst.

Another advantage of solar energy installations is that their net energy return is rather high, i.e. not very much energy goes into making the components composing a solar power plant facility. Apparently, this is not the case with certain nuclear plants and in a recent study in the United States by E.J. Hoffman, December 1971, entitled, "Overall Efficiencies of Nuclear Power", he concludes:

"In sum, the net energy realized by nuclear fission may be nearly a full order of magnitude (factor of ten) below that predicted. In other words, instead of plant or thermal efficiencies of 30%, the net plant efficiency realized -- based on the ideal value for the fuel -- may run as low as 3%."

In Canada, it is reputed that our CANDU nuclear reactor is more efficient. If the above figures are true, then it is certainly to be hoped that this is the case.

Clearly then, it is essential that in the future, planners and legislators will pay more heed to net energy production from these facilities in reaching their decisions. It is easy at this time of relative plenty to overlook this factor, for we are effectively robbing Peter to pay Paul. What will happen to these energy intensive systems when we can no longer provide them with the vast amounts of energy needed to process their "fuel". It is essential in planning for tomorrow's world of scarce resources that we institute the concept of an "energy quotient" for materials, processes and systems. Society will then have to decide to which degree it can tolerate energy intensive undertakings in view of our rapidly dwindling reserves.

The balance of this report addresses itself to the four questions raised by the Chairman of this Committee.

1. Briefly, what is the present state of the art in the solar area in which you are most actively involved?
2. What do you see as the present problems and barriers to successful implementation of your objectives in the area of solar energy conversion?
3. What would be an appropriate Federal role in assuring the success of your objectives?
4. What specific comments do you have on the language of this legislation?

Replies to Questions 1 & 2 are combined together. In addition, short sections on the following subjects have also been included for the reference of the committee.

a. Where Can Solar Energy Research and Development have its Greatest Immediate Impact?
b. Alternative Uses of Solar Energy in Urban Areas.
c. Solar Energy and Agriculture
d. International Cooperation - Canada - United States of America.

II. Present State-of-the-Art of Solar Energy Activities Currently Under Investigations at the Brace Research Institute

In accordance with the request of this Committee, the following section resumés the current activities at the Institute in the field of solar energy. Some of the principal problems and barriers to successful implementation are listed after each section.

a). PROVISION OF SMALL SCALE SOLAR DISTILLATION TECHNOLOGY TO RURAL AREAS FOR THE PRODUCTION OF FRESH WATER

The technology of solar distillation has been studied by the Institute and others for the past fifteen years. Systems have been given some field trial testing. Most of the basic knowledge of the production of reasonably efficient, practical solar stills is known. Results have indicated that solar distillation is an Appropriate Technology for the provision of small amounts of water in arid areas. Most of these regions are inhabited by poorer populations who could not afford sophisticated equipment.

IMPEDIMENTS TO IMPLEMENTATION

Further studies are needed on the development of a systems approach to the whole problem of establishing solar distillation plants conforming to normal civil engineering standards.

Demonstration tests in rural arid areas would be excellent means of foreign aid, with-no-strings attached, for it places the focus on the participation and development of the local populations. Their usage would have to be locally desired and oriented to ensure maximum success. It is hoped that demonstration facilities will lead to a better understanding of the problems involved in the field and to the spreading of this technology.

b). SOLAR POWERED ORGANIC FLUID RANKINE CYCLE ENGINES

The objective is to develop a solar powered engine to provide small amounts of power for water pumping or the generation of electricity. The solar energy can be harnessed either in solar collectors or solar ponds.

A French firm with whom we collaborate, SOFRETES, Montargis, France, has supplied us with an organic fluid Rankine cycle engine, which produces power from any two temperature difference sources with a 17^{o}C differential. Improvements will be undertaken on the engine operating efficiency as well as that of the overall system. A number of installations exist in Africa, and several more are planned for North America and elsewhere.

These engines have potential in extracting energy from waste heat sources. Additional studies are needed on improved solar collector designs. Different sizes of engines must be developed for alternative applications. Controlled demonstration experiments would yield considerable new data. During the winter, there is a potential in using them to extract energy in polar regions, using the difference in temperature between the sea water, under the ice cap, and the prevailing low ambient air temperatures.

c). STUDY OF THE POTENTIAL OF SOLAR PONDS FOR ENERGY COLLECTION

Non-convective solar ponds have been proposed as an effective collector of solar energy. Convection is prevented by means of a salt concentration gradient which maintains a stable density gradient. The incident solar radiation is absorbed throughout the depth (about 1 meter) and on the black absorbing bottom of the pond. Because of the absence of convection it is possible to develop high temperatures (90°C) in the lower layers of the pond. Energy may be extracted from the hot layers and used - possibly for the operation of organic fluid Rankine cycle engines.

Continuing from work, started last year, further studies were carried out on the laboratory solar pond model. An analysis of the initial temperature build-up has been completed. This finite-difference numerical model includes the effects of variable fluid and thermal properties as well as the variation of the spectral absorption co-efficients due to the presence of the dissolved salts required to generate the stable density gradient.

Laboratory experiments using heat lamps to simulate the solar radiation were performed. The predicted temperature build-up agreed well with that measured in the laboratory experiments. As a result of these studies a good understanding of the temperature build-up under laboratory conditions has been obtained.

Construction has begun of a small field model solar pond at the Macdonald College Campus which will be subjected to solar radiation during the coming summer months. Although the primary purpose of the proposed tests is to study the temperature build-up under field conditions some attempt may be made to extract heat from the pond to simulate operating conditions. A theoretical analysis of the fluid mechanical and heat transfer problems involved during heat extraction has been started.

This year, Dr. G.C. Jain, of the Central Salt and Marine

Chemicals Research Institute, Bhavnager, India, who operates the largest solar pond currently in existence, spent 3 months at the Institute. Further collaborative efforts are planned.

IMPEDIMENTS TO IMPLEMENTATION

Solar ponds are combined solar collectors and storage systems. They have potential applications in desert areas, for the collection of heat, or the operation of motors. There is a need for scientifically controlled pilot demonstration plants. Their utilization potential in colder climates has yet to be determined.

d). LOW COST HOUSING

In conjunction with the School of Architecture at the University, studies in low cost housing for developing areas have been undertaken for several years now. The objective has been to examine water and energy requirements of individual housing units. An experimental solar and wind powered house, designed for arid areas, has been operated for 3 years on the Campus at Macdonald College. Operational data from this experimental set up will eventually be used in the design of a solar and wind powered facility - possibly for the indigenous populations of Northern Canada. In addition, there are the housing and energy requirements of the population living in the more southernly regions of the Country. Technological assessment of a solar/wind powered demonstration house for the different climatic regions of the country would provide data on the feasibility of this process.

A major preliminary report on the potential of solar heating for regions in Canada in the vicinity of Montreal has just been completed by the Institute. The field of housing and its associated energy, water and refuse disposal systems is vast, continually involving adaptation and innovation.

e). THE DEVELOPMENT OF AN ENVIRONMENTALLY DESIGNED GREENHOUSE FOR COLDER REGIONS

For the past three years, the Institute has studied the problem of developing low cost greenhouse structures which would be less expensive to heat during our cold winters. In November 1973, an environmentally designed unit was built and operated over this winter. It has been possible to reduce the heating requirements, compared to a standard plastic-covered greenhouse by over 40%. In addition, the extra reflected radiation from the inclined, insulated North-facing wall has produced increased yields of vegetables in the experimental greenhouse.

Impediments to Implementation

These are principally financial, due to the relative lack of interest of governmental authorities in the problem of establishing a viable greenhouse industry. The Provincial Government of Québec has funded an inter-disciplinary team to investigate the potential of this industry, but efforts will have to be more substantial if results are to be satisfactory. The recent increase in transportation charges has made the necessity for a locally based food industry more urgent.

f). STATE OF THE ART REVIEWS

Several state of the art reviews are being undertaken by the Institute to determine what has been done to date, and what areas need further attention.

Energy Storage

Full literature survey of heat storage materials and of proposals relating to energy storage and recovery. The present review covers only this aspect of the work. It is proposed this review treat heat storage both for flat plate solar collectors and for much higher temperatures which can be achieved using parabolic reflectors. Energy should be stored in such a way that it can be used either in driving heat engines or for heating of homes.

Solar Refrigeration and Air Conditioning

This is a "state of the art" investigation and has been undertaken to review and critically analyse all the past research into solar refrigeration and air conditioning. This is being done with a view to determining the technical and economic feasibility of continued work in this field so as to suggest possible new directions for future research.

A Manual of Solar Agricultural Dryers

A manual is currently under preparation, with funding from the Canadian International Development Agency, covering the theory of solar dryers, detailed descriptions of solar dryer experiments, and construction considerations. It will be completed by the autumn of 1974.

Commercially Available and Experimental Windmills

All known manufacturers have been requested to assist with literature, plans and specifications and performance characteristics of their wind machines for electrical generation and pumping. This is intended to facilitate performance evaluations of the numerous wind machines available, including those currently under research and development.

The investigation has been categorized under the following headings:

1. Review of the commercial wind generators now in production.
2. An assessment of the capacities under various wind conditions.
3. Cost of such machines, related to their performances.
4. Present state of wind generators under R & D projects, and prospective useful potentials, with estimated costs.
5. A review of all data, and suggested direction of future investigations.

Impediments to Implementation

It is essential that further and more detailed state-of-the-art surveys be carried out in order to bring together the great amount of knowledge which has been amassed over the years.

This should be a priority of any Office of Solar Energy Research which will be established. These reviews can quickly bring researchers up to date and so permit research contracts to be more complete. In addition, they can be used to help Third World Scientists in their research efforts, as they are often more isolated from the mainstream of scientific activities.

g). WINDMILL DEVELOPMENT PROGRAMS, BRACE RESEARCH INSTITUTE

A number of different projects are under study.

Electrical Power Transmission for a Free-Running, Fixed Pitch Windmill

This project is based on the concept of the wind as a low grade power source to be used as and when available. Transmission of the power from the windmill site to the point of use is in general best accomplished electrically. The complete power train from windmill to delivery point is envisaged with a view to maximum simplicity, reliability and economy. The windmill would be of the fixed pitch, free-running type coupled, through step-up gearing to a three-phase permanent magnet alternator. Transmission distance will be short, a maximum of one or two kilometers. At the receiving end, power would be either converted to heat in resistors or would drive a squirrel-cage induction motor coupled to a positive displacement pump or other load.

The project is intended to clarify the design criteria of such a system, to allow the prediction of energy output under different wind regimes and to define its stability under gusty conditions.

The study is advanced and the final programs will permit the performance of any windmill, whose characteristics are known to be determined, given the hourly variation of windspeed for any specific note.

Design Optimization and Commercial Development of the Brace Windmill

A study has been undertaken to examine details of the Brace 32-foot diameter wind machine developed in 1966 with a view to optimizing its component parts and submitting these to manufacturers so that the windmill will be commercially available. Several different designs of towers have been investigated and costed.

The salient features of the modified design incorporates improvements which permit the whole of the rotor assembly to be traversed normal or away from the wind, by turning it through gearing which engages with an internal rack. The whole of the system, or power unit, is supported on a roller path at the top of the tower. Alternative methods have been investigated by which the rotor can be oriented to face the wind and when velocity exceeds a predetermined value, automatically turns the rotor parallel to the wind stream, thus obviating any manual regulation. These methods of control are applicable whether the mill is used for pumping water or generating electricity.

The complete windmill systems have been designed and the production drawings submitted to industry for costing. The windmill blades, of reinforced fibreglass are manufactured under license by Epothane Ltd., Montréal. Complege cost data is now available for anyone interested in purchasing a windmill for use either to pump water or to generate electric power.

Development of a Sail Type Windmill

In collaboration with Windworks of Mukwanago, Wisconsin, a low speed sail windmill has been developed for use in rural developing areas of the world.

The approach has been to present the sail windmill first in generalized concept, then in specific details with options. The key to usability is that the design be adaptable to local resources. The generalized concept outlines the types of loadings to be encountered, the relative loading for different operating conditions, and the types of structure suitable for the various tasks. The specific details cover Windworks' solution to the loading problems, given their conditions while the options give feasible substitutions in accordance with local tools, skills and materials.

Impediments to Implementation

Studies in the field of windpower must be extended to cover areas where man can either use windpower directly or is affected by windpower. In eastern Canada, there is a need for a two-horsepower windmill, of robust construction and low cost which could be used for draining fields in the spring in order that crops may be planted earlier. Unfortunately, none are available commercially. A number of other specific applications should be examined with a view to determining their suitability in meeting our national requirements. Studies must also be undertaken in an advanced manner with regard to the effects of wind energy around buildings. This has become a significant problem in urban areas. The role and effects of wind breaks also need close attention.

Where can Solar Energy Research and Development have its Greatest Immediate Impact?

The answer to this question seems obvious and yet it often leads to controversy. The principal efforts must be made in those areas where solar energy is currently utilized now, i.e.:

a) in the climatization of buildings for man, his animals and plants,

b) in the field of agriculture.

In dealing with the former it is essential that significant attention be paid to the climatization of our buildings through the development of designs of structures which will be environmentally adapted to the particular region in which they are built. It seems futile to place endless rows of solar collectors on the roofs of many of our structures. Considering that nearly one-third of our national energy budget is allocated for the conditioning of our buildings, then it is significant that a considerable effort be made in this regard. However, the philosophy which must be adopted should be in establishing an awareness in all segments of the population that the wastage of energy, as well as the wastage of resources, is detrimental to our national interests. Consequently, one needs a massive education program which can only bear fruit in the long run. We can't easily legislate energy conservation nor, unfortunately, can conservation be instituted by simply raising prices of energy supplies. It should be seen as a national obligation. Consequently, only when it enters into the realm of education as part of the curriculum of our schools, in particular our engineering and architectural faculties, will it gain respectability and acceptability.

In recent years, we have seen a proliferation of enterprising entrepreneurs offering to sell a variety of solar devices. In some respects, these organizations do the technology more harm than good - for not all the parameters of solar energy conversion are fully understood. One of the greatest difficulties in solar energy utilization is the individuality of each and every application. This is so with the harnessing of any natural energy source.

In summary, therefore, with respect to buildings, the following priorities would be proposed:

1) Provide funding to encourage the introduction of courses of heliotechnology into schools of engineering and architecture.
2) Provide funding for education, "animation sociale" of the public toward accepting and desiring both conservation of energy and utilization of natural energy resources.

3) Stress the importance of the development of environmentally designed buildings, not those incompatible structures erected for their aesthetic or ulterior considerations.

4) Develop the supplemental solar powered heating systems which will be needed to power these environmentally adapted structures so that one can formulate a series of acceptable designs.

5) Examine for particular climatic regions, the degree of hybridity* between the systems which utilize solar energy as a supplemental heat source in meeting the energy requirements in houses. While economic factors will vary considerably, both with location and time of the year, it is important to establish for different regions the feasibility of these degrees of hybridity.

6) Examine in detail methods of energy storage such as water storage, rock pile storage, the lodging of heat in exotic materials, such as heat of fusion salts, etc. This must be investigated with a view to economics as well as to the long-term availability of these materials on the market. It is, therefore, sensible to give the greatest attention to the use of naturally available materials for storage purposes. The storage of thermal and electrical energy is probably one of the greatest challenges facing the solar energy technologists.

7) Study the incorporation of both these storage systems and the integration of their accompanying solar collector systems directly into the structure of the buildings so as to reduce overall costs.

8) Investigate in detail the consumption of energy in buildings with a view to instituting methods of conservation which will reduce the load on the natural energy supply systems. This would include the incentives for increasing building insulation, reducing lighting requirements, etc.

9) Provide technology, so that the roofs of already existing buildings, poorly designed from a solar viewpoint, can be utilized to transform the incident solar radiation into supplemental heat sources.

It is to be hoped that many of these existing structures of lesser historical significance can eventually be eliminated once having made use of these partial measures. What the planners in any country should be aiming for, however, is the development of standards for new and future building designs. Obviously, there will be a need to develop new materials, hopefully from renewable resources, which might better suit the technical requirements of these particular systems.

* Hybrid systems are combined solar-electric or solar-fossil fuel powered systems.

Basically, the technique in solar climatization is known. What is needed is more long-term evaluations of scientifically controlled demonstrations of solar climatization of buildings, so that technical assessment can be undertaken for the benefit of society. It must be understood that these developments will take many years to come to fruition. The formulation of solar powered systems cannot be done, notwithstanding the claims of some, in a short time, It is a long, slow, rigorous approach that is needed in order to produce systems which are technically, economically and socially compatible.

Finally, it is essential that the legislators of society begin the task of examining the many social and legal implications involved in the individual proprietor's right to solar energy. As existing non-renewable resources become less available, the question as to whose privilege and right it is to utilize the sun or to extract power from the wind or the rivers becomes more and more essential. Obviously the rights of the individual need to be protected.

Solar Energy and Agriculture

Through the action of photosynthesis, the sun affects all biological matter. No attempt made to utilize solar energy should overlook the potential of biomass energy. In this section, suggestions for methods to improve the utilization of solar energy in agriculture will be listed. As with buildings, solar energy has been utilized in the agricultural process since the dawn of civilization. What we must do is improve the efficiency of this utilization as well as develop new methods related to this field.

Among the matters requiring additional attention:

1) investigate methods for warming the soil with solar or wind energy in the early spring in order to permit the earlier planting of crops;
2) investigate thoroughly the mechanics, efficiency and operation of cold frames, hot frames, greenhouses, etc., with a view to extending this industry;
3) study the mechanism of solar crop drying systems with a view to extending their application in rural areas, thus relieving the demand on fossil fuels, principally propane. Solar crop dryers with storage systems might be combined with solar house heating systems on the farm, due to their different periods of usage;
4) investigate the anaerobic decomposition of animal and vegetable waste products, for the production of methane;
5) investigate the pyrolysis of organic surplus material for the production of fuels;
6) investigate the feasibility of the concept of "energy" farms, i.e., the continual harvesting on a large scale of organic matter - where would it be possible, and what impact would it have on our national energy system. Can new faster growing trees be developed which would still be ecologically compatible? These questions need answers.
7) investigate the role of windpower in meeting the farmers'power needs, whether for pumping water, generating electricity or for power purposes.
8) investigate all farm needs for power with a view to determining how each might best be supplemented or powered using natural energy. This is particularly true as regards fuels needed for tractor operation. Can methane be used effectively for this task.

More reports like the excellent study by the Agricultural

Economics Research Council of Canada entitled, "Agriculture and the Energy Question", are needed, as well as subsequent action.

For years we have insisted that our farmers make their farms more energy intensive. Nor is this energy used efficiently as Dr. G. MacEachran, author of the above mentioned report stated:

"... It is with a sense of shock that I find that if Canadian agriculture is judged on the basis of energy utilization and conservation,our great industry is not only inefficient,but well below that of the so-called primitive Chinese wet rice agricultural system where 53.5 BTU's of energy are produced from each BTU of human energy, while for each unit of fossil fuel used in North American agriculture it is estimated we receive one-fifth BTU in food energy. ...."

If we are to tackle the true major problems facing our nation today, energy and food, then we must start with a reassessing of the scene in agriculture from a rational viewpoint. One possibility would be the re-introduction of the use of renewable natural energy sources so that the farmer can be independent in his power requirements.

Alternative Uses of Solar Energy in Urban Areas

It must not be forgotten that the heating and cooling of buildings is not the only area where solar energy can have an impact on the urban environment. As our country develops, we are, unfortunately, becoming more and more an urbanized society. This means that a greater percentage of our population is living in the cities in somewhat crowded conditions. In the long run, it will be essential to counteract the resultant sociological and environmental problems with more natural solutions. The ever-increasing search in the urban centers for additional living space as well as additional recreation areas is being only partially met with existing programs in order to make our enormous cities more habitable. There are some research projects underway between different departments at McGill University aimed at making better use of the flat roof areas which characterize the cities of our northern climate. These flat areas are being investigated in conjunction with Government departments in order to determine their suitability for use as additional recreation areas, garden areas for summer usage or roof-top greenhouses for year-round use. Studies are underway to examine the feasibility of using the large flat roof areas of shopping centers, factories, schools and the like, for large scale, commercially operated greenhouses. These would be located in the very heart of our major urban areas and would have a readily available market in the adjacent communities. Plans are being made for heating the greenhouses, utilizing the waste heat exhausted from chimneys of conventional heating systems. This often amounts to as much as 20 to 30% of the heat-equivalent of the fuel supplied to these buildings. Some effort might also be made to extract some of the carbon dioxide in the exhaust gases in order to enrich the atmosphere within the greenhouses, thus increasing the rate of photosynthesis. Social and economic studies are also underway to determine the effects these greenhouses will have on the urban environment. The recent dramatic increase in fuel costs and the subsequent increase in transportation charges makes the prospects of growing one's food supply adjacent to the areas of maximum consumption, more attractive.

This constitutes an effective use of solar energy within our urban centers, requiring additional research and development.

International Cooperation - Canada - United States of America

In considering tapping the vast amounts of natural energy sources, such as solar and wind energy available to neighbouring countries such as ourselves, sharing an extensive common frontier, it would be wise to contemplate the benefits of international collaboration. In view of the cultural and climatic similarity in bordering geographic areas, a regional approach towards investigations should be considered. These investigations would include the effects on agriculture, housing, power plant operations, etc.

Professor Heronemus, from the University of Massachusetts, delivered the key note address at a recent wind power symposium at the Université de Sherbrooke, Québec. His address stressed the desirability for examination of joint United States and Canadian ventures in exploiting wind power. Certain areas of our country, will never have large populations due to climatic conditions. Nonetheless, the availability of a considerable amount of wind power in these areas has prompted Professor Heronemus to propose that both of our governmental authorities examine carefully the desirability of collaboration in the joint exploitation of this resource. Our Institute, as well as other Canadian organizations have their record of close collaboration with counterpart American organizations.

Our relations with the established centers of learning in the field of solar energy in the United States of America have existed for many years. On a smaller, more regional scale, however, a typical example of this type of collaboration can be cited in relation to the introduction of environmentally adapted greenhouses to reduce heating loads. Since the autumn of 1973, we have collaborated with Dr. Justin Voss, environmental economist, with the Institute of Man and His Environment, Miner Research Centre, Chazy, New York, on assessing the commercial and economic feasibility of greenhouse agriculture in our respective areas. This has been undertaken through the development of an environmentally appropriate technology in making better use of solar energy in greenhouses. We, through our research committees in Québec, and Dr. Voss at the Miner Centre in northern New York State, have begun investigating the technical, economical, and social factors affecting the utilization of greenhouses by small farmers who live on both sides of our frontier. In this small way, it is hoped to indicate the mutual advantages of international collaboration in the better utilization of solar energy as a common resource for our people.

This field is new. There are, no doubt, other areas where possible collaboration would be fruitful and mutually beneficial.

Comments on the Appropriate Federal Role in Assuring the Success of Solar Energy Conversion Programs

Solar energy, one of the first terrestial energy sources used by man, is nonetheless in our modern society, relatively new and novel. It thus carries all the stigma associated with relatively undefined, untested, new technology. In order for this technology to be accepted, it will be essential for the public to be made aware of the potentials of this resource. Solar energy is truly a national resource, but in order for it to be effectively accepted, a certain amount of "animation social" is necessary. The federal authorities, both in the United States of America, Canada and elsewhere can accomplish this role in the following manner:

1). Encourage through their respective departments of education the introduction into syllabuses of the different levels of educational institutions, courses which develop an awareness for energy, energy conservation, development of natural resources and particularly the role that renewable resources will play in the future developments of our society.

2). More specifically, in the field of education, stimulate the introduction of courses in schools of engineering and architecture, heliotechnology. As a parallel, the professional societies of these fields, i.e. in the Corporation of Engineers, the Associations of Architects, should be made aware of the particular role that solar energy plays in, for example, the environmental design of building so that we will start having a more rational, orderly approach to these problems. This role the federal authorities can undertake with a minimum of effort and financial expenditure for the common good. Naturally, it will take time before the long term effects of these programs filter down to the public. In Canada, our nationally owned media such as Radio Canada, the Canadian Broadcasting Corporation, the National Film Board, etc. should be encouraged and supported to examine questions dealing with solar energy, renewable resource development and Appropriate Technology in order that they make the public more aware of the desirability and the need for utilizing our renewable resources. Efforts should be made to encourage the investigation of the many technical problems which will present themselves as well as to the legal, social and economi- results whill ensue from the potential large scale utilization of solar energy.

3). Parallel to these efforts, federal authorities should fund demonstration plants which will utilize the combined talents of researchers and industrialists directed towards the field of industrial innovation. It is important to demonstrate the proof of concept of these solar systems in the industrial engineering development stage. It is essential that governments fund initial demonstration feasibility plants which will look at systems embodying various components of solar energy utilization. This may be in the field of solar house heating, solar water heating, solar agricultural drying systems, greenhouse developments, wind power demonstration systems, the anaerobic decomposition of organic waste, etc.

4). There is, of course, still a further role for governments to play beyond the simple technological assessment embodied in demonstration pilot plants. This is in establishing, through various coordinated research bodies, a comprehensive program of long term scientific research which is deemed essential to the national good by the Federal authorities.

There are many areas of solar energy utilization which have not been specifically referred to. This is not an omission through ignorance, but rather somewhat deliberate. There are no doubt other representatives here today who can give you much more valid arguments as to why these should be examined at this point of time. Whatever may be the essence of these arguments, the ultimate utilization of these technologies nonetheless involves a certain amount of preliminary research and development.

In this regard, therefore, it is felt that these schemes should be looked at in their totality in conjunction with the development of a national energy policy. Admittedly, governments should view the development of solar energy technology for industrial applications, i.e. large scale power plants, photo-voltaic conversion systems, the development of hydrogen through a number of processes in such a manner as to integrate these into a national energy development scheme.

Many questions remain as to which organizations will DEVELOP and market these possible solar power plants of the future. Is society to pay for the research and development necessary for the development of this technology and then hand over the know-how to generate the power needed? In Canada, we have by and large eliminated this question as most of the power generating plants are publicly-owned utilities.

In a country where these utilities are privately owned, the question requires a decision of policy by its citizens. Who will generate the solar-photo-voltaic power of the solar produced hydrogen needed to power future utilities? Surely, these are questions of principle to which any society must address itself.

Specific Comments on the Language of Act S3234

The proposal to establish an office of Solar Energy Research is certainly a laudable one. Once again it places the United States in the forefront in the field of Science and Technology. It is a proposal I wholeheartedly endorse and I would urge you to give this matter the serious attention and study it deserves. In 1972 in commissioning the NSF/NASA Solar Energy Panel study which reported on "Solar Energy as a National Energy Resource", your Administration took the leadership of governmental action in this field in the world. This report has already paid untold benefits both within your country and in other areas where it has been used both as a model and guide. Obviously, this current Bill is the embodiment of positive action in this regard.

The United States Authorities have already set a precedence in this matter of focusing attention on a problem of global concern. I refer to the establishment in the early 1950's of the Office of Saline Water, U.S. Department of the Interior to investigate the problems associated with the conversion of saline water to fresh water. The very fact that a Secretariat existed stimulated this field of endeavour and did a tremendous amount to boost the world-level of knowledge in this field. In addition its presence, publications and effort were particularly beneficial to those lesser developed regions outside the U.S.A. - and this type of goodwill is by far the best type of external aid and relationship that any country could hope to achieve.

Specific Comments on the Bill

1) It must be assumed that Sect. 3(c) is worded in this fashion in order to speed up the implementation of this Act; otherwise the wording is vague.
2) The Act is unclear as to which Ministry, Department or Agency the new OSER* will belong. Is it the Atomic Energy Commission?
3) Who will appoint the new Administrator and his staff - does this Act envisage an OSER* interim advisory panel which will carefully select the officers of this body?
4) During its operations, which guidelines will ensure that not all the funding is channelled in any particular direction to the detriment of others. The vast numbers of subjects to be investigated, each championed by organizations with vested interests, require that some safeguards be

* Office of Solar Energy Research

established. It would be a pity if this Office to which Americans will no doubt feel attracted, funnelled most of its funding into one or two objectives, with one or two industries primarily benefitting. It is appreciated that Section 5, Part C(Clause 2) does make allusion to this point.

5) There is no discussion of re-evaluation or eventual dissolution of OSER.* The aims and achievements of the Organization must be critically and publicly re-examined in five years to ensure that it has striven to meet its objectives. These latter points should be continually re-assessed in the light of changing external requirements and priorities.

6) There is no clause in the Bill dealing with energy and resource conservation. The very essence of the utilization of a diffuse energy source such as solar energy must embody a new philosophy of approach to the utilization of resources - with a definite emphasis away from the current wasteful exploitation of materials and energy.

7) If this Office were to be established in Canada, it would be essential to delineate what impact its findings would have on the determination of a National Energy policy. Consequently the role of this Office within the framework of your Federal agencies dealing with the determination and implementation of National Energy programs should be specified.

8) The concept of "net" energy production from any energy collection system should be specified as a criteria for the evaluation of any proposed systems to be funded and investigated.

9) As solar energy utilization will eventually result in the formulation of new community administrative legislation, etc., it will be essential that the OSER*have a department which specializes in legal and legislative matters to ensure that the results of the Research and Development programs can be translated into action within society.

* Office of Solar Energy Research