RECOMMENDATIONS FOR SOLAR ENERGY RESEARCH AND DEVELOPMENT IN CANADA

BRACE RESEARCH INSTITUTE'S
REPORT TO THE
MINISTRY OF STATE FOR
SCIENCE AND TECHNOLOGY

BRACE RESEARCH INSTITUTE

MACDONALD COLLEGE OF McGILL UNIVERSITY
STE. ANNE DE BELLEVUE 800
QUÉBEC, CANADA

TELEPHONE (514) 453-6580

REFERENCE

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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

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

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Finally we wish to acknowledge the assistance and active cooperation of H. Flynn, of the Ministry of State, Science and Technology, Ottawa, whose help and advice were invaluable in the preparation of this report.

Finally, we wish to acknowledge the grant of $5,000 made by the Ministry of State, Science and Technology to undertake this survey. We are pleased to participate with our governmental authorities in informing them of subjects which will benefit the nation. However, it must be appreciated that little can be done with such modest funding. Therefore, while we welcome comments, critisims and suggestions; we would ask that this report be judged with this in mind. Many other surveys have been undertaken in the past, requiring far greater expenditures. We hope that this effort will make a contribution to our National picture.

Ste. Anne de Bellevue, Québec
25 October, 1974

T. A. Lawand

R. Alward

H. P. Budgen

A. Russel

E. Brunet

B. Saulnier

T. Johnston-Stewart

D. MacDonald

B. Sachs

EXECUTIVE SUMMARY

Solar, wind and biomass energies are Canadian resources and deserve the same attention and interest given to other resources we currently exploit. These energies are renewable, non-polluting and available in situ. As a nation, Canada lags behind others in that it has never made a committment to investigate the potential of these resources in partially meeting our future energy requirements. Canada possesses the climatic potential, the expertise, and a solid, and willing commercial and industrial base to exploit these energy resources, which could be used in the initial instance to supplement our current energy supplies.

Looking ahead to the year 2000, this report proposes a research and development program which would have as a philosophy, the following concepts:

a. to investigate methods of making more efficient use of solar energy where it is currently used--i.e. in housing and in agriculture.
b. to investigate methods of capturing these freely available resources wherever they exist in sufficient amount in various parts of the country to deem their exploitation meaningful.

As a result, four principal programs are proposed for research and development.

1. The use of solar, wind and biomass energy in partially meeting the heating, hot water and cooling requirements for residential, commercial and industrial buildings in Canada.

   No. of years: 20 Estimated funding/annum: $1,725,000

2. The use of solar, wind and biomass energy in meeting the requirements of the Canadian Agricultural industry, as well as investigating the potential for larger scale energy production.

   No. of years: 20 Estimated funding/annum: $1,900,000

3. In view of the large land mass and dispersed population of Canada, a program is proposed for meeting the power requirements of remote locations throughout the country using solar, wind and biomass energy.

   No. of years: 20 Estimated funding/annum: $700,000

4. An office of solar energy assessment is proposed to examine programs in other countries and the above mentioned fields in general so as to advise the authorities and Canadian industry, when involvement in a particular field of solar, wind or biomass energy appear to be logical.

   No. of years: 20 Estimated funding/annum: $150,000

The sponsorship of this program should act as a seed to industry to enable them to develop adequate systems for public consumption. In addition, it should be accompanied by a massive program of public education and "animation sociale" in which the authorities, through our nationally owned communications media, would stress the importance of utilizing these natural, renewable, non-polluting Canadian resources as a national obligation.

For the sake of future generations, we must stop the wasteful practises of the past of consuming all our non-renewable energy resources, and leave some resources as a heritage for our successors. Finally, the use of these energies will involve to some extent the participation of the average citizen, increasing his awareness and appreciation for the mechanisms controlling society. The citizens must be made more aware of their natural environment if they are to participate in the difficult decisions to be made in the next few decades, when we must collectively decide on the future, rational course of development of the manner in which we live.

SOMMAIRE

Les énergies, solaire, éolienne, et de la biomasse sont des ressources canadiennes qui méritent notre attention au même titre que les autres ressources naturelles actuellement exploitées. Ces énergies sont renouvelables et non polluantes tout en étant disponibles sur les lieux. Dans ce domaine, le Canada semble à la traîne comparablement à d'autres pays du fait qu'il ne s'est jamais proposé d'examiner le potentiel de ces ressources pour supplémenter nos besoins énergétiques dans le futur. Le Canada possède certains avantages climatiques, l'expertise et surtout une base industrielle et commerciale désireuse et apte à gérer ces ressources énergétiques qui pourraient s'ajouter dès maintenant à nos ressources énergétiques.

Ce rapport se propose d'envisager jusqu'à la fin du siècle un programme de recherche et de développement qui aurait comme base philosophique les concepts suivants:-

A) Examiner les méthodes permettant une meilleure utilisation de l'énergie solaire, là où elle est employée maintenant, par exemple dans l'habitation et en agriculture.

B) Examiner les méthodes de captage de ces ressources libres, là où elles existent en quantité suffisantes dans diverses régions du pays, tout en projetant de façon sensée leur exploitation.

De ceci découlent quatre principaux programmes pour la recherche et le développement.

1. Utilisation des énergies solaire, éolienne, et de la biomasse comme supplément aux besoins en chauffage et en climatisation des bâtiments commerciaux, industriels et résidentiels du Canada -

   Nombre d'années - 20

   Estimé des Fonds/annum $1,725,000

2. Utilisation des énergies, solaire, éolienne, et de la biomasse, pour aider aux besoins de l'industrie agricole canadienne, et rechercher les moyens de produire cette énergie à une plus grande échelle -

   Nombre d'années - 20

   Estimé des Fonds/annum $1,900,000

3. Tenant compte de l'immensité du pays et de la dispersion de la population au Canada, il est proposé d'étudier et de répondre aux besoins en énergie des régions isolées et peu accessibles par l'utilisation de l'énergie solaire, éolienne, et de la biomasse -

   Nombre d'années - 20

   Estimé des Fonds/annum $ 700,000

4. Proposition de la mise sur pied d'un bureau d'étude sur l'énergie solaire chargé d'examiner les programmes entrepris dans les autres pays et les champs d'études ci haut mentionnés, afin de renseigner les autorités et l'industrie canadienne sur l'à-propos de leur éventuelle participation dans le domaine de l'énergie solaire éolienne ou de la biomasse:-

Nombre d'années - 20

Estimé des Fonds/annum $150,000

La promotion de ce programme devrait agir comme un stimulant pour l'industrie et lui permettre de développer des systèmes adéquats pour le consommateur. De plus un programme élaboré pour l'éducation, l'animation du public, et l,utilisation des média de communication nationaux insistant sur l'importance de l'utilisation de ces ressources naturelles renouvelables et non polluantes, devraient compléter l'ensemble.

Par égard aux générations futures, nous devons mettre fin à notre vieille habitude d'exploiter jusqu'au bout les ressources énergétiques non renouvelables, et penser un peu à ce que nous laisserons à nos successeurs. Enfin, l'utilisation de ces énergies demandera une plus grande participation des citoyens, ce qui devrait accentuer leur prise de conscience et leur receptivité sur les mécanismes contrôlant notre société.

Les citoyens doivent se sensibiliser aux problêmes de notre environnement naturel puisqu'ils devront de toute façon participer aux décisions difficiles qui seront prises dans les prochaines décades. Nous devrons alors déterminer de façon rationelle de quelle manière nous voulons vivre dans le futur.

AN OVERVIEW OF SOLAR ENERGY - AS A NATURAL RESOURCE

The population on the planet Earth continues to rise at a significant rate. Currently 3.5 thousand million people are estimated to inhabit the world, with a predicted doubling of this population during the next 30 to 40 years. At the same time, advances have been made in the fields of education, health and welfare, technology, etc. The standard of living of people continues to rise all over the world. Planners must come to grips with the ever-increasing demand for more resources to power the commerce and industry of this burgeoning population. Two factors have emerged pre-eminent in man's struggle to keep pace with the increasing demand for resources - the need for more food and additional supplies of energy. There is a significant interaction between food production and energy, the combined effects of which are currently being manifested by rampant inflation. (Clothing and housing are equally significant requirements of man).

The need for power and fuels has caused an upsurge of interest in the exploitation of natural energy sources. There is one motivating factor for this increase in interest - energies based on the power of the sun are renewable. It is this non-depleting feature of solar energy which is appealing. Even our fossil fuel supplies originated from the sun - however, their time constant - many millions of years - leads us to consider them as finite resources. One of the contributing factors of many nations of the world today coming face to face with energy problems, has probably been that they have regarded their fossil fuel resources - coal, oil, natural gas - as being available in infinite quantities. The shock of not having these fuels at their beck and call, in whatever quantities required, all for a modest price, was probably one of the best injections of reality that man has had in many years. Man should now hopefully be viewing his energy, and other resources, exploitation practices, with some element of common sense. He has perhaps in desperation turned to nuclear energy as the future panacea of energy needs. Let us hope that he will not come to regard this decision disfavorably in the future. One tends to feel that not all the future consequences are considered or recognized in initiating new technological ventures - but once society has contributed such extensive financial, material and human resources into resolving and perfecting technologies such as nuclear energy, it is often difficult to call them to a halt or in some cases, even to control them. Nuclear energy is no doubt going to supply a good portion of our future energy requirements. Nuclear energy might even be considered a technological expedient with a finite lifetime. It is to be hoped that it receives from our officials the proper scrutiny and attention that it deserves from an environmental, social, economic and political point of view.

The main purpose of this report is to look at solar energy, and to examine what possible role this might play in meeting our national energy requirements in the future. It must, of necessity, not be regarded in opposition to existing or projected systems, but rather in a more positive manner as to what contributions to the national scene it could make either on its own or in combination with other forms of energy. The same close attention that is demanded vis-a-vis nuclear energy must also be required towards solar energy. The sun's energy is not necessarily free--it requires collecting and storing. Also unless carefully planned, it is not necessarily pollution free --but then, on both these scores solar energy has great potential. We must not view its exploitation through yesterday's eyes with our push button mentality, which has led to a polluted environment and a society on the brink of economic and social instability. Rather, in re-discovering the use of solar energy as a source of supply, we must adopt a more rational philosophy of approach and develop methods of Appropriate Technology which will rightly site our technological needs, after taking into consideration their social, cultural, economic and political ramifications.

Recommended Research & Development Program for Canada in the Field of Solar Energy

In order to fully exploit the potentials of the abundant natural energy received on the land mass of Canada, a significant program of research and development would be necessary.

a. to adapt known solar technology for the resolution of existing problems;
b. to investigate new, promising areas which would yield benefits to the nation in the long term.

The task given to this Institute has been to examine the State-of-the-Art of solar energy while stressing those areas where research and development funding would produce beneficial results in meeting our energy needs. The funding provided for this study was extremely modest. What should be done is the following:

a. the energy supply-demand patterns for Canada past, present and future should be examined with regard to;

   1. type of category of demand
   2. the current energy source used to meet this demand.

In this regard, the energy consumption patterns in Canada would be categorized. This information is no doubt available here. Many countries of the world have begun detailed assessments of the manner in which their energy is used. It is essential that this basic statistical data be available, as the day may come when society will have to regulate the consumption of energy in certain areas. If the patterns of consumption are known, then it will be that much easier to institute these regulations.

Similarly, the relation of different energy sources to the demand requires full investigation as well. The trend towards an eventual fully electric system of operation might simplify these supply-demand relationships --placing most of our emphasis on the need for many central generating stations, coupled with good distribution systems. Of course, accessibility to fuel needed to power these central stations will have to be studied closely.

Placed in this context, planners will have to examine the totality of our demand patterns as well as the methods in which our supply of energy is generated in order to determine how economies can be effected. The keynote must be efficiency of energy usage. Power plants must be judged by their net productivity. Consumers must learn to use less energy. Normally, in a free market economy, it is felt that price will regulate the demand. Is this really so in the complex world of today and will it be so in the Canada of tomorrow where we will have to learn to cope with shortages of materials, resources and energy? Surely society must find a better mechanism of governing its use of scarce commodities. The need to change the populations "optique" from one of a consuming society to one of a conserving society must form part of our material planning priorities.

Obviously this will mean dislocation in certain industries--but are we to wait till we are on the edge of the waterfall before taking corrective measures?

THE STATE OF THE ART

It is impossible under the existing terms of reference of this contract to undertake a full scale survey of the State of the Art in solar energy research and development. This would produce a massive document whose validity would have to be gaged in terms of the rapidly changing scene today in these fields, in view of the fact that an increased amount of funding is being pumped into this area. An outline is presented in the hope of eventually stimulating such a comprehensive study and facilitating its execution.

SOLAR ENERGY RESEARCH AND DEVELOPMENT OUTLINE

A. Basic Measurements, Fundamental and Applied Research

1. Solar Radiation Measurements

    i. Solar constant
    ii. Global, direct and diffuse components
    iii. Incidence on differently oriented planes
    iv. Preparation of solar maps
    v. Spectral characteristics as a function of location, seasons and time of day
    vi. Instrument design, standardization and control.

2. Collector and Concentrator Design and Technology

    i. Flat plate collectors
    ii. Focusing collectors
    iii. Materials technology - glasses, plastics, etc.
    iv. Selective surfaces and antiradiant structures and geometries
    v. Effects of convection.

3. Thermal Storage

    i. Storage and sensible heating materials
    ii. Heat affusion materials
    iii. Storage in the earth
    iv. Storage systems engineering

4. Thermal Cycle Conversion

    i. Choice of cycle and system
    ii. Heat and mass transfer within the system

5. Photovoltaic Conversion

   i. Silicon cells
   ii. Cadmium sulfide-copper sulfide cells
   iii. Other semi-conductors

6. Photochemical Conversion, including Phytosynthesis

7. Thermoelectric Conversion

8. Building Design and Construction

   i. Town planning
   ii. Location and design of structures
   iii. Construction materials
   iv. Visual and other health aspects of sunlight in buildings
   v. Environmental design of building

B. <u>Solar Energy Applications with Conversion</u>

1. Water Heating

   i. Domestic hot water
   ii. Swimming pools

2. Drying

   i. Agricultural
   ii. Industrial

3. Greenhouses

4. Water Distillation

5. Space Heating

6. Natural Radiative cooling

   i. For cooling of buildings
   ii. For refrigeration
   iii. For water purification

7. Cooking

8. High Temperature Furnaces

   i. For research
   ii. For production of chemicals
   iii. For production of refactoring bricks and other industrial processes
   iv. For smelting exotic metals
   v. For commercial production of synthetic diamonds

C. Applications Requiring Small-Scale Conversion

1. Heat Engines

   i. Organic Fluid Rankine Cycle Engines
   ii. Pumps
   iii. Refrigerators
   iv. Stirling Engines
   v. Other Engines, e.g. Hot Air Engines

2. Photovoltaic Devices

   i. Lighthouses
   ii. Radio and television receivers
   iii. Other communication uses
   iv. Power for satellites

D. Systems with Intermediate or Large-Scale Thermal or Photovoltaic Conversion

1. Solar Ponds

2. Solar Farms (terrestrial collection, thermal conversion and electricity production on a large scale)

3. Dissociation of Water to Produce Hydrogen as a Fuel

4. Space Collection by Satellites

E. Systems Using Photosynthesis and Other Chemical Processes

1. Direct Products of Photosynthesis

   i. Tree Farming
   ii. Grasses
   iii. Algal cultures
   iv. Water plants

2. Biophotolysis of Water to Produce Hydrogen Gas

3. Conversion of Organic Material to Fuels or Heat Energy

   i. Combustion
   ii. Bioconversion to methane
   iii. Pyrolysis to gas, liquid and solid fuels
   iv. Chemical reduction to oil
   v. Enzymatic reduction

F. Systems Using the Hydrological Cycle, Atmospheric Convection and Ocean Currents and Gradients

1. Heliohydroelectric - Power Generation

2. Ocean Temperature Gradients

3. Energy Extraction from Waves; Sea and Rivers

4. Tidal Energy

5. Windmills

   i. Wind Speed Measurements

      a. wind speed measurements
      b. gusting
      c. wind direction - frequency of changes
      d. preparation of wind potential maps
      e. variation of windspeed with height
      f. instrument design, standardization and control

   ii. Windmill Components, Design and Technology

      a. rotors
      b. vertical axis machines
      c. horizontal axis machines
      d. transmission systems - within windmill assembly
      e. towers
      f. systems

   iii. Energy Storage

      a. electrical storage (also for solar energy)
      b. thermal storage
      c. hydraulic water potential energy storage
      d. other storage systems

   iv. Applications of Wind Power

      a. Windmill Energy Systems

         1. Mechanical Shaft Power Production

            i. Pumping
            ii. Compressing Gases, Air
            iii. Power other mechanical equipment, Grinding, Shellers, and wider agricultural services

         2. Electrical Energy Production

            i. Systems with small scale individual storage, as now commercially available frcm Europe

ii. Systems too large for any electrical storage methods, but used to heat massive inorganic materials.

iii. Systems of the largest size envisaged, which would be designed to feed direct into a grid. Voltage and Hertz regulated to maintain constant performance irrespective wind potential variations.

3. Other Applications

4. Specific Systems - P eculiar to Regions and demands

5. Large Scale Windpower Applications

The Future Role of Natural Energy Sources

It was essential to set down this preamble, if only to place the possible future role of solar and wind energy in its proper perspective. This report, therefore, will deal primarily with the technological capabilities of natural energy resources in meeting our national needs. Much of the rationale behind the statements are contained in Appendix AA, of Appendix A, which deals with a brief submitted on this subject, to the United States Senate in a bill dealing with the establishment of an office of solar energy research and development.

There should be two guiding principles to the philosophy that governs our use of natural energy resources.

a. We should utilize to greater advantage these energy sources where they are currently being utilized. This is a short term objective.

b. Wherever these natural, renewable energy sources exist today in the country, we should be investigating methods of capturing this energy for use in the meeting of the country's energy requirements.

The use of natural energy supplies will have a two fold effect. It will a). reduce our dependence on fossil fuel, nuclear and hydro energy and b). it will permit us to utilize these resources far more efficiently and effectively in our overall economic situation.

Natural energy supplies properly utilized in systems which are economically feasible from the nation's point of view, will permit a more effective maximization of our benefits, derivable from other national resources such as oil, gas and coal--which have value in chemical form exceeding that of their value in pure fuel form. The hydro and nuclear energy units producing electricity, therefore, would continue to be used in providing electricity for power purposes, illumination, etc., rather than being used for providing heat energy, for example.

Bearing this approach in mind, the following main areas of activities in the field of research and development can be envisaged:

I. The use of solar, wind and biomass energy in partially meeting the heating, hot water and cooling requirements for residential, commercial and industrial buildings in Canada. Varying estimates indicate that this employs up to 30% of our national energy budget. This should be kept as an overall long term objective. In this regard, a more detailed research and development program is appended.

II. The use of solar, wind and biomass energies in meeting the requirements of the Canadian agricultural industry. As a priority, a research and development program would investigate methods of directly meeting on-farm energy requirements. A second priority would investigate the possible production of an energy surplus which would be directed into partially satisfying overall national requirements.

III. In view of the large land mass in Canada, a program is proposed for meeting power requirements of remote locations throughout the country using solar, wind and biomass energies.

IV. Finally, an office of Solar Energy assessment is proposed which will keep abreast of all subjects in the field. Their primary task would be to inform governments when, in the future, to embark on new imaginative courses of action. This will be contingent on technological developments in other countries in the fields of solar, wind or biomass energies. It may require joint investigations and commercial relations with outside organizations, as they essentially will have been doing the research. In the initial phases some research and development should be funded by this office. It could make use of existing Canadian expertise in these areas of specialty.

I. PROPOSED RESEARCH AND DEVELOPMENT PROGRAM IN MEETING ENERGY REQUIREMENTS FOR THE SOLAR HEATING AND COOLING OF BUILDINGS

1. It is proposed that funding be provided to encourage the introduction of courses of heliotechnology into schools of engineering and architecture.

   No. of years: 5 to 10 — Estimated funding/annum: 20 schools at $10,000 - $200,000

2. Provide funding for education, "animation sociale" of the public toward accepting and desiring both conservation of energy and utilization of natural energy resources.

   No. of years: 5 — Estimated funding/annum: to fund Canadian Broadcasting, National Film Board: $75,000

3. Undertake data collection to determine the available roof areas, south vertical walls, etc. of Canadian buildings which might have potential for direct collection of solar energy.

   No. of years: 5 — Estimated funding/annum: $50,000

4. Develop concepts of environmentally adapted buildings of different types and for different regions of the country. Develop environmentally adapted designs for the year 2000. Determine the possibility of long life; energy conserving buildings.

   No. of years: 25 — Estimated funding/annum: $100,000

5. 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.

   No. of years:
   heating - 10
   cooling - 20

   Estimated funding/annum:
   heating - $75,000
   cooling - $75,000

6. To fund and evaluate demonstration units on the basis of the above considerations of Items 4 and 5.

   No. of years: 10 to 20
   2-5 units/year

   Estimated funding/annum:
   $100,000 to $250,000

7. To examine within the context of Items 4,5 and 6, appropriate housing for Canadian population, whether single dwelling, cluster housing or apartment complexes.

   No. of years: 5 to 10 — Estimated funding/annum: $50,000

8. Examine heating requirements and design modifications for environmental adaptation of commercial and industrial buildings.

   No. of years: 5 to 10 — Estimated funding/annum: $100,000

9. In the context of Items 4 to 8, to examine for particular climatic region, the degree of hybridity* between the systems which utilize solar energy a a supplemental heat source in meeting the energy requirements in houses. While economic factors will vary considerably, both location and time of the year, it is important to establish for different regions the feasibility of these degrees of hybridity.

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

No. of years: 10 to 20 Estimated funding/annum: $50,000

10. In conjunction with Items 4 to 9, to 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.

No. of years: 20 Estimated funding/annum: $100,000

11. Parallel to Items 4 to 10, to 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. In addition, central storage systems for groups of buildings should be considered. (see Appendix)

No. of years: 20 Estimated funding/annum: $100,000

12. Preliminary and parallel to all above considerations to 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, increasing building thermal mass, etc.

No. of years: 10 Estimated funding/annum: $75,000

13. In parallel with the above program, a program must be established to provide technology so that already existing buildings can be retrofitted with solar collectors, storage systems, etc. in order to transform incident solar radiation, wind energy and biomass energy into supplemental heat sources, even though the building itself might be thermally inefficient.

No. of years: 20 Estimated funding/annum: $100,000

14. To fund and evaluate demonstration units on the basis of Item 13, above, i.e. for the retrofitting of selected existing buildings.

No. of years: 2-5 units/year Estimated funding/annum: $50,000 to $125,000

15. To fund a national trust to eventually decide which buildings of lesser historical and economic importance might one day be eliminated because of poor thermal design. This commission shouldconserve our national heritage and culture while recommending plans of action for the future.

No. of years: 20 Estimated funding/annum: $50,000

16. To develop legislation which will examine the legislative, tax and building regulations of different authority on all levels of government, co-ordinating these activities to produce energy-sound structures for the population of the country.

No. of years: 20 Estimated funding/annum: $50,000

As a support program for these efforts, the suggested research program on the measurement of natural energy sources in the attached section would also have to be funded. Kindly refer to this section for these recommendations.

In addition, it will be required to undertake some basic studies into fundamental and applied research programs to support these activities. These will include some studies in heat transfer, the development of collectors which can resist freezing, the measurement of absorptive and radiation characteristics of materials used in the solar collectors, thermodynamics of storage systems and development of component parts, etc. For this program to be effective, it will be required to fund these studies at a rate of:

No. of years: 20 Estimated funding/annum: $150,000

The total investment in this program would probably be less than $2,000,000 per year spread out over a period of 5 to 20 years.

It is estimated that the total program presented above for solar heating and cooling of buildings would amount to $1,725,000 per annum, and might taper off in subsequent years to more like $1,000,000 per annum after 5 to 10 years. Obviously, these figures would have to be quantified more in the future. It is felt that industry will move rapidly into this field once the authorities have demonstrated feasibility through proof-of-concept projects, etc. A similar trend is forecast in other countries as well. The research and development program suggested herein is, of course, far more modest in this field than that underway both in the United States of America and Japan.

The above program can be viewed in terms of short, intermediate and long term objectives. The short term activities should be given immediate attention since the technology is sufficiently far advanced for considerable results to be realized with a relatively minor input of funding. Immediate activities should include:

1. in depth analysis of existing solar houses in Canada.
2. begin retrofitting program and installation of equipment on several existing houses.
3. initiate accelerated program of meteorological observations.
4. initiate courses of heliotechnology in engineering and architectural schools.
5. initiate program of education and "animation sociale" of the public.

Programs of intermediate duration should receive funding as soon as possible; however, due to their nature, the development programs will be expected to cover a 5 to 10 year period.

Such programs would include:

1. development of solar powered heating and cooling systems.
2. development of environmentally adapted, energy conserving and solar energy utilizing housing structures.
3. development of energy storage systems.

The long term objectives would essentially be to develop Canadian Industry potential and capability to design and build solar equipment for house heating purposes.

Supplemental Solar Water Heating Program

Cne of the fields which is the most advanced commercially in the world is that of solar water heating, for the provision of hot water for domestic, commercial and industrial uses. Concurrent with the above program on solar space heating and cooling should be developed a program of solar water heaters for Canadian conditions. To operate satisfactorily in Canada, solar water heaters will no doubt have to be used in conjunction with other energy forms such as gas, oil or electricity, in order to provide supplemental heating.

Amongst the problems requiring research and development are the following:

1. the development of solar water heaters which can operate in Canada on a twelve month of the year basis.
2. the development of collectors which can resist freezing or can utilize fluids which do not freeze.
3. the integration of the solar water heaters into the building structure from an economic and aesthetic viewpoint.
4. the development of a solar water heater industry in Canada, etc.

No. of years: 5 Estimated funding/annum: $80,000

II. SOLAR, WIND AND BIOMASS ENERGIES FOR AGRICULTURAL PRODUCTION

The development of supplementary energy systems for Canadian farm use includes the general categories of energy supply from sun, wind and biomass. In the following, we have attempted to isolate proposed developmental programs into each of these three areas. However, there is a quite obvious overlapping of several of the projects in these different areas since many of the programs are interdependent due to the very nature of the energy sources involved.

In addition, there is an overlapping of many of these projects, geared specifically towards farms and agricultural production, with several of the programs listed in the sections dealing with Solar Heating and Cooling of Buildings, Power Supplies for Remote Areas and The Office for Solar Energy Assessment.

A. Wind

1. Survey of Canadian farm energy needs that could potentially be met either in whole or in part, by wind power generating systems. This survey would include a general tabulation of windmill systems currently in use, either for water pumping or electricity generation on farms in Canada.

   No. of years: 5 Estimated funding/annum: $30,000

2. Development of windmills to provide shaft power for such purposes as feed grinding, shredding of vegetable materials and crop residues or wastes, sawing, etc.

   No. of years: 5 Estimated funding/annum: $45,000

3. Research and analyses of candidate energy storage systems which could overcome periods of no wind.

   No. of years: 10 to 20 Estimated funding/annum: $50,000

4. Experimental investigation and demonstration units illustrating the the effectiveness of windmill operated pumps for irrigation and drainage of farm land.

   No. of years: 5 Estimated funding/annum: $60,000

5. Development of new windmill systems for pumping water for human and animal consumption. These new systems would have to take into consideration current and potential water requirements. As part of this study, combination systems whereby the windmill could produce electricity as well as shaft power, might be considered.

   No. of years: 5 Estimated funding/annum: $40,000

6. Research into wind operated compression systems for air and gases for the operation of farm machinery and tools.

   No. of years: 5 Estimated funding/annum: $40,000

7. Development of wind systems for use in ventilation of farm buildings.

No. of years: 5 Estimated funding/annum: $30,000

8. Studies and experimental program into wind generated air circulation systems for low temperature drying processes.

No. of years: 5 Estimated funding/annum: $30,000

9. Program for development of wind turbines capable of electricity generation for general farm use. This would include installation and analysis of several prototypes on various sized farms.

No. of years: 5 Estimated funding/annum: $75,000

10. Investigations into the heating of various farm buildings using direct resistance heating of a large thermal storage volume.

No. of years: 5 Estimated funding/annum: $50,000

B. Greenhouse Research Program

There are numerous areas in greenhouse development in which natural energy systems can be incorporated for a more effective environmental design. Some of these will be touched upon in other sections dealing with wind and biomass. The following will include only those areas related to crop growth and the potential utilization of solar energy. The greenhouse industry is important because it helps Canada to maintain self-sufficiency in food supply.

Proposed areas of research are listed below:

1. Design, development and optimization of greenhouse structures adapted to the different latitudes and climatic zones in Canada. This would pertain to making more effective use of wind and solar energy supplies. In addition, it would include research into such subject areas as size and shape of greenhouses, partially underground structures, utilization of natural slopes, etc. This might entail construction of several models.

   No. of years: 10 Estimated funding/annum: $80,000

2. Research into heat storage potential within greenhouses. This would touch on such areas as storing excess daily heat during periods of intense solar insolation, storage of summer heat for use in autumn and winter periods, rock pile storages, thermal mass of building components, etc.

   No. of years: 10 Estimated funding/annum: $50,000

3. Detailed investigation into means to present heat losses in greenhouses during the night; for example: moveable insulation panels, bead walls,reflective curtains, etc.

   No. of years: 5 Estimated funding/annum: $30,000

4. Study of shading, cooling and ventillating techniques specifically adapted to Canadian conditions. This would potentially involve development of new materials with variable light transmittance characteristics, air re-circulation systems utilizing the coolness stored in rock piles, etc.

   No. of years: 10 Estimated funding/annum: $50,000

5. Research into new building designs that would give maximum plant growing efficiency during all seasons. This would include areas such as buildings with moveable walls and roof sections such that plants would receive optimum solar intensity throughout daily and seasonal climatic variations. Development of several prototype models.

   No. of years: 5 Estimated funding/annum: $50,000

6. In depth studies, including an experimental program, into the more scientific utilization of cold frames and hot beds for the earliest starting of crops and potential extension of the growing season into the fall. This would incorporate many of the techniques and materials utilized in Items 1 to 5 above.

No. of years: 5 Estimated funding/annum: $50,000

7. Studies into the use of excess greenhouse heat for supplying supplemental heat to other farm buildings. This includes research into determining the feasibility and practicality of combining house and greenhouse structures in order to economize on heating systems.

No. of years: 5 Estimated funding/annum: $40,000

8. Experimental program and evaluation of roof top greenhouses for urban areas.

No. of years: 10 Estimated funding/annum: $50,000

9. Investigate the potential of incorporating greenhouses into the roof structures of animal enclosures. This would allow excess animal heat, which would normally escape through the roof, to be used for providing part of the heat for the greenhouse interior.

No. of years: 5 Estimated funding/annum: $15,000

10. Study of the use of new long lasting inexpensive materials in greenhouse constructions. This would include transparent materials for roof and walls, heat storage materials for construction members, insulation materials for non-transparent surfaces, etc.

No. of years: 5 to 10 Estimated funding/annum: $50,000

11. Research into developing high nutritive value plant species specifically suitable to growth in greenhouse climates. This would include plants adaptable to the wide temperature fluctuations found in minimally heated greenhouses during colder seasons.

No. of years: 20 Estimated funding/annum: $20,000

12. Further research into comparison cropping and more effective use of relay crop techniques for greenhouses.

No. of years: 5 Estimated funding/annum: $10,000

13. Development of species related effective growing media for greenhouse crops.

No. of years: 10 Estimated funding/annum: $10,000

If the Canadian Government makes a committment to supporting the greenhouse industry as a mechanism in reducing our over reliance on food importation, then obviously it would have to make additional investments to the whole field of greenhouse agriculture including agronomy, plant pathology, marketing, economics, etc. An excellent example of this form of committment is the interdisciplinary working team funded by the government of Québec. The group is the "Group de Recherches sur les Serres Maraîcheres" based at Laval University of Laval, Québec.

C. BIOMASS RESEARCH SECTION

1. Conduct an inventory of present biomass formation in Canada, both natural and cultivated.

   This should include:

   a) crop residues

   b) biomass production by energy farming

   c) urban solid wastes (garbage)

   d) animal wastes (manure)

   e) forest residues — 5 years — $50,000

2. Conduct an inventory of land and water area capable of supporting biomass production classified by estimated capacity per acre.

   3 years — $50,000

3. A taxonomic classification of both cultured and natural (including weeds) plant species including the optimum upper and lower limits of factors affecting growth such as:

   a) insolation, steady and periodic

   b) temperature, soil and air

   c) humidity

   d) moisture, root and/or leaf canopy

   e) soil texture

   f) soil composition including added nutrients

   g) carbon dioxide (CO_2) concentration

   h) susceptibility to photorespiration control

   i) response to leaf canopy nutrients

   5 years — $60,000

4. Analysis and modelling of complete energy recovery systems including the location, energy content, availability and costs of the organic wastes, their collection, shredding and compaction and the location of the residues with respect to their points of ultimate disposal by digestion, fermentation, incineration or pyrolysis.

   5 years — $30,000

5. Research into the effects on soil properties of removal of crop wastes from the land for energy recovery. This would include both a basic and applied research program involving use of several experimental field stations.

   10 years — $30,000

6. Research into the direct pyrolysis of crops, timber and urban residues either for fuel extraction or directly to thermal energy. This would include establishment of 2 to 5 pilot plants for operation in different regions of Canada.

10 years $100,000

7. Experimental research program into methods of anaerobic digestion for the production of methane or alcohol from crop and animal wastes. Establishment of 2 to 5 pilot plants to be operated under different conditions.

10 years $100,000

8. Investigate methods of transferring the methane or alcohol produced (in section 7) to power farm tractors and other machinery currently using fossil fuels.

5 years $ 80,000

9. Establishment of an experimental research program into methods of aerobic decomposition for the production of fertilizers, and reclamation of derelict land. This would imply the construction of 2 to 5 pilot plants.

10 years $100,000

Agriculture - Basic Research

10. Selection of appropriate varieties of plants and vegetables, making more efficient use of sun's energy and ambient climatic conditions.

10 years $ 20,000

11. Research in plant genetics to optimize solar energy fixation by plants. Use of pulsed solar radiation to create mutant species of increased nutritive content (similar to current Russian research)

10 years $ 20,000

Applied Research

12. Investigation of various integrated systems where natural energy plays the role of flow activators - i.e. fish production or agriculture where solar energy is used - for heating water - algae production - plant propagation - and vegetable garden production, and where wind energy is used for circulating water - aeration of tank systems.

The above example of integrated system could be applied to various production schemes where an ecological approach is considered. A wide range of scenarios could be worked out on a computer simulation with a thorough investigation of energy flows in various regions of Canada.

5 years $ 20,000

The development resultant from these numerous proposed research programs should be made easily available to the people interested in the field of Agriculture, through the actual Agriculture journals and publications, as well as through specific bulletins which could be widely dissemated to organizations and individuals.

D. The Use of Solar Energy in Agriculture

1. Survey of Canadian farm energy needs that would potentially be met, either in whole or in part, by solar energy systems.

   No. of years: 5 Estimated funding/annum: $30,000

2. Development of agricultural dryers suitable to the farm production (crops of cereals, maize, vegetables, etc.) supplemented by solar energy heating (small and large scale). This would include demonstration installations.

   No. of years: 10 Estimated funding/annum: $100,000

3. Improvement or adaptation of farm buildings to allow a more significant use of the sun's energy for heating and cooling purposes. E.g. development of low heat solar collectors using the usual large roof area of farm buildings, utilization of animal heat, etc.

   No. of years: 5 Estimated funding/annum: $75,000

4. Use of solar energy as a source of supplemental heat in the anaerobic methane digestion process combined with heat storage.

   No. of years: 5 Estimated funding/annum: $30,000

5. Undertake a study on using the sun as a source of heat for production of hot water including storage of heat.

   No. of years: 5 Estimated funding/annum: $30,000

6. Incorporation of in-the-field solar devices, primarily for market gardening, either for increasing the intensity of sun on plants (reflectors), or for shading of the plants in the warmest parts of the day. These devices can act as wind breakers helping to alleviate sudden climate changes affecting the microclimate of plants.

   No. of years: 5 Estimated funding/annum: $40,000

7. In view of the widespread use of septic systems in rural areas, a small program should be undertaken to study ways of utilizing solar energy to maintain optimum temperatures in these pits, especially during winter months.

   No. of years: 5 Estimated funding/annum: $10,000

Summary of Section

The Research and Development program for Solar, Wind and Biomass Energies for Agricultural Production is proposed to last for a period of 20 years. Total cost of the program is roughly estimated at some $1,900,000 per annum. This is broken down in the following manner:

Solar Energy Program	$315,000 per annum
Wind Energy Program	$450,000 per annum
Biomass Energy Program	$660,000 per annum
Greenhouse Program	$505,000 per annum

It is quite obvious that some cutback in several of the above programs could be considered since in some instances, use could be made of the results emanating from other research and development programs in the other three major areas that have been outlined.

It is estimated that costs would remain fairly constant over the 20 year proposed program. Phasing out of the earlier surveys and research programs would be replaced by prototype development and installations.

III. <u>Power Requirements from Alternative Energy Sources for Remote Locations in Canada</u>

In order to undertake a meaningful research and development program in this area, it will be essential to determine the following:

1. To undertake a survey of present and projected future power requirements in remote locations in the country.

   No. of years: 5 to 10   Estimated funding/annum: $60,000

2. To survey all existing commercially available equipment utilizing solar, wind and biomass energies, and relate these to the potential availability for the particular area, outlined in the study on the measurement of natural energy.

   No. of years: 5   Estimated funding/annum: $50,000

3. Once Items 1 and 2 have been correlated, to develop a program for the engineering production of solar, and more probably, wind energy equipment towards development of units producing 10 Kw, 50 Kw, 100 Kw and 500 Kw systems. Then this will require the following program of research and development (for each selected size range).

   It is impossible to go through the development of each range of windmill. Hence, as an example, a 10 Kw windmill development project has been selected. Probably the survey of demand for energy may reveal a number of separate size requirements. For example, in some isolated parts of Québec, 50 to 100 Kw are required. There is an economic advantage to doing this research, as Québec Hydro is often forced to pay 20 to 25 cents per kilowatt hour which they in turn sell for just over one cent per kilowatt hour.

   Hence the following program has been elaborated:

   - the development of a 10 Kw windmill to produce electricity or mechanical shaft power
   - the procedure involved in developing large scale windmills
   - some other useful windpower developments

   a. the building and testing of some demonstration wind electric or wind water pumping systems, utilizing some commercially available equipment such as the 10 meter diameter, 10 Kw Brace Research Institute windmill in selected sites across Canada. A similar program to be undertaken utilizing the National Research Council Vertical Axis Windmill.

      No. of years: 5   Estimated funding/mill: $75,000

   b. the development of autosynchronous controls to maintain constant frequency irrespective of wind velocity.

      No. of years: 5   Estimated funding/annum: $75,000

c. to investigate electrical storage systems which could be used to store energy in remote areas.

No. of years: 10 Estimated funding/annum: $75,000

d. to investigate systems of powering compressed air storage systems in large cylinders underground, or in caverns, and their coupling with air turbines for the production of energy. These might also be hybrid systems which are combined for greater efficiency, with fossil fuel supplies.

No. of years: 10 Estimated funding/annum: $100,000

e. to adapt the systems outlined in Section (d), but utilizing the windmill to compress natural gas near oil fields either for pressurizing spent wells, or for compressing the gas for more convenient transportation to market.

No. of years: 15 Estimated funding/annum: $150,000

f. for the above systems Sections (b to e), to develop component parts for entire systems, including rotors, transmission systems, generating components, control systems, etc.

No. of years: 15 Estimated funding/annum: $100,000

This program would cost around $700,000/annum over a period of 5 to 15 years.

Please note that there is a section on the use of windpower in agriculture which should be related to this section.

Large Scale Windmill Development

The design and development of large scale windgenerators present a most pressing requirement. The contribution to any existing power plant has to be in the order of 100 Kw to be of serious value. As this is well beyond the capability of any existing system, it might be well to examine what would be required of plants, of say, 1 to 10 Kw. The requirements for windmills of this size might possibly be:

1. Six large rotors each operating self-contained generating and control units.
2. The rotor systems all incorporated in one large structural tower.
3. The rotor blades, on account of length, to be stiffened by external guys, thus eliminating much of the bending and risk of root fatigue.
4. Each rotor assembly to be self-orienting, and the blades to feather against winds above a determined velocity.
5. The output from each power unit would be corrected for Hertz of 60.
6. The blades would be profiled steel, with the roots bonded to a carbon fibre matrix, which has a very high fatigue limit.
7. The voltage generated at optimum speed would be around 5000 A.C. This would keep the conductors to a minimum size.
8. The entire assembly would have to be designed to meet the severity of Canadian conditions, particularly in winter.

It would take a rather extensive program of research and development to produce viable, large scale windmills of this size.

This program might take 10 years with a total expenditure of $5 to $10 million. Its development would have to assessed in view of the national needs and energy requirements.

Other Useful Windpower Programs

1. To develop the shrouded small wind rotors, make prototypes and finalized designs. All, for utilization of such units on high rise buildings in cities. Power used for air conditioning; using small refrigerators. Alternatively, systems to elevate water to different heights in a building for intermediate storages - used for water supplies of different levels, and fire protection. Such a system would avoid high pressure pumping from the mains, economizing electric power and necessity of reducing valves for lower level use from the present high elevation storages.

No. of years: 4 Estimated funding/annum: $55,000

2. Develop further the use of wind to oscillate by restrained movements of a permanent magnet armature between wound coils. Power gained to charge batteries, located in Navigation Buoys, with photo-cell "off-on" for night illumination. Applications of this device can be applied on any ship for signal, right-of-way lighting, etc.

No. of years: 4 Estimated funding/annum: $60,000

3. Develop by design and prototypes, wind generators for mounting on all power driven ships. Such machines placed in front and below the ship's bridge. The rear vortex is carried through a flume, spilling overboard, or directed in the tropics, along gangways for cooling, or into the holds for air circulation to avoid fires. This device would be used for part of ship lighting - only when in port are the auxiliary power units brought into service. Considerable stream lining of the frontal area of most ships is highly desirable to save fuel.

No. of years: 5 Estimated funding/annum: $100,000

IV. Proposed Office of Solar Energy Assessment

The utilization of solar, wind and biomass energies covers all possible sources of energy on earth apart from nuclear and geothermal energies. The research and development program suggested under sections I, II, covers areas where solar energy is used currently, while section III proposes using alternative energy forms in remote areas of the country, because these energies are available in situ.

There are other aspects to the conversion of solar, wind and biomass energies as catalogued in the State-of-the-Art research and development outline. In the initial instance, it is proposed that the Government fund an Office of Solar Energy Assessment. Its terms of reference would be:

a. to document all solar energy technology.
b. to follow closely the state-of-the-art of selected areas which seem to have potential in the Canadian context.
c. to advise the Government when it is time to fund active research and development in one of these alternative programs.

Some areas which could be surveyed closely in view of the large investment of time, effort and research funding made by other countries are:

1. Solar Thermal Power Technology
2. Photovoltaic Conversion of Solar Energy to Electricity
3. Power from Ocean Thermal Differences (particularly from Northern Regions of Canada)
4. Power production from Photosynthetic processes -
   - pyrolysis of organic wastes to produce fuels
   - power production from energy plantations
   - power production from algae
5. The Direct Production of Hydrogen by Photo-Chemical means, e.g. Photolysis
6. The Use of Windmills for the Production of Hydrogen
7. The Large Scale Use of Windpower for feeding directly into Electrical Grids
8. The Combined Large Scale Use of Windpower and Hydro Electric stations to Pump Water Back over the Tops of Dams

This office could fund small state-of-the-art surveys on solar energy subjects and make these available to the Canadian public. It should co-ordinate the activities of Canadian researchers so that the science will advance and avoid duplication of effort. It could fund some basic research in certain fields deemed valuable for the national interest. Obviously, its budget would vary from year to year, but its very existence, surveying other countries' acitivites, informing Canadian scientific and industrial personnel of these developments would bring long term benefits to the country.

No. of years: 20 Estimated funding/annum: $150,000

THE MEASUREMENT OF NATURAL ENERGY SOURCES

The government has indeed had the foresight to establish an excellent chain of meteorological stations across the country which measure solar radiation and wind speed on a regular basis. The solar radiation network is under the able direction of J. R. Latimer, of the Department of the Environment, Toronto. His work in this field has earned CANADA an international reputation of the highest regard. The solar radiation data is published in the Monthly Radiation Summaries. Wind speed and direction data is published in Meteorological Observations in Canada, Monthly Records. The Department of Transport has computer programs which permit the extraction and analysis of this data. Reports in this field come to make this data more available to Canadians. Amongst these are:-

> A New Estimate of Average Global Solar Radiation in Canada by R. L. Titus and E. J. Truhlar Department of Transport, Meteorological Branch, 3 July, 1969

In addition, students working under Dr. F. K. Hare, of the Department of the Environment have developed methods to estimate solar radiation, percent albedo, net insulation, net infrared and net radiation levels. Another study:-

> Daily Solar Radiation Differences between Stations in Southern Canada by R. G. Wilson and D. E. Petzold of McGill University April 1972,

provides an experimentally proven method of predicting solar radiation intensities at intermediate points between existing recording stations in Southern Canada. A subsequent as yet unpublished report by the same authors confirms the validity of these results for stations in Northern Canada. Obviously, these efforts should be strengthened and expanded.

SUGGESTED RESEARCH PROGRAMS

A) The solar radiation networks should be expanded and adapted to the needs of the country, in particular in these areas where the utilization of solar energy as a power source has direct potential. This expansion should be under the control and supervision of the Department of the Environment. In the past, they have not wished to become involved in collecting data emanating from research-type activities. In the future, however, it might be necessary for them to extend their networks into those areas where solar energy will be utilized, particularly in urban centres, in order that we might have available more accurate basic radiation data in analyzing the performance of existing solar installations. This would serve to predict the performance of solar powered equipment in future applications.

Estimated Funding Expenditures $125,000 per annum

B) A similar situation exists with wind measurements. Good data is not available in some remote mountainous or coastal sites where windpower has the greatest potential.

Estimated Funding Expenditures $125,000 per annum

C) An effort should be made to develop an instrumentation manufacturing industry in Canada which will make solar radiation equipment, anemometers for measuring wind speed and direction, etc. A series of sensors for precision and engineering evaluations should either be developed or manufactured under license. This would be necessary in view of the large landmass of the country and the potential for utilization of these energies under widely varying conditions. Grants to industry.

Estimated Funding Expenditures $50,000 per annum

D) Maps should be prepared for the entire country indicating the extractable energy for the direct utilization of solar and wind energies. These maps might show the extractable number of heat units, or kw hrs or hp hrs in any particular area, using a number of different solar and wind powered units whose performance characteristics are known. It is on the basis of these "availability" charts, that the proper assessment of equipment performance will be made for and by the ordinary Canadian living in different parts of the country. These charts will be particularly useful in the fields of solar house heating, solar crop drying, wind energy for pumping and for electrical generation.

Estimated Funding Expenditures $75,000 per annum

Estimated Timing - 5 years

Resumé

In order to operate an effective solar and wind energy powered economy, wherein these natural energy sources contribute in supplemental form to the existing energy supply systems, it will be necessary to undertake these suggested measurements.

Total Estimated Expenditures - $375,000 per annum

OPERATION OF A RESEARCH AND DEVELOPMENT PROGRAM IN THE FIELD OF SOLAR ENERGY

In view of the fact that very little has been done in this field in the past, it would be wise to consider how governmental authorities in the country might co-ordinate their research and development activities in these fields. Examples have been given in Appendix F as to how both the United States Federal authorities and the Japanese Government have approached this problem. In the former case, the United States Government grants effectively act as a seed to industry. They encourage competition and proposals are funded, in some instances, even though on the surface the project might appear infeasible. It is in this manner, through the spending of considerable amounts of research funding, that the American authorities have in the past often achieved success. The process seems outwardly to be inefficient and certainly, if one were to scrutinize it closely, the cost of obtaining results in this manner tends to be rather high.

In Japan, the situation is one of greater control and co-ordination, even though the funds allocated to research are not inconsiderable. National objectives are set and research teams are commissioned to undertake programs of development. Obviously, each of these relatively contrasting programs is geared to some extent to the temperament of the society which it will serve.

It must be pointed out that the American Government is in the process of giving considerable attention to a bill calling for the establishment of an office of solar energy. The proposed initial budget, at this state, is $100 million for the first year's activities. A copy of the highlights of an additional solar demonstration bill is listed in Appendix F . This deals primarily with solar heating and cooling of buildings. At the same time, a final draft of the bill S3234 by the United States Senate, to which T.A. Lawand of the Brace Research Institute made a submission, (see Appendix A) relative to Canadian conditions, has been formulated and is available. While the initial budget is $100 million for the fiscal year, ending 30 June 1976, it is proposed in Section 2, Article 4, that a five year $1 billion research, development and demonstration program be undertaken. At the time of writing this report, it is not possible to determine whether this has been passed in this form. However, reports from personnel in Washington indicate that the present bill has a relatively good chance to succeed. Obviously, Canadian authorities should follow these developments closely. The structure proposed for the implementation of this program is contingent on the different Federal agencies and the role that each will play.

The new Solar Energy Co-ordination and Management Project will have members from the following organizations: National Science Foundation; Housing and Urban Development; the Federal Power Commission; the National Aeronautic Space Administration; the Atomic Energy Commission.

The President of the United States will designate a sixth member as well as designating one member of the project to serve as chairman of the Project. The entire Project will be related to the Federal Energy Research and Development Administration. This Project will be implemented through an assistant administrator for solar, geothermal and advanced energy systems.

The specific solar energy technologies to be addressed or dealt with in the program shall include:

1. direct solar heat as a source for industrial processes, including the utilization of low-level heat for process and other industrial purposes;

2. thermal energy conversion, and other methods, for the generation of electricity and the production of chemical fuels;

3. the conversion of cellulose and other organic materials (including wastes) to useful energy or fuels;

4. photovoltaic and other direct conversion processes;

5. sea thermal power conversion; and

6. windpower conversion

It is clear that the administrative pattern will be flexible and no doubt subject to change as these programs develop.

How should Canada approach this same problem? Currently, energy projects are funded by a host of individual ministries, i.e. Energy, Mines and Resources; the National Research Council and others. Will we be establishing a similar office and research and development programs as the Americans reputedly will be doing? If this is done, then logically their pattern will have to be examined and modified to meet local conditions.

If on the other hand, we continue with the present format, then the following options will be open.

The future energy recommendations for the country in the field of solar, wind and biomass energy might be handled in the following manner:

1. a commission could be set up under the control of different representatives of the Governmental departments with possible participation of outside institutional and industrial members, to disperse allocated research and development funding. This might constitute some form of Central Council to co-ordinate research and development in this field. The direction of this work would have to be dictated by a program of priorities which the government itself would have to establish in co-ordination with its proposed plan of action for the long term development of energy resources in this country.

2. Another course of action might be taken in the short term in which the government authorities would ask specialized agencies in this field such as, for example, the Low Speed Aerodynamics Lab. of the National Research Council for wind power; the Biomass Institute for biomass energy and the Brace Research Institute for solar energy to act as co-ordinators of research and development programs for Canada. This is not being made as a specific suggestion, for not all the potential groups with expertise have been mentioned. However, a

structure of this type could be envisaged in any interim period in view of the fact that most governmental departments do not have considerable expertise in the fields of solar, wind and biomass energies. It is evident that two factors should hold in the interim period:

a). the work of these three commissions operating through contracted agencies should be fully integrated.

b). each commission might be based, for administrative purposes, at the organizations listed above for an example, but they should operate in such a fashion that the panels deciding on the allocation of research and development funding come from Canadian expertise within each of these fields.

Finally, some mechanism should exist whereby the results of these activities should be co-ordinated into the nation's total energy policy and objectives.

APPENDIX A

BRACE RESEARCH INSTITUTE

MACDONALD COLLEGE OF McGILL UNIVERSITY
STE. ANNE DE BELLEVUE 800
QUÉBEC, CANADA

TELEPHONE (514) 453-6580

REFERENCE

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

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

July 1974

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BRACE RESEARCH INSTITUTE
MACDONALD COLLEGE OF McGILL UNIVERSITY
STE. ANNE DE BELLEVUE 800
QUÉBEC, CANADA

TELEPHONE (514) 453-6580 H9X 3M1 REFERENCE

15 July 1974

PROGRESS REPORT TO

MINISTRY OF STATE FOR SCIENCE AND TECHNOLOGY

TITLE:

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

Contract Serial Number

OSU4-0013

DSS File Number

SU2.0S002-4-D150

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 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 Enorgy 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 different 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 Caradians 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 developpd 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 concret 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° 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 's 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

$ 794,100

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 enbrgies 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.

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 17ºC 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. Complete 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

APPENDIX B

CURRENT ACTIVITIES IN THE FIELD OF SOLAR, WIND AND BIOMASS ENERGIES IN CANADA

There is an increased interest in these fields in Canada, stimulated by the substantial amount of activities being undertaken all over the world in the area of energies. In this section, we have attempted to document as many of the recent activities, and events which have taken place in Canada in recent times. The list is far from complete, as it is growing on a daily basis.

Its inclusion in this report at this time is done with the purpose of indicating that the study and application of natural energy sources is not only of academic interest, but increasingly of significance to the majority of the Canadian population as a whole.

This Appendix includes sections on:

1. Research Activity to Date in Canada
   a) Maritime Provinces
   b) Province of Québec
   c) Province of Ontario
   d) Western Provinces

2. Seminar on Solar Heating and Cooling of Buildings

3. Symposium; Wind Energy: Achievements and Potential
   Université de Sherbrooke, 29 May 1974.

4. Current Happenings in the Field of Solar Energy in Canada

RESEARCH ACTIVITY TO DATE IN CANADA

The interest in natural energy sources in Canada in the past has indeed been limited. While events are moving quickly at the moment, due to the heightened interest in the country in solar energy, it would be worthwhile to resumé briefly Research and Development activities in this field both past and present, in order to put them in their proper perspective with regards to potential application in Canada.

The following cross-Canada survey beginning with the East coast indicates some of the research activities with which the authors are aware.

MARITIME PROVINCES

No specific activities are known in solar energy. However, there are some activities in the field of wind power at Memorial University, Newfoundland.

Several Provincial Maritime Government departments have expanded specific interests in wind power application. A number of windmills are under test. These include a 4Kw Aerowatt windmill in Labrador and a 400 watt Lubing wind electric generator operated by the Canadian Broadcasting Corporation in St. John's, Newfoundland.

PROVINCE OF QUEBEC

In the field of solar energy, Brace Research Institute has been active since 1959 in investigating methods of the utilization of solar and wind energy primarily for developing areas.

In more recent times, however, attention has also been focused on the application of these energies in meeting Canadian energy requirements. The principal activities are the following:

a) Provision of small scale solar distillation technology to rural areas for the production of fresh water.
b) Solar powered organic fluid rankine cycle engines.
c) Study of the potential of solar ponds for energy collection.
d) Low cost housing - the application of space heating for the provision of heat for housing in populated or isolated regions of the country.
e) The development of an environmentally designed greenhouse for colder regions.
f) State-of-the-Art reviews which include:
   - energy storage
   - solar refrigeration and air conditioning
   - a manual of solar agricultural dryers
   - commercially available and experimental windmills
   - impediments to implementation

g) Windmill development programs of the Brace Research Institute involves studies in the following:

1. Electrical Power Transmission for a Free-Running, Fixed Pitch Windmill
2. Design Optimization and Commercial Development of the Brace Windmill
3. Development of a Sail Type Windmill
4. Impediments to Implementation

These topics are covered in greater detail in Appendix "A" "A" of the progress report, July 1974; of this report see Appendix A

Various researchers are working on solar house heating at Institut de National Recherche Scientifique, as well as Centre de Recherche en Enérgie du Québec and also Centre de Recherches Industrial du Québec has been doing studies in this field under Guy Beauvent.

In the field of windpower, the Département de génie mécanique, Université de Sherbrooke, has an active program on wind energy under the direction of B. Ashikian. They are studying two types of windmills, the classical horizontal axis wind turbine and the venturi. Their studies include the utilization of wind energy for the production of heat by means of viscous dissipation and the operation of heat pumps by means of windmills. They are also studying the use of venturis to power electric induction generators.

The Institut de Recherches Eléctriques de Québec has been studying the possibility of supplying electric power to remote regions of Quebec through the use of a wind powered generating system. As part of their design study, they have been investigating a wind powered system operating a compressor, which would pressurize air in a cavern. The air would then be led from the storage system through an air turbine for the production of electric power. They have selected for their initial study the installation of such a system on the Magdeleine Islands in the Gulf of St. Lawrence.

PROVINCE OF ONTARIO

In the Province of Ontario, some of the more significant solar and wind energy work has been undertaken by the following individuals and organizations:

Researcher	Organization	Fields
R.K. Swartman	University of Western Ontario	Solar Refrigeration, Air conditioning.
J. Bolton	University of Western Ontario	Solar Energy and Photosynthesis.
J. Shewchun	McMaster University	Cu_2S semi-conductors for direct energy conversion.
D. Goldsock et al.	Laurentian University	Copper-Cuprous Iodide graphite photo-galvanic cell as possible inexpensive solar photo battery system, spacing heating with heat pumps.
T. Hollands et al.	Waterloo Univeristy	Interest in a number of solar and wind energy applications.
D. Stephanson et al.	Division of Building Research, National Research Council, Ottawa	Transmission of solar radiation through glass fenestrations, solar energy and buildings, etc.
J.R. Latimer et al.	Radiation Laboratories Dept. of the Environment	Solar radiation, sensor evaluation, calibration measurements, etc.
R.S. Rangi & P. South	Low Speed Aerodynamics Labs., National Research Council	Development and testing of vertical axis windmills.
T. Base	University of Western Ontario	Performance of windmills in turbulent airstreams .
J. Moore	Defense Research Establishment, Ottawa	Use of windpower to charge electrical storage batteries.

WESTERN PROVINCES

In the Western Provinces, some of the more significant solar and wind energy work has been undertaken by the following individuals and organizations.

Researcher	Organization	Field
J. Kentfield	University of Calgary	Savonius rotor, windmill - aerodynamics.
I. Iqbal	University of British Colombia	Heat transfer, solar energy.
E. Robertson et al.	Biomass Institute, Winnipeg	Biomass energies, methane generation from organic wastes.
S. Li	Vancouver	Practical applications of solar energy

Only some of the researchers active in Western Canada have been listed in this section.

SEMINAR ON SOLAR HEATING & COOLING OF BUILDINGS

Sponsored by the faculty of Engineering Science of the University of Western Ontario and the Solar Energy Society of Canada Incorporated, London, Ontario, 18 October 1974.

This was the first seminar of its kind held in Canada and is indicative of the growing interest being generated in this field. One hundred persons attended the seminar. These included delegates from Federal and Provincial Government agencies, universities, business and industry & service groups in addition to a number of private individuals & students.

Six invited speakers presented an overall picture of the present status of solar heating & cooling in the world, with particular emphasis on the relevance to Canadian conditions. The speakers & the titles of their talks is presented below.

R. T. Hamblyn - Ways to Cut Down our Energy Needs

J. Bolton - The Energy Picture - Why Bother Considering an Alternative such as Solar Energy?

R. K. Swartman- How Would Solar Energy Work for Heating and Cooling?

D. Lorriman - The Design of a Solar House

R. Alward - What is going on Around the World in Solar Energy?

R. Latimer - How much Solar Energy is there in Canada?

In addition to the above presentation, a panel discussion was held on the subject of "What will make the use of Solar Energy Possible in Canada?"

The panel included the following:

Professor Frank Hooper
Department of Mechanical Engineering
University of Toronto

and

Mr. John Wadsworth
Coordinator, Technology Development
Development Group
Central Mortgage and Housing Corporation

Resumé of the papers presented at the Symposium held on 29 May 1974.

Symposium

WIND ENERGY: ACHIEVEMENTS AND POTENTIAL

University of Sherbrooke, 29 May 1974

Symposium organized by the Dept. of Mechanical Engineering, Faculty of Sciences under the Sponsorship of ACFAS.

Some of the principal papers presented were as follows:

LECTURES:

The Potential of Windpower in Meeting Canadian Energy Needs:

T.A. Lawand, Brace Research Institute

Windpower Development; A Program Appropriate for Joint Canadian and U.S. Efforts:

W.E. Heronemus, University of Massachusetts

SESSION 1: CURRENT PROJECTS

Windpower and the Vertical-axis Wind Turbines Developed at the National Research Council

R.S. Rangi, P. South, R.J. Templin, National Research Council

Windpower Development Program at the University of Massachusetts

F. Stoddard, University of Massachusetts

Enérgie éolienne: revue des travaux en cours à l'Université de Sherbrooke

R. Camarero, Université de Sherbrooke

Review of the Windpower Activities at the Brace Research Institute

R. Alward, Brace Research Institute

Closing Remarks

P.E. Coulter , Florida International University

SESSION II: WIND CONVERSION DEVICES

Tests of a Vertical Axis Windmill-Savonius Rotor

B.G. Newman, McGill University

Experimental Investigation of the Use of a Savonius Rotor as a Power Generating Device

C.E. Carver, Jr., & R.B. MacPherson, University of Massachusetts

The Performance of an Airscrew Windmill in a Turbulent Airstream

T.E. Base, The University of Western Ontario

A Modified Savonius Wind Turbine with Good-Low Velocity Ratio Torque Characteristics

J.A.C. Kentfield, University of Calgary

SESSION III: INTEGRATED SYSTEM

Introductory Remarks

N. Galanis, Université de Sherbrooke

A Wind Powered Electrical System for Remote Areas

J. Van Sant, Hydro-Quebec Institute of Research

The Potential Conversion of Wind Power to Electrical Power

J.E.C. Moore, Defence Research Establishment, Ottawa

Closing Remarks

J.A. Randle, Montreal Engineering Company

SESSION IV: COORDINATION OF RESEARCH & DEVELOPMENT

H. Flynn, Ministry of State, Science and Technology

CURRENT HAPPENINGS IN THE FIELD OF SOLAR ENERGY IN CANADA

Pacific National Exhibition: August 1974

Was sponsored through the support of the Province of British Colombia--an Alternative Energy Show. In addition to a series of exhibits on energy, conservation and the use of solar, wind and biomass energies, a series of seminars were held on a variety of subjects dealing with alternative energy. Central Mortgage & Housing Corporation sponsored a display on solar house heating. The seminars and the exhibits were well attended. R. Alward and T.A. Lawand of the Brace Research Institute participated in the seminars as well as Ernie Robertson of the Biomass Institute and R. Swartman of the University of Western Ontario.

International Solar Energy Society:

There is a professional society dealing with solar energy known as the International Solar Energy Society. Its aims and purposes are to bring together technical and scientific personnel working in these fields to encourage research and development into the utilization of solar energy and to sponsor scientific conferences.

On the International Board, Canada is represented by R. Latimer, Department of the Environment and T.A. Lawand of the Brace Research Institute. On the regional level, in the U.S. Section (which includes Canada), T.A. Lawand is on the Board of Directors. He undertook a survey of Canadians interested in solar energy in August 1974, to determine whether a Canadian Chapter should be set up. In response to these wishes, the Canadian members of the International Solar Energy Society decided to set up a temporary secretariat in the office of:

Dr. R. Gemmil
Research Branch
Dept. of Public Works
Province of Manitoba
1700 Portage Avenue
Winnipeg, Manitoba

The acting secretariat at the Brace Research Institute has been transferred to Manitoba, pending the convening of a National Conference representing all levels of interest in the country. At that time, the modalities of a proper chapter will be worked out by designated Canadians. A bilingual newsletter will be issued periodically.

It was decided not to set up a separate section, but a chapter affiliated with other members from this Continent. We have proposed the name to be changed from the U.S. Section to the American Section of the International Solar Energy Society similar to (AIChE, ASME, ASAE, etc.), comprising Canada, U.S.A., Mexico, Carribean, Latin America. This proposal is currently being presented for approval to the Board of Directors.

As the membership of the U.S.A. Section quadrupled in the last 4 years, it was also proposed to set up chapters to improve communication, and the New England States have already met and would like to enhance the close contacts they have with Eastern Canadian organizations and individuals.

A meeting was held on 1 October, of interested members of the Solar Energy Society in Winnipeg. An interim Board of Directors has been approved and work has begun to establish a nation-wide society which will bring information on this field to the attention of its members. The number of members has increased from 30 to 60 within a period of a few weeks. It is proposed that a national conference be held in Ottawa within the next year in order to establish the chapter as a legitimate entity on the Canadian professional scene as well as to stress the importance of renewable energy resources in the future development of this country. It must be stressed that the Canadian Solar Energy Society covers all aspects of solar energy including wind and biomass energy as well.

Windpower Symposium, Université de Sherbrooke:

This was held on 29 May, with over 80 delegates participating. Already as a result, some specific collaboration has been established with the Brace Research Institute. The proceedings have been been published and are now available. This meeting served to bring delegates in the wind power field together.

Biomass Energy:

The Biomass Institute continues to hold a series of conferences dealing with biomass energy as well as problems relating to this field.

Surveys on Solar Energy:

A number of Government departments and affiliated agencies have begun investigating the potential of solar energy. These include Ministry of Energy, Mines and Resources; Ministry of State, Science and Technology; Science Council of Canada, etc. There must eventually be better coordination of these activities, in order that the information collected be more easily and readily available. In addition, the Advanced Concepts Centre of the Dept. of the Environment in Ottawa has been undertaking surveys on the availability and effectiveness of alternative energy equipment.

Canadian Industrial Involvement:

A number of companies are interested in solar and wind energy equipment manufacture. Already a number of smaller manufacturing facilities have been reputedly set up to fabricate windmills of the NRC design and others.

In Montreal, for example, one of the largest fuel oil distributors, S. Albert and Co., has built several solar water heaters and J. Meunier and Co., is collaborating with the Brace Research Institute on the development of solar collectors for the export market and possible home consumption.

In response to the extensive demand of 50 to 300 requests per day, the Brace Research Institute has assisted the formation of an agency, Budgen and Associates, Pointe Claire, Québec, to handle these enquiries. Several windmills of European manufacture have been sold, after careful study, to Canadian individuals and organizations for use both in Canada and overseas.

It is interesting to note that a number of large consulting firms have approached the Brace Research Institute and have begun involvement in this field. One such firm, SINTEC, La Société Internationale d'Equipment et de Conseil, Inc., is collaborating very closely on a proposal to set up some demonstration cluster housing which would be partially powered by the Sun and the Wind. See Appendix for list of papers presented at this conference.

K. Bea of Karl Bea Associates, Syracuse, New York, is undertaking a program to develop a 100 hp windmill to power a gas compressor for use in compressing natural gas for oil fields. The compressed gas would be forced down oil wells in order to pressurize spent oil fields. The first prototype is scheduled to be installed in oil fields in the vicinity of Calgary, Alberta. He has asked the Brace Research Institute to assist the project through utilizing its library facilities, undertaking wind projects of the Calgary area, and other potential areas in the country. Finally, the Institute has been asked to conduct a literature search of all relevant information on large scale windmills used in the past. Mr. Bea hopes eventually to design and build longer sized windmills - up to 1000 hp. The design considerations for the 100 hp unit are nearing completion.

APPENDIX C

SOLAR ENERGY APPLICATIONS ON HOUSES IN CANADA TODAY

Currently there are several houses in Canada using solar collector systems to supply energy for space and domestic water heating. A number of these houses are mentioned below. The buildings discussed are not intended to be an exhaustive list of all these utilizing solar energy in the country, but are intended as more of a representative sampling. They are illustrative of some of the interest that Canadians have in this new energy field.

1. Gananoque House
2. Hoffmann House
3. Demonstration Solar and Wind Energy House
4. Swimming Pool Heater

SOLAR HOUSE HEATING STUDIES

A number of studies have been done recently across Canada in Universities, principally as final year student projects. It will be impossible to mention all of these here, however, the following two reports are typical of the interest which is developing in Canada.

A) Solar House Heating by
D. Stien and B. Wexler.
Department of Civil Engineering, McGill University (1974)

B) The Design of a Solar House by D. Lorriman
School of Architecture
University of Waterloo, Ontario (1974)

There are many other studies that are currently being undertaken in this field, which tends to be popular amongst the students attending Canadian Universities.

Currently investigations are underway involving the School of Architecture of McGill and the Brace Research Institute to apply principles of solar house heating, hot water heating to appropriate housing for Communities in Northern Canada. Windmills will be integrated into the housing units for the pumping of water and the provision of electricity if required.

Some investigations are being undertaken by researchers at the Institut National de recherche scientifique, Institut de rescherche en énergie du Québec, and the Centre de recherche industriel du Québec as well as the école polytechniqué of the l'université de Montreal. In general they are examing the possibilities of adapting the vertical wall solar collector with the concrete wall storage unit as developed by the researchers in France. Interest in this field of activity was heightened by the visit in June, 1974 by M. Jacques Michel, an architect from France and holder of the Trombe-Michel Patent.

As part of their activities dealing with problems of significance in the future, the Rideau Institute, 4427 Sherbrooke St. W., Montreal has, under the directorship of Dr. J. Davis & Dr. S. Skoryna, undertaken to apply the Trombe-Michel principle of a vertical, south facing glass covering a concrete heat reservoir. As part of their program, in the summer of 1974, an existing 2 storey farm house near Brockville, Ontario has been retrofitted with a vertical house solar collector heating panel. The house will be tested to determine the effectiveness of this type of system

GANANOQUE HOUSE

Location - Larry's Landing R.R. #3 Gananoque, Ontario

Latitude - 44½ degrees North

Designer - Builder - Greg Allen

Owner - Larry South

Date Built - 1974

Description - This is a two story, 4 bedroom house with minimum wall exposure on the north side. Earth is banked against the north wall to a level of three feet below the roof. East & West exposures have similar earth embankments, decreasing to ground level along the south wall.

The house is built on and around a large rock which occupies the north half of the lower floor. Total useable floor area is 2200 square feet excluding the garage.

Collector - The two story south facing wall is almost entirely glazed allowing maximum penetration of direct solar radiation to the interior of the house. Moveable insulation panels cover much of this glazing at night to retain the house heat. In addition, along the ridge of the roof is 240 square feet of south sloping flat plate collector, heating water for use in both domestic hot water supply & space heating.

Heat Storage System - The hot water from the collector panels passes directly into two large containers holding a total of 4000 pounds of paraffin wax. The wax & water channels are essentially a sandwich arrangement separated by metal sheet. The heat of the water is stored in the wax as heat of fusion. Space heating is obtained either directly by water circulation from the collectors, through the heat of fusion material & into hot water radiators or, at night, by circulating water between the radiators & the paraffin wax storage.

In addition, the large mass of the exposed rock face inside the house provides thermal storage of the sun's energy that has been transmitted directly through the south wall during the day. A large stove fireplace provides additional mass for thermal storage. The large thermal inertia which these stone masses provide has a double effect. It reduces the heat build up in the living space during the day & provides a storage of heat for the interior at night.

Back-up Heating System - The stone fireplace provides the back-up heat required. Flue gasses heat up water circulating in stainless-steal clad tubing that surrounds the flue. This hot water passes through the heat of fusion storage system and is used for space heating as before.

Other - The house is divided into two basic heating areas. The bedrooms, which are very little used during the daytime, have very little window area and are very well insulated, so that both day and night time heat losses are minimal. The rest of the house has a generally open structure and receives much of its daytime heat from the south window area.

Percent Solar Heated - It is estimated that about half of the space heating will be provided by the flat plate collector arrangement. The rest will come from the radiation through the large south facing window area and wood burned in the fireplace.

HOFFMANN HOUSE

Location - Surrey, B.C. - near Vancouver, B.C.

Latitude - 49 degrees North

Designer - Erich W. Hoffmann

Owner - Erich W. Hoffmann, 5511 128th St. Surrey, B.C.

Date Built - 1971

Description of House - This is a one story house with partially heated basement. Total floor area, including basement is 2700 sq. ft. The house was built in 1968 and the solar heating system in 1971. A separate swimming pool heater was added in 1974.

Collector - The collector is a flat plate type installed on the south facing roof, sloping 58 degrees from the horizontal. Total collector area is 460 square feet. Double glazing is used in front of a copper tube-sheet arrangement. Exposed metal surfaces are painted with a non-selective flat black coating. Insulation behind the collector plate is 6" of glass wool. Water is circulated through the collector by a small centrifugal pump. The water rises to a header along the top of the collector plates and flows by gravity down through the copper tubes and into storage tanks. The collector is automatically drained at the end of the day so there is no danger of water freezing in the system.

Storage - Heat storage is in two vertical cylindrical uninsulated tanks totalling 800 gallons capacity. These tanks are located in an insulated basement room. Maximum temperature achieved in tanks in summer is 170 degrees F. The storage capacity is sufficient for one January day with no sun.

The house is heated by air that has circulated by gravity convection through the tank room.

Other - Domestic hot water is pre-heated as it passes through a heat exchanger inside the storage tanks. Until the late summer of 1974, swimming pool water was heated in the same manner, however, in September 1974, a separate gravity flow water heater was installed for the swimming pool. In this system, water is allowed to flow down an exposed un-glazed south sloping dark surface, picking up heat and carrying it directly into the swimming pool.

Percent Solar Heated - An estimated 50% of space & domestic water heating is provided by the flat plate collector system. 100% of swimming pool heat is supplied by the sun.

Auxiliary Heat - Electric baseboard heaters.

Location	-	Macdonald Campus of McGill University, Ste. Anne de Bellevue, Québec
Latitude	-	45 degrees North
Designer-Builders	-	Brace Research Institute and Minimum Cost Housing Group both of McGill University
Date Built	-	1972

Description -

This is a low cost house designed for the tropics & in particular, for isolated arid areas lacking conventional fresh water resources. The house is built in two basic sections - a wood room and a sulphur block room, separated by an enclosed patio.

A separate structure housing the water recycle unit, including toilet and washing facilities, is immediately adjacent to the central patio. Total floor area, including patio and water recycle unit,is 500 square feet.

The roofing of the main house and patio is effectively an overlapping tile roof made by cutting asbestos cement sewer pipe in four lengthwise sections and interlocking the spans.

The roof of the water recycle unit is made up of two pre-fabricated asbestos cement solar distillation units, integrally mounted on the asbestos walls.

Both roof structures serve as rain catchment areas. The floor is for the most part covered by sulphur block tiles.

Services -

The water and power supplies to the house have been designed to make maximum use of natural energy sources.

Water is collected from rain falling on the roof. Some of this water is heated in a gravity convection solar water heater integrated into the concave sections of the tile roof. Heated water is used for domestic purposes in the water recycle unit. Shower water is collected after use & stored in underground containers. It can then be pumped back up for use in flushing the toilet, or for distillation in the solar stills on the roof. Distilled water from the roof is used for cooking & drinking purposes.

All electrical services are supplied from the wind generator near the house. These services include light bulbs, fans and other small appliances.

Solar energy is also used for cooking purposes, operating an environmentally designed greenhouse & to assist in food preservation by means of solar drying.

Other - This house has been designed for warmer, arid areas of the world, and as such, it is occupied only during the warmer months of the year, mainly April through October. During this time almost all energy supplies to the house come from wind, solar or human power. Electric baseboard heaters provide back-up heat during April & October.

SWIMMING POOL HEATER

Location - 102 Brentwood Avenue, Beaconsfield, P.Q.

Latitude - 45½ degrees North

Owner - J. B. S. Oldaker

Date Built - 1974

Description of Heating System - Water is pumped from the swimming pool to a perforated header pipe along the upper edge of a south facing section of roof. The perforations allow the water to flow more or less uniformly down the south roof slope, during which it picks up heat from the dark coloured roof surface. This warm water is collected in the rain gutter system & gravity fed back into the swimming pool after passing through a filter.

APPENDIX D

COMMERCIALLY AVAILABLE SOLAR AND WIND ENERGY EQUIPMENT IN CANADA AND ELSEWHERE

In order to facilitate the reader's appreciation of the commercial and industrial situation at this time in the field of solar and wind energy lists have been made of commercially available equipment. The names of companies are given along with their address and phone number as well as some comments as to their products and potential. Three separate lists have been collected:

1. Manufacturers of Solar Collectors and other Solar Energy Equipment
2. Commercial Windmill Manufacturers and Agents Operating in Canada
3. Commercial Windmill Manufacturers outside of Canada

APPENDIX D

1- MANUFACTURERS OF SOLAR COLLECTORS AND OTHER SOLAR ENERGY EQUIPMENT

This is a partial list of some companies manufacturing solar energy equipment. Not all this equipment has been fully field tested and evaluated. The claims made by manufacturers are largely their own at this time. The Brace Research Institute maintains dossiers with full information on most of these firms and their products. Where available, phone numbers and specific contact persons have been listed.

1. OLIN BRASS (of Olin Corp.)

   East Alton, Ill. 62024
   Tel: 618-258-2000

   Manufacturers of ROLL-BOND panels used at the collector surface in flat plate solar collectors. A tube-in-sheet product in which tubular passages are generally integrated within the thickness of a metal sheet intended to be used primarily with a heat exchange fluid such as a water-glycol mixture.

   Contact: J. I. Barton, Marketing Manager

2. ENERGEX CORPORATION

   481 Tropicana
   Las Vegas, Nevada 89119
   Tel: (702) 736-2994

   Manufacture three(3) types of solar collectors as well as water and pool heaters and solar instrumentation equipment.

   Contact: Alfred Jenkins

3. REVERE COPPER AND BRASS INC.

   Research & Development Center
   P.O. Box 151
   Rome, N.Y. 1344
   Tel: 315-338-2022

   Manufacture Copper-wood laminated collector panels in standard and custom made sizes.

4. ENERGY SYSTEMS, INC.

   643 Crest Drive
   El Cajon, Calif 92021
   Tel: 714-440-4646/7 or 447-1000

   Planning and installation of Solar and conventional heating and Air Conditioning systems.

5. P.O.G. INDUSTRIES

1 Gateway Center
Pittsburgh, Penn. 15222
Tel: (412) 434-2645

Manufacture of Boselin Solar Collector.

Contact: Mr. R. R. Lewchuk

6. MARTIN MARIETTA

Denver Division, Colorado

Manufacture of Optical Black Coating

7. RHO SIGMA

5108 Melvin Avenue
Tarzana, 91356
Tel: (213) 342-4376

Manufacture of Differential Thermostat to provide control functions for solar heating in buildings.

8. SOLORON (Solar Energy Products Co.)

121 Miller Road
Avon Lake, Ohio 44012
Tel: (216) 933-5000

Manufacture of Soloron Primary heat system for drying crops.

9. SPECTROLAB SOLAR POWER SYSTEMS

12484 Gladstone Avenue
Sylmar, CA 91342
Tle: (213) 365-4611 (TWX. 910-496-1488)

Manufacture of Spectrolab Power Supply Self Sufficient photovoltaic power unit. Also build solar simulation equipment

10. SOLAR SUNSTILL, INC.

Setauket, N.Y. 11733
Tel: (516) 941-4078

Manufacture of Sun Clear and Varishade glass or plastic coating to control amounts of solar light and heat penetration

11. SOLAR ENERGY CORP.

810, 18th St. N.W.
Washington, D.C. 20001

Manufacture of batteries for storing solar power.

12. GENERAL ELECTRIC CO.

Philadelphia, PA.

Research and prototype production of modular solar photovoltac cells

13. BOING AIRCRAFT

Seattle, Washington

Manufacture of thin cadmium - sulphide solar cell arrays.

14. EXXON - SOLAR POWER CORP.

196 Forbes Road
Braintree, Mass. 02184

Manufacture of photovoltaic Solar Cell Systems and arrays.

15. SHELL-SOLAR ENERGY SYSTEMS CORP.

Newark, Delaware

Research and prototype production into long life cells for household, business and industrial use.

16. IBM

Huntsville,

Research on solar cells and solar energy recording systems. Prototype Gallium - Arsenide cells

17. TEXAS INSTRUMENT

Attleboro, Mass.

Research and Prototype production of flat plate solar collectors

18. Lockheed Corp.

Polo Alto, Col 97304

Research & prototype production of flat plate solar collectors

19. ZOMEWORKS

Albuquerque, N.M.

Manufacture of vertical and horizontal louver devices for capturing and holding solar heat.

20. SOLAR SYSTEMS INC.

P.O. Box 744
Tyler, Texas 75701
Tel: 214-572-0945

Manufacture of solar collectors and selective coating .
Contact: Mr. John L. Deckes

21. UNIT SPAN ARCHITECTURAL SYSTEMS INC.

6606 Variel
Canoca Park, CA 91303

Manufacture of solar collectors for house and water heating

22. AIRCRAFT ARMAMENT SYSTEMS INC. (AAJ)

P. O. Box 6767
Baltimore, MD. 21204
Tel: (301) 666-1400

Manufacture of complete heating and cooling systems for commercial and residential use. Also make a "Roof" Top Concentrator" Collector

23. MIROMIT LTD.

44 Monte Fiore St.
Tel Aviv, Israel

Manufacture of solar water heating collectors and storage tanks

24. ANCOR EXPORT CO. LTD.

P.O. Box 2850
Tel Aviv, Israel

Manufacture of solar water heating collectors and storage tanks

25. SUNWORKS, INC.

669 Boston Post Road
Guideford Conn. 06437
Tel: (203) 453-6191

Manufacture of solar collectors

Contact: Mr. Everett Barber

26. HONEYWELL, INC.

Systems & Research Center
2700 Ridgeway Parkway
Minneapolis, Minn. 55413
Tel: (612) 331-4141 Ext. 4078

Manufacture of high performance solar collectors.

Contact: Mr. Roger Schmidt & Mr. Jerry Maylan

27. HUGHES AIRCRAFT

Los Angeles, Cal.

Manufacture of flexible rolled-up solar wall array of 100 KW capacity.

28. SOLAR PRODUCTS CORP.

Denver, Colo.

Manufacture of low-cost cooking units.

29. SUNWATER CO.

1112 Pioneer Way
El Cajon, Cal.
Tel: (714) 442-4742

Manufacture of Solar distillation, house heating, and water heating units.

30. THERMOELECTRON CORP.

Waltham, Mass.

Manufacture of Rankine cycle engines for use with solar energy heat source. Units from 6 to 140 HP.

31. W. R. ROBBINS & SONS

1401 N.W., 20th St.
Miami, Fla. 33142

Manufacture of Solar water heaters.

32. SKYTHERM CORP.

Los Angeles, Cal. 90017

Manufacture of solar heating/cooling systems

33. ENERGY SYSTEMS INC.

643 Crest Drive.,
El Cajan, Cal. 92021

Manufacture of solar heating and storage systems for residential use.

34. ASG INDUSTRIES INC.

P.O. Box 929
Kingsport, Tenn. 37662
Tel: 615-245-0211

Manufacture various grades of glass highly suited for solar collector applications.

Contact: Mr. Thomas R. Coffin.

35. RAM PRODUCTS

1111 North Centerville Rd.
Sturgis, Michigan 49091
Tel: (616) 651-9351

Manufacture acrylic mirrors, adaptable to e.g. Greenhouse and Collector application

36. ENVIRONMENTAL EDUCATION GROUP

6731 Lurline Avenue
Canoga Park, Colo 91306

Manufacture of "SOLARGEN" power plant to dissociate water at 2500 C (obtaining hydrogen) in Solar Furnace.

37. ELECTROLYSER CORP. LTD.

122 the West Mall
Etobicoke, Toronto, Ont. M9C1B9
Tel: (416) 621-9410

Manufacture of electrolytic hydrogen plants & generators.

38. TRANTER, INC.

735 E. Hazel St.
Lansing, Mich. 48909
Tel: (517) 372-8410

Manufacture of "Econocoil" solar water heater collector plates.

39. TEXTRON(HELIOTEK DIV)

Sylmar, Cal., 91342

Manufacture of solar cells & solar cell arrays. (Photovoltaic cells)

40. EDWARDS ENGINEERING CORP.

101 Alexander Ave.
Pompton Plains, N.J. 07444

Manufacture, design & installation of complete systems for space heating/cooling, hot water, ventilation, etc.

41. SOLARON CORP.

4850 Olive St.
Denver Colarado 80022
Tel: (303) 289-2288

Manufacture and sale of solar energy equipment and systems for residential and commercial buildings

42. LAB SCIENCES INC.

P.O. Box 1236
Boca Raton, Florida 33432
Tel: (305) 395-1917

Manufacture of solar pond unit with instrumentation for research and educational application. Offers three various equipment and instrumentation packages under titles of Project 140 or 145 or 147.

43. DURACOTE CORP.

Revenna, Ohio 44266

Manufacture of DURACOTE - FOYLON, an aluminum foil-fabric hybrid with particular properties such as: high heat radar and light reflectance, flammability protection and an increased insulation value.

44. NMD INC.

P.O. Box 15534
Atlanta, Georgia 30333

Manufacture & sales of Solarlab kits which may be employed in teaching and research of solar energy problems and applications

45. SOLAR ENERGY RESEARCH CORP.

Route 4, Box 26 B
Longmont, Colorado 80501
Tel: (303) 772-4522

Manufacture of Module Spray Collector with high economic efficiency. No freezing or corrosion problems.

46. HELIOTEK, INC.

33 Edinboro Street
Boston, Mass.

Manufacture of "Solar Membrane", a transparent insulation material useful in solar collectors and greenhouses.

47. JOHNS-MANVILLE

Greenwood Plaza
Denver Colorado 80217

Manufacture of "AEROTUBE" tubing of foamed plastic insulation with built in vapour barrier.

48. JOHNS-MANVILLE

Aerospace Products
22 East 40 th St.
N.Y., N.Y. 10016

Manufacture of fibre glass batt. insulation (in 100 foot rolls of ½" thickness) useful for continuous exposure at temperatures to 850°F. Also standard fibre glass insulation for homes & buildings

49. SIMPLEX HEATING SYSTEMS CANADA LTD. (P.S.A.-C)

800 Place Victoria,
Montreal
Tel: (514) 866-7686

Manufacture, Distribution and Sale of "Simplex" hot water radiator systems.

2-

COMMERCIAL WINDMILL MANUFACTURERS AND AGENTS OPERATING IN CANADA

A number of organizations operate in Canada dealing with windmills. A list of their principal activities is given. This information has been compiled for the greater part by Mr. Bruce McCallum:

Advanced Concepts Centre
Department of the Environment

who has participated at the Brace Research Institute in the preparation of this section.

1. ENERGY AND ENVIRONMENTAL PRODUCTS

16 Leacock Lane
Kanata, Ontario
OOA 2CO
Tel: 225-2850

Manufacturers of the vertical axis windmills.

2. PAR INDUSTRIAL CONTRACTORS LTD.

#10-2405 Ongman Rd.
P.O. Box 2328
Prince George, B.C.
Tel: (604) 564-4471

Agents for electrical generation, Quirk's Windmills from Australia. The company builds its own towers.

3. INTERNATIONAL AERADIO LTD.

1165 Leslie St.,
Don Mills, Ontario
(416) 449-3122

Agents for the Aerowatt windmills from France.

4. BUDGEN AND ASSOCIATES

72 Broadview Avenue
Pointe Claire, Quebec
(514) 695-4073

Agent for Lubing Maschinenfabrik electrical generating and water pumping windmills (West Germany). Elektro G.m.b.H. electrical generating windmills (Switzerland).

ea.

Also handles manufacture and sale of Brace Research Institute's 10 Kw windmill, as well as the fibreglass airscrew blades.

5. THE WIND AND WATER TURBINE COMPANY

3995 Lasalle Street
Verdun, Quebec
Tel: (514) 761-5795

Experiments with a number of windmills which they hope to manufacture in Canada, probably in the Maritimes.

6. ODIN WIND TURBINES (Division of Global Wind and Electric Collective)

66 Rideau Street
Ottawa, Ontario
Tel: (613) 238-1310

Experiments with some wind electric generators.

7. BRACE RESEARCH INSTITUTE

Macdonald College of McGill University
Ste. Anne de Bellevue, Quebec
H9X 3M1
Tel: (514) 457-6580

Has developed a number of experimental windmills including a Savonius Rotor of different models, a 10Kw windmill, reinforced with fibreglass blades and a structural tower system, a 25 ft. diameter sail windmill. Have also tested a Lubing electric generator for the past 3 years.

A considerable amount of data is available in the dossiers of the Brace Research Institute and with the Advanced Concepts Centre of the Department of the Environment. These manufacturers and agents are operating in Canada and information is also available from other manufacturers in different parts of the world.

3- COMMERCIAL WINDMILL MANUFACTURERS OUTSIDE OF CANADA

The following is a partial list of windmill manufacturers throughout the world. Many of these windmills are sold through agents operating in Canada.

Much of this list has been compiled by M. F. Merriam of the University of California, Berkeley, in conjunction with the Brace Research Institute.

1.	Aermotor Division of Braden Ind.	800 E. Dallas St. Broken Arrow Oklahoma 74012	waterpumping	multivane fan. Reportedly all manufacturing is now done by Argentine licensee.
2.	Metalurgica	Belgrano 728 Piso 1º Buenos Aires Argentina	waterpumping	multivane fan. Aermotor licensee
3.	Heller-Aller	Perry & Oakwood St. Napoleon, Ohio	waterpumping	Trademark "Baker" multivane fan
4.	Dempster Industries	P.O. Box 848 Beatrice, Neb. 68310	waterpumping	multivane fan.
5.	H. J. Godwin, Ltd.	Quenington Gloucestershire England GL75BX	waterpumping	multivane fan
6.	Sidney Williams	Constitution Rd. Dulwich Hill Sydney Australia	waterpumping	multivane fan trademark "Comet". large sizes (to 30 ft. diameter).
7.	Aetna Steel Industries	613 Roman Santos Bldg. Plaza Coiti Manila, Philipines	waterpumping	Trademark "Southern Cross" multivane fan.
8.	Cytra, Inc.	Ambrosio Bldg. Buendia Cor Bantista Makati, Philippines	waterpumping	helical rotor
9.	Lubing Maschinenfabrik	2847 Barnstorf P.O. Box 171 Germany	electricity generation and water-pumping	Trademark "Lubing" modern airfoil design 3, 4 or 6 blades. Under 1 kw

10.	Aerowatt S.A.	37 Rue Chanzy 75-Paris 11e France.	electricity generating	from 25 watts to a few kilowatts
11.	Bucknell Eng.	10717 Rush St. So. El Monte California	electricity for charging batteries	manufactured on receipt of order 200 watts
12.	Dyna Technology	P.O. Box 3263 Sioux City, Iowa 51102	electricity for charging batteries	Trademark "Win-charger" Shipment from stock. 200 watts
13.	C.I.A.M.O.	Alfred Herlicq & Fils 111 Quai Andre-Citroen Paris, France	electricity generating	1 kilowatt, 2.5 kilowatt, 5 kilowatt, 24 volt, 110 volt
14.	Elektro	Elektro G.M.B.H. Winterthur St. Gallerstr. 27 8400 Winterthur Switzerland	electricity generation	25 watts - 6000 watts
15.	Quirk	Bellville Rd. Sydney N.S.W. Australia	electricity generation	400 - 2000 watts
16.	Dunlite Electrical Company	21-27 Frome St. Adelaide, South Australia, Australia.	electricity generating	up to 2 Kilowatts
17.	Domenico Sperandio	Via Cimarosa 13-21 58022 Follonica (GR.) Italy	electricity generating	7 models from 100 to 1000 watts

APPENDIX E

THE ROLE OF ENERGY CONSERVATION AND ITS EFFECT ON FUTURE REQUIREMENTS

It is inconceivable to plannify future energy policy, envisaging the utilization of alternative energy sources without some attention being paid to the reduction and control of wasteful energy consumption. The question of increased energy efficiency in our residences, buildings, factories, farms etc. is logically tied to economic parameters. One should not envisage over-engineered technological developments for the sake of a minimal increase in the efficiency of energy utilization. By the same token, in view of our relative disregard of energy as a limiting factor in the past, the bulk of our technology can be overhauled without unnecessarily excessive expenditures in order to ensure that the energy utilized is more efficiently put to work.

In the field of building design, some organizations report a fifty percent reduction of energy consumption without drastic modifications to the structure or its mode of operation. Obviously much can be done in the field of housing and buildings in general. This is touched upon in Appendix AA, of the mid term report (See Appendix A). It is significant to note that the National Research Council has sponsored a seminar during the months of October, November 1974 entitled, "Energy Conservation and Building Design." This travelling seminar received wide attention in 6 major Canadian urban centres from Halifax to Vancouver.

While the use of energy in buildings consumes roughly one third of our energy budget, it must not be forgotten that industry and agriculture each probably account for one-quarter of our total energy demand. It is extremly encouraging to note that technical journals like Chemical Engineering are sponsoring energy saving contests for industrial applications. The response (see Vol. 81, No. 16 Issue of 2 Sept. 74, and Vol. 81, No. 20, Issue of 30 Sept. 74) indicates that the interest for energy conservation exists amongst our technologists as well obviously with their companies. Canadians should possibly follow the examples of other societies, who make issues such as resource and energy conservation part of overall National objectives and obligations.

It should not be envisaged that we can resolve our future energy problems solely by conservation and more efficient utilization. Rather we must accept the fact that rational advances in these areas will dent the rate of increase of the consumption of energy. The very fact that the population will increase over the next few decades makes this task all the more difficult.

Recently T. A. Lawand of the Brace Research Institute attended a conference sponsored by the Institut de la Vie in Paris, looking into resource availability and exploitation in the future. The projected pattern of energy, or material, supply and demand in the future is obviously not known. Unfortunately, it goes beyond the scope of the terms of reference of this report. There is a great divergence of opinion amongst experts from different parts of the world! At the Paris Conference, the energy section was presented with opposite viewpoints - on the one hand as proposed by some American delegates forecasting rates of increase. of energy consumption of 3.5 to 4.0 percent per annum, and on the other hand, French delegates who saw a certain saturation of demand for energy in the future, with future rates of increase more like 1.5 to 2 percent per annum. Distinguished American delegates forecast the need for 3,000 new nuclear reactors over the next 30 years. Where are we to find the resources, technology and capital to undertake such a massive program?

The absolute value of these predictions is not as important as the fact that they differ by roughly a factor of two. To what extent does the conservation of energy affect these rates? What fraction of the increase goes into providing energy for the increased population or increased expectancy of a nation's inhabitants? Where is this energy utilized and by whom? Surely a society and its government officials which does not address itself to the determination of answers to these basic questions will one day find itself facing serious difficulties. It is in times of energy and material plenty in Canada when we must, as a nation, pose ourselves these questions!

Most delegates agreed at the Paris Conference that the next 30 years were indeed going to be difficult ones for all of mankind. We had better know where we are going in our resource supply - demand relationships in order to avoid possible severe future economic disruptions which might upset significantly the often delicate mosaic structure of this country.

Finally, it is essential that the government to whom we as a nation invariably turn for solutions, take the initiative in finding policy investigation structures whose primary role would be to come to grips with the real issue at stake, i.e. how will decisions regarding allocations of scarce resources be made in the future. It is the duty of all Canadians to give serious consideration to this point, for it will affect the very basis of our way of life in generations to come. At the conference in Paris most delegates agreed that the old order and systems often were not able to cope with current crisis. The price mechanism as a method of controlling the market place was falling down. We must, as a nation, start giving serious consideration to the real problems of future decision making, even if it goes against that basic component of our national character - i.e. avoiding philosopical issues and getting on with the job by sweeping contentious problems under the carpet.

The problem of energy and resource allocations will no doubt be at the heart of many of our national debates of the next few decades. Obviously society collectively will have to decide how these priorities should be established.

What we must be doing now is researching possible methods as to how we can make these decisions in the future.

The Need for Imaginative Thinking

If we are to ensure that,in the future,we will have self sufficiency in our energy supplies, then we must resort to imaginative thinking. We cannot solve tomorrows' problems with yesterdays' solutions. We must be flexible and imaginative in our solutions of our technological problems involving energy.

For example, much more public transportation should be funded and encouraged as the consumption of energy per individual transported per kilometer is significantly less than for the private automobile. If the future dictates that the automobile must eventually be suppressed or restricted in usage, we must not hold this up as a symbol of our high standard of living, otherwise we will be expending unwarranted amounts of energy to maintain inefficient systems.

One example of imaginative thinking is the use of central heating systems for cities. This would make the use of solar and wind energies far more easy to envisage, in that a grid would be provided around urban areas into which these collection systems could feed their energy.

Central Heating Systems

The application of solar and wind energies in meeting the countries' future energy requirements cannot be viewed in an isolated manner. It must be considered along with imaginative alternative programs which consider the more efficient use of energy resources. One such scheme is Central Heating Systems for cities etc. The well known use of these systems to heating buildings in Iceland (from geothermal heat sources), Sweden and the U.S.S.R. need not be repeated at this time. The economies of scale and the elimination of large numbers of less efficient heating systems make this system attractive. A centralized system of control, which is quite foreign to our current life style, is utilized. Is it not possible that our society might be forced into experimenting with these alternative systems in the future?

The latest country to join the trend towards national central-heating systems is West Germany. Plans call for the establishment of such a system to service all towns with a population in excess of 40,000 persons by the turn of the century. This would supply 94% of the heat required by the country. Heating plants would be combined with electric generating facilities, obviously to make use of cooling water, and other heat sources. The first stage of the project, involving a study of $4 million dollars, has begun to develop a "heating atlas" which would chart heat requirements in relationship to climatic conditions, present heating systems, consumer behaviour and seasonal changes. It is this type of study which Canada as well should undertake. Obviously solar and wind energy could be combined to fit into this national "grid" which would act as the heat storage reservoir. Solar energy supplemental heating could be envisaged either directly at the load sites or at intermediate steps along the way. There is no evidence as yet as to whether the West Germans will eventually consider a hybrid solar-conventional fuel system.

APPENDIX F

SOLAR ENERGY RESEARCH PROGRAMS IN OTHER COUNTRIES

It would be fair to state that the entire world is examining the potential of solar energy in meeting future energy requirements. Canada possesses the expertise in the field, the industrial base and the climate wherein solar energy can be tapped. As a nation we have been indeed slow to recognize the potential of renewable energy resources.

This section deals with the approach taken principally by the United States of America and Japan in investigating the Use of Solar Energy. A considerable amount of data on the U.S.A. programs and legislation is given in Appendix A.

There are about 40 bills before the United States Congress dealing with various phases of solar and wind energy utilization in meeting its future requirements. It is somewhat significant that as a neighbouring country receiving roughly 80 percent of the solar radiation levels, there is currently not one bill before the Canadian P arliament. It is not the purpose of this exposé to examine the reasons for this dichotomy. Canadians, both in public and private sectors,will undoubtedly have to realize that natural, renewable and non-polluting forms of energy will form part of the future energy supply picture for this country,in spite of the significant amount of time it has taken for us to recognize their potential.

In the United States, the U.S. Senate Committee is debating a bill calling for the establishment of an office of solar energy research whose initial 4-year projected budget was six hundred million dollars. It seems somewhat inconceivable that our nation should not at least be considering some of the alternatives presented in the use of these energy sources. The United States has embarked on a substantial program of research and development in this field.

In the financial year 1974, the projected R & D expenditure of the National Science Foundation which is one of the U.S. Federal funding agencies in this field, was 12 million dollars. It has now been extended to $50 million dollars. We cannot, as has been suggested in the past, just import all of this technology. Why should it necessarily be available to us? Currently we have the knowledge and the facilities to launch a solar energy program.

Research grants were made both to university research centres and to industrial enterprises. These grants are listed in Appendix A. They fall under the following heading:

- heating and cooling of buildings
- photovoltaic conversion
- solar thermal conversion
- biomass production and conversion
- wind conversion and general projects.

The United States federal authorities have recognized the necessity for developing expertise in these fields. While a portion of these activities has been directed towards the advancement of basic scientific knowledge related to solar energy, a not inconsiderable amount has been used to initiate research on proof of concept technologies. These projects combine research institutes, universities, consulting engineering firms and industrial organizations. In this manner, they hope to establish a pattern of development in which solar energy will become integrated into the domestic, commercial, academic and industrial patterns of the society. An official plan as a preliminary step was undertaken with a publication in December 1972, entitled, "Solar Energy as a National Energy Resource". Basically the National Science Foundation and National Aeronautic Space Agency solar energy panel with Chairman and consultants drawn from different disciplines and various organizations throughout the country have put together a report which forms the basis for a plan of action in this field.

It must also be noted that considerable efforts have been made by state legislatures in the United States, private industry and independently funded research organizations in the field who have also provided funding for investigations and applications along these lines. As a concrete example, the United States authorities at the height of the "so-called" energy crisis of late 1973 and early 1974, funded a crash proof of concept program which provided partial solar heating for 4 schools located in different parts of the country.

Four states here enacted legislation encouraging the use of solar energy for housing, and providing incentives for home owners who utilize natural energy sources. The state Florida has passed a law requiring that all new housing units have plumbing connections on the roof to take solar water heaters or collectors.

It has been possible for our neighbours to act in such a way as they have effectively commited themselves to being independent with regards to energy by 1985. Coupled with this, the public media, television, press and radio, has begun a concerted campaign of informing and educating the public in this domain. The tax payer in the society, therefore, has become conditioned to accept and respect the need for investigations in the use of alternative energy sources.

These activities have not been limited to the United States alone. In a number of European countries, considerable efforts are now being formulated towards this direction. The Japanese government has instituted a program primarily directed at assisting industries called the "Sunshine Program" discussed in this section; the Japanese trade commissions in Canada have already begun visiting different organizations, such as the Brace Research Institute in order to establish the potential for markets in Canada of Japanese solar equipment. In many developing countries, committments have been extended in the field of solar energy.

One particular case in which we are familiar, has been the appointment of one of our collaborators for many years past, Dr. M.A.S. Malik, to head an expanded and revitalized office of solar energy research in his home country of Pakistan. The existing laboratories will be expanded to permit Dr. Malik to have 50 qualified scientists in this field, permitting Pakistan, a country with few fossil fuel resources, to become much more energy independent in the long term. While these developments are evolving around the world, we, as Canadians, should be asking ourselves what role these resources might play in meeting our future energy needs.

Solar Demonstration Bill

The following are the major provisions of the Solar Heating and Cooling Demonstration Act of 1974 (HR 11864), which was approved by Congress Aug. 21, and signed by President Ford Sept. 3:

Goal: The bill designated federal agencies to provide for the demonstration within a three-year period of the practical use of solar heating technology and the development and demonstration within a five-year period of combined solar heating and cooling technology.

Agency Roles: The sole role in procuring solar energy systems goes to the National Aeronautics and Space Administration (NASA) and the lead role in demonstrating them to the HUD Department. HUD is directed to install solar heating and combined solar heating and cooling systems in "a substantial number of residential dwellings." With respect to demonstrations in apartments and other buildings, the NASA Administrator is to pick the appropriate federal agency to carry out each project. The Secretary of Defense is specifically directed to install solar systems procured by NASA in a substantial number of residential homes which are located on federal property.

The National Science Foundation, designated by former President Nixon as the lead agency in solar research, is directed to continue its research programs in the solar area and to report to HUD and NASA on a continuing basis with any test information that could be of use in the demonstration program.

Comprehensive Plan: The program is to swing into action within four months after the bill's enactment when HUD and NASA must submit a comprehensive plan for the demonstration program to the President and both chambers of Congress.

Performance Criteria: As soon as feasible after results of the demonstrations are in, the HUD Secretary, assisted by the director of the National Bureau of Standards, must develop definitive performance criteria (with regional variations where necessary) against which solar systems will be tested and certified.

In the meantime, the HUD Secretary is directed to establish interim performance criteria within 120 days for solar heating systems and "as soon as possible" after results of additional developmental work are in for solar heating and cooling systems.

Design Competitions: Following promulgation of the interim criteria, HUD will select - on the basis of open competitions - a number of designs for various types of residential dwellings suitable for solar systems that meet the criteria.

Geographical Spread: The bill directs that homes and buildings selected for the demonstration program be located in a sufficient number of different geographical areas (in rural as well as urban settings) to assure "a realistic and effective demonstration."

Terms: Title to any dwellings constructed with the bill's funds will be conveyed to purchasers under terms prescribed by the HUD Secretary, including a requirement that the purchaser will observe and report to HUD on the performance of the system for a five-year period.

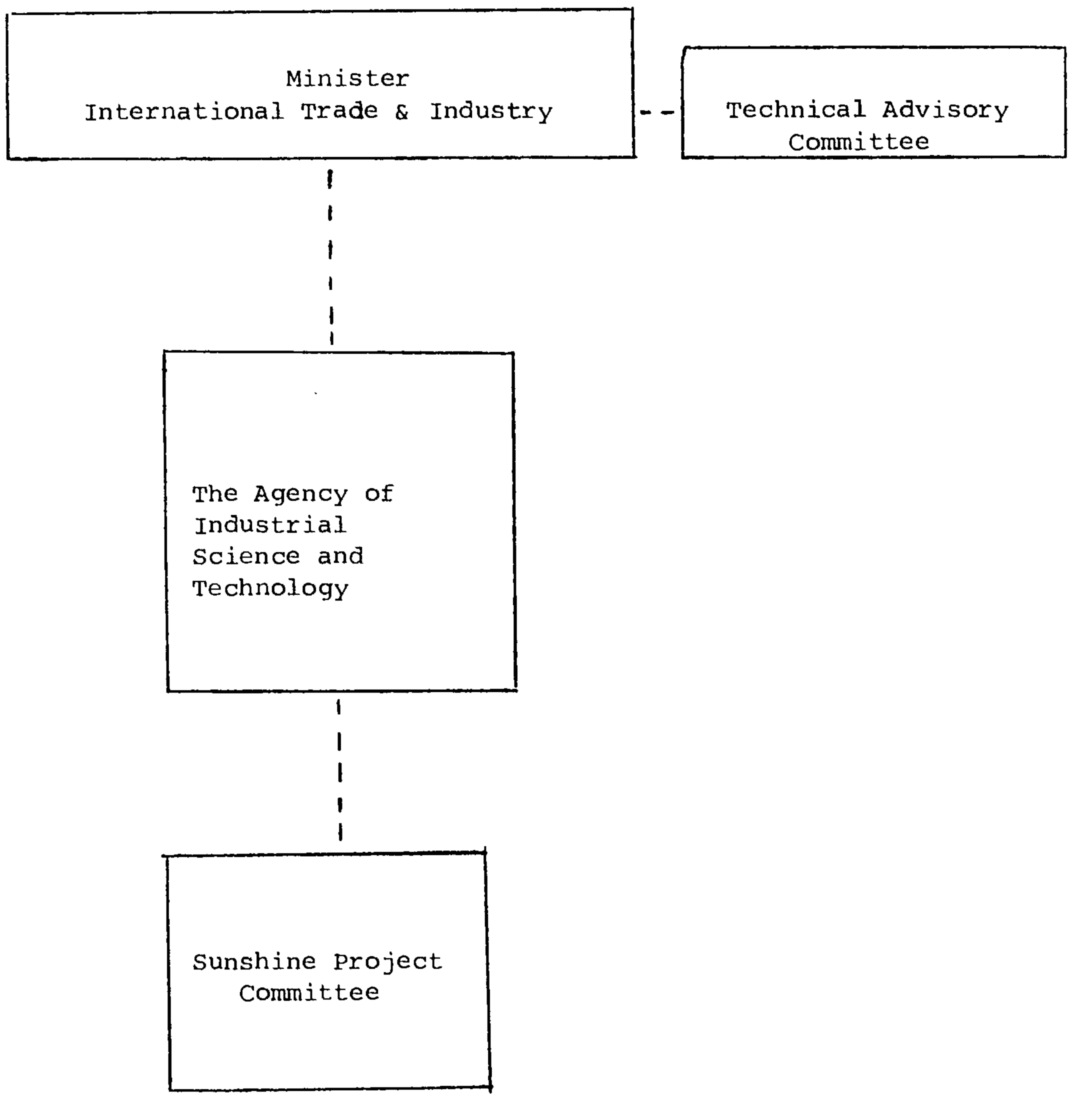
Mortgage Limits: For persons who agree to make their own homes available for the demonstrations, the bill increases the maximum amount of federally assisted mortgage money by the amount that the cost of the home with the solar unit exceeds that of a home with a conventional heating or cooling system.

Appropriations: The bill authorizes appropriations of $60 million for the program, including $5 million each for HUD and NASA in fiscal 1975. The remaining $50 million is to be parcelled out as the Administration sees fit in fiscal 1976 through 1979.

Transfer to ERDA: Within 60 days after the passage of pending legislation to establish an Energy Research and Development Administration (ERDA), the bill authorizes the transfer to ERDA of all NASA and NSF solar research activities established under the bill.

PROJECT SUNSHINE, JAPAN

The following information was given to T.A. Lawand by Dr. Tetsuo Noguchi of the Government Industrial Research Laboratory. He was the chief architect of this project. It is a new initiative on the part of the Japanese authorities in combination with industry and research organizations to attempt to resolve some of their energy problems. Project Sunshine consists in the use of solar energy, coal gasification, SNG (Synthetic Natural Gas) and geothermal energy. The object is to investigate closely the utilization of as many indigenous resources as possible to permit the Japanese to have as automous an energy supply system as possible. This must be considered in the light of the fact that no new power plants have been built in Japan since 1972. Structurally, the organization is set up as follows:



Section I and II

General Planning and Total Systems

This will look at the feasibility of systems, using solar energy, including general considerations, total systems approach, the use of photovoltaics, heating and cooling of buildings, large scale furnaces, etc.

They will also look at insolation rates and climatic factors, the development of patents and technical assistance.

Section III

Solar Thermal Conversions Systems

This will be primarily under the organization of the following companies:-

HITACHI
MITSUBISHI

Section IV

Photovoltaics

This will be coordinated by the government run - Electro Technical Labs in Tokyo. There will be three pairs of teams working on different aspects of the problem;-

One:	Toyosilicon Toshiba	(Silicon solar cells)
Two:	Nec Hitachi	(Polycrystalline structures)
Three:	Matsushita Sharp	(Cadmium sulphide Cells)

Section V

Heating and Cooling of Buildings

This section is discussed in detail in the following paragraphs.

Section VI

Solar Collectors

FINANCIAL AND STRUCTURAL SETUP

The amounts of grants that are currently being allocated to industry are of the order of 20 to 50 million yen per year. It is interesting to note the philosophy of approach that the Japanese authorities have adopted. The total budget provided for Project Sunshine in 1974 will be in the order of 2.4 billion yen ($7.5 million). This is the total program including R & D into the production of synthetic natural gas, hydrogen and geothermal energy.

The amount of money allocated to the solar energy programs in this year was roughly 870 million yen ($2.7 million). Of this amount, 278 million yen ($870,000) was allocated to government research institutes, the balance was given to industry.

It must be appreciated that industry is also expected to make substantial contributions. This includes contributions of personnel, research facilities as well as financial resources. More than 50 proposals have been received from industries. At this stage, the prime contacts are being awarded to large scale industries as the authorities feel that they are the only organizations who have sufficient credit and financial and personnel resources to be responsible for long range programs. It is envisaged that Project Sunshine will last at least 20 to 30 years. Small companies will be later incorporated into the system as sub-contractors to the large ones. Universities and research institutes are acting as consultants to these primary large scale contractors. Project Sunshine is a concordat between government and industry. Though competition is keen between the various industrial organizations, the overall project is viewed in the light of national requirements and obligations. There will be an interchange of information available from this project for all other industries, government departments, etc.

The total budget envisaged for this project will be of the order of 2.5 trillion yen ($78 billion).

The total budget up the year 2000 starting from the year 1974 in solar energy will be 450 billion yen ($1.4 billion). By the year 1985, the expenditure will be 43 billion yen ($135 million). There will be a gradual increase from the current level up to this figure. From 1985 for the next 5 years the expenditure will be 43 billion yen per year ($135 million). This will obviously be the period of the greatest concentration of activities. After 1990 the rate of expenditure will also be considerable. New projects will be formulated to carry on after the year 2000.

At this stage in the solar energy program, there is no work being carried out directly on ocean temperature difference utilization for power source, wind energy or biomass energy. These may be taken up later. Concurrent to these studies, however, they are carrying feasibility studies at the moment on the storage of electricity, the use of super conductive magnets, the generation of power from ocean temperature differences, high temperature (plasma) ionization and biomass energies.

International Collaboration

In principle, the Japanese are in favour of international collaboration in this field, in particular in dealing with the standardization of equipment, the development of simulation models, the exchange of installation data and the expansion of these networks, the adoption of uniform methods of gaging the efficiency of collectors, etc.

SOLAR HOUSE HEATING AND COOLING

There are four main thrusts connected with this project. Basically, all the research will be carried out in the private sector. It will be a combination of companies producing equipment for the air conditioning industry, heat pumps and other household heating and cooling equipment, combined with contractors.

Area One: Residential solar powered houses for the year 2000

This concerns the development of new housing designs for residential purposes.

Principal equipment company--SANYO
Principal contractor entrepreneur--OBAYASHI

Area Two: Retrofitting existing houses

This will look into the utilization of solar energy for existing structures.

Principal equipment company--MITSUBISHI
Principal contractor entrepreneur--TAISEI

Area Three: Apartment Buildings

This will be handled by:

Principal equipment company--ISHIKAWAJA
Principal contractor entreprenuer--TAKENAKA

Area Four: Schools, Businesses, Commercial Buildings, etc.

This will be handled by:

Principal equipment company--KAWASAKI
Principal contractor entreprenuer--KASHIMA

SOLAR COLLECTORS

In principle, they are looking into the development, from a materials engineering point of view of collectors in the following categories. All material systems will be fully tested.

Glass — Principal Investigator: NIHON GLASS

Plastics — Principal Investigator: TORAY COMPANY

Aluminum — Principal Investigator: SHOWA ALUMINUM

NOTE: They are planning to use the Roll bond type collectors. They have had problems since 1957 with this type of collector. Consequently, they are thinking that they may have to zinc plate their collectors. Their experience with aluminum collectors is that problems develop after three to seven years operation depending on the water utilized.

GENERAL NOTE

Dr. Noguchi and his team have completed a survey to calculate the number of factories in Japan as well as calculating the roof areas of these factories. They have found that there is a total of 4300 square Kilometers of potential collector surfaces on these factory roofs. This gives a total area of 4.3×10^9 sq. meters of collector area potential. The average insolation in Japan per sq. meter is equivalent to roughly 4Kw hours per sq. meter. If 80% of the roof area is utilized at an efficienty of 25%, this would give roughly a potential of 3.5×10^9 Kw hours of energy which can be usefully recuperated. It is this type of census and analysis which should be undertaken in other countries to indicate the available potential of existing structures in meeting future energy needs. It must be noted that this survey in Japan only covers roof areas of factories. This could be supplemented through the utilization of roof areas from schools, public buildings and other large structures.

THE MAIN THRUST OF THE PHOTOVOLTAIC PROCESS

In general, there are 6 photovoltaic projects underway:-

1. The development of vertical silicon ribbon crystals.

2. The development of horizontal silicon ribbon crystals.

3. The development of polycrystalline silicon thin films.

4. The effect of accelerated methods photocell such as iron implantation and non-accelerated methods such as chemical vapour deposition, sputtering and vacuum deposition.

5. The development of cadmium sulphide photocells and other intermetallic semi-conductors such as:-

   cadmium telluride
   gallium arsenide
   gallium phosphide

6. Device structures which will look after the housing of solar cell systems in collectors, combined solar heater and electric production solar collectors using photocells as absorber plates and the effect of concentrators on solar cell performance.

TEMPORARY GOALS OF SUNSHINE PROJECT

A) Solar Thermal Conversion

Up to 1985, it is proposed that the work would concentrate on the construction of pilot plants producing power from solar energy in sizes up to 1000Kw.

B) Photovoltaics Conversion Programs

The objective is to reduce the costs of photocells produced to $1.00/watt.

C) Solar Heating and Cooling

The objectives are to complete the technology of solar house heating and hot water supply within 5 years. It is estimated that the cooling of buildings will probably take another 5 years, that is, the development of the technology on solar cooling systems will probably take 10 years in all. It is interesting to note that these projects and time scale will parallel the efforts in the U.S.A. From 1976, they will build houses of a demonstration nature as Stage One. Stage Two will be in the four categories previously ennunciated and will probably take another three years of further development. They will also incorporate focusing collectors for cooling systems.

Heat pumps are being actively examined from an energy viewpoint.

To date the studies on the feasibility of solar heating and cooling have already been proven. The programs in Japan now will concentrate on the development of collectors and suitable complete systems.

APPENDIX G

ADDITIONAL INFORMATION ON SOLAR AND WIND ENERGIES

In order to complete the requirements set out in the contract to do this study, some additional data on wind speed, wind power availability and solar Agricultural Drying, and Ocean Wave Energy Potential have been included for the reference of the reader. There is a considerable amount of additional information available on these and other solar, wind and biomass energies in the litirary and documentation centre of the Brace Research Institute.

This information is available to Canadians who wish to consult this facility.

SOLAR AGRICULTURAL DRYING

One of the oldest applications of solar energy is the dehydration of agricultural produce.

The amount of agricultural produce dehydrated in 1968 using solar energy amounted to 225 million tons (according to the F.A.O. Worldbook). In that year, Australia alone exported 72,000 tons of sun-dried fruit worth over $27,000,000. The size of the industry is worldwide and significant. If all of this drying were to be done using fossil fuel, it would put an even greater strain on our limited fossil fuel reserves.

The total amount of dried foodstuffs, grains, animal fodder, lumber, etc. in Canada is not quantified. Statistics Canada gives the following data which shows the magnitude of this industry:

1. Crop dryers with heating units (for grain, hay, etc...) were 3,778 units sold ($4,759,606 total value)

   Reference: Statistics Canada, Catalogue 63-203, Annual Farm Implement and equipment sales 1973 Page 9.

2. The Production in Canada of:

	AREA	YIELD/ACRE	TOTAL PROD. (BUSH.)
Dry Peas:	68,600 (mainly Man.)	24.0	1,649,000
Dry Beans:	133,200 (mainly Ont.)	21.7	2,885,000

   Reference: Statistics Canada, Catalogue 21-003 Quarterly Bulletin Trimestriel de la Statistique Agricole Oct. - Dec. - 73 Page 242-243

3. The Production in Canada of powered skim milk was 49,798,000 pounds in 1973. This was 5.8% lower than in 1972.

   Reference: Statistics Canada, Catalogue 21-003 Quarterly Bulletin Trimestriel de la Statistique Agricole Oct. - Dec. - 73 Page 263

4. The Production in Canada of Dry Onions was 110,000 metric tons, from a total cultivated area of 4000 hectares.

   Reference: Food and Agriculture Organisation (U.N.) Production Yearbook 1972 Vol. 26 Rome

It must be recognized that these statistics are not complete, in that they do not indicate the fraction of the crop in Canada which is dehydrated by the sun. Nonetheless they indicate that dehydration is a valid method of preservation of surpluses. In more recent times, the trend away from natural or solar dehydration has taken on greater significance. During the "energy crisis" of 1973-74, one of the first areas to be cut from supplies of propane, especially in the United States of America, was solar agricultural drying.

As a consequence, there has been a increased interest in the use of solar powered agricultural dryers. Several research contracts have been funded by the U.S.A. authorities. In essence, they are doing little more than repeat earlier experiments, with perhaps somewhat more systems engineering, making use of more recent developments in materials.

Heat can be extracted from roofs of buildings in the form of warm air. This permits the dehydration of crops brought in from the fields. To be truly appropriate, the entire system must be studied. In this manner the solar energy component can be examined from a meaningful point of view.

OCEAN WAVE ENERGY POTENTIAL

It has been estimated power in the Atlantic waves rolling across a North-South line 250 miles long to the West of the Hebrides is roughly equivalent to the total electricity consumption in Britain.

The Department of Trade and Industry approved a grant in October of $137,400.00 towards exploiting this potential form of energy, and developing a system of harnessing wave action, invented by Stephen Salter of Edinburgh University, reported recently in the "Sunday Times" - London, England.

There are about one hundred British patents on wave energies, many very ingenious, mainly consisting of floats rising and falling on waves, and a similar number in the U.S.A., some dating back to 1890.

The newer scheme, which interests the British Government, consists of a series of vanes, which appear like giant cams, mounted on a long cylindrical axis. The cams face the waves so are lifted and lowered. This oscillating motion would drive water pumps, producing pulses of high pressure water to drive electrical generators, Tank tests have shown waves rocking cams up and down are able to extract 90% of energy from passing waves, compared with 20% from bobbing floats.

The size of the cam-like floats would be huge, and the axis about which they rock could be 30 to 60 feet in diameter. The vanes, of which there may be 40, each 100 feet wide, (or about 4,000 feet total length) would be separated by buoyancy tanks, to adjust floation level. The movement of the vanes would be limited between up and down oscillations, by stops.

The scheme has merits, but faces immense structural and civil engineering problems. It is contended the system could be adjusted to float below sea level, to protect it against the worst storms.

It is suggested the scheme could be in operation by 1990, at which time the North Sea oil begins to run dry.

It is contended the completed assembly could be towed out into the Atlantic to produce hydrogen, then allowed to drift towards shore, the stored hydrogen reaped, instead of building transmission pipes to shore.

From a practical stand-point, we see problems, far exceeding the installation of drilling rigs for oil in 400 feet of water.

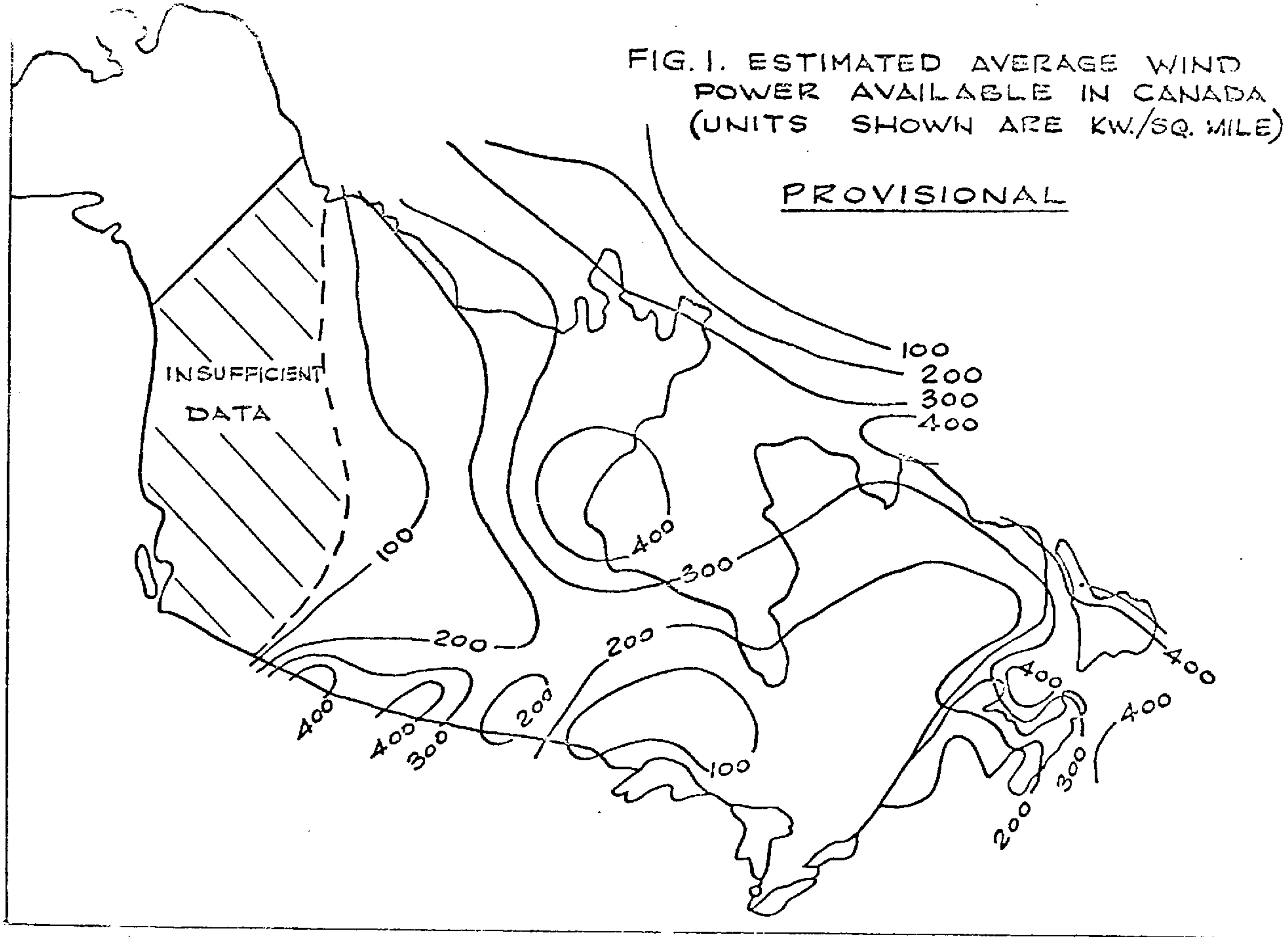
This figure is extracted from the paper "Wind Power and the Vertical - Axis Wind Turbine Developed At the National Research Council, Ottawa, Canada", by R. S. Rangi, P. South and R. J. Templin. Paper presented at the symposium "Wind Energy: Achievements and Potential", University of Sherbrooke, May 29, 1974.

The contour lines show the estimated values of wind power in kilowatts of shaft power available per square mile, assuming that the energy is converted by widespread arrays of windmills.

In calculating the contour lines, overall wind conversion efficiency has been assumed to be 35% and windmill spacing is about 30 rotor diameters apart.

FIG. 1. ESTIMATED AVERAGE WIND POWER AVAILABLE IN CANADA (UNITS SHOWN ARE KW./SQ. MILE)

PROVISIONAL



Charts on Seasonal Mean Wind Speeds

These four charts for Winter, Spring, Summer and Autumn mean wind speeds, are extracted from "Climatological Atlas of Canada", prepared by Morley K. Thomas for the Division of Building Research, National Research Council, and the Meteorological Division Department of Transport, Ottawa, December 1953.

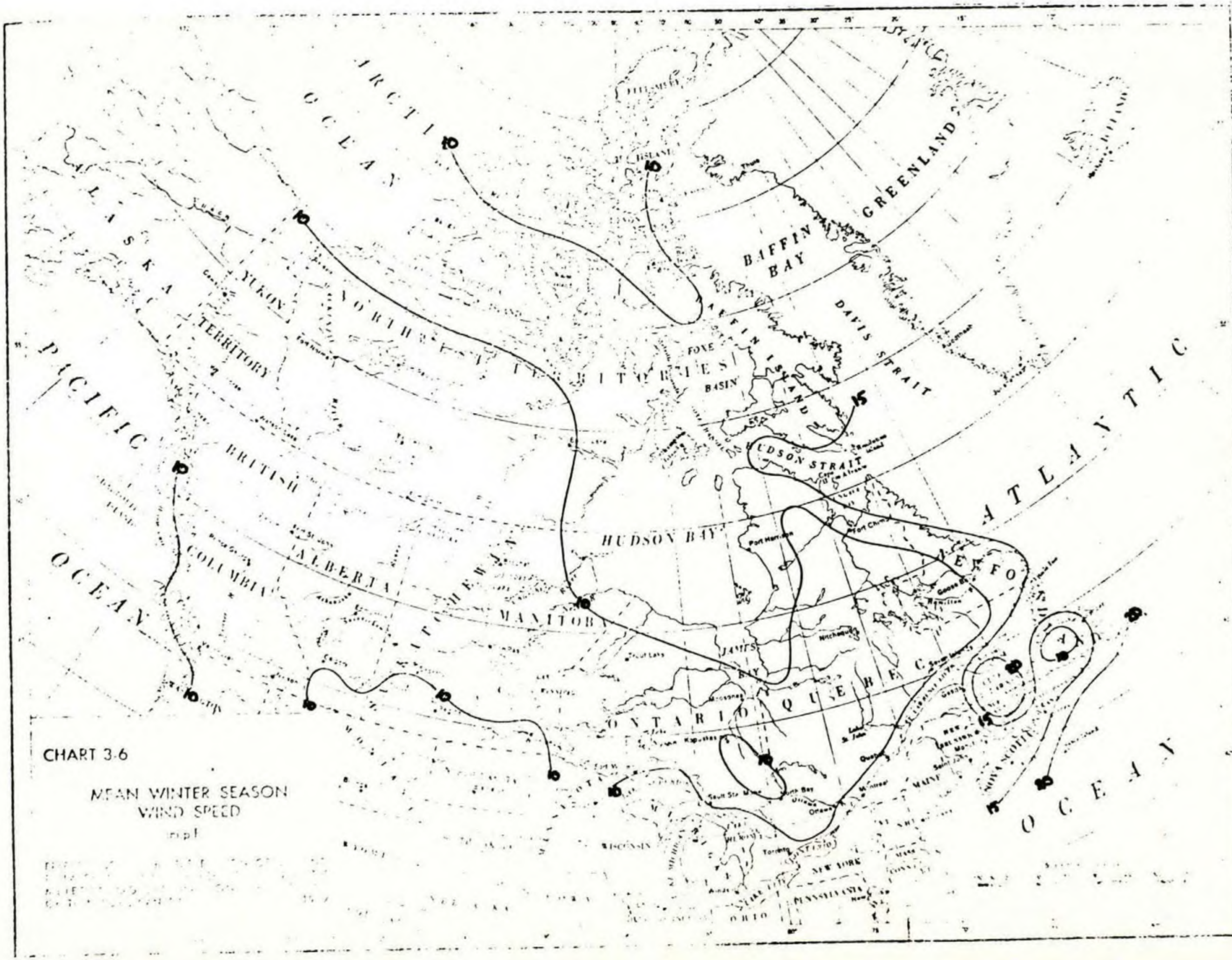


CHART 3-6

MEAN WINTER SEASON
WIND SPEED
mph

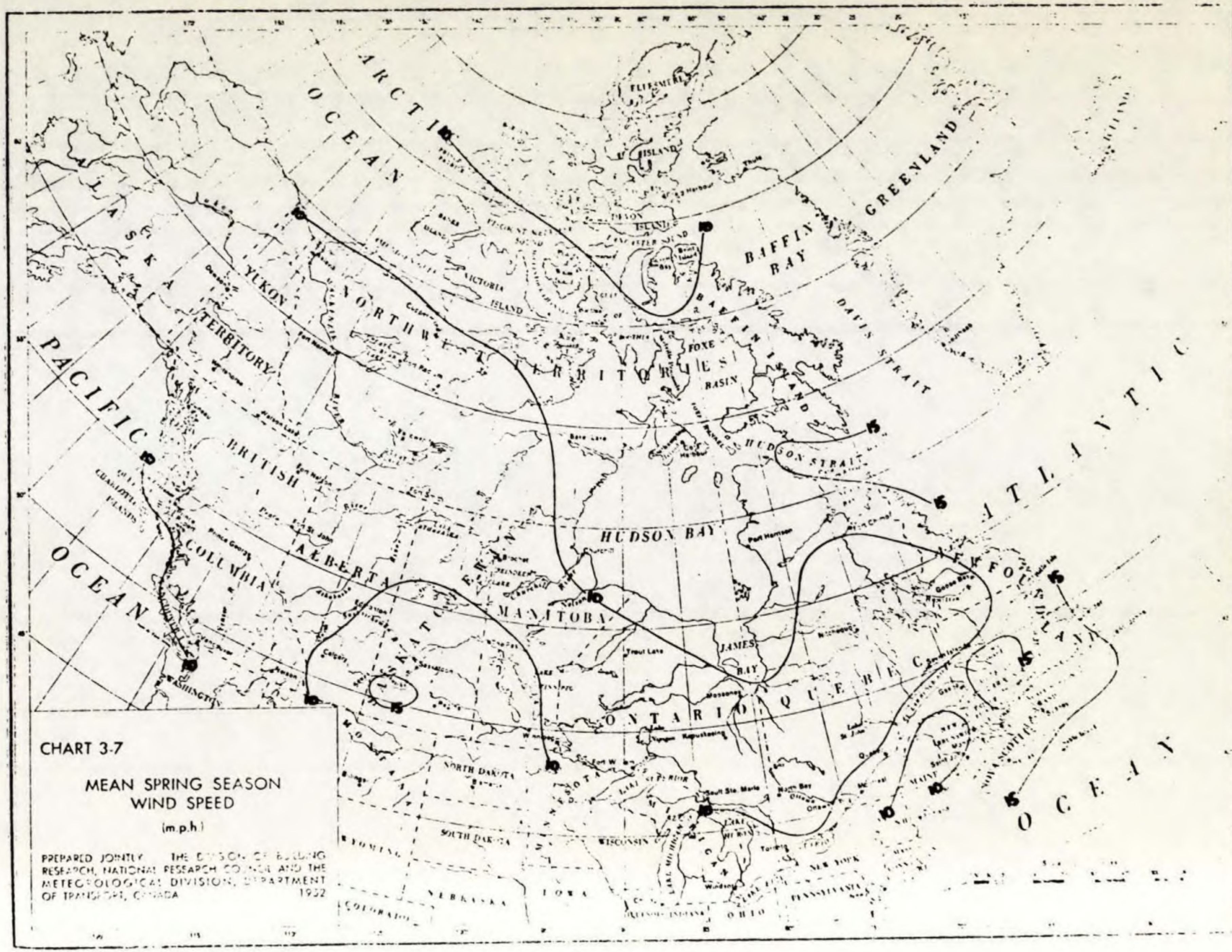


CHART 3-7

MEAN SPRING SEASON WIND SPEED

(m.p.h.)

PREPARED JOINTLY THE DIVISION OF BUILDING RESEARCH, NATIONAL RESEARCH COUNCIL AND THE METEOROLOGICAL DIVISION, DEPARTMENT OF TRANSPORT, CANADA 1952

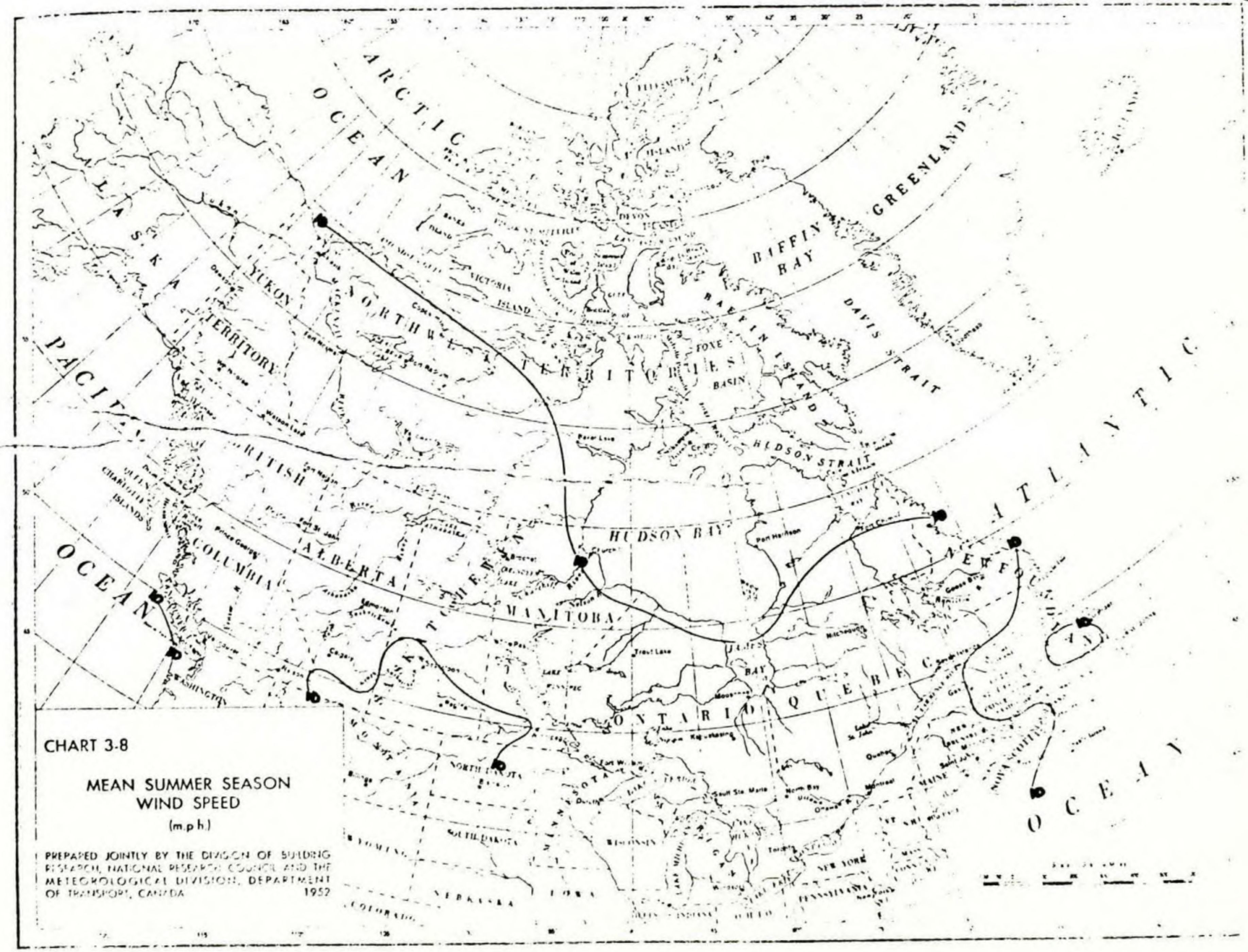


CHART 3-8

MEAN SUMMER SEASON WIND SPEED (m.p.h.)

PREPARED JOINTLY BY THE DIVISION OF BUILDING RESEARCH, NATIONAL RESEARCH COUNCIL AND THE METEOROLOGICAL DIVISION, DEPARTMENT OF TRANSPORT, CANADA 1952

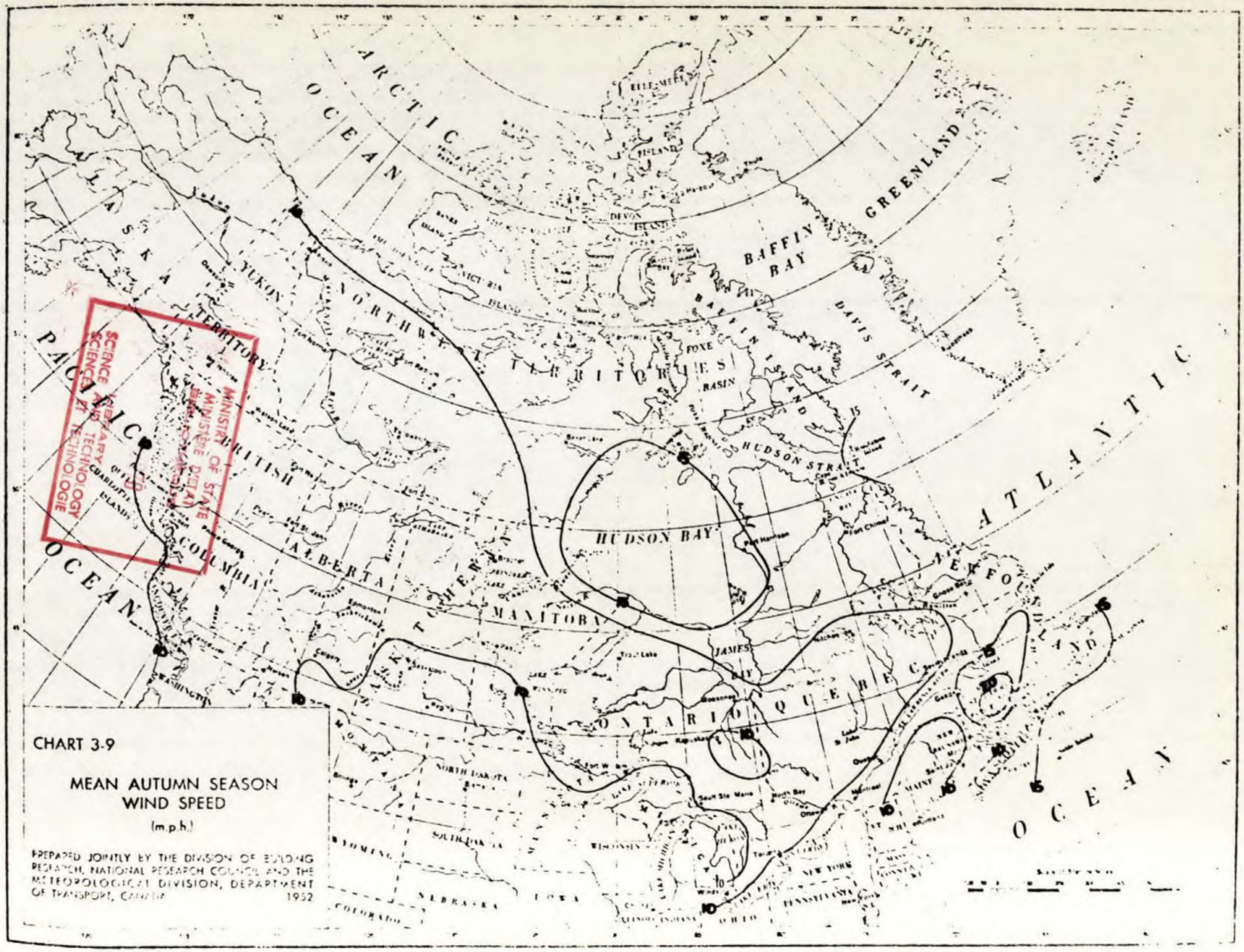


CHART 3-9

MEAN AUTUMN SEASON WIND SPEED

(m.p.h.)

PREPARED JOINTLY BY THE DIVISION OF BUILDING RESEARCH, NATIONAL RESEARCH COUNCIL AND THE METEOROLOGICAL DIVISION, DEPARTMENT OF TRANSPORT, CANADA 1952