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1. OVERVIEW OF CANADIAN ENERGY SCENE

Canada compared to most countries, is extremely well endowed with energy resources. It is, in fact a net exporter of energy. However it is in no sense insulated from the energy concerns which affect the rest of the world, since, like most countries, Canada imports oil. About 43% of Canada's primary energy consumption is oil of which currently one-quarter (gross) is imported. Net imports of oil are currently about 140,000 barrels a day.

Prior to the international oil price increases and availability problems of 1979-1980, this import dependence was expected to grow as domestic producibility from conventional oil reserves fell, with net imports reaching some 600,000 barrels a day by the mid 1980's. This would be counterbalanced by increasing exports of natural gas, electricity and coal.

Canadian energy policy now centres on the reduction of this import dependence through the development of indigenous resources (natural gas, coal, nuclear fuels, unconventional oil and renewable energy), substitution of other energy forms, including renewables and wastes, for oil consumption wherever possible, and reduction of demand through improved efficiency and conservation. The overall aim is to eliminate oil imports by 1990, reducing oil consumption to only 10% of energy demand in each of the economic sectors, with the exception of transportation. Oil will then represent 27% of total consumption, rather than the present 43%. Many new programs of incentives and regulation are being put in place to achieve these objectives by both Federal and Provincial Governments, including a number concerning new and renewable energy. Conventional hydro-electric generation currently supplies more than 60% of Canada's electricity (about 24% of its total primary energy). With this exception, renewable energy is not expected to make a major contribution in the next decade. However, it is seen as the key to a stable long-term energy future. Government programs are encouraging this long-term development of renewable and alternative energy with R&D assistance, demonstrations, industrial support and market stimulation, and as the prices of other forms are allowed to rise the economic competitiveness of various renewable applications will continue to improve.

In terms of its energy consumption, Canada is also in many ways a unique country. It is one of the highest users of energy per capita in the world due in part to its climate, long transportation distances and dispersed population, and its energy intensive industrial structure based on its indigeneous natural resources. Now Canadian patterns of energy use are changing to incorporate conservation and substitution, and expertise is being developed in areas of special concern to Canada, such as conservaton in the forest-based industries and new sources of fluid fuels. In the near term, and probably to the end of this century, conservation is likely to play a bigger role than most renewable energy sources in contributing to energy self-sufficiency in Canada.

The diversified resource base and the geographic and social structure of the country have ensured the development of special Canadian expertise in many specialised aspects of new and renewable resource production and use. Transfer of this experience constitutes the main contribution Canada can make to the developing countries. For example, Canada has experience and expertise in such areas as energy planning and systems development, engineering and design for unique applications, transmission and transportation techniques, remote community applications, development of hydro resources, forest management and use of biomass in forest industries.

In Canada, the energy scene is complicated by the balance of powers between federal and provincial governments. The provinces have ownership and control of resources within their borders, and also have jurisdiction over many of the activities involving energy demand. They make a substantial contribution to the funding of research and development associated with energy projects. The ubiquitous and non-depletable nature of most renewable energy sources means that both levels of government can be, and are, involved in the encouragement of their promotion and exploitation, often with overlapping or joint activities. Many provinces, such as British Columbia, are just now establishing the details of a renewable energy strategy which will cover the elements of resource assessment, development and demonstration, followed by eventual commercialisation of appropriate technologies. Others like Quebec (as early as 1978), had established a renewable energy strategy and are implementing policies promoting the development and the use of new and renewable energy sources.

However in cases where resources are localised in specific areas of the country, policies may differ in perspective among provincial governments and between federal and provincial governments. At the present time, for example, discussions and negotiations are continuing between the federal and western provincial governments on revenue distribution and other issues related to tar sands development, and the final outcomes in terms of resource availability and pricing are still unclear.

In the following sections, Canadian government strategy and programs, and industrial capability and expertise are discussed for each of the new and renewable sources of energy, and conservation. Although conservation is not officially included in the coverage of the Conference, it is included here because of its relative importance for Canada, and indeed for the rest of the developed world, in reducing dependence on insecure energy resources. Those aspects of Canadian capabilities that relate to developing countries, including possible transfer of information, expertise and hardware, are then set out.

2. NEW AND RENEWABLE ENERGY IN CANADA

Introduction

Canadian government interest in renewable energy was demonstrated in 1974 with the establishment of a program of renewable energy research and development. A further major initiative in 1978 launched several new programs oriented toward industrial development in the area. More recently the 1980 National Energy Program emphasized the future role of renewable energy sources in providing for a stable and independent future. The following passage from the NEP illustrates this perspective:

> "Canada is well endowed with non-renewable resources that can provide a bridge into a future where Canadians use less energy in their daily lives, and renewable energy plays a much larger role. Renewable energy in the form of hydro-electricity already contributes 24 per cent of Canada's energy. Other renewables contribute a share approximately equal to that of nuclear power. (...) The realities of the energy future indicate the wisdom of accelerated efforts to develop new and renewable energy forms, to stand beside hydro-electricity as the basis for a sustained, clean, and economically viable energy structure.
>
> The National Energy Program envisages a much greater role for renewable energy. The Government of Canada believes that economic realities now favour a range of renewable energy options. The National Energy Program will provide further incentives to the commercial use of these resources, both within the comprehensive off-oil effort already described, and in the form of special new or enriched programs. It will also provide increased funds for research, development and demonstration of renewable energy."

This encouragement of renewable energy options, and conservation is echoed also in the policies of most of the provincial governments of Canada, and jointly funded demonstration projects exist across the country.

Currently, aside from the supply of conventional (ie. large scale) hydro-electricity, renewable energy (statistically) supplies about 3.0 - 3.5% of Canada's total energy needs - almost entirely from biomass. Under the National Energy Program (NEP) this contribution should double by the year 1990 to about 6.0% and triple by the end of the century - with a large proporton from biomass. (The true size of the renewable energy contribution is difficult to assess since a great deal does not enter conventional markets and thus is excluded from energy statistics).

The most important provision of the NEP specific to renewable energy is the establishment of Canertech, a new Canadian alternative energy corporation, with a mandate restricted to renewable energy and conservation technology. This crown corporation, with initial funding of $20 million, will focus on supporting commercial production of these technologies, reinforcing the work of Canadian businesses in this field by joint ventures and equity investments and other assistance. It may also carry out research, development and demonstration.

In addition, the off-oil incentives of the NEP (Canadian Oil Substitution Program, COSP) are neutral as to the substituted energy form, and conversion to renewable energy will qualify. Under COSP, a grant is available to consumers (businesses and homeowners) for conversion from oil to gas, electricity (in some cases) renewable or other resources, of 50% of the cost to a maximum grant of $800. This grant can be used for the installation of wood-burning appliances, or for solar heating, where they substitute for oil. Financial support is also promised for the expansion of distribution systems (gas, electricity in some cases) to facilitate off-oil conversion, and this will be applicable to special off-oil projects in remote communities and possibly some elements of wood supply infrastructure.

Another general, and very successful, program available across the country for the encouragement of renewable energy development is the joint federal-provincial program of agreements to demonstrate, on a cost-shared basis, a wide range of new technologies for renewable energy and conservation. Total expenditures are expected to be $300 million over the period 1978-1983 ($113 million federal share). It is hoped that these demonstrations will accelerate the introduction, on a commercial basis, of those technologies which are close to economic readiness. A number of these demonstrations are described in the following section on the specific renewable energy sources.

2.1 Oil Sands and Heavy Oils

The oil sands and heavy oils of the Canadian provinces of Alberta and Saskatchewan are among the world's largest known deposits of petroleum hydrocarbons. The oil sands cover a total area of more than 53,000 square kilometres in the north of Alberta, with the four main deposits containing about 150 billion cubic metres of crude bitumen. It has been estimated that with favourable developments of technology the whole area may yield 13-31 billion cubic metres of synthetic crude oil, but development so far has shown that its extraction will be slow, difficult and costly. Too fast a growth rate in oil sands extraction could put considerable pressure on the technical, financial and labour resources of the country. Exploitation of the heavy oils of Western Saskatchewan and Eastern Alberta, where there is as much as 5 billion cubic metres in sandstone deposits 300 - 600 metres below the surface, will depend on developments in enhanced recovery techniques and agreements on pricing policies.

Increasing world and domestic prices for conventional petroleum are making the large scale production and upgrading of these resources more likely, and with declining producibility from conventional wells, Canada will rely on its heavy oils and oil sands to contribute to the goal of self-sufficiency in oil by 1990. The National Energy Program recognizes the need for incentives for the exploration of frontier and off-shore regions and the exploitation of high cost oil, which may not be economic at current domestic prices, and pricing schemes and other incentive mechanisms are presently under discussion with the provinces.

Two oil sands plants are currently in operation in Canada (with capacities of 50,000 and 125,000 barrels of synthetic crude per day), and several more are planned. The two companies use surface mining methods of different types, and the hot water extraction process. High environmental standards will be met, including re-landscaping and treatment of the water before returning it to the Athabasca River.

Because of the vast potential of its own resources, Canada has made a contribution to world technology development in this area and is also gaining valuable practical experience from its operating plants. R&D are continuing in all areas of recovery and upgrading, including *in situ* mining processes, improved flotation processes, improved and more efficient refining, and the reduction of coke and sulphur production. Considerable basic experience is available on resource characterisation, including exploration and sampling, research on the physical properties of oil sands and crude bitumen, and the classification and dissemination of information.

With the two plants now in operation, and more proposed, Canadian firms are showing an increased ability to supply equipment and engineering requirements, although most of the large and more sophisticated equipment, some of which requires exotic alloys that are unavailable domestically, is still imported. In many cases, only a handful of foreign companies service the global market. Canadian engineering services will likely assume particular importance in servicing overseas requirements. However, the countries to which such expertise might be supplied are limited. Major accumulations of oil sands and extra heavy oils are limited to nine countries of the world: Canada, USA, Venezuela, Trinidad, Columbia, Madagascar, Albania, Romania and the USSR, with over 95% in the first three mentioned. Research and test scale developments are in progress in USA, USSR, Albania and Venezuela.

Much of Canada's production of heavy oils (currently production runs at about 15% of total crude oil, or about 220,000 barrels per day) has been exported to the USA. The major domestic market has traditionally been the asphalt industry. However, research and development are now concentrating on future production and upgrading for domestic use. Tertiary methods of recovery, which it is hoped will eventually allow yields well above the 10% that is obtained by waterflooding, and new upgrading methods, are under intensive investigation (including experimental pilot projects). A considerable amount of government assistance is available for this purpose, through federal-provincial agreements, and through the national oil company, Petro-Canada. A dedicated heavy-oil upgrading plant is likely to soon be constructed in Saskatchewan, and possibly in Alberta.

In addition to the heavy oils, it is hoped that enhanced recovery techniques now under development will allow greater yields to be obtained from the conventional oil fields of Western Canada.

In 1975 the Government of Alberta set up the Alberta Oil Sands Technology and Reserch Authority, AOSTRA, which over the past five years has represented a centre for research and development funding, technology assessment and information transfer in the areas of oil sands and heavy oils. The main objectives of AOSTRA's program are to work with petroleum companies to field-test advanced technologies, and to harness the various research capabilities of Canada in the search for new concepts for the recovery and upgrading of bitumen and heavy oils.

AOSTRA is actively pursuing opportunities for international co-operative programs of technology development including the exchange and training of personnel, technology transfer, and the provision of assistance for resource evaluation. With the United States and Venezuela, Alberta is a founding member of a world information centre on oil sand and heavy oil technology.

2.2 Oil Shales

Although Canada does possess substantial oil shale deposits, these resources are of low quality, and interest has centered on the more promising and economic opportunities for liquid fuels in heavy oil upgrading, oil sands, and coal liquefaction. Oil shale development is unlikely in Canada in the foreseeable future, although there is currently some significant activity in the resource evaluation area. This expertise together with Canadian mining and oil upgrading expertise would, however, be transferable to oil shale development in other countries.

2.3 Alternative Liquid Fuels

Liquid fuels are of particular importance to Canada, firstly because at present this is the one fuel Canada does not produce in sufficient quantity to meet domestic needs (other fuels are in surplus supply); and secondly because of their convenience for transportation, which for a country the size of Canada is a large element in energy demand.

Opportunities for new fuel products and new sources of liquid fuels such as gas, coal, wood and garbage are therefore being pursued aggressively.

Biomass sources and liquid products are discussed in more detail in Section 2.11. While coal will not be further discussed as it is not one of the subjects of this conference, it should be noted that Canada has a large resource base of coal and is actively developing liquefaction options. In addition, propane is produced in Canada, mainly in the west (105,000 barrels per day). While transportation facilities eastward require expansion, demonstration and financial incentive programs by federal and some provincial governments are beginning, in order to increase consumer acceptance of this fuel particularly for fleet motor vehicles.

2.4 Conventional hydro-electricity

Canada is one of the foremost countries in the world in hydro development: hydro-electricity supplies about 24%* of present total primary energy and constitutes more than 60% of total electrical production. The provinces of British Columbia, Manitoba and Québec rely almost entirely on hydro power, while hydro supplies more than half of the electricity in Ontario and the Atlantic provinces. Only the two prairie provinces of Alberta and Saskatchewan rely primarily on other sources of electricity (mainly coal). Electrical consumption is expected to rise by some 20% over the next ten years as oil substitution programs take effect. A number of conventional hydro sites remain unexploited in British Columbia, Manitoba, Quebec and Newfoundland and could contribute to this growth. The Governmnent of Canada is encouraging such developments and, through the formation of the Lower Churchill Development Corporation is actively participating with the Government of Newfoundland in the future development of some 2300 MW of capacity in Labrador.

Generation facilities in Canada range in size up to the 5000 MW Churchill Falls project in Labrador, and the 10,200 MW James Bay development in Quebec. Many projects are in isolated locations, distant from population centres, so that Canadian expertise has developed in remote control techniques and sophisticated load forecasting, grid integration, and transmission technology,as well as in the development and manufacture of distribution systems designed to serve a wide variety of customers. Canadian firms and utilities (mainly provincially owned) have participated in hydro power development schemes in more than 30 countries, supplying generation and control equipment of their own design and manufacture, providing power planning and market analysis assistance, hydrological surveys and site feasibility studies, and offering support and training services for local personnel. Canada (Manitoba and Quebec) is recognised as a leader in transmission line technology, particularly very high voltage transmission.

2.5 Small Scale Hydro

There are relatively few smaller hydro sites (under 10 MW) operating in Canada today, and still fewer in the mini and micro hydro ranges· under 1 MW. However, rising fuel prices have spawned a number of studies of the power potential of small rivers in Canada, and preliminary estimates suggest that the potential may be above 67,000 MW installed capacity. The most promising locations are in remote, off-grid areas where small hydro can substitute for

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* based on 10,000 Btu/kwh primary equivalent.

local diesel generation (flying in the diesel fuel greatly increases its costs). A survey of British Columbia indicates that more than 50% of diesel-fired generation could be displaced in that province, saving (directly) some 250,000 barrels of fuel per year.

Some provincial utilities are already planning or installing small schemes, industrial firms are undertaking R&D to reduce equipment costs and government funded demonstration projects are being built to prove concepts and confirm performance: for example, a joint federal/provincial 425 KW demonstration is currently operating in Newfoundland, and a 150 KW unit in Ontario, and four federal/provincial high-head demonstrations ranging from 30 KW to 100 KW are under way in British Columbia. Most components are available from domestic manufacturers, and several Canadian firms report involvement in designing or installing small hydro facilities overseas. One firm has developed a prefabricated mini-hydro package which can be easily transported, and installed at a remote site with minimal preparation and skilled labour, and others are involved in the development and demonstration of micro hydro units in the 5-50 KW range.

For domestic sites, perhaps half would be technically and economically feasible for development at current diesel prices (based on a survey of British Columbia), and consideration is being given to government incentives under the oil substitution program. Equipment for sites of under 15 MW capacity is already classified in a category allowing a fast (2-year) tax write-off. In addition, a national inventory of sites is being prepared, and a Guidance Manual on survey procedures for feasibility studies of small hydro in remote communities has been produced by Canadian consulting firms with federal and provincial funding.

2.6 Geothermal Energy

Canada has considerable geothermal potential in two main areas: the sedimentary rocks of the prairies containing water at about 60-80°C, and the Rocky Mountains, where volcanic action brings rock temperatures into the 100° - 300°C range, within accessible drilling depths. Surveys are underway to locate and assess the potential of these localities, but there is no operating site in Canada and therefore no bank of private sector expertise.

Two demonstration projects have begun, with federal and provincial government assistance. The first, at the University of Regina, will supply 3-5 MW of 60°C water for space heating. A second, being developed by B.C. Hydro, is a proposal to build a 55 MW electrical generation site at

Meager Mountain in B.C. However this project is still in the exploration stage and no reservoir is yet confirmed. There is little private industry involvement in either project. Geothermal energy is regarded only as a long-term prospect for Canada.

The main Canadian capability that might be of interest to other countries in this area is in exploration and prospecting, where the considerable expertise and manufacturing abilities built up in the provision of services to the huge mining industry of Canada is readily adaptable to preliminary geothermal exploration (for example, airborne remote sensing, geophysical prospecting and drilling equipment).

A few smaller Canadian consulting firms have direct experience in geothermal resource assessment, gained both in Canada and in countries of South America and Africa.

2.7 Ocean energy, including tidal

The most important of the various types of ocean energy which may be tapped. (tidal, wave, ocean currents, thermal or salinity gradients) is for Canada. the tides of the Eastern seaboard. The Bay of Fundy, Nova Scotia, is one of the most technically promising tidal sites in North America. A feasibility study carried out in 1977, based on a barrage and turbine concept, indicated that supply costs of electricity from one possible site would be 3-4¢/kwh, about double those for conventional nuclear or coal-electric supply - suggesting that future trends in prices and technology might render exploitation economically competitive. The Nova Scotia Tidal Power Corporation, with federal government support, recently began construction of an 18 MW demonstration facility, which should be operational by 1983. The system to be used is a scaled up version of systems in use in European river hydroelectric developments.

It is unlikely that other areas of ocean energy will be exploited in Canada for many years. However, Canada is co-operating in a number of the International Energy Agency projects on large-scale wave generating system design; a Canadian firm which is expert in underwater pipeline technology is developing a small, dispersed wave system with units linked by underwater cables; another firm is experimenting with a novel system for harnessing currents. Canada has little present interest in thermal or salinity gradients. Federal R&D support and incentive programs are concentrated on other areas of renewables which show more short and medium term promise domestically.

Canadian skills in the area of ocean energy are thus based primarily on our expertise in the area of hydraulics and of very large engineering projects.

2.8 Wind Energy

Wind energy system applications are many and varied, and several technologies appear promising for Canada. The main opportunities in the short and medium term appear to be in (i) remote power systems for unmanned instruments and weather stations; (ii) remote communities, isolated from the grid, to back up diesel generation (c.f. small hydro); and (iii) large wind turbines for grid-connected generation. There is considerable activity in the latter area, including R&D and demonstration projects (both stand-alone and grid-coupled). A major wind resource assessment program is being carried out by the federal Atmospheric Environment Service.

The federal government is spending $26 million in energy R&D funds over the next five years for wind technology development by supporting, for example, special small applications (1-3 KW) in telecommunications; grid coupled field trials in collaboration with utilities (50 KW); development of a wind/diesel hybrid system; a 230 KW vertical axis turbine integrated with a small diesel fired grid in the Magdalen Island of Quebec (first operational in 1977); and a large grid coupled Eolus 4 MW vertical axis prototype wind turbine to be built after location on the St. Lawrence River in Québec, scheduled to be operational in 1983. The latter two projects are funded by the National Research Council and Hydro-Quebec in cooperation with the Aerospace Industry.

Canada is particularly involved in the development of vertical-axis wind turbines. Many such turbines are now in field trials and are also on test in other countries. In addition, other federal/provincial demonstrations are underway across the country, and an Atlantic Wind Test Site is being established in Prince Edward Island.

In the area of incentives, wind generators are exempt fom the 12% federal sales tax, and under the oil substitution program demonstrations of wind energy (among other renewable applications) will be funded in remote northern communities. In addition, studies by government are continuing on the potential for wind, industrial development strategy, and remote area deployment.

In developing areas, wind turbines have other important applications such as water pumping. There is little direct Canadian experience of developing country applications, although the Brace Research Institute has designed and operated wind turbines appropriate for rural tasks. However industrial capability for component production is good and could expand to meet the needs of foreign markets. Considerable expertise is available in wind monitoring, in planning and site selection, and in maintenance.

2.9 Solar Heating Applications

Despite its latitude and its harsh climate, there is considerable technical potential for solar thermal applications in Canada. Some applications however. although technically feasible, are not cost-effective at this time and will require a continuation of technological improvement and also higher prices of competitive fuels or technologies to make their implementation economically attractive.

Space heating provides the largest single requirement for energy in Canada: approximately 30% of the total annual energv requirment is for heating of homes, commercial buildings, factories etc. The use of so-called "passive" solar energy - i.e. solar gain through windows - is difficult to document, but it is virtually the only present contribution of solar energy to the national energy budget. Solar energy contributes perhaps 1.5% of annual household heating requirements. "Passive" solar heating is beginning to be an important aspect of building design. This is of course closely linked with energy conservation strategies for buildings. Because of its climate, and high space heating requirements, Canada has concentrated on the design and construction of extremely energy-efficient buildings, some using as little as 10% of the average consumption in existing conventional building.

Active solar heating is the most commonly recognised solar thermal application, including space and service water heating and industrial process heat. Active solar heating employs specific collectors (flat plate, evacuated tube, concentrators) incorporating a heat transfer medium (air water or other fluid) and possibly a storage system. Most of Canada's effort has been in the area of flat plate collectors using a liquid transfer medium, although there are a few manufacturers of other components. Several firms produce complete packaged systems.

Solar heating systems are not generally economic anywhere in Canada at present. Space heating has the great disadvantage of peaking during the period of lowest insolation, and this plus competing conservation measures, may severely limit future markets for solar space heating. For the provision of domestic hot water, solar systems may be cost-effective in areas where electricity is oil-generated (hence more costly). if they are owner-installed.

It is difficult to assess the total future contribution of active solar heating in Canada, because of technical and economic uncertainties. Discussions are continuing concerning the advisability of establishing solar contribution goals and associated cost goals for the next 20 years, toward which policy and programs may be directed.

Federal programs in this area began with the renewables R&D program in 1974, and in 1978 several new initiatives were designed to launch active solar heating technologies and support a developing solar industry in Canada. Further initiatives were added in the 1980 National Energy Program.

Current Federal programs in this area include R&D support, industrial assistance, demonstrations (in conjuction with provincial governments) and consumer incentives. For example,

- federal R&D expenditures are $11 million per year, covering product and systems development oriented mainly to provision of service hot water;

- Program of Assistance to Solar Equipment Manufacturers (PASEM) $(4.1 million over two years) which provided grants to solar industries to assist in designing and developing solar equipment;

- Purchase and Use of Solar Heating (PUSH) which calls for the procurement of $125 million of solar systems by the government for its own facilities;

- Renewable and conservation demonstration agreements with the provinces, which have resulted in expenditures of about $800,000 to date on solar heating, including a 100-unit demonstration of solar domestic hot water in B.C.;

- a 1000 unit demonstration across the country of domestic hot water systems, costing $5 million and including evaluating and monitoring of reliability and performance, and developing preliminary infrastructure;

- a fast (2 year) tax write-off for commercial and industrial solar heating installations;

- the applicability of the $800 off-oil grant (see above) to solar heating.

The Province of Ontario, under its new five year Solar Energy Strategy has recently announced a program to demonstrate and stimulate the market for solar systems, principally for hot water, by providing up to 90% of purchasing and installing costs in the commercial, industrial or institutional sectors.

There is a small group of solar industries in Canada, which is maturing with the experience gained under the above programs. The technical challenge is to achieve high performance, reliability and durability and minimal production costs. Canadian production capabilities for water heating far exceed domestic markets at the present time, and will likely continue to do so even with the consumer incentives under the NEP. Consequently several firms are actively exploring foreign markets, and adapting their equipment for tropical use and eventual local fabrication (with local partners). Canadian equipment successfully competes with that from other industrialised countries. Considerable scope exists for joint ventures with developing countries. As with other sources, expertise also exists in the areas of resource assessment, system design and program evaluation which could be transferred to other governments or local industries.

Some other special applications of solar energy exist, such as crop drying, where Canadian expertise and research could contribute to developing country uses, although fabrication would likely be local. Federally and provincially sponsored research encompassing different scales of application for different crops is going on, particularly in Saskatchewan and Ontario. The Brace Research Institute has compiled information on solar crop drying activities, with an emphasis on the needs of the developing world.

2.10 Photovoltaics

Electric generation using solar cells in Canada is limited, as in most countries, to very specialized applications in remote areas where reliability and maintenance-free operation is important, and the electrical load is small-e.g. for navigational aids, environmental monitoring devices, rail signals, and communications installations. Nevertheless, the speed with which technological developments are occurring in this area, and with which costs are falling, due to aggressive programs of R&D in several countries, means that photovoltaics can no longer be regarded as important only in the dim and distant future. Canada is following world developments closely, with a view to introducing programs at the appropriate time to prove and demonstrate this technology in broader applications, and to help develop markets (both domestic and overseas) for a fledgling Canadian industry.

Research and development, funded both privately and federally is occurring on a limited scale in Canada, on specific aspects of materials technology, cell and module fabrication, and system development. Proof of concept and demonstration experiments are beginning, in one case with considerable electrical utility involvement and funding.

Three Canadian firms are capable of producing cells (single crystal silicon) and modules on a relatively small scale, and both these firms and others are capable of designing and fabricating the remainder of the system. Many Canadian firms are interested in developing applications technology, and some have already become active in developing countries with for example, a unique water pump design. Canada also has acknowledged expertise in microelectronics and communications technology, making it uniquely suited to developing that particular photovoltaic application, which will be of special use in the developing world. In addition, there is considerable experience in engineering design and systems development in Canadian industry, which will be the most important aspect of photovoltaic applications once the present concentration on cell technology has reduced unit costs to an economically attractive level.

2.11 Biomass

Because of its immense forest resources, wood-based industries (including pulp and paper) are among the most important in Canada, generating about 8% of its gross domestic product. This, plus its vast primary agricultural interests, has put Canada in the forefront of much of the research, development and application activity that is concerned with the use of forest biomass, and wood and agricultural wastes, to produce energy and synthetic fuels.

Biomass now contributes perhaps 3.5% to total primary energy use in Canada. This comprises mainly the use of wastes in the forest and pulp and paper industries (for example, about 50% of the total mill wastes generated are used as fuel). There is also some use of fuelwood in the residential and other sectors. With rising energy prices and the present government programs available to encourage the use of wood and wood wastes, the total contribution of biomass is expected to increase to 6% of total energy by 1990.

Federal programs to encourage the use of biomass in Canada include R&D support, industrial assistance, demonstrations and consumer incentives. For example,

- Federal R&D expenditures are currently $7 million per year, with increases expected to cover expansion of effort in the producton of liquid fuels.

The major component is the Energy from the Forest (ENFOR) program, which finances innovative R&D on biomass energy issues such as improved forest productivity, soil fertility, harvesting technologies, improved combustion technologies including the use of fluidised bed systems, and associated environmental issues. In-house research at the Department of Energy, Mines and Resources includes combustion technology and performance testing of wood-burning appliances;

- Forest Industry Renewable Energy (FIRE) program, which provides direct financial incentives to any industry or commercial establishment to use wood wastes or other biomass resources instead of fossil fuels;

- Development and Demonstration of Resource and Energy Conservation Technology (DRECT) program funds the development of new technologies to produce energy from industrial and municipal wastes;

- the Federal-Provincial cost-shared demonstration agreements include biomass projects, with some 25% - 30% of the total funding going to demonstrations of technologies for biomass such as wood gasifiers and municipal waste burning equipment;

- the off-oil incentive grant under COSP will be available for conversion from oil to wood;

- the distribution system expansion funding under COSP may be applicable for the development of wood supply infrastructure and related issues.

As well as the direct combustion of biomass to produce heat and/or electricity, Canada is active in conversion technologies, including gasification and the production of fluid fuels such as ethanol and methanol. Canada has, however, many other options (oil sands and other non-conventional oil, propane, compressed natural gas, liquid fuels from coal) which may be more competitive economically. Biomass and wastes do have three important advantages: they are renewable (if properly managed); they are more evenly distributed across the country, thus helping to moderate problems of regional resource distribution; and they call for labour intensive operations and may therefore confer socio-economic benefits on remote/rural regions.

The following are some of the key areas in which Canada has expertise:

(i) <u>forest management</u> - many private firms in Canada are capable of providing the full range of forest management services. Some have been active internationally, particularly in the area of forest inventory studies (CIDA has financed such studies in over 20 countries). Many forestry students from other countries have gained their technical training in Canada. Forestry research is a very active area for governments and private institutions, particularly forest regeneration. The International Development Research Centre has supported research into the special problems and opportunities of tropical forests. Considerable practical expertise is available in the forest products industry, and a number of Canadian companies manufacture and distribute machinery for cutting, preparing, loading and transporting wood, including a very advanced mechanical tree harvester.

(ii) <u>rapid silvicultural/biomass production techniques</u> - the Ontario Ministry of Natural resources in cooperation with the Federal Government has developed a strong capability in the area of hybrid production using fast growing species such as hybrid poplar. 5000 acres of plantations are already under development and a major expansion of the program is planned. This will coincide with the selection of Canada to lead the IEA group on research in rapid silvicultural techniques and the establishment of a Biomass Technology Institute in Ontario.

(iii) <u>wood burning stoves for heating, cooking</u> - most Canadian equipment concentrates on heating rather than cooking. However the Brace Research Institute has developed a series of very inexpensive, efficient cooking stoves that burn sawdust, wood or dung, suitable for many developing country conditions.

(iv) <u>combustion boilers</u> - Canada is a world leader in the engineering, design and construction of energy recovery facilities using wood waste, and this expertise is increasingly being put to use in conversion of other biomass fuels. There are three major manufacturers who are already very active internationally.

(v) <u>gasification</u> - Canada has developed an advanced fluidised bed gasifier which is undergoing its first full-scale commercial trial at a plywood mill in Ontario, where it will burn mill waste. This technology produces gas for heat, and can be adapted to produce synthesis gas which can be used to produce liquid fuel (methanol). There are several other Canadian actors in wood gasification, including the B.C. Research Council.

(vi) anaerobic digestion - considerable research is underway in this area in Manitoba, Ontario and Quebec, for digestion of farm wastes and sewage. Canada's principal contribution would be in the development of this technology for operation under cold weather conditions.

(vii) alcohol fuels - Canada has enormous supply potential for methanol, from coal, natural gas or residual oil as well as biomass sources. The economics of large scale production favour coal or natural gas, but the advantages of renewability and wide distribution have sustained interest in biomass as a feedstock. The regional economic benefits have attracted some provinces to this option. In some locations, cheaper, more competitive biomass feedstocks are available.

Considerable research has been done in Canada on biomass-based production of methanol, particularly from synthesis gas produced by the fluidised bed gasification technique. The market in Canada however is currently limited by constraints on the use of methanol in engines designed for hydrocarbons, particularly in Canada's harsh climate. Further technological developments may resolve these problems. Because of its enormous supply potential Canada could become a leader in methanol technology, and could expand export markets for the fuel, and for technological expertise.

Less research has been done on ethanol or butanol from biomass, but the potential for major technical advances makes this now a very attractive option for Canada. Of the two main methods of hydrolysis, the basic process for producing ethanol or butanol, the enzymatic route shows greatest promise, and is advancing rapidly toward cost-effectiveness. Canadian firms have pioneered the development of an inexpensive pre-treatment process for lignocellulosic materials. Several private firms are active in this area, and government support of R&D is to be expanded. Cellulosics (wood) and wastes are the most likely candidates for feedstock: in Canada, agricultural crops tend to have a higher value as food or feed, although dedicated crops are grown for ethanol production in other countries. Canada now produces industrial grade ethanol from waste pulp liquor and has the potential for higher outputs from this source and from food processing wastes. With the rapidly advancing technologies of cellulose hydrolysis however, there is the potential for Canada to produce very large quantities of fuel grade ethanol from wood and other lignocellulosic feedstocks.

The province of Saskatchewan has recently announced the building of a 3 million gallon per year ethanol plant, using barley as a feedstock, as well as a feasibility study for a pilot plant to produce ethanol from lignocellulosics. The Province of Quebec, through its alternative energy corporation Nouveler, is financing the development of a methanol plant using gasified wood as feedstock.

Canadian expertise in beverage alcohol production including design of distilleries is considerable, and some of these companies are beginning to explore foreign markets for design and construction of fuel alcohol plants.

In Manitoba, a beverage distillery is being converted to produce ethanol from barley for gasoline blending. Manitoba has removed the provincial road tax on gasohol.

2.12 Peat

The resource base in Canada for peat is one of the largest in the world, but the development of this resource has not been pursued to any extent. There have been some studies on the feasibility of using peat for power generation in eastern Canada (New Brunswick), and Hydro-Quebec Research Institute (IREQ) has carried out feasibility studies on using gasified peat to produce electricity in remote areas where peat is abundant, and two thermal plants using gasified peat are at the final planning stage.

Harvesting peat is a particular problem in Canada because of the climate and environmental concerns, and some research is going on to find methods of harvesting throughout the year. In addition, some gasification R&D is being applied to peat, including fluidized bed combustion. In Newfoundland, which has no coal, the pulp and paper industry, with funding from the federal and provincial governments, is experimenting with the use of peat mixed with mill residues to fire steam boilers.

2.13 Conservation and Efficiency

Along with the development of oil supplies in Canada, and the substitution of domestic resources, including renewable energy, for oil demand, conservation and increased efficiency are key features of the National Energy Program and of the energy strategies of all provincial governments. Emphasis is on oil conservation, particularly in the eastern provinces, but programs are generally not commodity-specific and improved efficiency in the use of all types of energy is encouraged.

Energy demand patterns in Canada are changing, as industries and individuals respond to the steadily increasing prices. There are shifts to more efficient automobiles for example, and industrial efficiency in terms of energy use per dollar of product has increased significantly over the past few years. Government programs can facilitate this response and help to overcome some of the barriers to increased energy efficiency which exist in the market place. Many of these programs overlap to some extent with those encouraging the use of renewable energy: for example, increased use of wastes as an energy source is a conservation measure and, since biomass is usually involved, it is also a renewable resource. More efficient building design will normally incoporate the use of passive solar heating or cooling.

All provincial governments in Canada have conservation programs, as does the federal government. Programs encompass information dissemination to promote increased awareness, direct grants or other incentives to remove capital barriers or to increase rates of return, taxation measures, regulation, removal of disincentives to efficiency, research and development, technology demonstration, and in-house example.

The principal conservation programs (other than R&D support) of the federal government in Canada are:

A. <u>Building</u>

(i) The Canadian Home Insulation Program, which provides grants to householders to upgrade the efficiency of their homes by the addition of insulation and other measures;

(ii) a "super-retrofit" program, whereby the "off-oil" grant may be used in certain areas of the country for additional conservation measures;

(iii) a demonstration of new super-efficient housing design and construction, comprising 1000 units to be built across the country;

(iv) the development of new efficiency standards for Arctic housing;

(v) a program to assist municipalities to undertake energy conservation initiatives in their areas of responsibility;

(vi) demonstration of enhanced conservation and renewable energy systems in a selected remote arctic community;

(vii) programs of improved operating efficiency and retrofitting of federal buildings;

(viii) a program of mandatory energy use labelling of appliances.

B. Industry

(i) working with Industry on a Task Force basis to develop efficiency targets and ways of meeting them, and monitoring performance;

(ii) the very effective "Energy Bus" program, whereby computer equipped vehicles with a program developed to perform a detailed analysis of energy consumption, and manned by energy analysis experts, visit establishments across the country to assess energy demand and recommend methods of improving efficiency of energy use;

(iii) provision of funds (cost-shared) to assist industrial and commercial establishments to audit their energy consumption and implement measures to improve efficiency;

(iv) grants to firms in the Atlantic provinces to help finance energy conserving investments;

(v) a fast (2 year) write-off tax provision for firms investing in qualifying energy conserving or renewable energy equipment.

C. Transportation

(i) introduction of legislation to enforce fuel consumption standards for new motor vehicles (currently voluntary targets exist);

(ii) establishment of ride-sharing centres, support for driver education programs, and fuel economy programs in the trucking sector;

2.14 Summary of Main Areas of Canadian Expertise

The main areas of Canadian activity in the new and renewable energy field, and hence the main areas in which it can aid developing countries, relate both to the distribution of indigenous conventional and non-conventional resources of the country, and to the nature of its demand patterns. These in turn are dependent on the specifics of Canadian geography and climate, the size and structure of the economy, settlement patterns and behavioural characteristics. For example, the diversity of resources and of the opportunities available has encouraged development of energy planning and analysis expertise; the climate has led to development of special cold weather technology and emphasis on durability; the small size of the economy and its proximity to the immense resources of the U.S.A. has led to the specialization of Canadian firms; the concentration of population in Canada's southern regions, and dispersed and remote nature of northern communities has led to special consideration for small and highly reliable systems based on dispersed and therefore locally available resources. With several specific exceptions, the Canadian contribution to meeting developing country needs would focus on the transfer of knowledge and expertise, rather than the provision of hardware. Policy development, planning, resource assessment and technology assessment are key areas of relevant Canadian expertise. (Annex A outlines in more detail the most promising areas for Canadian contributions).

3. Application of New and Renewable Techologies in Developing Countries

3.1 Introduction

In developing countries, energy must be placed in the context of a strategy for national development. Many low income countries which are heavily dependent on imported energy could greatly benefit from the development of indigenous energy resources. While a justifiable pre-occupation of many policy makers is oil substitution in the commercial[1] energy sector, emphasis must also be given to non-commercial energy serving the rural areas where its availability will help to meet growing rural energy requirements for food production.

3.2 Supply and Demand

Developing countries without petroleum resources account for 49 percent of the world's population but consume only 9 percent of the world's commercial energy. Although the commercial energy consumption of these countries has been increasing rapidly, it was still only about 20 percent of the world average in 1973.

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(1) Commercial energy in this sense is oil, gas, electric power and coal produced in quantity at central plants and distributed over extensive networks and grids.

Commercial energy consumed in developing countries is overwhelmingly provided by oil products. For the developing world as a whole, in 1975, liquid fuels accounted for 61 percent and natural gas for 15 percent of the total commercial energy use. Rising costs have, however, severely restricted the ability of the developing countries to maintain imports and have contributed to delayed development and large balance of payments deficits. Real world prices for oil are projected to continue to increase. Simultaneously, reserve depletion and discovery rates for hydrocarbons indicate that production may peak around the turn of the century. Not only does this imply increased scarcity of hydrocarbon resources, but it also highlights the need to change to other energy sources.

There is clearly a link between increased GNP and increased commercial energy utilisation in developing economies. In 1977, the estimates of developing countries' rates of energy consumption growth, based on GNP projections, ranged from three to four percent. If growth is to be maintained, petroleum based energy sources must be augmented from alternative sources. The traditional non-commercial energy sources are also dwindling and cannot be expected to sustain the vastly expanded requirements.

Vast quantities of oil and natural gas are often used for the production of electricity for centralised systems. Hydro electric or geothermal generation can often be used to substitute for these hydrocarbons and installations can be of such a size as to have a major impact on the oil and gas requirements of the country concerned.

In the non-commercial subsector, wood, dung, and animal power constitute the main source of energy in rural areas of developing countries and charcoal is still used extensively in the cities. The short term possibilities of finding substitutes for them are limited. The replacement of such non-commercial fuels at present often implies a transition to kerosene which is itself becoming increasingly scarce and costly in foreign exchange. In the meantime, large-scale dependence on wood and dung has resulted in depletion of forests, soil erosion, desertification and a steady decline in crop yields.

Properly used, small and perhaps intermittent amounts of energy can be of critical value to the rural economy. Although the provision of such small amounts of energy is not, by itself, sufficient for the improvement of economic and social well-being, it is often a key factor.

3.3 Energy in the Context of Social and Economic Development

The centralised energy-supply systems for oil, gas and electricity that have evolved in conjunction with large scale, highly concentrated urban and industrial centres, have often proved to be inadequate for the needs of the rural populations and of the urban poor of developing countries.

Electricity is only one form of energy required for rural purposes and to the extent that it does not meet other rural energy needs, it is only a partial solution.

While centralised systems have played and will continue to play an important part in rural development, there is an undeniable requirement for attention to rural energy systems that would encompass all facets of rural energy supply problems and that would result in optimum matching of supply with demand, in which both large and small scale renewable systems will play their part. Interplay between the energy requirement and the type of energy source on the one hand and the social attitudes, the physical environment and economics on the other cannot be overstressed.

It is important to note, however, that generalized studies and models for rural areas are no more useful in real situations than purely technological studies. Any attempt to find a general model for all of these situations would be so full of generalities as to be of slight value to the specific micro-economies for which solutions must be found.

Of the wide range of technological options, only a few mav be of actual relevance in specific situations as regards local needs, aptness, capital costs, the absorptive capacity of the rural population and the reliability of technological hardware.

Renewable energy technologies are site specific and thus are not easily evaluated outside their context of use. Nevertheless, there is much optimism based on experiments and social response, that suitable technologies for the production of heat, mechanical and electrical energy from biological wastes and solar, biomass plantations, wind and water power are available and can be adopted for widespread application in rural areas in most developing countries. The geoclimatic conditions, levels of technological development and economic circumstances of the developing countries are often favourable for the application of one or the other of these technologies or of a combination of them. However, the aggregated environmental effects of multiple micro-energy projects, operating through environmental linkages can be large. Careful analysis is required to avoid creating new problems while ostensibly solving others.

In addition to the undoubted importance of the rural sector, centralised systems will continue to expand at increasing rates and supplies from major prime energy sources will be needed. Wherever bulk oil supplies might be augmented by local hydrocarbon production or by production of oil from shales or oil sands, the technical and economic feasibility should be studied as a high priority option.

The geothermal and hydraulic energy potential of each developing country should similarly be investigated through surveys and, if warranted, follow-up studies should be undertaken to reveal their competitive position as candidates to displace oil imports. Studies of this nature should range far beyond the normal socio-economic comparison of projects and reach into the heart of the developmental strategy of the country concerned. Indeed they may in some cases demand a regional approach involving neighbouring countries.

From the foregoing it is evident that the new and renewable energy techniques for the developing countries may be categorised in three distinct groups:

1) Those with potential for near term and significant impact on hydrocarbon demand. In this category, only the following techniques appear viable:

   a) Hydro electric schemes; and

   b) Improved energy efficiency.

2) Those with potential for significant impact on hydrocarbon demand in the medium term would appear to be:

   a) Geothermal energy (in limited situations);

   b) Oil sands and shale development (where available and economic);

   c) Biomass energy (plantations, combustion and large scale conversion systems);

   d) Solar energy for direct heat in concentrated commercial and industrial applications; and

e) Commercial and industrial energy efficiency schemes.

3) Those with potential for impact in isolated situations but demanding pilot projects, demonstrations, research work and social studies for their implementation. These projects could nonetheless start in pilot form in the immediate future:

a) Biomass energy (small scale conversion systems);

b) Wind energy systems;

c) Solar energy for use as direct heat;

d) Solar-electric power systems;

e) Village scale energy efficiency schemes; and

f) Tidal power systems (very few viable sites).

All the above techniques will probably be able to make significant contributions to the energy pool in the future years as the techniques are better developed and larger scale installations become technically and economically feasible. In the cases of smaller scale application, the social and human benefit may often be substantial even if its impact on hydrocarbon demand is negligible.

3.4 Energy Planning in Developing Countries

While much useful energy development has been able to proceed in the absence of integrated national energy planning, such planning is increasingly recognized as an integral part of any national economic, political, industrial and social development. In determining the nature of energy needs of developing countries, however, several issues need to be addressed.

3.4.1 Supply and Demand Assessment

Given a proper survey of a country's energy resources and a study of the environmental and social benefits and hazards involved in developing them a comparative energy analysis can commence. Such a comprehensive energy analysis is a prerequisite to establishing a national energy plan. This analysis would, ideally, include an assessment of both current and projected demand and available energy resources and technologies. The concept of performing such assessments is well under way in many developed and developing countries. Planning methodologies which are flexible enough to accommodate the needs and aspirations of individual countries need to be better developed. To accomplish the degree of flexibility required along with the necessary expertise often means strengthening existing institutions, creating new institutions where required, and ensuring that the numbers of qualified people necessary to operate in local circumstances are available. (See Annex B for an outline of tasks involved in integrated energy planning).

Although much of what is needed to be done to plan for a non-conventional fuel future for developing countries will have to be done by those countries themselves, there is considerable scope for mutually advantageous cooperation between some of them and developed countries. Common elements among certain developing countries make it not only possible but also desirable for them to co-operate, to share experiences and even to develop coordinated R and D programmes, both bilateral and multilateral.

3.4.2 Institutional Problems

The lack of energy delivery infrastructures in many developing countries constitutes a real constraint not only to the development of appropriate technologies but also to their extension and acceptance. Technologies that are of immediate relevance in developing countries are now available and, while improvements may be required in individual cases, especially to reduce production costs, the hardware for harnessing alternative energy sources is relatively well known and reliable. What is required is therefore an appropriate institutional infrastructure capable of planning and implementing a coordinated programme at all levels and of mobilizing community support for it at the economic levels where it would be implemented. An adequate institutional framework might include institutional capacities.

For surveying energy potentialities and planning;

For R and D to indentify appropriate technologies, to adapt available types to suit local conditions, to introduce innovations and to develop prototypes;

For field testing of prototypes for suitability as well as compatability with local customs and tastes;

For studying the competing demands on the resource base in order to provide the information needed for making sound development decisions;

For extension services;

For training technicians and villagers in the operation, maintenance and repair, as well as the local fabrication, of equipment;

For promoting and encouraging establishment of energy related industries and the commercial production of equipment;

For operating schemes of financial incentives, subsidies and assistance for both adoption by villagers and commercial production and marketing;

For sustaining the programmes at the village level.

In many developing countries the requisite institutional apparatus is either non-existent or inadequate. The planning machinery, R and D structure, extension and training agencies, manufacturing capacity and community institutions will gradually need to be established, augmented and oriented, both technologically and culturally, to the new strategy of integrated energy development. This strategy will require an integrated institutional approach involving political will to support it consistently, institutional arrangements to implement it and involvement of the people in order to sustain it.

3.4.3 Financial Incentives/Disincentives

Any scheme to develop alternative energy sources to meet developing country needs may have to be supported by a deliberate policy of incentives and disincentives. On the one hand, use of renewable energy supplies may often need to be encouraged consciously through a scheme of incentives, subsidies and assistance, not only for the application of alternative techologies but also for the commercial manufacture of the requisite equipment. On the other hand, the continued use of conventional hydrocarbon based sources of energy may have to be deliberately discouraged through a rational scheme of disincentives.

Based on these related considerations, which necessitate a reorientation of the strategy for energy supply, the Governments of developing countries might devise overall energy policies that include the following objectives:

1. Reduction of dependence on hydrocarbon imports;

2. Enhanced energy development in rural areas;

3. Increasing reliance on new and renewable sources of energy, with priority to suit local climates environments and resource potentials;

4. Concerted efforts to improve local knowledge of the availability and reliability of existing and new types of renewable energy installations with potential for local application and manufacture;

5. Technological adaptions and innovations, with special attention to the experience of other developing countries and to local raw materials, through continuous R and D.

3.4.4. The Technological Dimension

Apart from the well-known large scale hydro electric projects, the problem becomes one of

(a) identification of available technologies,

(b) testing them for suitability to local situations and for acceptability in relation to their economic and social costs and

(c) ensuring that the technological capacity exists to operate, maintain and repair the hardware involved and to manage resources within the environmental constraints that may exist and taking advantage of local environmental opportunities. The technological problems of adaption and innovation to match the available technologies and hardware with local circumstances may prove to be a serious constraint in many instances. However, these problems will need to be divided into manageable proportions and priorities established in terms of what is available for immediate application and what needs further R and D. The essential distinction between the generation of energy from non-conventional sources and its actual application must constantly be kept in view so that an excessive preoccupation with the problems of developing energy supplies from alternative sources will not overshadow the equally important technological problem of creating the necessary conditions for application of the type of energy thus made available.

A related technological problem would be fabrication of the requisite equipment. Among the salient considerations here would be: local availability of materials, indigenous manufacturing and design capacities, the degree of requirement for site-specific adaptations of the equipment and the comparative economic advantage of local regional production.

3.5 Opportunities for International Cooperation

The energy problems of developing countries are serious and complex, and demand urgent international attention. Individual country responses to the need for international action will vary significantly but there are opportunities for cooperation open to both developed and developing nations which must be pursued if renewable energy systems are to be put in place in the developing countries to relieve the present and future energy difficulties.

Programs will be required in renewable energy research, demonstration, promotion, financing, delivery and operational training to achieve the announced objective. Significant channels will be international assistance, trade, industrial cooperation, research and development cooperation and training at all levels.

The renewable energy programs in many developed countries are still in embryonic form. Indeed in some instances the renewable energy programs in the developing countries are already ahead of equivalent programs in the industrialized countries.

There is a need for collaborative research, development and training program leading to pilot projects and finally to larger scale projects in which aid and trade will be important factors.

The Canadian Government is anxious, in consultation with international agencies and developing countries, to make the best use of Canadian technolgy planning strengths, research capability, policy advice and management and training techniques to promote a more secure and lasting energy future for developed and developing countries.

The contribution of each country to an international cooperative effort will be based on its experience and expertise. In the area of new and renewable technologies, its resource base and previous technical experience will lead Canada to focus on the following five energy sources: (a) fossil fuels, (b) hydro-electric power. (c) biomass energy including firewood, (d) wind power and, (e) direct solar radiation. While the first of these will continue to play a key role for the foreseeable future, developing countries without these resources must import them. The other four have the advantage of being renewable.

Firewood

Firewood supplies most of the energy used in the rural areas of developing countries: typically 80 to 90 per cent and sometimes more of the total energy used. In many areas there is now an acute and growing shortage of firewood, with the attendant problems of deforestation and soil erosion. There is an urgent need to attack this problem. There are several approaches that are already in hand in many developing countries but the present effort is not strong enough to avoid the onset of actual crises in many countries in the Sahel, Nepal and others.

The following types of programs will continue to form part of the Canadian initiatives in this field.

i) To introduce ways and means of increasing the efficiency with which traditional fuels are used;

ii) To set up reforestation and afforestion programs and to attempt to increase yields;

iii) To rationalise firewood and charcoal supply industries;

iv) To check the feasibility of fuel delivery from remote locations and to implement viable systems;

v) To find substitute fuels or methods of displacing the need for firewood;

Biomass Energy Combustion and Conversion Systems

New sources of feedstock for all the principal processes for the conversion of biomass should be investigated, among them crop residues and aquatic plants. The types of loads which these systems might serve must also be identified. The International Development Research Centre in Canada has carried out a state-of-the-art study on biomass conversion systems; this review has drawn attention to the following recommended lines of research in relations to developing country needs:

(a) Investigation of new feedstocks, including crop residues and aquatic plants;

(b) Investigation of new microbial strains for anaerobic digesters;

(c) Study of the chemical engineering aspects of digesters in order to reduce cost;

(d) More investigation of the use of carbohydrates as feedstocks for fuel alcohol production (the inter-relationship between energy and food production must be carefully considered);

(e) Further development of small pyrolysis units;

(f) Investigation of effects of changing the flows of material that supply the nutrients essential to agriculture;

(g) Identification of immediate opportunities for installing large or multiple unit facilities in the developing countries using present technology.

Hydro-electric Power

There is little doubt that there will be a continuing and even expanding requirement for large hydro stations to feed urban, industrial and rural loads and thereby to assist in displacing hydrocarbon fuels. However, small-scale plants can also have an important role.

Canada is already routinely supplying for worldwide use small plants in the 1 - 10 MW range and is now on the threshold of having 100 - 1,000 KW mini or microhydro plants available.

Scope exists for machines to be designed for which maintenance requirements are low and a local manufacturing capability could be readily developed. The cost of extensive front-end studies to install small machines of this nature cannot be justified. Consequently Canada is investigating the possibility of setting up small hydro "satellite" projects in developing countries where large hydro projects are already underway and qualified staff is available. Installations may be supervised by N.G.O. groups, or university student volunteers working with local personnel under occasional guidance from the professionals on the larger projects.

Resources data in the form of hydrological and climatological surveys will continue to be needed and this information will form the basis for both large and small scale hydro power initiatives in the context of national energy planning. It will also allow water management and environmental aspects to be taken into account.

Wind Power

Many locations in the developing world are known to have the climatic conditions and local situations suitable for the installation of wind powered machines for pumping and mechanical or electric power drives. These types of projects do not seem to have been given high priority in many developing countries. While wind-powered machines are still in a state of development, there is undoubtedly great potential for demonstration programs with potential industrial spinoff. The first step would be to explore possibilities and interest in joint demonstration projects and proceed to implementation of such projects where circumstances warrant.

Direct Solar Radiation

The direct use of solar radiation is particularly appropriate to the climatic regimes of many developing countries, but in many areas there is a need for far better meteorological data collection and analysis systems, to assess the potential of this resource.

Flat-plate collectors: The priorities for the use of flat-plate collectors to supply low grade heat in developing countries are: hot water, particularly for process heat; provision of potable water; crop drying and cold storage for agricultural products. The basic difficulty that prevents their more widespread adoption is the cost of construction. Effort is therefore required in the development of low-cost materials, and an improvement of manufacturing techniques, particularly for water heaters which could result in lower construction costs. Larger production would assist in achieving economies of scale. Canadian units are now in service in several developing countries and Canadian sponsored factories in the developing countries have begun production.

Solar heat concentrators are needed to provide a source of high-grade heat that could be used for cooking. Canada is not heavily involved in work on concentrators.

Mechanical power (heat engines): Mechanical shaft power is now available from a number of solar-powered prototype engines. While these engines are satisfactory from a technical point of view, further development work is required to reduce their cost. Mechanical shaft or oscillating power is required for many applications, of which pumping is probably the most important.

Photovoltaic generation of electricity: Prototype generators are now available and undergoing field tests in a number of situations. As with mechanical power, the problem is one of cost, but substantial reductions are expected over the next few years.

Photovoltaic systems are especially appropriate for many developing countries: characteristics such as very low maintenance requirements and suitability for small-scale applications make them uniquely adaptable to rural areas and small village operation. Canada is particularly interested in their applications in communications technology.

Hybrid systems: There may be an advantage in using solar generators to provide both mechanical and electrical power to satisfy several different requirements. This could well result in an economically feasibly system. This possibility should be explored further. The Canadian Brace Institute has performed studies of these hybrid systems.

Industrial Cooperation

Among the more difficult problems for the developing countries in the introduction of renewable technologies are their cost and the need for adaption to local conditions. Both of these problems can be partly alleviated by manufacturing equipment locally using indigenous materials and local labour.

The key appears to be industrial cooperation programs whereby the industries would set up or assist in the setting up of local factories for the manufacture of renewable energy equipment. Obviously such a program touches on trade, aid, and R and D aspects of manufacturing. Encouragement can be given to industries to seek cooperative ventures in the developing countries by using incentive programmes such as the Canadian International Development Agency's Industrial Cooperation Program, designed for this specific purpose.

ANNEX A

The following are the most promising areas for a Canadian contribution to the international bank of knowledge and expertise in the areas of new and renewable energy:

A. General areas

- energy planning, systems development, integration of policies and objectives;
- resource assessment and characterisation (wind, hydro, solar, forest);
- remote applications;
- rural energy development;
- transportation/transmission;
- design of special appliances to meet specific or unique requirements;
- systems engineering;
- cold temperature operation and design;
- training in any of these general or specific areas.

B. Specific areas

(i) oil sands and heavy oils
- resource characterisation
- technology development and engineering
- operational experience
- tertiary recovery techniques

(ii) hydro-power (conventional and small)

- all aspects of conventional hydro, including planning, development, design, construction, supply of all equipment, remote control and monitoring, load managment, operation, environmental assessment, etc.
- small hydro resource assessment and feasibility studies
- general hydraulics and hydraulic engineering (in relation also to other applications such as tidal power)

(iii) wind

- resource assessment and monitoring
- vertical axis generators

(iv) solar thermal
- resource assessment, insolation monitoring
- low energy building design, including passive design techniques
- hardware supply, especially packaged systems (flat plate type) for domestic and service water heating
- joint ventures with local fabrication

(v) photovotaics

- systems design for special applications
- associated with communications technology
- systems engineering

(vi) biomass

- forest management, especially inventory estimation, reforestation, rapid silvicultural techniques, soil science and integrated utilisation of forest product
- combustion technology
- gasification technology
- alcohol fuels technology

Outline of tasks involved in integrated energy planning

At the national level, an energy planning program might include:

1) Strengthening the machinery for energy planning and policy making
2) Assessment of overall energy needs
3) Identification of types of energy required to suit each need
4) Identification of alternative resources and technological possibilities
5) Ecological and environmental studies to identify benefits and penalties
6) Identification of competing demands for basic energy resources and environmental priority
7) Matching of needs and energy resource options
8) Completion of any outstanding surveys for indigenous energy resources
9) Formulation of a comprehensive national policy on the utilization of various new and renewable energy source including decentralized systems as part of a comprehensive national energy policy
10) Formulation of a system of fiscal and monetary incentives, subsidies and assistance to encourage the use of alternative energy technologies and the commercialization of processes and prototypes as well as a system of disincentives to the continued use of conventional hydrocarbon energy sources
11) Intensification of applied R and D efforts in terms of extensive trials of available technologies and equipment to test their suitability

And, with particular reference to the rural sector:

12) Promotion of technologies and related equipment appropriate to local environment, social, economic, and developmental conditions
13) Establishment of adequate extension agencies to propagate approved technologies and to train villagers in the operation, maintenance and repair of the equipment used
14) Training villagers, wherever feasible, in the local fabrication of equipment using local materials
15) Identification of rural based community institutions to support and maintain the alternative energy technologies as well as to manage the production and distribution of energy at the grass-roots level

16) Establishment of a network of rural technology training for application of appropriate technologies, including alternative energy technologies and conversation in rural areas

17) Formulation and implementation of a planned afforestation programme, with special emphasis on programmes for the development of agro-forestry for small farmers.

18) Water management training programmes

19) Establishment of centres to advise on environmental matters and to perform continuous environmental monitoring