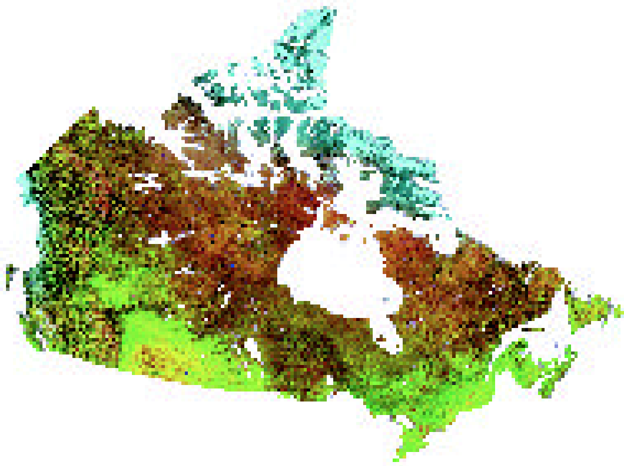

Renewable Energy in Canada
Status Report 2002

A National Report
prepared for the Renewable Energy Working Party (REWP)
of the International Energy Agency (IEA)

Natural Resources Canada
Ressources naturelles Canada

Canada

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March 2002

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Acknowledgements

We would like to thank all officers of the Renewable and Electrical Energy Division, Natural Resources Canada, for preparing a previous draft of the report *Renewable Energy in Canada - A Market Overview*, which served as the basis for this report. Similar information was also published under the report *Energy in Canada 2000* listed in the bibliography. Many specialists at Natural Resources Canada's CANMET Energy Technology Centre also provided valuable information and reviews on specific sections of the report. We thank them all.

Catalogue No.: M92-264/2002
ISBN: 0-662-67111-2

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Executive Summary

Canada currently derives 17 percent of its primary energy supply from renewable energy sources. This is a significant quantity of energy given the fact that total primary energy supply is about 11 Exajoules (EJ) annually. Hydroelectricity is the single most important source of renewable energy, accounting for about 11 percent of total primary energy and over 60 percent of electricity generation or about 342 000 GWh annually. Energy from biomass is the second largest source of renewable energy, accounting for about 6 percent (over 620 Petajoules/y) of total primary energy. Energy production from these sources has increased over the last decade. Hydroelectricity has increased by about 15 percent ten years ago and bioenergy has increased by 35 percent in the same period. Renewable energy from emerging technologies, such as energy from wastes, ethanol from grains and electricity from wind and photovoltaics are now starting to grow in importance. These latter technologies currently account for over 20 Petajoules/y of primary energy.

Bioenergy feedstocks include firewood and wood processing residues, landfill gas methane, municipal solid wastes, and industrial wastes and sewage biogas. A major application is the combustion of waste materials from the forest products industries to generate electricity, steam, and heat for their own use. On a smaller scale, residential space heating using wood and the recovery of landfill gas are additional sources of energy from biomass.

Active solar energy technologies have been deployed most cost effectively in low-temperature heating applications, such as domestic water heating, pool heating and pre-heating of commercial/industrial ventilation air. Over 12,000 residential solar hot-water systems and about 300 commercial/industrial systems are currently in operation. Other potential markets include solar heating for car wash water, residential swimming pool water, and seasonal systems at recreation sites.

The installed capacity of photovoltaic (PV) systems in Canada in 2000 was approximately 7.2 MW and is growing rapidly. The bulk of this capacity is for off-grid applications where PV is proven to be price competitive against grid-extension or conventional stand-alone power systems. Typical applications include: electric power for telecommunication systems; water pumping and purification; remote monitoring and control; and coast-guard lighting and beacon systems. At the same time, there is strong public interest in demonstrating PV on buildings.

Total installed capacity of wind turbines is growing rapidly as a result of strong public interest and new government incentives in response to climate change concerns. Current installed capacity is about 200 MW, with a projected annual energy generation in excess of 500 GWh. Under the new Wind Power Production Incentive program, the Government of Canada will provide financial support for the installation of 1000 MW of new wind energy capacity over the next five years.

Current forecasts indicate that hydroelectricity will grow to about 398 000 GWh by 2020, while other renewable energy forms, particularly bioenergy and wind, are also expected to grow significantly. The principal driving force will be the need for meeting the Kyoto targets of reduced CO_2 emissions by six percent below 1990 levels by 2010. Despite these increases, the renewable energy share of total primary energy production in Canada should remain relatively constant.

The principal barriers to extensive deployment of renewable energy technologies in Canada are economics and technology. However, there is a need for improved standards and regulations, and better education of the public on the value of using renewable energy.

Programs to assist research and development and commercialization of renewable energy have been in place for over 25 years, funded by various levels of government in response to defined policy objectives. The main funding organizations are the Office of Energy Research and Development for research and development (R&D) and the Renewable and Electrical Energy Division of Natural Resources Canada for market development. The main performer for energy R&D is the CANMET Energy Technology Centre at Natural Resources Canada.

1. Background

Energy from renewable sources has long been important in Canada, particularly prior to the turn of the twentieth century. For centuries, wood was used for heating and cooking, while water and the wind were initially used for mechanical power and later for electrical power as relevant technologies evolved. The term “renewable energy” refers to several energy sources that have little in common from a technology standpoint, but share one characteristic: they all produce electrical, thermal or mechanical energy without necessarily depleting the resources. Renewable energy sources generally include energy from water, biomass, wind, solar, earth, and wastes. Renewable energy technologies other than hydro and conventional combustion of biomass options are often referred to as “emerging” technologies. In this paper, “emerging” refers to energy from newer biomass technologies, wind, solar, earth and wastes.

All renewable energy technologies aim to substitute for conventional fuels in a sustainable and environmentally sound manner thus promising to maintain and improve the quality of life of present and future generations of Canadians. Because of our extensive geography, Canada has ample renewable resources that can be used for energy. They range from the use of wood for residential heating in rural Canada, to solar collectors for domestic and swimming pool water heating for middle class Canadians, to industrial process heat and steam from thermal plants using biomass residues, to electricity generation from hydro-electric projects across the country. In addition, newer technologies to generate electricity with wind turbines and solar photovoltaics, as well as biochemical and thermochemical processing of biomass for the production of gaseous and liquid fuels, are gaining importance and are the focus of recent interest.

Wood was the major energy source in Canada until the end of the nineteenth century (Table 1). In the twentieth century, the use of convenient fossil fuels led to the industrial revolution, urbanization and heavy use of transport. Although the use of wood declined during the first half of the twentieth century, the use of hydroelectricity rose quickly, contributing in large part to the electrification of Canada. Currently, renewable energy sources, primarily hydraulic and biomass such as fuel-wood and wood residues, account for about 17 percent of Canada’s primary energy and are an important economic activity for many parts of our society. These contributions put Canada among the world leaders, in terms of renewable energy production. Large-scale hydroelectricity constitutes the bulk of renewable energy supply in Canada and accounts for over 60 percent of total electricity generation. Biomass has doubled its contribution in the last 20 years to about six percent of the total primary energy. In short, renewable energy in Canada is a major business and is growing constantly with the introduction of new sources as technologies improve.

From an energy policy point of view, public interest in renewable resources emerged and grew during the oil supply crises of the 1970s and early 1980s. Canadians, like citizens of other International Energy Agency (IEA) member countries, have been keenly interested in renewable energy for a long time. Even though many Canadian provinces had been deriving most of their electricity from hydroelectric power, the first oil crises of the 1970s ignited a strong interest in all forms of renewable energy. In the late 1970s the Government of Canada and most provincial governments responded to the strong public interest for the substitution of oil and other fossil fuels with renewable energy sources. It was recognized at the time, through resource assessment surveys, that Canada had large physical reserves of biomass as well as ample potential of solar, wind, geothermal and other forms of sustainable energy to develop and commercialize. A number of initiatives were started then to research, develop, demonstrate and commercialize renewable energy technologies. Most Government of Canada expenditures in support of renewable energy occurred in the early 1980s, when it allocated about $100 million per year to expedite the development of technologies and encourage their market penetration.

Under the evolving policy objectives of “energy self-reliance”, “security of energy supplies”, “energy diversity”, “sustainable development”, “clean air” and “climate change” initiatives, the Canadian governments introduced many programs over the last few decades in support of renewable energy. These programs took the form of cost-sharing research, development and demonstrations for new energy technologies and, in some cases, fiscal measures that provided tax incentives to encourage the broad market penetration of renewable energy. Other related activities included informing the public about the merits of renewable energy, facilitating the development of standards and training tools, and streamlining regulations.

In addition to federal government resources, Canada’s ten provincial and two territorial governments play a key role in the development and commercialization of renewable energy. While federal jurisdiction on the energy market refers to international and inter-provincial trade and facilities, provincial governments are responsible for energy production and distribution within the province. Any regulatory initiatives to increase production must be undertaken at the provincial level. In the case of hydroelectricity, the provincial governments, through their hydro utilities, are the main players in developing and managing these resources. In the past, provincial programs for emerging renewable energy technologies usually complemented federal government efforts. They were aimed primarily at demonstration projects and/or consumer information initiatives. Although many provincial programs related to emerging renewable energy technologies have, for the most part been eliminated, a few provinces maintain some core expertise and programs. Being close to the local scene where projects are taking place, they continue to provide valuable assistance in terms of project selection, monitoring and dissemination of results.

Initial objectives for market share of emerging renewable energy in Canada were optimistic and successes were not always commensurate with expectations. The lack of quick breakthroughs in technology improvements, as well as the expanding availability of natural gas and low oil prices moderated expectations for quick market acceptance of new products, especially those based on emerging technologies. On the positive side, renewable energy in Canada has constantly grown in applications where it made economic sense, such as the use of biomass residues in thermal and electrical applications, solar heating of swimming pools, and innovative hydro projects (less than 20MW). New technologies developed through R&D and growing market acceptance include: the Canadian-designed Solarwall™ system which uses metal solar collectors that transfer heat to ventilation make-up; PV and small hybrid systems for off-grid applications; wind energy for utility-scale applications; and efficient wood stoves. A more complete description of these successes follows later.

Current overall impressions are that renewable energy is a viable energy source in a growing number of applications and offers many environmental benefits as well as increased local economic opportunities. As in many IEA member countries, Canada looks at renewable energy development and commercialization as one of the key drivers to help address Kyoto and other global environmental objectives. Many of the current programs in support of renewable energy in Canada are driven by realistic expectations, and the stakeholders involved have a better understanding of the timeframe required to perfect new technologies and compete in the marketplace.

Table 1

Percentage Share of Canada's Energy Consumption by Source

Year	Oil	Gas	Coal	Hydro-Electricity	Nuclear	Wood and Other
1871	0.5	0	11	0.0	0	88
1900	1	0.0	51	0	0.0	47
1920	6.8	0.4	75.0	1.5	0	16.3
1940	20.1	2.7	57.5	6.5	0	13.2
1960	54.4	13.2	16.9	10.8	0.0	4.7
1980	50.1	21.4	11.5	9.9	1.6	5.5
1997	39.5	28.1	12.2	11.4	2.8	6
1998	41.6	26.4	13.0	10.9	2.3	5.7
1999	41.7	26	12.8	11.0	2.5	6

2. Overview of the Renewable Energy Industry in Canada

Canada is a world leader in the production of renewable energy with about 17 percent of its primary energy supply coming from renewable sources. By comparison, the average for IEA member countries was six percent in 1996 (IEA report on the Evolving Renewable Energy Market). Canada's renewable energy production is primarily derived from two sources: water and wood.

Hydroelectricity from conventional large- and smaller-scale systems represents 11 percent of Canada's primary energy supply and is the dominant source of electricity in Canada, representing over 60 percent of total generation. Most of this hydroelectricity comes from large projects developed by electric utilities and, to a lesser extent, by various industries for their own use.

Generation by electric utilities and major industrial producers amounted to 341 944 GWh in 1999 with a plant-gate value, assuming a wholesale price of $0.03 per kilowatt hour (kWh), or about $10 billion. About one-tenth of this power is exported to the United States, either as firm or interruptible power, with an export value of about $1 billion. The remainder of Canada's renewable energy supply comes from conventional combustion of biomass and from sources considered to be emerging. Biomass energy provides a significant fraction (six percent) of Canada's primary energy supply, in the form of combustion of wood and wood derivatives for industrial process heat, generation of electricity, and space heating. Biomass from grains such as corn and wheat, and from waste streams containing sugar or starch is also used to generate ethanol for transportation purposes. Various emerging technologies based on biochemical and thermal conversion are being adapted to a wide range of biomass applications.

Other emerging renewable energy sources include wind for electricity production and mechanical power, earth heat for space and water heating and cooling using ground-source heat pumps, and the sun for both thermal energy and electricity generation. Small-scale independent hydroelectricity is considered by some to be emerging because the focus of hydro development during the second part of the twentieth century has been on large-scale projects. Technologies are also being developed to harness the power of low-head hydro resources, i.e. falls with a vertical drop of less than five to six meters. A priority in both areas is to minimize the ecological and environmental effects of energy projects by developing fish-friendly turbines and civil works.

Table 2 provides data on energy production by source. Statistics are available for hydroelectricity and the industrial use of biomass. However, the production of energy from many emerging sources is not measured by regular surveys. Thus, Table 2 provides estimates by technical experts working in these fields that are presented here for comparison purposes.

Table 2

Estimates of Primary Energy Production from Renewable Sources, 1990 and 1999				
	Electrical in GWh		Thermal in PJ (input)	
	1990	**1999**	**1990**	**1999**
Hydro	293 980	341 944		
Tidal	26	29		
Wind Electricity	<1	222+		
Solar Photovoltaics	<1	6+		
Biomass				
Industrial Pulp and Paper –Electricity from Wood Wastes and Spent Pulping Liquor	2099+	4767+		
Independent Power Production (IPP) –Electricity from Wood Wastes	189	1626		
Electricity from Landfill Sites	0	670+		
Electricity from Municipal Solid Wastes (MSW)	19	19		
Waste Water Treatment Plants	23	58		
Industrial Pulp and Paper – Heat from Wood Waste			376*	513*
Residential Space Heating			84	95
Thermal Energy from Landfill Sites			N/A	2.4
Thermal Energy from MSW				12.0
Ethanol from Biomass				4.1
Earth Energy Systems				1.0
Active Solar – Thermal (Water and Air)			0.1	1.1
Total Renewable Energy	296 338	349 341	460.1	628.6

+ Current generation is likely higher. Reported generation usually underestimates real activities because of the difficulty in differentiating between various fuels used as input.

* Total thermal energy in the fuel used. It includes the electrical output shown under 'Industrial Pulp and Paper'.

N/A: not available

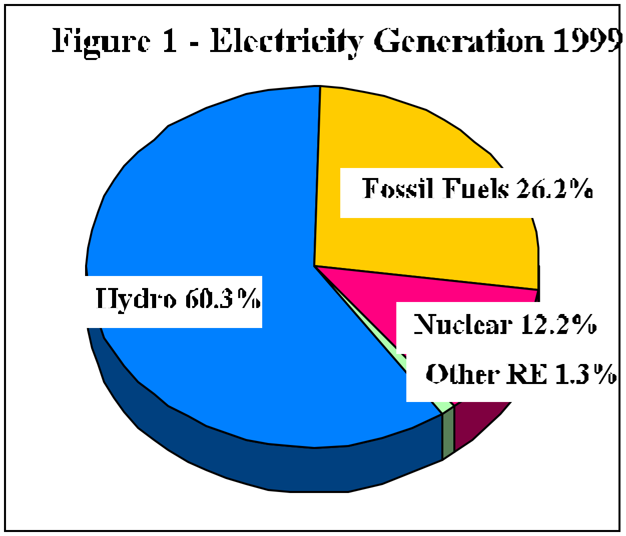
Source: *Renewable Energy Market Overview 2000*, Statistics Canada and others.

In 1999 the segment of the industry considered as emerging had gross revenues of about $1.4 billion, including $400 million in exports. It employed an estimated 3,700 Canadians. Sales and employment often vary substantially on a yearly basis, depending on the number and size of projects underway.

The segments of the emerging renewable energy industry with the best prospects for growth in the short to medium term, appear to be wind and photovoltaics. In addition to the improving economics of these options and growing niche markets, there is strong public interest that often results in additional policy initiatives supporting commercialization efforts. In the longer term, with improvements in technology and additional climate change related initiatives, there is great hope for both electricity and liquid fuel options from renewable energy.

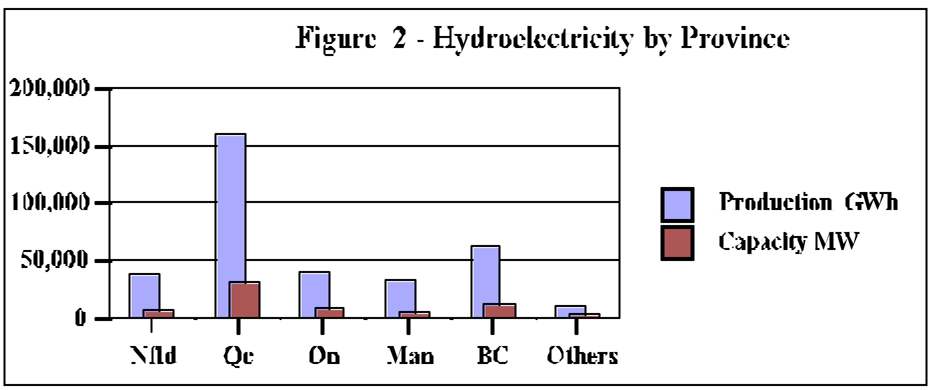
3. The Status and Potential by Energy Source

3.1 Hydroelectricity



Canada has abundant water resources and a geography that provides many opportunities to produce low-cost energy. Thus, it is no surprise that hydroelectricity has played a major role in the economic development of Canada. During the twentieth century, major hydroelectric projects were established throughout the country resulting in the current dominant position of this supply option.

As shown in Figure 1, hydroelectricity remains the dominant source of electricity (60.3 percent) in Canada, with fossil fuels and nuclear providing most of the balance. Canada is the world leader of hydroelectricity production with about 342 000 GWh/y, followed by the United States and Brazil. Installed capacity is over 67 GW, with a high capacity utilization rate of 50 percent due to large reservoirs. Proper management of reservoir water is important because most of the water is available in the spring from precipitation and melting of snow while peaks in demand occur in December and January for heating purposes.



As Figure 2 indicates, the bulk of this production is generated in about half of Canada's provinces, with Quebec leading. The largest producers are provincially owned electric utilities such as Hydro-Québec, BC Hydro, Newfoundland and Labrador Hydro, and Manitoba Hydro. These utilities have developed a series of large-scale hydro sites across the country. The La Grande complex on the Quebec side of James Bay is the largest hydroelectric development in the world, with a capacity of over 15 000 MW.

In addition to the provincial electrical utilities, several industries own and operate hydroelectric facilities for their own use. In many cases, this practice goes back to the first half of the twentieth century and pre-dates the general electrification of Canada by the electric utilities.

A more recent trend has been the development of an industry of independent power producers during the 1980s and 1990s as a result of gradual deregulation of the industry. These producers usually sell their power to electric utilities. They develop small-scale projects, usually in the 1 to 50 MW range, which help utilities match the growth in demand with small increments in capacity. This field presently accounts for about 1800 MW of installed generating capacity producing some 9000 GWh/y of energy.

Traditionally, the cost of generating hydroelectricity in Canada has been one of the lowest in the world. This allows for very low retail electricity prices, which benefit residential users and electricity-intensive industries, such as the aluminum industry. According to recent estimates, development of new hydroelectric sites could enable more low-cost electricity production ($0.03-$0.045 per kWh).

According to *Canada's Energy Outlook* (1997) and *Canada's Emissions Outlook: An Update* (1999), hydroelectricity production is estimated to increase by about 15 percent during 2000-2020 to 397 740 GWh/y. Increased generation is expected to come from a variety of projects in Quebec, British Columbia and Manitoba. The continuously increasing demand for electricity and the need for reducing greenhouse gas emissions, as well as the competitive cost of hydroelectricity, will undoubtedly contribute to significant additional growth in the future. In fact, Canada's federal and provincial energy and environment ministers concluded at their October 1998 meeting that hydroelectricity can play an essential role in Canada's domestic and international climate change strategy. For more information on hydroelectricity in Canada, please visit the Canadian Electricity Association web site at: www.canelect.ca

3.2 Tidal Power

The continuous movement of ocean water in the form of waves and tides embodies a huge amount of energy. However, to harvest this energy is quite challenging. One way to do so is to capture ocean water in reservoirs at high tide, and later release it through hydroelectric turbines as the tide ebbs. There are only a few tidal power plants around the world operating in this way. The largest is the 240 MW plant on the La Rance River in France. The second largest one is the Annapolis Tidal Generation Station in Nova Scotia, Canada, which has a capacity of 20 MW.

The bay area between Nova Scotia and New Brunswick is one of few places in the world where tides rise about 10 m high and occasionally as high as 16 m. Following feasibility studies on the potential for tidal power in the Bay of Fundy during the 1960s and 1970s, the Annapolis plant was built as a low-head demonstration project and started operations in 1984. The plant has an annual output of about 30 GWh/y.

Currently, extraction of energy from the tides is considered practical only where large tides and suitable geography provide favourable conditions for tidal plant construction. Estimates for world capacity range from a conservative 100 GW to as much as 1000 GW. In Canada, *potential* future supplies exist in several locations, and especially at three different sites in the Bay of Fundy considered the best economical potential with a total capacity of 8500 MW and an annual production of 22 000 GWh.

Environmental concerns, particularly the impact on migrating fish stocks, as well as the high capital costs of tidal sites and the need to synchronize tidal power production with utility system load requirements are key challenges that reduce the prospects of significant near-term development of tidal power.

3.3 Bioenergy

Biomass resources are widely available worldwide and provide a major share of renewable energy in most countries. In Canada, bioenergy provides six percent of primary energy, the second most important source of renewable energy after hydroelectricity. A major application is the combustion of waste materials from the forest products and pulp and paper industries to generate electricity, steam, and heat for their own use. On a smaller scale, residential space heating using fuel-wood, and landfill gas are other significant sources of bioenergy. Biomass feedstocks in Canada include: fuel-wood, wood processing residues (often called “hog fuel” in western Canada); landfill gases methane; municipal solid wastes (MSW); industrial wastes; and sewage biogas. There is also interest in developing additional energy supplies and liquid fuels from crop residues, short rotation energy plantations and agricultural crops such as willow, poplar, and switchgrass.

Table 3

Bioenergy Generation and Potential by Sub-technology						
Sub-technology	Current (1999-2000)		Physical Potential		Realistic Expansion by 2010	
	Electrical GWh	Thermal PJ	Electrical GWh	Thermal PJ	Electrical GWh	Thermal PJ
Forest Industry Related (hog fuel and spent pulp liquor)	6393*	513		Large		12-30
Residential Heating		95		Large		N/A
Energy from Wastes	747	14	1500	Large	600	N/A
Emerging Supply Options (crops, ethanol, etc.)		4.1	Large	Large		5+
Totals for Bioenergy	7140	626	1512+		600+	15-35

* Electrical energy generated from combustion of various residues. It is included in the 513 PJ reported in the next column for thermal energy derived from hog fuel and spent pulping liquor.

The contribution of the main bioenergy sub-technologies is shown in Table 3. Because of the extensive land base available in Canada, there is large physical *potential* for additional solid, gaseous and liquid fuels and chemicals, as well as electrical energy from biomass. The main barriers preventing the realization of this potential are the costs of capital for the initial equipment associated with bioenergy systems and the operating costs related to biomass fuels.
When all is considered, the final cost per unit of energy produced is often not competitive with the cost of useful energy produced from systems using fossil fuels. For example, compared to fossil fuels (oil and natural gas), wood and other agricultural sources have low energy density, and high collection, transportation and handling costs per unit of energy. Unlike fossil fuel utilities, they do not have a common fuel distribution infrastructure. Efforts to decrease these bioenergy supply costs could lead to a significant increase in the use of biomass in the future.

The industry involved in bioenergy activities is diverse. It includes manufacturers of boilers, wood stoves and other combustion appliances, manufactured fuels such as pellets and liquid fuels, as well as the large number of part-time suppliers of fuel wood. In total, there are several thousand people employed full-time or part-time in this industry.

3.3.1 Bioenergy from Forest Industry Activities

Energy from wood biomass often comes as a byproduct of Canada's many forest industry activities. For example, wood waste is produced in sawmills during the manufacturing of lumber, in furniture plants, doors and other millwork, and the production of pulp and paper and allied products. The wood waste produced is often in the form of bark, sawdust, planer shavings, pulping byproducts and others. It must be disposed of in the most economical and environmentally benign manner. In the past, much of this residue was combusted in special waste burners or dumped in piles and left to gradually decompose. The shortage of energy has brought about the development of modern bioenergy technologies that allow the handling and combustion of these residues for the generation of heat, steam and electricity. In many cases, surplus residue that is not needed at the site of production is shipped to other plants where it is used as a fuel. Commonly, the solid wood industries generate more residues than they can use for their own energy needs and they sell the surplus to either nearby pulp mills or independent power producers. The last two categories have large boilers that use their own residue plus purchased wastes and generate process heat, steam and electrical power with steam turbines.

The use of wood waste and spent pulping liquor by the Canadian forest industry amounted to 513 PJ of *thermal energy* in 1999. The single largest user of industrial biomass is the pulp and paper industry. In fact, half of the pulp and paper industry's energy needs are met with bioenergy. The second most important user of bioenergy is the sawmill industry, which often uses wood residues to heat lumber drying kilns.

In terms of *electrical energy*, the pulp and paper industry has about 1500 MW of electricity generating capacity in co-generation units. Typically, a plant has large boilers that are fueled with biomass wastes and other fuels such as fuel oil and natural gas. The steam produced is used to generate electricity in conventional steam turbines and the balance is then used for processes such as drying.

Beyond the pulp and paper industry, several *independent power producers* (IPP) were established in the last 20 years which generate electricity from the combustion of wood wastes usually obtained from sawmills eager to dispose of them. A dozen such plants in Canada with an installed capacity of about 128 MW produce electricity to sell to electric utilities. The largest plant, at William Lake, British Columbia, has a capacity of 66 MW.

Total electricity generation at both the pulp and paper and IPP sites is dependent on many operational factors. These include: the fluctuating capacity of the plants generating the residue; the operations of the residue users such as pulp and paper factories; and the price and availability of fossil fuels. The electricity production reported by Statistics Canada is fairly low considering the installed capacity (6000 to 7000 GWh). This seems to indicate either an erroneous system of reporting or a sporadic use of biomass for electricity generation in pulp and paper facilities.

Overall, it appears that the use of bioenergy in industry has increased by one-third over the last ten years. But the trend has been shifting recently because of lower energy prices and the recognition that the net delivered costs for new bioenergy systems are often higher than those using fossil fuels. The diminishing availability of inexpensive residues, and the high capital and operating costs, inherent to the nature of biofuels, as well as environmental constraints and regulatory uncertainties, have lessened interest in such projects in favor of energy efficiency
and/or switching to natural gas. The potential for expanded supply of bioenergy seems to have moderated.

Sector-specific analyses carried out in 1999 under the Climate Change Initiative to identify opportunities for reducing CO_2 and other emissions provided a much-needed analysis of options. These assessments, under fifteen Issue Tables, took the form of discussions by expert groups and developed Options Reports for each subject matter area. In the case of bioenergy from forest resources, it was concluded that, through the use of surplus sawmill residues, the contribution of bioenergy could increase by another 12-30 PJ. This potential new energy will probably be realized at co-generation facilities similar to those operating now, where inexpensive residues are combusted in large boilers generating both heat and electricity. This additional energy can only be realized either at higher energy prices or buy-back rates that take into consideration the environmental advantages of renewable energy. The projects being considered are at several sites in Quebec and western Canada, where there is sufficient concentration of residues and steady demand for low-grade heat.

It should also be noted that the above potential for future expansion of this option is dependent on technological developments within the forest industry. For example, it appears that the availability of residues from forestry operations has been declining in the last few years. Overall annual surplus residue has been estimated in 1999 at just over five million tonnes. The decline came about as a result of the increased use of the same residues within the forest industry (e.g. sawdust and low-grade chips) and for energy or in new processes and/or products such as new pulping technologies and medium density fiberboard. There is potential to bring additional logging residues in from the forest but the delivered costs for such fuels are not currently competitive with natural gas and petroleum products.

The Canadian Boiler Society is the association of the major boiler manufacturers usually involved with projects in this area. Information on their activities can be found at: www.canadianboilersociety.ca

3.3.2 Residential Space Heating with Wood

Using wood for residential space heating and cooking has a long history in Canada and around the world. While most Canadians now prefer the convenience of electricity and fuels like natural gas and fuel oil, wood heating remains part of the Canadian way of life. About one-third of Canadian households have wood burning equipment. The incidence of residential homes using fuel-wood is highest in Atlantic Canada (especially Newfoundland and Labrador) and lowest in the Prairies.

Home heating usually takes the form of stand-alone wood stoves, water or forced-air wood furnaces, fireplaces with advanced combustion inserts, high-efficiency fireplaces, and high-thermal-mass masonry heaters. Survey results show that there are over 1.5 million Canadians who use wood for home heating. Another 1.5 million households use wood as a secondary source of heating. Open fireplaces are also common in many older homes in Canada but are not considered here as heating applications. Round wood is usually the fuel of choice, but alternatives include wood chips and wood pellets. A significant portion of firewood is harvested and prepared by the end-user. The rest is usually supplied by small operators, such as farmers who own small wood lots, either as split firewood ready for use or as longer logs for final processing by the purchaser. Natural Resources Canada estimates the primary energy value of the wood used for residential space heating to be about 90 to 96 PJ/y.

Technology advancements over the past decade are making residential wood heating a more attractive proposition. New stoves using advanced catalytic combustion technologies minimize the amount of smoke and other air pollutants. Particulate emissions are reduced by about 80 percent relative to conventional stoves manufactured before the mid-eighties. The systems allow for a more complete combustion of the fuel and consequently provide more heat inside the house than conventional stoves. As well, the aesthetic appeal of new stoves has increased, as large ceramic glass windows allow the homeowner to view the flame without sacrificing efficiency.

In many circumstances, heating with wood makes good economic sense. Several factors are at play. The nearby availability of a low-cost high-quality fuelwood supply is important. The cost of conventional energy sources such as fuel oil, natural gas and electricity is another important factor. High fuel heating costs create a strong incentive for homeowners to use wood as a secondary heating source. An impediment to growth is the lack of large firewood suppliers as in the case of fuel oil, natural gas and electricity. Wood heating is not resource constrained. Canada has a large forest resource and only a marginal fraction of its exploitation is currently for energy purposes. There is potential for increased fuel-wood use in residences under higher conventional energy costs and/or improved fuel supply mechanisms.

In addition to home heating, wood is used for **commercial and institutional buildings**. However, there is no detailed data on this practice. There are a few biomass-based district energy systems in Canada. The largest is the 1.2 MW district heating system in Charlottetown, Prince Edward Island. In operation since the mid-1980s, the system is currently serving over 60 customers and 84 buildings using sawmill and other biomass wastes. In the village of the Oujé-Bougoumou Cree Nation of Quebec, a wood-fired heating plant has supplied both heat and hot water to all the buildings of the village since 1992.

There are numerous other biomass space heating applications, including farm use, rural stores, schools, hospitals, and government buildings. Most of these are of small capacity systems in the 50 to 300 kW range.

For more information on the use of wood for residential heating, please visit:
www.nrcan.gc.ca/es/erb/reed/wood

3.3.3 Energy from Wastes

Bioenergy derived from wastes is gaining momentum in Canada. Energy recovery from landfill sites, from biogas generated by various sources and from combustion of municipal solid wastes is proving to be the most sensible way of dealing with an environmental problem. Total energy generation from wastes is currently about 747 GWh (Table 3) with a potential to double over the next decade.

Landfill gas (LFG) generated at municipal waste landfill sites contains approximately 50 percent methane (CH_4) and 50 percent carbon dioxide (CO_2), plus some trace compounds. It is a major source of anthropogenic methane and accounts for 21 percent of Canada's methane emissions. Methane has a global warming potential 21 times higher than CO_2. There are two ways to manage LFG once it has been captured: it can be flared or used as an energy source. Flaring converts methane into CO_2, a lesser global warming gas. As well, it eliminates odour problems and destroys contaminants. When LFG is used for energy, it successfully deals with the problem and also conserves non-renewable sources of energy.

In 1999, 290 kilotonnes of methane were collected and either flared or used to produce energy in Canada. These practices reduced greenhouse gas (GHG) emissions by about six million tonnes of CO_2 equivalent (6Mt CO_{2e}), which has the same effect as taking 1.5 million cars off the road! About 97 percent of the methane captured for energy purposes was used to generate electricity for sale to electric utilities. Installed electrical generating capacity totalled 86.8 MW in 1999 which, assuming a 90 percent capacity utilisation, could produce about 670 GWh of electricity per year.

The *Climate Change Municipalities Table Options Report* confirmed that it is possible to double the amount of landfill gas captured at Canadian landfill sites, from 6 to 12 Mt/y of CO_2. Such a measure could encourage the generation of electricity from the captured gas, hence reducing the need for electricity generation from other sources.

Methane can also be produced by anaerobic fermentation during the treatment of sewage and industrial effluents. This process breaks down biological solids produced by a wastewater treatment system. Over 78 percent of Canadians are now using sewage systems connected to some type of wastewater treatment plant. In most cases, these plants use part of the methane production to heat their digester. In at least nine plants, the methane is used in a cogeneration mode. The total installed capacity is estimated at 17 MW with an estimated annual generation of 58 GWh.

For more information on this sector, please visit the web site of the Landfill Gas Industry Alliance: http://www.lfgindustry.org

An alternative to the landfill of municipal solid waste is direct combustion. About six municipal waste incinerators in Canada have energy recovery plants. These plants combust 1.2 million tonnes of municipal solid waste which has a primary energy content of 12.5 PJ. Some produce steam for sale to nearby industrial facilities. It is also possible to generate both steam and electricity in a cogeneration mode. After transformation losses, the energy produced by these plants is estimated at 6.3 PJ.

In Canada, the waste disposal practice has tended to be toward landfilling rather than combusting the waste because of the availability of land. Also, past incinerator projects have generated public concerns about air emissions, partly due to old incineration systems designed without proper pollution control equipment. However, this impediment should no longer be the case, as modern, properly run municipal incinerators have a long history of good performance and low air emissions.

While it is unclear whether new plants would be built in the near future, difficulties in securing new land for land-filling waste will likely lead to consideration of the energy recovery option. Many opportunities in this area are now being assessed under new programs announced by the Government of Canada under its climate change policies. The Green Municipal Funds Program has a budget of over $125 million to carry out assessments and assist projects that will help Canadian municipalities improve their infrastructure for better environmental practices. Several projects will address issues related to extraction of energy from wastes.

Crop residues from large cereal and canary seed operations in regions of southern Manitoba that have surplus straw are being combusted in bail burners on farms. It was estimated that the total Canadian agricultural residues available for energy contain the equivalent of several hundred PJ.

The Department of Agriculture and Agri-food Canada recognizes that animal litter (manure) from animal husbandry operations presents disposal problems and contributes about 3.4 percent of Canada's GHG emissions. If used properly, the heating value of dry manure ranges from 14 to 18 Gigajoules per tonne. The total available energy is 42 PJ/y.

3.3.4 Bioenergy for the Future

As mentioned earlier, because of the extensive land base and the available skills in both forestry and agriculture, Canada has the potential to develop much more of its energy needs from renewable biomass. **Biomass plantations** are sustainable sources of energy when the fuel is grown and harvested in a sustainable manner. During the 1980s, a number of experimental plantation sites were established in Canada for: the selection and testing of hardwood species and clones; the improvement of productivity through hybridization; and the genetic transformation and nitrogen fixation for many short rotation tree crops including willows and poplars. While these plantations have proven that the development of bioenergy crops could be feasible, no sale of energy has taken place as yet.

Similarly for agricultural crops, experimental plantations have been established and monitored with switchgrass and other grasses. Canada has over 20 million hectares suited to energy crops. However, the exact potential and energy crop plantation resource is yet to be determined. Although yields from such crops were impressive, there are many technology and economic issues remaining to be addressed. For a summary of activities under the ENergy from the FORests Program (ENFOR) visit the web site:
http://www.nrcan-rncan.gc.ca/cfs-scf/science/enfor/index_e.html

Ethanol produced from agricultural sources through fermentation and distillation can be blended with gasoline at concentrations of up to 10 percent ethanol and used in conventional internal combustion engines without any engine modifications. In Canada, there are currently about 1,000 service stations offering ethanol-blended gasoline at blends varying from five to ten percent ethanol, depending on the retailer and provincial requirements. In order to be used as a high proportion of the fuel content, or as the only fuel for a car, conventional car engines will need to be altered. Some North American car manufacturers are now offering vehicles that can use a blend of up to 85 percent ethanol in gasoline, called E85. However, there are no public E85 refueling stations. Natural Resources Canada has one of the few private E85 refueling stations feeding a fleet of departmental cars.

In Canada, five plants located in Manitoba, Saskatchewan and Ontario produce ethanol from corn or wheat for use as transportation fuel. Based on the installed production capacity in 1998, annual production of ethanol is estimated at 215 million litres. About 15 million litres annually are produced from pulping process wastes in Quebec. About 164 million litres/year of ethanol are used to blend into gasoline and represent an energy value of 4.1 PJ.

Several new ethanol plants are at the advanced planning stage. They include projects in Ontario, western Canada and Quebec. Should these projects proceed, the production of fuel ethanol would increase substantially, reaching about 500 million litres during the next few years. Along with the existing plants, the new plants would produce ethanol from grains such as corn and wheat. The process for producing ethanol from these starch-based feedstocks is mature from a technology point of view. However, the ethanol produced is currently not cost competitive with gasoline and it is made possible in part because of federal and provincial tax incentives.

In an effort to reduce the cost of producing ethanol to make it cost competitive with gasoline on a non-subsidised basis, research is underway to develop technologies for the production of ethanol from plentiful, low-cost cellulosic biomass such as wood or agricultural crop waste. Substantial savings would arise from the reduced cost of such feedstock. Technology being developed envisions "biorefineries" that use the raw material in an optimal manner to derive a wide range of fuels and chemicals. Current targets are for producing 200 to 400 million litres/year of ethanol from this source within 10 to 15 years at a cost equivalent to gasoline produced from oil at $32/barrel (approx. US$20/barrel).

For more information on ethanol activities in Canada, please visit the web site of the Canadian Renewable Fuels Association at: http://www.greenfuels.org

3.4 Geothermal Energy and Earth-Energy Systems (EES)

Truly geothermal energy from the earth's crust is found in several parts of Canada, especially in the western provinces. Following initial outlining of the resource for possible use of the steam for electrical generation, activities have stopped. In recent years, the term "geothermal or ground source" has been applied to an end-use technology for space-conditioning and domestic water heating. It incorporates piping systems to capture and upgrade through heat pumps, the heat from a ground or water source.

A geothermal heat pump or ground-coupled heat pump (GCHP) system uses the subsurface temperatures of solar-heated earth or water as a main heat source and sink in order to provide heating or cooling. Natural heat from the earth or water source is absorbed into a liquid, heat transfer medium circulating in buried pipes and carried to a building. It is then upgraded to a comfortable room temperature through a heat pump unit. When cooling is required, the system is reversed. Heat is returned to the cooler ground and/or water source and is again transferred back to the building where it is distributed at cooler temperatures. Ground source heat pumps use the earth or ground water as a source of heat in winter and as a "sink" for heat removed from indoor air in summer. For this reason, ground-source heat pumps have come to be known as "earth –energy systems (EES)".

EES are primary energy production devices. While they require electrical energy to power their loop and heat pumps, EES typically generate three to four units of energy output per unit of input. There are approximately 30,000 residential EES in Canada. Annual sales peaked in the early 1990s, primarily as a result of an Ontario Hydro incentive program. During that period, Ontario Hydro provided cash incentives for the residential installation of GSHP in areas not serviced with natural gas.

Sales of EES in Canada represent less than one percent of the total heating, ventilation and air conditioning (HVAC) market. According to a recent market development study carried out for the industry, there are 1,500 to 2,200 units sold and installed per year. About two-thirds are in the residential sector, mainly in new homes with the remainder in the commercial/ institutional sectors. Total installed value of these units is about $10 million. Most of this market is in the provinces of British Columbia, Ontario, Nova-Scotia, Manitoba and Quebec.

The main barriers to the rapid commercialisation of EES are economic. EES often have a higher capital cost than competing systems due to the installation of the underground loop. This may discourage potential buyers. However, operating and maintenance costs are greatly reduced and EES can be quite appealing when considered on a life-cycle basis. The economics of EES must be compared to alternatives for both heating and cooling. It is particularly attractive in areas where the costs of heating fuels and electricity for conventional cooling are high.

Other barriers include a general lack of familiarity with the technology, higher transactional costs due to inefficiencies in the marketing infrastructure, as well as a need for streamlining and harmonisation of standards and test procedures.

For more information on the EES option in Canada, including member companies, please visit the web site of the Earth Energy Society of Canada at: http://www.earthenergy.ca/conta.html

3.5 Electricity from Wind

Wind energy is the fastest growing renewable energy technology worldwide. It is almost universally considered the most promising technology for pollution-free electricity generation in the short to medium term. Technical advances combined with marketing innovations and low interest rate financing have combined to expand capacity from about 2000 MW in 1990 to over 20 000 MW in 2001. Current annual sales of wind turbines and associated equipment are over $5 billion. Recent installations are primarily in Europe because of higher electricity prices and national commitment to the Kyoto Protocol. In Denmark, 12 percent of national electricity supply is derived from wind, and Danish legislation demands an increase to 50 percent by 2020.

Canadian interest in wind as a source of energy was rekindled following the oil crises of the 1970s and 1980s. Early efforts to quantify the physical resource were based on existing meteorological data and predicted a potential of about 28 000 MW, which could meet 11 percent of Canadian electricity demand. These estimates were based on the potential proximity of wind farms to existing transmission lines. Local resource assessment studies carried out more recently suggest that the above early estimate may be conservative.

The first commercial Canadian wind project was established about ten years ago at Cowley Ridge, near Pincher Creek, in southern Alberta. The Cowley Ridge wind farm has since been doubled to over 40 MW and other installations in southern Alberta now total an additional 60 MW. In 1998/99 a 100 MW wind farm (Le Nordais) was built on the south shore of the St. Lawrence River on the Gaspé Peninsula in Quebec. The project comprises 134 turbines, each with a capacity of 750 kilowatts. Electricity production of about 300 000 MWh/y is sold to Hydro-Québec under a long-term contract paying a reported $0.058 per kWh.

In 2001, a 5 MW wind farm was commissioned on Prince Edward Island to utilise the strong winds of the Gulf of St. Lawrence. Suncor and Enbridge, two major fossil fuel organizations in Saskatchewan, are completing the 11 MW SunBridge wind farm near Gull Lake. The wind-generated power will be supplied by the province's electric utility, SaskPower, to federal government offices across the province. In June 2001, SaskPower announced the construction of a second wind farm in the province. This 5.3 MW wind farm will supply electricity to the Saskatchewan government's facilities and SaskPower's head office. Excess capacity will be offered to SaskPower customers. This should lead to a green power product option for all Saskatchewan residents and to more wind-generated power. The second wind farm should be running by August 2002. In Prince Edward Island, a similar Green Power Program is already underway (early 2002) with over 200 customers.

Several other individual large wind turbines were recently erected throughout Canada, often as forerunners at potential wind farm sites, bringing total installed capacity to about 200 MW with a projected annual energy generation in excess of 500 GWh.

To date, the uncertain nature of the Canadian wind energy market has inhibited the establishment of significant indigenous wind turbine manufacturing companies. Nevertheless, the current wind industry in Canada consists of about 50 firms, employing approximately 300 people and generating about $18 million in annual sales. With the increasing capacity of wind energy, these sales will increase quickly. Some manufacturing of small wind turbines and major components for utility-scale turbines is done in Canada, including towers, fibreglass blades, and all civil and electrical engineering work at site. With the introduction of new initiatives by the Government of Canada a few months ago, the Canadian wind energy industry is looking to the future with optimism.

Although the deployment of wind energy in Canada will continue to be influenced by our abundant, low-cost, traditional sources of electricity, the growing public and political concern for the environment and Canada's repeated commitments to meet Kyoto goals hold promise for increasing importance of this option. The concomitant industrial and societal benefits of sustainable indigenous energy supplies provide additional arguments for increased deployment of wind energy. In 2001, the Canadian Wind Energy Association released a plan proposing installation of 10 000 MW of wind electric generation capacity by 2010. In its latest budget, the federal government provided up to $260 million over 15 years as production incentives for wind-generated electricity. Details of the Wind Power Production Incentive Program are now being defined. However, the Government of Canada is expected to provide financial support for the installation of 1000 MW of new wind energy capacity over the next five years.

The federal and certain provincial governments have also committed to purchase portions of their in-house electricity from sustainable sources. Despite the turmoil of deregulation, several provincial utilities have shown strong interest in integrating wind energy into their generation mix. Wind energy may be offered to retail customers as a supply option, either as a result of deregulation in some provinces, or as a decision by a utility to offer consumers a choice. For example, Enmax, the City of Calgary electric utility, has been successful in offering wind energy on a premium basis to its residential customers since the fall of 1998. Hydro-Québec is also showing interest in the further development of wind energy. In its recent strategic plan (October 2001), it announced that purchases of wind-generated electricity may reach 50 MW/year by 2004 or 2005. The projected price for such purchases is of the order of $0.05-$0.06 per kWh. In parallel to the Hydro-Québec initiatives, the Quebec government budget of November 2001 announced further support for private sector-initiated wind projects that have the potential for job creation.

In addition to grid-coupled wind farm applications, there is a market for smaller wind turbines (less than 1MW) for integrated wind/diesel power plants in small communities beyond the main electricity networks. This requires that special considerations be given to operation in harsh northern climates, and to installation and maintenance procedures compatible with equipment and skills in these locations. Though important in terms of industrial activity and pollution reduction in remote areas, such applications do not contribute significantly to regional or national energy supplies.

Finally, there is a market for small, autonomous wind turbine systems for cottages, communications relay stations, navigational beacons and other similar applications.

As a result of strong public interest, improved economics and government incentives wind energy deployment in Canada should accelerate. Summaries of various wind energy activities in Canada as well as member companies are listed in the Canadian Wind Energy Association web site at: www.canwea.ca

3.6 Mechanical Power from Wind

In addition to generating electricity, wind is used in Canada for mechanical power. The most common application is for water pumping. Underground water can be pumped to the surface and stored in a basin, for example, to provide drinking water to cattle. There are several thousand water-pumping windmills, primarily in the Prairies. Another application is the use of windmills to aerate ponds and lakes.

3.7 Solar Energy

Contrary to common belief, the solar resource in Canada is generally very good and compares favourably with other regions of the world due, in part, to our clear sky climate. There are several technologies which exploit solar energy for specific purposes. These include active and passive solar energy for heating water and air, and photovoltaics for the generation of electricity. More information on the industry may be found at the Canadian Solar Industries Association web site at: www.cansia.ca

3.7.1 Active Solar Energy

Solar technologies that provide heat and hot water for residential, commercial and industrial use have a long history of commercial applications. Several million solar hot water systems have been installed worldwide. Historically, the United States, Japan, Israel and Australia have had the largest share of the solar thermal market. More recently, there has been significant growth in Europe and Asia. For example, Germany and Austria have a combined market of over 500 000 square meters (m^2) of solar thermal collectors annually, while over one million m^2 of solar thermal collectors are installed annually in China.

In Canada, the most cost-effective active solar energy technologies are those used for low-temperature heating applications, such as domestic water heating, pool heating and heating of ventilation air for commercial/industrial buildings. An estimated 606 000 m^2 of solar thermal collectors are currently in use in Canada of which 493 000 m^2 are used for residential pool heating, 72 000 m^2 are used for domestic hot water, and 41 000 m^2 are used for ventilation air heating for commercial/industrial buildings. There is also a small number of commercial solar water heating systems installed. Energy production from these systems is estimated at 1.1 PJ/y. Following the collapse of oil and gas prices in the mid-1980s and the termination of off-oil government programs, sales of new systems slowed down considerably. As a result of strong public interest, improved economics and government incentives, active solar deployment in Canada should accelerate. Presently, a few hundred new systems are installed annually, representing sales of $2-3 million.

The technical potential for active solar energy applications in Canada is large. According to studies carried out over the last several years, the potential market for solar domestic hot water, heating of swimming pools and ventilation air is as much as 135 PJ installed capacity. Allowing for a realistic market penetration of about ten percent of the above potential, under current and projected costs for solar heating, the projected market has been estimated at over 9 PJ installed capacity.

Residential water heating is a solar heating application that has recently received renewed interest in Canada from the private investment community, utilities and energy service providers. Water heating in Canada currently accounts for approximately 20 percent of the residential energy use, representing about 15 megatonnes of CO_2 emissions per year for an average of two tonnes of CO_2 per water heater. Solar water heaters can make a significant contribution to CO_2 emission reduction as each installation reduces conventional energy use by 40-50 percent. There are approximately 12,000 solar water heaters currently in use in Canada, representing less than one percent of the market. Market penetration has been limited to date primarily due to high cost. New, advanced low flow, solar water heaters planned for commercialization in 2002 should have a significant impact on the market. Through assistance from the Climate Change Action Fund (CCAF), utility partners should install about 100,000 units over the next 10-15 years, delivering energy at a cost to the consumer of approximately $0.05 per kWh, competitive with electricity and natural gas prices.

Pool heating is another application where solar technology should increase market share. More than 600,000 Canadian homes – about ten percent of the total low-rise housing stock – have outdoor swimming pools and approximately one-third of these are heated. Solar heaters currently have about ten percent market share, representing more than 20,000 units. The main barrier to increased market share has been the lack of awareness of the cost/benefits of solar heating. Recent studies in Canada concluded that solar pool heaters could provide the performance that pool owners desire and have a simple payback ranging from two to four years. The studies indicate that solar could capture 40-50 percent of the pool heating market in the long term. Test promotions during 2001 at three locations in Canada confirmed this potential.

Other water heating applications in Canada where solar technology is expected to gain market share include aquaculture process water heating (fish hatcheries) and car washes. There are approximately 1,500 car wash facilities across Canada consuming a total of 17 million m^3 of hot water per year (>2 PJ/y). There is a trend toward more touch-free facilities which use double the hot water compared with the more conventional friction type washes due to the use of warm water for both the wash and rinse cycles. Studies show that the solar heating for such car washes can result in payback periods ranging from five to seven years. A pilot project will begin in 2002 to demonstrate the use of solar heating at one of Canada's largest car washes operated by Sunoco.

In addition to solar hot water systems, the heating of ventilation or make-up air for industrial plants has proven to be one of the most cost-effective applications for active solar technology in Canada. Conserval Engineering Inc. continues to enjoy success in both domestic and international markets with its Solarwallä technology. Solarwallsä are unglazed perforated metal sheets that act as very efficient solar absorbers and are mounted vertically on south-facing walls of buildings like conventional wall cladding. This technology can meet up to one-third of a building's annual make-up air heating load and is easily retrofit to offices, apartments, warehouses and manufacturing plants. Clients to date include Ford, General Motors, Canadair, Bombardier, and Fedex. Annual sales have increased since the introduction of these systems in the early 1990s but are still below $1 million per year. The total surface area of Solarwallä installed in Canada is about 41,000 m^2, representing an annual energy production of about 0.1 PJ. The market in Canada for Solarwallsä was estimated in the 1993 report to be almost 4 PJ representing well over one million m^2.

The Solarwallä technology has also been targeted for international market applications, particularly for commercial drying applications. A major pilot project is underway under Canada's Climate Change Action Fund to demonstrate the technology in Central America, India, and China for various agriculture drying applications including coffee, fruit and spices.

Other applications for solar in Canada currently in the development stages include desiccant cooling systems for commercial applications where humidity control is important and solar detoxification incorporating advanced oxidation technologies which use ultraviolet light and a photocatalyst to treat organic contaminants in polluted wastewater streams.

The Canadian active solar industry is composed of about 20 companies involved in the manufacture of collectors and systems, and an estimated 24 dealers/installers. Total employment is estimated to be less than 100 – smaller than in the mid 1980s because the major solar demonstration programs ended and fossil fuel prices collapsed. The industry is now picking up as a result of renewed interest by the public and private investment community and government support for solar commercialization activities. It now appears that the industry has gone through the difficult adjustments of the 1980s and is poised to grow in a sustainable manner with cost-effective products in favorable niche markets. To help stimulate demand, Natural Resources Canada's Renewable Energy Deployment Initiative (REDI) encourages the use of active solar space heating systems in commercial businesses and federal facilities in Canada including a 25 percent rebate on qualifying systems. More information on this program may be found on page 32 of this report.

3.7.2 Passive Solar Energy

Passive solar technologies involve the design of buildings and employ special components for the purposes of space heating, day lighting and shading. Experience has shown that the most important building component used in passive solar applications in Canada is windows.
Advanced windows can actually be net energy suppliers with better net annual energy performance than the most tightly insulated walls. The Canadian market for high-performance windows in residential and light commercial applications is growing. About 40 percent of windows sold for such applications employ high-performance windows with low emissivity glass. The field of passive solar energy is usually considered an energy efficiency issue in Canada. Therefore, it is not described in detail in this section.

For more information on passive solar envelope designs, please visit the Buildings Group web site of CANMET/Natural Resources Canada at: http://buildingsgroup.nrcan.gc.ca/pub_e.html#Passive

The Canada Mortgage and Housing Corporation is also involved in energy-efficient designs: www.cmhc.ca

3.7.3 Solar Photovoltaics (PV)

Photovolaic systems use semi-conductor materials to convert sunlight into electricity. They are used in off-grid applications or connected to the grid. According to IEA reports, the world PV market has been expanding at the average rate of 20 percent per year over five years and accounts for over 1.3 GW installed capacity. In OECD countries, about 60 percent of the PV installations are for grid-connected applications while the rest are off-grid. Global annual sales are well over $3 billion.

The installed capacity of PV systems in Canada was approximately 7.2 MW in 2000, with an estimated annual production of 7.2 GWh of electricity. This is more than double the capacity and production of just three years ago. The bulk of this capacity is for off-grid applications where PV is proven to be price competitive against grid-extension or conventional stand-alone power systems. Typical applications include: electric power for telecommunication systems; remote monitoring and control; remote residential properties; coast-guard systems; and road signage for transportation.

Although PV costs have declined significantly over the past two decades, it is not yet price-competitive with conventional utility electricity. Achieving cost reductions through technological improvements and manufacturing automation is the industry’s main challenge.

Table 4

Installed PV Electricity Capacity in Canada (MW)	
1992	0.96
1993	1.24
1994	1.51
1995	1.86
1996	2.56
1997	3.38
1998	4.47
1999	5.826
2000	7.154
2001	8.5 (estimate)

The Canadian PV industry has grown steadily over the past few years, serving both domestic and export markets. In 2000, there were more than 150 businesses active in Canada, mostly system suppliers and installers. Approximately 12 companies are involved in manufacturing. The industry workforce totalled 250 and industry revenues reached $40 million in 2000. The industry installed 1.3 MW of new photovoltaic generation capacity in Canada, and an additional 0.2 MW in export markets. Domestic PV power sales have grown at an annual rate of 25 to 30 percent during the past six years. As the price of PV continues to decrease, growth should be sustained in coming years as current markets are further penetrated and new markets developed.

In addition to the cost-effective off-grid market for small systems, there is strong interest in promoting wider market demonstrations of PV in grid-connected applications in buildings. The phenomenal success in reducing the cost of PV technology by a factor of five over the last 20 years, coupled with strong public interest in solar energy, has led many Canadians to consider solar-generated electricity as a viable option for decentralised power. Governments are supporting an increasing number of demonstration projects in order to sensitise more Canadians to this clean and sustainable energy option and assist the local industry to gain valuable PV-building experience. Each kW of installed PV capacity will offset, on a life cycle basis, 1.6 tonne of CO_{2e} from coal, 1.3 tonne from diesel, and 0.73 tonne from natural gas-operating generating stations. Current efforts to promote the installation of 30 MW of PV systems in the built environment by 2010 could further strengthen the Canadian industry.

The Canadian Solar Industries Association represents the PV industry. Details on member companies may be seen at their web site at: www.cansia.ca

4. Outlook for the Future – Barriers and Policy Drivers

According to *Canada's Energy Outlook* prepared by Natural Resources Canada in 1997 and *Emissions Outlook: an Update* (1999), renewable energy production will continue to grow in Canada. Under the assumption of relatively stable energy prices and GDP growth of 2.3 percent per year between 2000 and 2010, hydroelectricity is predicted to grow to 382 650 GWh per year, an 11 percent increase. According to the same projections, it will grow to 397 740 GWh per year by 2020, an overall increase of about 15 percent over 2000 generation. Other renewable energy forms, particularly biomass and wind, are also expected to grow, but the projections are not firm. Despite these increases, the share of renewable energy of total primary energy production in Canada is predicted to remain relatively constant because of a parallel increase in conventional energy use, primarily natural gas. These forecasts were developed based on a business-as-usual scenario reflecting market conditions and government policies at that time, and do not reflect the Kyoto commitment to reduce greenhouse gas emissions.

At the time of preparing this report, there was still intense discussion at all levels on the issue of ratifying the Kyoto agreement. Nevertheless, it is safe to say that Canadians envision all renewable energy options as important players in the search for solutions to the emissions reduction objectives. Promising areas, in terms of both impact and marginal cost of reducing CO_2, appear to include energy efficiency and generation of non-hydrocarbon electricity (hydro, wind). Additional thermal energy could come from residues within the forest industry, energy from wastes, as well as from solar heating and earth energy.

In addition to climate change, it is argued in Canada that wide implementation of renewable energy will provide benefits to the economy in the longer term. It is often mentioned that many of the new technologies and products will provide local employment and other social benefits. Strong expertise in certain areas can help exports for goods and services. Canada already participates in many international forums for the development and commercialisation of renewable energy. More details on international co-operation are provided on page 35.

Most renewable energy options are considered technologically reliable and are being used successfully in Canada and around the world. Furthermore, these systems are considered cost-effective on a life-cycle basis in many niche markets. Nevertheless, several barriers and challenges restrict their rapid deployment in wider energy markets. These barriers include the following:

Prospective customers have limited knowledge about and experience with renewable energy systems. Preference is usually given to well-established, off-the-shelf space solutions that are perceived to be risk-free and affordable.

Negative experience with earlier renewable energy technologies may have tarnished the reputation of certain systems. For example, system reliability issues plagued some first generation technologies introduced in the late 1970s and early 1980s. In other cases, the promised financial savings did not materialize due to the drop in oil and gas prices in the mid-1980s.

Some renewable energy systems have higher purchase and installation costs compared to conventional technologies. Where construction budgets are predetermined, increasing the cost of the heating system, for example, would require cuts in other areas of the project. If the owner does not expect to pay for the future operating costs of the building, there is little incentive to minimize life-cycle costs.

Environmental benefits arising from renewable energy systems have not, so far, been considered in the decision-making process.

The long period of low energy prices in Canada created a climate of comfort with end-users, where little value is placed on moving away from conventional fuels to protect against future price increases.

Existing regulations on safety or environmental impact often hinder the implementation of new technologies. These are based on the performance of old technologies that have little in common with newer, cleaner and safer options. The renewable energy community is working hard to address these barriers through seminars and courses, and the development of standards and test procedures.

Finally, a common barrier in marketing renewable energy options is the lack of the relevant infrastructure associated with expertise, commercial channels of distribution and service.

5. Programs in Support of Renewable Energy

Various levels of government provide support for the development and commercialization of renewable energy in response to the policy objectives outlined above. Most support is in the form of financial incentives (usually cost sharing or project costs for research, development and demonstrations) or support to address other barriers. The level of assistance is usually small and aims to be just enough for the recipient to go ahead with the project. In some cases, the public funds are repayable.

An introduction to the programs in support of renewable energy may be seen at the Canadian Renewable Energy Network (CanREN) web site: http://www.canren.gc.ca/default_en.as

5.1 R&D Programs and Budgets

Assistance programs for research and development in renewable energy have been in place for over 25 years. The main funding organization is Natural Resources Canada through the federal Program of Energy Research and Development (PERD). In the mid-1980s, at the peak of energy R&D expenditures, the federal government's total budget for renewable energy was in excess of $40 million per year. Current support is of the order of $15 million annually. Table 5 shows the allocations by technology area.

The main component of this R&D effort is the Renewable Energy Technologies Program (RETP). It supports efforts by Canadian industry to develop and commercialize advanced renewable energy technologies such as active solar, wind power, bioenergy and small hydro that can serve as cost-effective and environmentally responsible alternatives to conventional energy generation. RETP's funding is repayable. More details on this program and references to sub-programs and related links may be found at the web site:
http://www.nrcan.gc.ca/es/etb/cetc/cetc01/htmldocs/funding_programs_retp_e.html

Table 5

Government of Canada Support for Renewable Energy Research and Development (C$ million)			
	Year		
Activities	1990	1995	1999
Total Solar	4.2	4.7	4.8
Solar heating and cooling	2.7	2.7	1.7
Photo electric	1.5	2.0	2.9
Thermal electric	0	0.0	0.2
Wind	1.4	1.5	2.2
Ocean	0	0.0	0.1
Biomass	6.7	7.7	6.0
Geothermal	0.2	0.1	0.1
Total Hydro	0.7	1.1	2.0
Large (capacity of 10 MW and above)	0	0.1	0.2
Small (less than 10 MW)	0.7	1.0	1.8
Total Renewable Energy Sources	13.2	15.1	15.2

The above funds are used internally within government laboratories that perform R&D, or within private-sector or institutional performers (university, provincial or industry laboratories).

Under its climate change initiatives, the federal government has announced a number of programs in support of renewable energy technology development and demonstration.
In the case of R&D, the main support program is Technology Early Action Measures (TEAM) under the Climate Change Action Fund. The program supports technology projects that hold the promise to reduce GHG emissions, nationally or internationally, while sustaining economic and social development. The program's objective is to help accelerate the demonstration and commercial deployment of new technologies. Proposed projects must be sponsored and co-funded by an existing government R&D program such as the RETP discussed above or another program (see below).

Examples of projects approved under this and related programs may be found in Appendix B of this report.

More details on climate change programs may be found at:
http://www.climatechange.gc.ca/english/index.shtml

The Industrial Research Assistance Program (IRAP) is a generic technology development program administered by the National Research Council. It provides assistance to small- and medium-sized companies to advance their technologies. For more details, please visit the following web site: http://www.nrc.ca/irap/aboutus.html#mandate

Another major generic technology development program that often provides assistance to renewable energy projects is Technology Partnerships Canada (TPC) administered by Industry Canada. It provides repayable financial assistance for the development of technologies directly associated with improved industrial processes. Support for environmental and sustainable alternatives is a program priority. More information on the program may be found at: http://strategis.ic.gc.ca/SSG/tp00170e.html

5.2 Commercialization Programs

The Renewable Energy and Electrical Division of Natural Resources Canada is the principal organization charged with promoting commercialization of renewable energy. It manages a number of government programs among them the Renewable Energy Deployment Initiative (REDI), associated programs for the purchase of green power and market development, and the Wind Power Production Incentive Program. A brief description of these programs follows:

Renewable Energy Capacity Building Program

An effective way to encourage the use of new cost-effective renewable energy sources is to provide decision-makers with technical information and related services. Under this program, an easy-to-use renewable energy project analysis software named RETScreen was developed. It has become the international standard in helping planners and decision-makers consider renewable energy projects at the critical early planning stages. For more information on RETScreen, please visit the web site: http://www.retscreen.gc.ca

Renewable Energy Deployment Initiative

The Renewable Energy Deployment Initiative (REDI) is a six-year $24 million program designed to stimulate market demand for commercially reliable, cost-effective renewable energy systems for heating and cooling. Under REDI, businesses and institutions may be eligible for an incentive if they install qualifying renewable energy systems including solar hot water, solar air heating and high efficiency biomass combustion systems. The incentive will cover 25 percent of the purchase and installation costs up to a maximum contribution of $80,000.

Under Climate Change Action Plan 2000, Natural Resources Canada announced a financial incentive for new renewable energy systems that targets the industrial sector. This represents a $2 million investment over five years to the end of March 2006. The incentive level for this measure is the same as that provided under the REDI program.

Wind Power Production Incentive

This 15-year, $260 million production incentive will support the construction of 1,000 MW of wind energy capacity during the next five years. Targeted consultations have started and final program details including eligibility criteria should be announced in Spring 2002. The incentive will be available for the first ten years of production and will help provide a long-term stable revenue source. This will result in more investments in wind energy projects in all regions of Canada to help address climate change and improve air quality. Provincial and territorial governments are encouraged to provide additional support for these wind energy investments.

Government Purchases of Electricity from Emerging Renewable Sources

Natural Resources Canada and Environment Canada purchase wind-generated electricity for their facilities in Alberta. This leads to an annual reduction in GHG emissions of about 11 kilotonnes. On behalf of the Government of Canada, Natural Resources Canada purchases wind-generated electricity in Saskatchewan and Prince Edward Island. The purchases lead to reductions of about 40 kilotonnes of GHG emissions annually.

In Climate Change Action Plan 2000, the Government of Canada committed to purchase 20 percent of federal electricity requirements from emerging low- or non-emitting renewable energy sources. This $30 million five-year program will help lower the Government of Canada's GHG emissions by about 235 kilotonnes annually.

Natural Resources Canada works in partnership with Public Works and Government Services Canada (PWGSC) and Environment Canada. As the lead department, PWGSC negotiates and signs purchase agreements. Natural Resources Canada provides renewable energy policy and market development capabilities, program analysis and evaluation. Environment Canada provides advice on environmental issues and program analysis support.

Market Incentive Program

The Government of Canada will provide a limited financial incentive to electricity retailers to stimulate sales of electricity from emerging renewable energy sources ("green" power). Details of this $25 million Climate Change Action Plan 2000 program have not yet been announced. A consultation process on the proposed elements of the Market Incentive Program will be held before finalizing it. With the help of this program, by 2010 the "green" power market could reduce GHG emissions by as much as 1700 kilotonnes per year.

Natural Resources Canada will develop green power market awareness, evaluate proposals, negotiate agreements, grant funds, report on the performance and effectiveness of the program, and conduct program analyses and evaluations. Environment Canada will develop environmental policies with

Natural Resources Canada, other federal departments, provinces and stakeholders. Environment Canada will also analyze the environmental benefits of the proposals. For more information on these and other related programs, please see: http://www.nrcan.gc.c.

In addition to the above, certain forms of renewable energy equipment generating electricity are also eligible for a faster than usual capital cost allowance treatment under the tax system. For example, the Class 43.1 Capital Class Allowance of the Income Tax act provides for an accelerated capital cost allowance of 30 percent per year on the declining balance of certain renewable energy and energy efficiency investments. In addition, the Canadian Renewable and Conservation Expense (CRCE) allows capital costs in certain new projects to be flowed through to investors using flow-through shares. Details of these incentives are provided in the *Class 43.1 Technical Guide* published by Natural Resources Canada. These include electrical generation technologies such as wind, small hydro, solar and others. Similarly, the excise tax on the ethanol component of blends of gasoline has been eliminated.

Under the Climate Change Action Fund and subsequent federal budget measures the Government of Canada announced several initiatives designed to provide assistance towards environmentally sustainable projects in specific sectors. Renewable energy commercialization projects are eligible for support under these programs. Some of the key elements are:

- Public Education and Outreach
- The Sustainable Development Technology Fund
- Green Municipal Enabling Fund – Federation of Canadian Municipalities (FCM)
- Green Municipal Investment Fund – FCM

A *Compendium of Federal and Provincial Government Initiatives* within the climate change effort was developed during a recent Joint Ministers of Energy and the Environment meeting. For details, visit the web site: http://www.nccp.ca/NCCP/joint_ministers/index_e.html

Several other government programs that aim to support industrial and regional development can also provide assistance to renewable energy projects that meet their criteria.

The Canada Foundation for Innovation (CFI) invests in infrastructure projects to support excellence in research at universities and non-profit institutions. More information is available at: http://www.innovation.gc.ca

6. International Cooperation Activities

Canada participates at the IEA Renewable Energy Working Party and the following Implementing Agreements related to renewable energy:

- Bioenergy
- Hydropower Technologies and Programmes
- Photovoltaic Power Systems
- Solar Heating and Cooling and several annexes,
- Wind Turbine Systems and several annexes
- Hydrogen

Canada also participates in other IEA agreements and annexes with programs related to renewable energy. They include programs under the following parties:

- Fossil Fuel (Fluidised Bed Combustion and others)
- End Use (Advanced Fuel Cells, Building and Community Systems, CADDET, Energy Storage, Energy Technology Data Exchange, Heat Pump Technologies, Pulp and Paper)

Bilateral Agreements

Under the Natural Resources Canada-United States Department of Energy Memorandum of Understanding (MOU) on Energy R&D, Canada cooperates with the U.S. in all fields of energy R&D except for nuclear fission and fusion. The MOU includes applied research, demonstrations, testing, technical information sharing, joint planning, exchange of researchers, and other related scientific activities. The R&D is carried out under implementing arrangements. Signed arrangements already provide for work in renewable energy subjects such as bioenergy, and microgeneration and communities. In addition to implementing arrangements, sectoral meetings are held to share information and to develop new cooperation on specific issues.

The APEC Expert Group on New and Renewable Technology Cooperation (EGNRET) is one of four expert groups under the Energy Working Group of APEC. It is the only group with a technology focus, covering renewable energy and some energy efficiency technologies. This expert group divided its work into eight “collaboratives”. Canada leads on Collaborative 7: Web-Based Technical and Related Information on Renewable Energy.

In 1995, the Canada-European Union Agreement on Scientific and Technological Cooperation established a reciprocal relationship that permits Canadian researchers and research organizations to participate in EU consortia conducting research and technology development under the auspices of the EU Framework Program. This agreement assures equivalent access for EU researchers to Canadian programs.

The current agreement (1998-2002) consists of four thematic programs that include sustainable industrial growth, energy and the environment. Two projects address technology issues related to the conversion of biomass to energy.

Other bilateral agreements allow for cooperation between Canada and other countries on technology implementation such as:

- Small Hydro Turbines (with Poland)
- Small Hydro Control Systems and Site Rehabilitation (China)
- Solar Crop Drying (Brazil)
- Natural Gas Vehicles (Romania)
- Waste Gasification (Spain)
- Biomass Gasification (China)

In addition, Canada and Mexico are exploring bilateral cooperation, while Canada, Mexico and the United States are exploring trilateral cooperation.

7. Conclusions

The main conclusions of this report are summarised as follows:

- Renewable energy has grown in importance in Canada over the last 20 years. It currently accounts for 17 percent of the total primary energy supply.
- Hydroelectricity is the single most important source of renewable energy with about 11 percent of the total primary energy supply or over 60 percent of total electricity supply.
- Bioenergy accounts for about six percent of total primary energy in applications within the forest industry, electricity generation and residential heating.
- Emerging new renewable energy technologies such as energy from wastes, low-head hydro and energy from wind are growing in importance in terms of future energy contributions.
- Solar technologies are growing commercial opportunities in niche markets such as solar air heating, swimming pool water heating and photovoltaics for electricity supply in off-grid and remote applications.
- In the longer term, there are hopes that the contribution of renewable energy for gaseous and liquid fuels will also increase through the development of new technologies that promise to improve supply economics.
- With increasing interest in sustainable sources of energy to address climate change issues, renewable energy should continue to grow in importance. Significant new contributions in energy supply are expected from hydroelectricity, biomass and wind energy in the medium and longer terms.
- Various levels of government in Canada are continuing their support for research, development and commercialization of renewable energy sources with the objective to overcome economic and other barriers hindering adoption of these options. Under the recently announced Wind Power Production Incentive Program, the Government of Canada will provide financial support for the installation of 1000 MW of new wind energy capacity over the next five years.
- The Canadian renewable energy industry and other stakeholders understand the challenges they face but also see the opportunities for expanded use of their products and services, and are working hard to realise the potential market rewards.

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Appendix A

Terms and Conversion Factors

The following abbreviations are commonly used:
K = kilo = 10^3
M = mega = 10^6
G = giga =10^9
T = tera = 10^{12}
P = peta = 10^{15}
E = exa = 1018

The watt is a unit of measurement used for electricity. It is used to express the generating capacity and, when expressed on a per hour basis, actual production. For example:

kWh = kilowatt per hour
GWh = gigawatt per hour
MW = megawatt

The joule is a unit of energy that is used to comparing different forms of energy. For example:

MJ = megajoule
GJ = gigajoule
PJ = petajoule

In the case of electricity, the following conversions are used:

1 kWh = 3.6 MJ
1 GWh = 3.6 PJ/1,000

All monetary estimates are in Canadian dollars. The exchange in early 2002 was $US=1.6$C

Appendix B

Examples of Renewable Energy Companies and Technology Development Projects

By searching the web sites of associations mentioned earlier under each technology, one can find a complete list of companies involved in each field. By way of example, we provide the names of a few companies involved in renewable energy in Canada.

Hydroelectricity

SNC - Lavalin, Montreal, Quebec (Engineering/Management)
ACRES International, Oakville, ON (Engineering/Management)
Many other companies can be identified through the CEA network.

Bioenergy

IOGEN Corporation, Ottawa, ON (Ethanol Technologies)
ENSYN Group Inc., Ottawa, ON (Thermochemical Conversion)
ENERKEM Technologies Inc, Sherbrooke, Quebec, (Thermochemical Conversion)

Solar Energy

Conserval Engineering, Downsview, ON (Solar Air Heating)
Thermo Dynamics Ltd, Dartmouth, NS (Active Solar Systems)
Arise Technologies, Waterloo, ON (Manufacturer/Distributor)
ATS Automation Tooling Systems, Cambridge, ON (PV Modules and Manufacturing Technologies)
NewSun Technologies, Ottawa, ON (PV Production Equipment)
Soltek Solar Energy Ltd, Victoria, BC (PV Dealer/Distributor)
Matrix Energy Systems, Kirkland, Quebec (Dealer/Distributor)

Wind Energy

Polymarin – Bolwell Composites, Huron Park, ON (Wind Turbine Blades)
Dutch Industries Ltd, Regina, Saskatchewan (Wind Powered Pumpers)
Vision Quest Windelectric, Inc., Pincher Creek, Alberta (Wind Power Developers)
Groupement Éolien Québécois, Gaspé, Quebec (Large Turbines)
Institut de recherche d'Hydro-Québec (IREQ), Varennes, Quebec (Technology Development),
Atlantic Wind Test Site, PEI (Wind Turbine Testing)

Examples of Technology Projects

Listed below are a few examples of technology development projects approved during the last two years under the Climate Change Technology Early Action Measures (TEAM) Program and related R&D programs such as the Program of Energy Research and Development (PERD):

Ethanol from Biomass Project

With its enzyme technology expertise, Iogen will produce ethanol at a lower cost than the grain ethanol currently employed in Canada, which only utilizes wheat or corn. Iogen anticipates this technology will lead to the widespread use of ten percent ethanol, blended with gasoline, as a motor vehicle fuel in Canada.

Turbine Power Generation System

Orenda is the first company in the world to successfully demonstrate the feasibility of a turbine power generation system for industry, which is capable of operating on liquid bio-oil fuel. This project will further advance the technology by developing and testing commercial-scale systems for engine operation on bio-fuel; redesigning and refining the combustion system; and developing specifications for a full commercial-level power generation system.

Green Diesel" from Biomass Pyrolysis Oil

To use Ensyn Technologies Inc.'s patented process to optimize and deploy a microemulsion technology that will allow bio-oils produced from the fast pyrolysis of cellulosic materials to be mixed with diesel. This bio-oil can be used for the production of heat and power, and as a ten percent blend in diesel fuel which would result in reduced greenhouse gas emissions.

Developing Photovoltaic Module Production Lines for Export

A project with Ontario based, ATS Automation Tooling Systems Inc. (ATS), to develop automated assembly lines to produce photovoltaic (PV) panels is underway. ATS will develop two production lines of varying degrees of automation.

Transfer of Small-Hydro Components to China

Powerbase Automation Systems Inc., will transfer its small automated turbine control unit to five small-hydro plants in China. Through improved energy efficiency and the displacement of energy produced by coal, the five demonstration sites will reduce carbon dioxide emissions by approximately 30 000 tonnes.

Nova Scotia Wind Energy Project

This project will show young Nova Scotians that wind energy could be a vital component in Canada's action to mitigate climate change and can be an important part of Nova Scotia's sustainable future.