National Energy Board | Office national de l'énergie

Emerging Technologies in **Electricity** Generation

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An **ENERGY MARKET ASSESSMENT** • March 2006

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FIGURES

TABLES

ACRONYMS

AEP	American Electric Power
AERI	Alberta Energy Research Institute
AMR	automated meter reading
AWTS	Atlantic Wind Test Site
BIPV	building-integrated photovoltaics
CAES	Compressed air energy storage
CanWEA	Canadian Wind Energy Association
CELA	Canadian Environmental Law Association
CES	Clean Energy Sources
CCA	capital cost allowance
CCPC	Canadian Clean Power Coalition
CDM	conservation and other forms of demand management
CELA	Canadian Environmental Law Association
CERI	Canadian Energy Research Institute
CETI	Clean Energy Transfer Initiative
HP	combined heat and power or co-generation
CIPEC	Canadian Industry Program for Energy Conservation
DC	direct current
DG	distributed generation
DOE	Department of Energy (New Brunswick, Ontario or U.S.)
DR	demand response
DSM	demand-side management
EER	Emerging Energy Research
ETS	Emission Trading Scheme
ELIIR	Extra Large Industrial Interruptible Rate
EMA	Energy Market Assessments
EnergyINet	Energy Innovation Network
EPRI	Electric Power Research Institute (U.S.)
EU	European Economic Union
G3	Genesee Phase 3
GDP	gross domestic product
GHG	green house gas
GSHP	ground source heat pump
HQD	Hydro-Québec Distribution
HVAC	heating, ventilation and air conditioning
IEA	International Energy Agency
IESO	Independent Electric System Operator
IGCC	Integrated Gasification Combined Cycle
IPPs	Independent Power Producers
LFE	Large Final Emitter
MOE	Ministry of Energy (Ontario)

NAIT	Northern Alberta Institute of Technology
NBSO	New Brunswick System Operator
NEB	National Energy Board
NEG/ECP	New England Governors/Eastern Canadian Premiers
NGL	natural gas liquids
NIMBY	Not in My Back Yard
NRCan	Natural Resources Canada
NSPI	Nova Scotia Power Inc.
OEB	Ontario Energy Board
OECD	Organisation for Economic Co-operation and Development
OEE	Office of Energy Efficiency
OPA	Ontario Power Authority
OREG	Ocean Renewable Energy Group
PEM	polymer electrolyte membrane
PV	photovoltaic
R&D	research and development
REDI	Renewable Energy Deployment Initiative
REI	request for expressions of interest
RFP	Request for Proposal
RPPI	Renewable Power Production Incentive
RPS	Renewable Portfolio Standard
RTP	real time pricing
SECA	Solid State Energy Conversion Alliance (U.S. DOE)
SEIS	Smart Energy Information Service
SOFC	solid oxide fuel cell
TOU	time-of-use
USGS	U.S. Geological Survey
YEC	Yukon Energy Corporation
WPPI	Wind Power Production Incentive

Abbreviations

Board	National Energy Board
CH_3OH	methanol
CH_4	methane
C_3H_8	propane
CO_2	carbon dioxide
H_2S	hydrogen sulfide
HYDRO	Newfoundland and Labrador Hydro
Maritime Electric	Maritime Electric Company Limited
NO_X	nitrogen oxides
Régie	Régie de l’énergie
SO_X	sulphur oxides
SO_2	sulphur dioxide

Energy Units

k	kilo	10^3
M	mega	10^6
G	giga	10^9

Voltage Measures

kV	kilovolt	= 10^3 volts

Power Measures

kW	kilowatt	= 10^3 watts
MW	megawatt	= 10^6 watts or 1 000 kW
GW	gigawatt	= 10^9 watts or 1 000 000 kW
TW	terawatt	= 10^{12} watts or 1 000 000 000 kW

Energy Measures

kW.h	kilowatt hour[1]	one kW for the period of one hour
MW.h	megawatt hour	one MW for the period of one hour or 1 000 kW.h
GW.h	gigawatt hour	one GW for the period of one hour or 1 000 000 kW.h
TW.h	terawatt hour	one TW for the period of one hour or 1 000 000 000 kW.h

1 A kilowatt hour is the amount of energy required to operate ten 100-watt light bulbs for an hour.

FOREWORD

The National Energy Board (the NEB or the Board) is an independent federal agency that regulates several aspects of Canada's energy industry. Its purpose is to promote safety and security, environmental protection and economic efficiency in the Canadian public interest within the mandate set by Parliament in the regulation of pipelines, energy development and trade. The Board has regulatory and advisory responsibilities. The main regulatory functions include regulating the construction and operation of pipelines that cross international or provincial borders, as well as tolls and tariffs; regulating international power lines and designated interprovincial power lines; and regulating natural gas imports and exports, oil, natural gas liquids and electricity exports, and some oil and gas exploration on frontier lands, particularly in Canada's North and certain offshore areas. The advisory responsibility includes keeping under review matters over which Parliament has jurisdiction relating to all aspects of energy supply, transmission and disposal of energy in and outside Canada.

The National Energy Board collects and analyses information about Canadian energy markets through regulatory processes and market monitoring. From these efforts, the Board produces publications, statistical reports and speeches that address various market aspects of Canada's energy commodities. The Energy Market Assessment (EMA) reports published by the Board provide analyses of the major energy commodities. Through these EMAs, Canadians are informed about the outlook for energy supplies in order to develop an understanding of the issues underlying energy-related decisions. In addition, policy makers are informed of the regulatory and related energy issues that need to be addressed. On this note, the Board has received feedback from a wide range of market participants across the country that the NEB has an important role and is in a unique position to provide objective, unbiased information to federal and provincial policy makers.

This report, *Emerging Technologies in Electricity Generation*, presents an assessment of those renewable and other emerging technologies that are thought to have significant promise and increasing application in Canada over the longer term. The report provides comprehensive information on the status and prospects for these technologies, related issues and regional perspectives.

During the preparation of this report, the NEB participated in a series of informal meetings and discussions with electric utility officials, independent power producers, provincial energy departments and regulators, power system operators, entities engaged in technology development, consumer groups and industry associations. This included on-site information gathering at wind farms, small hydro facilities, biomass and geothermal operations and other facilities relating to the technologies covered in this report. Overall, about 50 parties were consulted. The NEB appreciates the information and comments provided and would like to thank all participants for their time and expertise.

If a party wishes to rely on material from this report in any regulatory proceeding before the NEB, it may submit the material, just as it may submit any public document. Under these circumstances, the submitting party in effect adopts the material and that party could be required to answer questions pertaining to the material.

EXECUTIVE SUMMARY

The National Energy Board prepared this Energy Market Assessment as part of its regulatory mandate to monitor the supply of energy commodities in Canada, including electricity, and the demand for Canadian energy commodities in both domestic and export markets. *Emerging Technologies in Electricity Generation* addresses those renewable and other emerging technologies that are thought to have significant promise and increasing application over the longer term.

Interest in wind power, biomass, small hydro, geothermal energy, fuel cells, solar cells ocean energy and clean coal as credible energy sources continues to grow in Canada. The heightened interest reflects concerns about electricity supply adequacy in most jurisdictions, the interest in energy supply diversification, regional concerns about air quality and overall concerns about climate change. Some provinces and territories also see emerging technologies as tools to optimize the operation of existing electric power systems and as opportunities for regional and local economic development. Demand management programs are also included in the analysis, as these may be considered energy sources that can address the above-noted concerns.

The preparation of this report included the NEB participating in a series of informal meetings and discussions with electric utility officials, independent power producers, provincial energy departments and regulators, power system operators, entities engaged in technology development, consumer groups and industry associations. This included on-site information gathering at wind farms, small hydro facilities, biomass and geothermal operations and other facilities relating to the technologies covered in this report. Overall, about 50 parties were consulted.

Due to the geographic and resource diversity in Canada, regional trends and issues are analyzed. The findings reveal that wind power, small hydro and biomass technologies are well established, currently operational, relatively well known to the Canadian public and have good growth potential in the near term and longer term. For most other technologies, further cost reductions and better access to markets are required to improve their competitive standing compared with other generation options.

Emerging Technologies

Wind power experienced a record year in Canada in 2005 in terms of capacity expansion. Factors contributing to this accelerated growth include the establishment of provincial renewable portfolio standards, requests for proposals for wind and other renewables, the strong wind resources in many regions, and the relatively short construction lead times for wind projects. However, the intermittency of wind resources requires backup power or energy storage to ensure reliability. Economic access to existing transmission facilities is often a decisive factor for project siting and feasibility.

Small hydro is Canada's largest contributor to the green power sector, with close to 2 000 MW of installed capacity compared with about 684 MW of wind power.[2] It is a conceptually simple and

2 The definition of small hydro varies across the country, typically referring to projects of less than 25 MW and up to 50 MW in some provinces.

mature technology. Small hydro projects have low capital and low operating costs, although capital costs can range widely depending on the location and configuration of the project. Output from small hydro facilities is subject to seasonal fluctuations. In many jurisdictions, developers face challenges associated with site approval and environmental assessments that may be disproportionate to the project size, thus imposing costs and time delays for project proponents. Small hydro has good near-term and long-term prospects because of the large number of potential sites in Canada. However, development has been constrained by local public opposition usually centred on environmental concerns.

Biomass makes up Canada's second largest renewable energy source after small hydro. Currently, industrial cogeneration (the combined production of industrial process heat and electricity generation) is the most common method of biomass generation, mostly found in the pulp and paper industries. The prospect for biomass generation, also called biopower, has improved because of high natural gas prices, the shift away from coal-fired generation, limitations on new hydro development and intermittency issues associated with other renewable technologies. The potential for biomass generation from landfill gas, municipal waste and agricultural operations varies widely by region and its development may be constrained by its relatively high start-up and operating costs.

Geothermal power plants extract naturally occurring underground steam to power a conventional steam turbine and generating unit. Upfront investments are high, but fuel costs are low and operating and maintenance costs are competitive with other technologies. Once operational, geothermal generation is extremely reliable and is suitable for base load power. There is a project underway near Whistler, British Columbia to build Canada's first commercial geothermal power plant. The long-term prospects for this technology are limited because there are few high quality sites in Canada.

Solar photovoltaic (PV) cells or solar cells are made of semiconductor materials, such as silicon, and produce electricity directly from sunlight. They are well suited to distributed energy applications (i.e., energy generation at the point of consumption in residences, commercial buildings or in industrial applications). Photovoltaic technology is well proven, but advancements must be made to reduce costs enough for the technology to be cost competitive in the Canadian market. Further, barriers to distributed generation, such as restrictive or unclear grid connection standards, make it difficult to install modules.

Fuel cells are electrochemical devices that produce electricity by combining hydrogen and oxygen and also produce water and heat. Fuel cells operate at high efficiencies (approximately 40 to 50 percent) over a wide range of loads. They can be manufactured in a broad range of sizes (fully scalable) and are well suited to distributed generation applications. When the waste heat from a fuel cell is used, the system's efficiency increases to more than 80 percent. Technological breakthroughs are required before fuel cells can become competitive with other generation sources, suggesting it will likely be at least five years before fuel cells begin to reach the commercial stage.

Ocean energy in Canada, apart from the Annapolis, Nova Scotia tidal power plant, is at the early stages of development, with some time to go before there is commercial or near-commercial production. The best prospects on the west and east coasts are now tidal current and wave power.

Clean coal technologies refer to the methods by which emissions resulting from coal-fired generation can be reduced. With escalating concerns about global warming, efforts to develop clean coal technologies are focusing more on reducing emissions of carbon dioxide (CO_2). Alberta, the province most likely to build coal-fired generation because of its abundant coal resources, currently favours supercritical coal-fired technology. While less efficient than integrated coal gasification combined cycle (IGCC) it has lower capital costs and, at this time, is more reliable. Longer term, the development of CO_2 sequestration techniques would greatly improve the prospect for IGCC power generation by improving the acceptability of coal-fired plants and lowering costs. There appears to be growing interest in developing a CO_2 sequestration system and increasing the use of IGCC end-products in the petrochemical and oil sands industries.

Demand management includes demand-side management (DSM), specifically energy conservation and energy-efficiency, and demand response (DR), actions by consumers to reduce demand on short notice in response to a pricing incentive. Demand management offers benefits in terms of stabilizing prices, improving the reliability of electricity supply and providing environmental gains. Interest in DSM and DR is continuing to grow along side new renewable sources of generation. All provinces have some type of formal demand management in the form of DSM or DR programs. An important question is to what extent these measures can be deployed.

A summary of technologies appears in Table 1, indicating their costs and unique characteristics.

Regional Perspectives

The prospects for emerging technologies vary among the provinces and territories. While some technologies such as wind, small hydro and biomass are broadly available, others such as geothermal, ocean energy and clean coal are more limited, depending on regional resources and provincial government policies and strategies concerning fuel preferences. Solar photovoltaics is used in niche applications, either where alternatives are expensive (isolated areas) or as a complement to grid-supplied power.

Provincial initiatives encouraging the development of emerging technologies also vary, and include: issuing requests for proposals to industry (e.g., by utilities or provincial governments) to supply clean or green power; developing renewable portfolio standards (RPS) or provincial policy targets for generation from these sources; establishing demonstration projects (e.g., fuel cells, solar photovoltaics) and developing grid connection standards.

Observations

Currently, there is low penetration of emerging technologies in power generation.

Across Canada, about three percent of the installed generating capacity consists of emerging technologies. This is in part because of the low costs of electricity derived from conventional sources (e.g., large-scale hydro, coal, nuclear power and natural gas). To some extent, the low penetration of emerging technologies is also due to the structure of the industry in which large publicly owned utilities have historically opted for a model with large central generating stations.

Developments in energy markets have created the conditions for rapid growth in emerging technologies.

These include:

- the large increase in fossil fuel prices in recent years;
- most of the low-cost hydro sites have been developed and there is considerable public concern about further development of nuclear power;
- a move toward more competitive generation markets in many provinces;

- increasing public concern with air quality issues and the long-term impacts of greenhouse gas emissions; and
- the costs of many renewable technologies have been decreasing because of technology improvements.

TABLE 1

Illustrative Power Generation Costs – Emerging Technologies and Conventional Generation

Technology[1]	Cost Range ($/MW.h)	Unit/Plant Size[3]	Comments
Wind power	50-100	1-2 MW; wind farms of 50-150 MW	• relatively short installation time • intermittent nature requires back-up/supplement from other generation sources
Small hydro	40-150	less than 25 MW	• well established technology • may encounter NIMBY opposition • limited/no storage; therefore, intermittency can limit attractiveness
Biomass	40-150	10-50 MW	• wide variety of technologies and feedstocks, including forest industry waste, agriculture, municipal waste and landfill gas • base load capability
Geothermal energy	40-100	100-200 MW	• limited sites available • may have high grid connection costs, depending on location • base load capability
Solar PV	200-500	varies at consumer level	• expensive; intermittent • distributed generation (DG) and niche applications, especially where alternatives are high cost
Fuel Cells	100-150	1-100 MW	• still expensive; costs do not include all plant infrastructure • a technological breakthrough is necessary to achieve costs at the lower end of the range • niche applications; cogeneration and peaking capability
Ocean Energy (wave and tidal currents)	80-190	less than 1 MW	• costs are uncertain (based on limited number of commercial projects) • intermittent, but reasonably predictable (tidal currents) • DG applications in coastal areas
IGCC (excluding sequestration)	50-60	250-500 MW	• expensive compared with conventional coal • there are few commercial projects currently • "pure" CO_2 stream is favourable for sequestration
Demand Management	0-50	varies at customer level	• some measures are virtually costless, while others require significant investment • potential benefits not always perceived to be achievable, thus limiting the uptake
Conventional Technologies[2]			
Recent Power Pool	50-100	250-500 MW	• typical range of prices in the ON and AB competitive wholesale markets; prices set mainly by gas, coal and market conditions in adjacent markets (i.e., in the U.S. and other provinces)
Recent RFPs	78-80	100-200 MW	• proposals "accepted" by the Ontario Power Authority/Ontario Ministry of Energy for RFPs issued in 2004 (mainly natural gas-fired generation)
Heritage hydro	28-33	100s-1000s MW	• costs based on Québec (2.79¢/kW.h) and Ontario (3.3¢/kW.h)

1. Costs for wind, small hydro, biomass, geothermal power, solar PV and ocean energy are from CANMET (NRCan) and the IEA. Fuel cell costs are NEB estimates; IGCC costs are from Ontario MOE and CERI. The demand management costs are based on recent studies undertaken in the U.S. and in Ontario, as referenced in section 3.9.

2. Costs for conventional technologies are based on prices in the Ontario and Alberta competitive wholesale markets, and announced results for Ontario RFPs. Heritage hydro costs are announced costs in Québec and Ontario. In Québec, these costs refer to the first 165 TW.h produced per year and in Ontario refer mainly to the hydro assets of Ontario Power Generation.

3. Plant sizes are illustrative and not directly associated with the costs.

A number of mechanisms promote the development of emerging technologies.

Provincial mechanisms include issuing requests for proposals or "expressions of interest," establishing renewable portfolio standards, developing standard offer contracts for smaller wind and small-hydro contracts (similar to the feed-in tariffs used in Germany and Denmark), and net metering, which allows utility customers with generation to effectively sell power to the grid when their own generation is greater than their consumption.

At the federal level, incentives are directed toward wind and other renewables, such as the Wind Power Production Incentive (WPPI), Renewable Power Production Incentive (RPPI) and Renewable Energy Deployment Initiative (REDI). However, industry participants generally believe a comprehensive renewables strategy is required. Natural Resources Canada is working with the industry toward such a strategy. There are other incentives available through the income tax system, such as accelerated capital cost allowances, which reduce taxes payable.

Barriers constrain the development of emerging technologies.

A major consideration is that the external costs, or "negative externalities," associated with air pollution and other environmental costs are not included in electricity prices. If market prices did take these factors into account (i.e., external costs were "internalized"), it is suggested by many that emerging technologies would be more competitive and possibly even lower cost than conventional generation.

It is often pointed out that electricity rates do not reflect actual costs because they are based on historical costs and hence prices are below the cost of developing new generation.[3] This causes consumption to be higher and lessens the motivation to make electricity investments in emerging technologies. Levelling the uneven playing field created by different price treatment would further enhance the competitiveness of emerging technologies.

Another barrier faced by emerging technologies is access to the transmission grid. To a large extent, power systems are set up to connect large-scale generating stations to load centres via extensive transmission networks, enabling the centralized dispatch of power. The rules for connecting smaller, remote generators are often unclear or apparently restrictive. To some extent, these issues are being addressed, perhaps more so in those provincial markets that have completely opened their system to competition.

At the project level, emerging technologies often face many of the same issues for project approval as conventional generators, including the NIMBY effect. Thus their smaller size can make regulatory requirements relatively more burdensome. Also new project proponents may have not developed the expertise to deal with the regulatory process.

Demand management has the potential to make immediate and substantial contributions.

There is widespread recognition of the potential contribution demand management can make in Canada, and most provinces have programs in place to encourage reduction of overall demand and peak demand. These programs enable utilities to use existing infrastructure more efficiently and defer costly facility and infrastructure additions.

3 This phenomenon is often associated with low cost large-scale hydro projects. These "heritage assets" are used as policy instruments in several provinces to dampen or mitigate the costs of more expensive new generation.

Frequently, however, electricity consumers do not take advantage of current technologies that would enable energy efficiency savings. Lack of awareness and access to funding are two of the most often-cited barriers for greater DSM participation. Large power users, such as manufacturers, often do not participate in DR programs because they are uncertain about whether the economic benefits will be realised and some lack the operating flexibility to shift load between peak and off-peak periods.

Governments have tended to support the traditional sources of generation.

Electricity is an integral part of the lives of Canadians. Electricity is used to illuminate homes and buildings, control traffic signals, power computers and electronics, and provide heating and cooling. Recognizing the importance of electricity, provincial governments have always taken an active role in the electricity industry. Governments set standards for electricity facilities, put in place the necessary organizations to oversee infrastructure, and ensure a reliable supply of electricity is delivered to consumers at acceptable prices.

Governments have supported traditional forms of electricity generation in a variety of ways. In most jurisdictions across Canada, vertically-integrated Crown corporations developed a provincial electricity system comprised of large central generators. Federal and provincial guidelines were developed that were appropriate for traditional generation sources, especially large hydro, coal, nuclear, gas and oil plants. Large projects, such as nuclear reactors and hydro dams, received guaranteed financing from provincial governments and ensured project costs would be recovered.

Options for Action

Governments have long recognized the benefits of a secure electricity supply. Canadians must now determine appropriate sources of electricity generation in light of increased concerns about the adequacy of supply, fluctuating energy costs, and the environment. Emerging technologies for electric power generation can potentially provide significant benefits to Canadians by:

- helping to ensure adequate and reliable electricity supply by developing additional and more diversified supply sources;
- improving air quality; and
- reducing CO_2 emissions from electric power generation.

For these reasons, emerging technologies may be an important part of Canada's future electricity supply.

Investors in all projects seek to reduce risk and improve certainty. High risks are inherent in the development of emerging technologies that are new and do not have established track records. Long lead times, including research and development and other barriers, such as unclear rules for access to the grid and lengthy environmental approval processes, can exacerbate the risks.

If Canadians desire to encourage the development of emerging technologies, governments will need to take steps to reduce barriers (options 1 and 2), promote cooperation (options 3 and 4) and improve certainty (options 5-7). An appropriate role for government is to help create an investment environment that reduces risk and remove undue barriers. This is consistent with the role governments played in the past with traditional sources of electricity. The NEB recognizes that each province is in a unique situation and will implement policies appropriate for its circumstances. However, to encourage the development of emerging technologies, governments could consider the following options for action:

1. Adopt rules for access to the power transmission grid that facilitate the development of emerging technologies. Provincial governments could consider adopting clear and consistent rules that require grid operators to attach alternative sources to the grid. Governments could also require system operators to give priority status in generation dispatch to emerging technologies in order to increase certainty.

2. Ensure regulatory timelines are clear and application requirements are commensurate with the size and scope of the proposed project. If there are no rules for particular emerging technologies, these should be developed in order to establish appropriate requirements and provide clarity to investors.

3. Continue to support research into emerging technologies. Given the potential long-run benefits to Canada of developing these energy sources, it is appropriate that governments bear part of the costs of their development. A coordinated approach to research could help to avoid duplication and address gaps, which would advance the state of the technology more quickly and efficiently.

4. Encourage regional or interprovincial solutions. Sharing resources can capture synergies, for example between wind and hydro regimes. Emissions trading would enable fossil fuel based systems to achieve air quality goals more efficiently and allow jurisdictions with green technologies to expand production and capture the value associated with lower emissions (green premium).

5. Continue to provide financial incentives to emerging sources of power. The type of incentive should be appropriate to the stage of development. Production incentives, such as the WPPI and RPPI, can assist near-commercial technologies, while other less-developed technologies, such as fuel cells, ocean energy and clean coal, would benefit from R&D incentives.

6. Allow electricity prices to more closely reflect current market conditions. In many provinces, the regulatory regime shelters consumers from competitive prices, often based on the cost of heritage assets that were developed with government support. Governments could consider pricing regimes that would enable the development of emerging technologies. These technologies require higher prices than those paid for power generation from historical assets.

7. Guarantee minimum prices to electricity generated from emerging technologies, such as the current proposal for standard offer contracts in Ontario. Some environmental costs (externalities) associated with power generation are not reflected in market prices, so guaranteed minimum prices could provide an incentive to emerging technologies that have lower environmental impacts. There is considerable risk involved in developing these energy sources and, given the broader benefits of their development, it is appropriate that governments, on behalf of the public, bear some of the risks of their development.

Introduction

This report reviews emerging technologies in Canadian power generation. Interest in wind power, small-hydro, biomass, geothermal energy, fuel cells, solar cells, ocean energy and clean coal as credible energy sources continues to grow in Canada. This heightened interest reflects concerns about electricity supply adequacy in most jurisdictions, interest in energy supply diversification, concerns about regional air quality, and overall concerns about climate change. Some jurisdictions also see the potential for these emerging technologies to provide tools necessary to optimize operation of existing electric power systems and opportunities for economic, local and regional development. This report also analyzes demand management programs in Canada because they may be considered energy sources or close substitutes for electricity generation.

The main objectives of the report are to:

- provide a balanced, objective assessment of the prospects for emerging technologies in Canada that can be used as a standard of reference; and
- inform the Canadian public, industry, non-government organisations, and governments and regulators with energy interests.

The report focuses on the trends and issues surrounding those technologies in which there is currently significant interest and that could have noticeable impacts on the electric generation mix, on either a regional or national basis. The analysis does not undertake specific projections for emerging technologies. Such projections would be better discussed in a total energy framework, such as in the context of the Board's long-term energy outlook.[4]

1.1 Emerging Technologies in Context

Some parties advocate developing emerging technologies, specifically green or clean technologies, because "it's the right thing to do." Proponents of this approach may argue that society should not use methods of generating power that damage health or the environment when more benign methods of electricity are available. Therefore, public policies and energy strategies should support or encourage green technologies on principle, and perhaps regardless of the cost.

The Board's approach in this assessment is grounded on the basis that decisions on the future electric generation supply mix should, to the extent practical, be based on market principles and competitive outcomes. However, the analysis in this report identifies a number of barriers and challenges facing the development of emerging technologies. These barriers or challenges, which prevent fair, competitive outcomes, could be addressed through policy initiatives that enhance or define the role of emerging technologies in electricity generation.

4 Refer to *Canada's Energy Future, Scenarios for Supply and Demand to 2025*, 2003

Another obstacle to competitive outcomes is that, with some exceptions, there is substantial regulation of electricity markets across Canada and provincial pricing policies are the result of social considerations, not purely economic decisions. The outcome is that consumers usually pay less for electricity than they would in competitive markets. Even if markets were completely open and competitive, some costs would still not be reflected in prices (e.g., environmental costs associated with generating electricity from fossil fuels). Not reflecting these costs or "negative externalities" in market prices has two potential impacts:

- it encourages over-consumption of the commodity, in this case electricity; and
- it discourages the development of emerging technologies, which may have higher project costs, but lower environmental costs.

It is generally accepted that if prices captured (or internalised) the externalities, the cost difference between conventional and emerging technologies would be reduced, removed, or reversed. This concept has important policy implications from the standpoint of actions that might be taken.

The Board has put forward in this report a number of options for action, which would reduce the obstacles to competitive outcomes. In formulating these options the Board is not advocating particular technologies either as a group, such as renewables, or individually, such as clean coal.

1.2 Report Content

The remainder of this report includes the following chapters:

- Chapter 2 provides an overview of emerging technologies, including international perspectives and recent trends in Canada along with overarching issues;
- Chapter 3 documents the assessment of nine emerging technologies;
- Chapter 4 provides an overview of provincial programs, strategies and prospects; and
- Chapter 5 contains overall observations and options for action.

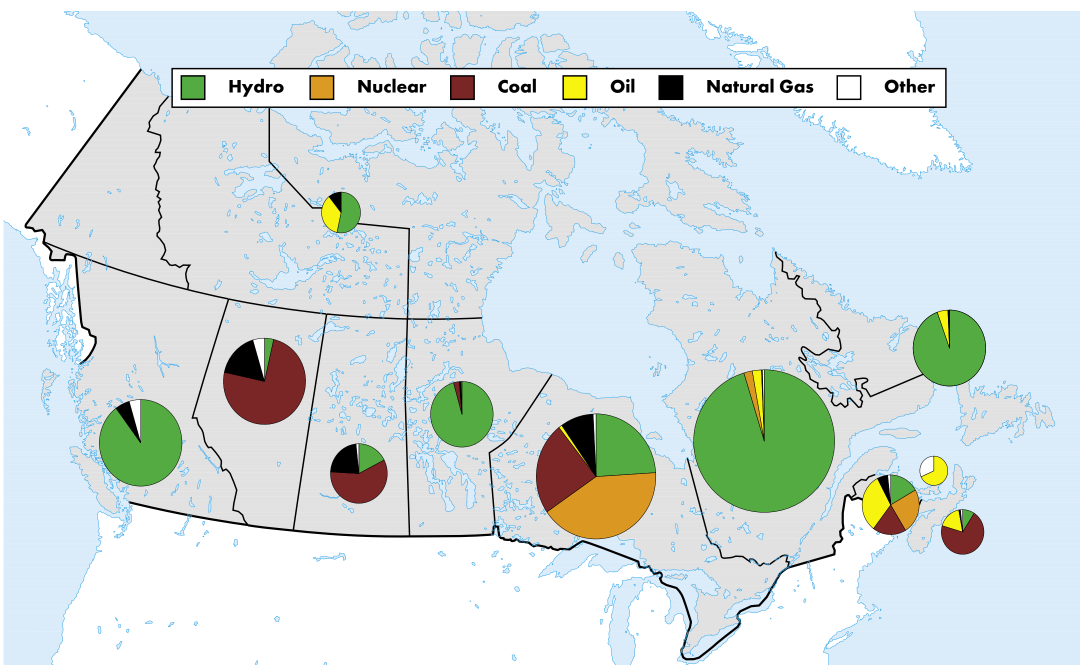
Overview of Emerging Technologies

This chapter presents an overview of the factors influencing the growth of emerging technologies, including an assessment of some the overarching issues, the mechanisms providing incentives for developments and the barriers to development. Much of the initial discussion focuses on renewable technologies. Trends and issues specific to each technology are presented in the following chapter.

About 98 percent of Canada's electricity is produced from hydro, nuclear, coal or other fossil fuels (Figure 2.1). Apart from conventional large-scale hydro, about three percent is produced from renewable sources. Concerns about the adequacy of future generation, air quality and longer-term impacts of global warming have caused many industry participants, policy makers and the public to focus more on renewable and other emerging technologies. For example, higher energy prices during the past few years have improved their commercial viability, stimulated R&D, and encouraged the rapid deployment of wind power.

FIGURE 2.1

Canada Electricity Generation by Fuel, 2003 (568 TW.h)



Source: Statistics Canada, NEB

2.1 International Perspective

Apart from large-scale hydro, Canada has a low penetration of renewable energy compared with other developed countries, notably European countries where use of wind and other renewable energy technologies is much higher. The market penetration of non-hydro renewables in Spain, Germany and Denmark is between 6 and 18 percent (2002). According to the International Energy Agency (IEA), under existing and anticipated policies, the market that renewables will capture in OECD Europe is expected to grow from about four percent to 17 percent from 2002 to 2030, whereas projections for North America suggest an increase from three percent to seven percent.[5]

The difference between the European and North American outlooks is largely associated with social attitudes and policy environments that promote renewables. In Denmark and Germany, for example, wind and solar PV receive higher prices than conventional generation and have guaranteed access to the electric grid through a mechanism known as a feed-in tariff.[6] Importantly, these incentives have spawned domestic supply expertise. A good example of this is the wind industry in Denmark, which now exports wind turbine and generator sets to North America and elsewhere.

2.2 Canadian Perspective

In Canada's current industry structure and pricing regimes, the emerging technologies covered in this report are not generally competitive with conventional generation. This is because:

- Canada has substantial conventional energy resources and is an exporter of all energy forms including electricity;
- Partly due to this resource advantage, Canadian electricity prices have remained among the lowest in the world; and
- In most Canadian jurisdictions, the price paid for electricity reflects the average cost, which is normally less than the (marginal) cost of new sources. It is often pointed out that this difference in pricing constitutes a barrier to entry.[7]

The use of renewables in Canada has been limited mainly to areas where there are specific economic advantages, such as wood waste in the pulp and paper industry and a variety of technologies in remote locations where the alternative is high-priced, fossil-fuelled generation.

In the NEB's last *Energy Futures* report it was projected that renewables, excluding conventional hydo, would increase to 10 percent of power generation by 2025, and would account for about 25 percent of the growth in generation.[8] More recent assessments suggest that the outlook for renewables in power generation could be significantly higher (Figure 2.2). This could be accounted for by differences in fundamental assumptions (e.g., prices, investment decisions and consumer choices) or outcomes that might result from specific policy decisions (e.g., phase-out of coal-fired generation in Ontario, implementation of the *Kyoto Protocol*). Another factor could be differences in the extent to which the barriers to implementation of emerging technologies are overcome.

5 *World Energy Outlook 2004*, International Energy Agency

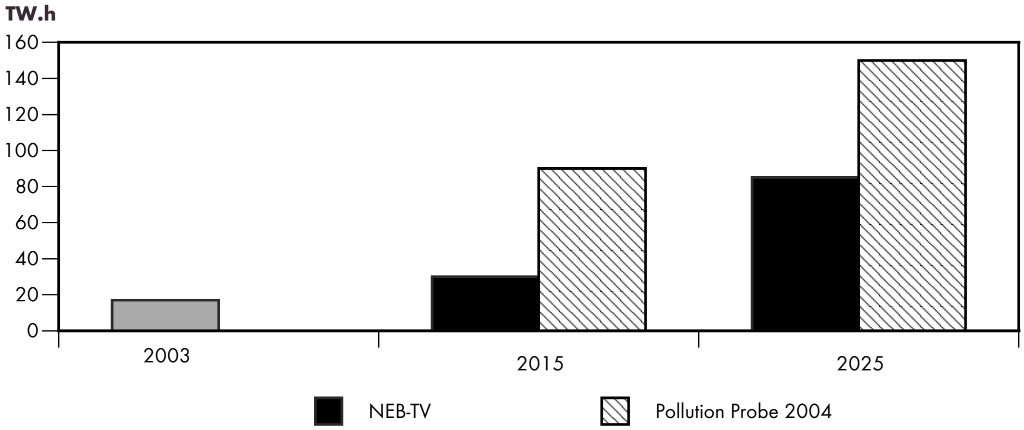
6 Typically, a feed-in tariff sets a price well above the market price with no limit on the quantity that can be offered for sale. Regulators review the price on a periodic basis.

7 That average cost is less than marginal cost results from the tendency of generation costs to rise over time due to inflation and other factors. It also results from the fact that the capital costs of existing resources have been largely amortised, or recovered, while the capital costs of new resources have not.

8 *Canada's Energy Future, Scenarios for Supply and Demand to 2025*, NEB, 2003

FIGURE 2.2

Electricity Generation from Renewables (TW.h)



Source: *A Green Power Vision and Strategy for Canada*, Pollution Probe, 2004
Canada's Energy Future, Techno-Vert Scenario, NEB, 2003

Notwithstanding the difference in outlooks, the growth in renewables is expected to be substantial.

The Consumer

The extent to which emerging technologies penetrate Canadian markets will depend to some extent on consumer awareness, which may translate to a preference for electricity generated from these sources. Research carried out by Canadian utilities and advocacy groups has indicated an increase in consumer interest and willingness to pay a premium for green power. As a result, some utilities have been successful in their green power marketing programs.[9] Now marketers face the challenge associated with electricity being an undifferentiated product at the end-use point, though it can be generated in many different ways. As indicated previously, in most jurisdictions green power tends to have higher costs than power from other sources.

2.3 Recent Trends in Canada

The interest in emerging energy technologies has escalated with wind power leading the way. Wind power capacity almost tripled between 2001 and 2005, accounting for close to 684 MW of installed generating capacity at the beginning of 2006. This is about 0.6 percent of the total Canadian generation capacity of 120 000 MW. With few exceptions, all provinces have significant developments underway. Recent projections by the Canadian Wind Energy Association (CanWEA) suggest there will be 7 000 MW of wind generation available by 2013.

2.3.1 Mechanisms Providing Incentives to Emerging Technologies

While there is obvious interest in wind, there is also strong interest in small hydro and various biomass projects and other technologies. This has prompted both the federal and provincial governments to re-examine and institute a number of strategies and programs to promote emerging technologies.

9 An example is the Greenmax program, sponsored by ENMAX, Calgary's gas and electric utility. Consumers have the option of paying an additional amount on their monthly bills to pay for the utility's purchase of wind power. Bullfrog Power, an Ontario marketer, sells green power at 45-55 percent above regulated rates.

The federal government has implemented instruments that reduce corporate income taxes, such as accelerated capital cost allowances and programs such as the WPPI and RPPI. Other incentives include funding to support clean coal developments and CO_2 sequestration and research into such diverse areas as ocean energy and fuel cells.

The provinces have directly targeted renewables through requests for proposals (RFPs) that invite competing bids from industry for a specific amount of renewable power or "clean energy." This puts participants on an equal footing, and contracts are awarded to the most competitive (lowest cost) bid. Other provinces (e.g., British Columbia and Nova Scotia) have developed RPS for utilities, which impose a legislated requirement on the minimum percentage of power generated from renewables. Ontario's RFP programs for renewable power are guided by policy targets of five percent renewables in the energy mix by 2007 and 10 percent by 2010. Québec has local content provisions in its wind RFPs.

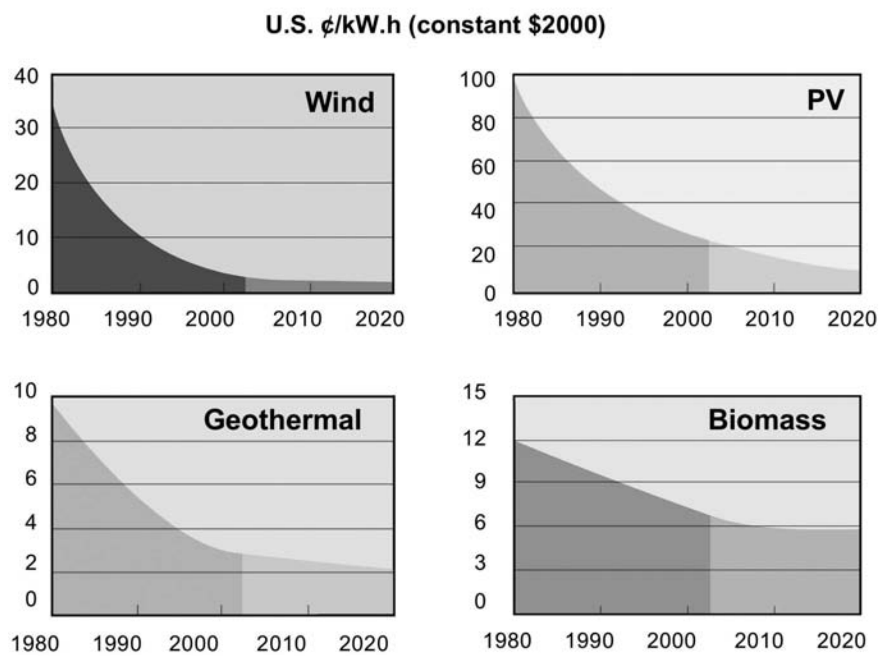
At both the federal and provincial levels, there is keen interest in leveraging R&D in emerging technologies into national and regional economic development in this rapidly growing sector. Fuel cells, clean coal and ocean energy benefit from federal and provincial government support.

The Canadian approach to promote the market development of renewables, largely through RFPs, contrasts with the European approach (e.g., in Denmark and Germany), which has used feed-in tariffs. Use of feed-in tariffs in Europe is credited with stimulating renewables development, especially wind and solar PV. In partially adopting this approach, the Ontario Power Authority is expected to implement a "standard offer contract" that will provide a fixed higher price for smaller electricity projects (less than 20 MW). The intent is to reduce the cost and complexity of the RFP process.

The decline in costs of emerging technologies has been substantial over the last 25 years (Figure 2.3) and further declines are expected. Reduced costs can be associated with specific developments such as

FIGURE 2.3

Renewable Energy Cost Trends



Source: National Renewable Energy Laboratory (U.S.), October 2002 (www.nrel.gov/analysis/docs/cost_curves) lighter materials, bigger and more efficient wind turbines and lower costs that result over time from economies of scale and experience.

Falling costs for emerging technologies and sharply higher costs for fossil fuels in recent years suggest that some emerging technologies may now be more competitive with conventional generation. Figure 2.4 illustrates that this is the case, particularly when emerging technologies (right-hand side of Figure 2.4) can be produced in the lower end of their respective range of costs. An advantage of many emerging technologies is that they have low, if any, fuel input so generation costs are not subject to the same volatility as natural gas-fired generation. However, if costs end up being higher than the price set by the cost of conventional generation (left-hand side of Figure 2.4) then they will not be competitive. In this case, the capital intensive nature of these technologies will result in the loss of investment dollars.

When used in distributed generation (i.e., where generation is located near the end-user), emerging technologies can have an advantage relative to conventional technologies. Whereas transmission costs need to be added to the conventional generation costs to arrive at consumer prices (shaded area of Figure 2.4), distributed generation does not require transmission. Therefore, the difference in costs, compared conventional generation is reduced by the amount of transmission savings.

2.3.2 Barriers to Emerging Technologies

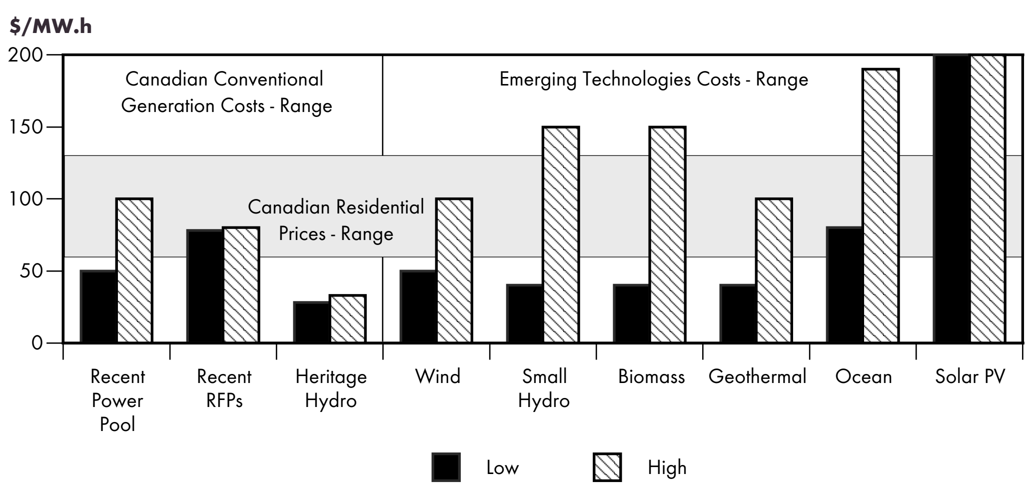
Externalities

When comparing emerging technologies with conventional technologies, a major consideration is that external costs (i.e., negative externalities) associated with air pollution and other environmental costs are not included in electricity prices. If market prices took these costs into account (i.e., external costs were internalised), proponents of this approach suggest that emerging technologies would be more competitive and possibly available at an even lower cost than conventional generation.

A related concept that could alter the total cost of generation is full-cycle costing. This takes into account the environmental costs at the initial point of production (e.g., natural gas used in electricity

FIGURE 2.4

Supply Costs – Emerging Technologies versus Conventional Generation



Source: CANMET, 2005, Ontario Ministry of Energy, *Hydro-Québec Electricity Price Survey*, 2005

Emissions Trading

The *Kyoto Protocol* has provided additional impetus for international carbon markets and emissions trading systems. Emissions trading is a least-cost way of enabling participants to meet emissions reduction targets. Participants can buy units to cover any emissions above their targets or sell units if they reduce their emissions below their targets. There are penalties for non-compliance. The presence of a market for these units creates a value for emissions reductions, which stimulates investment in the most cost-effective areas.

There are basically two types of emissions trading:

- cap and trade systems; and
- non-capped sources, such as credit-based systems.

Cap and trade programs are closed systems that allow for permit trading. A cap on the number of permits allocated to a company creates the scarcity needed for a trading market to emerge.

A non-capped source or credit-based system is an open system. Emission credits are accumulated through projects that reduce emissions below a baseline. Certified emission credits can then be sold in an emissions trading scheme or used to offset another emissions obligation (e.g., through the Clean Development Mechanism of the *Kyoto Protocol*).

Emissions trading offers the following advantages:

- flexibility for emitters to choose to emit or abate;
- innovation and investment in new technology is rewarded; and
- a common price signal to ensure reductions take place where they are the least costly.

The disadvantages to emissions trading include:

- the need for ongoing monitoring, reporting, verification and compliance infrastructure (like traditional regulation); and
- the potential for allocation of targets/allowances to be highly contentious.

The European Union (EU) Greenhouse Gas (GHG) Emission Trading Scheme (ETS) commenced operation on 1 January 2005 as the largest multi-country, multi-sector, cap and trade emission trading scheme. Some 12 000 factories and power stations have CO_2 quotas, covering 45 percent of the CO_2 emissions in the EU. During the first trading period, from 2005 to 2007, the ETS covers only CO_2 emissions from large emitters in selected energy intensive sectors, although a review will take place for the second phase of trading in 2008 to 2012 to allow for improvements in the market rules and to consider extending the market to other sectors.

The Government of Canada is in the process of developing a GHG emissions trading scheme for large industrial energy users in Canada. Canada's overall Kyoto target is to reduce GHG emissions by 270 megatonnes or six percent below 1990 levels. The Large Final Emitters (LFEs), representing 700 Canadian companies in the oil and gas, electrical generation, and mining and manufacturing sectors, are a key aspect of Canada's plan to reach its Kyoto targets. The LFEs will be regulated to reduce GHG emissions by 45 megatonnes or 15 percent below Business as Usual emissions during 2008–2012. The cost of emissions reductions is capped at $15/tonne of CO_2 through 2012.

Under Canada's domestic emissions trading system, LFEs will be able to meet their emission reduction targets by investing in in-house reductions or by buying emission reduction credits. Credits can be purchased from a number of sources including: other LFEs that have surpassed their targets; through an offset market where projects create credits by reducing emissions from a baseline such as land fill gas capture and flaring, and agriculture and forestry reductions and removals; and internationally through international emissions trading, joint implementation mechanism or clean development mechanism, under the *Kyoto Protocol*.

generation has upstream emissions in production and transmission), not just consumption, and the costs associated with retiring or scrapping an asset (e.g., long-term costs of nuclear waste disposal).

A higher value associated with clean generation technologies may be captured through emissions credits or emissions trading programs on a regional or national basis. The intent of these programs is to use market mechanisms to efficiently reduce emissions.

Other Barriers

It is often pointed out that electricity rates do not reflect actual costs because they are based on historical costs and are, therefore, below the cost of developing new generation.[10] This causes consumption to be higher and lessens the motivation to make investments in emerging technologies. Levelling the uneven playing field created by different price treatment would further enhance the competitiveness of emerging technologies. To some extent this can occur through RFPs directed at renewables or clean energy.

Another barrier faced by emerging technologies is access to the transmission grid. To a large extent power systems are set up to connect large-scale generating stations to load centres via extensive transmission networks, enabling the centralised dispatch of power. The rules for connecting smaller, remote generators are often unclear or apparently restrictive. However, there can also be reliability issues associated with connecting many small generators without careful system planning and clear rules for grid access. To some extent these issues are being addressed, perhaps more so in those markets that have completely opened their system to competition. For example, Alberta has committed to upgrade its transmission system to enable wind generation and development.

At the project level, emerging technologies often face many of the same issues for project approval as conventional generators, including the NIMBY effect. However, the smaller size of these projects can make regulatory requirements relatively more burdensome and, as well, the project developers may not have developed the regulatory expertise. This has caused some project developers to call for regulatory requirements, specifically associated with environmental assessments that are consistent with the project size and scope.

2.3.3 Demand Management

The same drivers that promote interest in developing new or clean electric generation technologies also encourage efforts to reduce or constrain energy consumption. In fact, in many jurisdictions around the world, including Canada and the United States, there is an observed tendency for renewables and DSM to be "bundled" in the pursuit of green strategies. For example, Ontario's 2004 renewables RFP included DSM bids. In a DSM bid, the applicant must demonstrate that it can make investments that will reduce consumption, which has the same effect as increasing generation.

In many cases, it is cheaper to save a unit of electricity than it is to purchase or generate one. This has rekindled an interest in DSM that has not been seen since the early 1980s. Implementing DSM provides a host of opportunities to save energy, but there are a number of barriers to successful implementation, including providing appropriate price signals to consumers and compensating utilities for potential income losses. However, lessons are being learned from experience in the natural gas industry, and policy makers, regulators and utilities across the country are establishing programs and targets.

10 This phenomenon is often associated with low cost large-scale hydro projects. These "heritage assets" are used as policy instruments in several provinces to dampen or mitigate the costs of more expensive new generation.

Programs can be aimed at managing the overall level of electricity consumption, or managing peak demand (demand response). Specific measures range from installing time-of-use (TOU) meters (e.g., in Ontario) to more traditional approaches of providing direct incentives to consumers (e.g., PowerSmart programs in Manitoba and British Columbia). Demand Management is addressed in section 3.9.

2.4 Summary of Technologies

Table 2.1 provides a summary of the technologies covered in this report, indicating an illustrative cost range for each technology. The main characteristics of each technology are based on the assessments in Chapter 3.

TABLE 2.1

Illustrative Power Generation Costs – Emerging Technologies and Conventional Generation

Technology[1]	Cost Range ($/MW.h)	Unit/Plant Size[3]	Comments
Wind power	50-100	1-2 MW; wind farms of 50-150 MW	• relatively short installation time • intermittent nature requires back-up/supplement from other generation sources
Small hydro	40-150	less than 25 MW	• well established technology • may encounter NIMBY opposition • limited/no storage; therefore, intermittency can limit attractiveness
Biomass	40-150	10-50 MW	• wide variety of technologies and feedstocks, including forest industry waste, agriculture, municipal waste and landfill gas • base load capability
Geothermal energy	40-100	100-200 MW	• limited sites available • may have high grid connection costs, depending on location • base load capability
Solar PV	200-500	varies at consumer level	• expensive; intermittent • distributed generation (DG) and niche applications, especially where alternatives are high cost
Fuel Cells	100-150	1-100 MW	• still expensive; costs do not include all plant infrastructure • a technological breakthrough is necessary to achieve costs at the lower end of the range • niche applications; cogeneration and peaking capability
Ocean Energy (wave and tidal currents)	80-190	less than 1 MW	• costs are uncertain (based on limited number of commercial projects) • intermittent, but reasonably predictable (tidal currents) • DG applications in coastal areas
IGCC (excluding sequestration)	50-60	250-500 MW	• expensive compared with conventional coal • there are few commercial projects currently • "pure" CO_2 stream is favourable for sequestration
Demand Management	0-50	varies at customer level	• some measures are virtually costless, while others require significant investment • potential benefits not always perceived to be achievable, thus limiting the uptake
Conventional Technologies[2]			
Recent Power Pool	50-100	250-500 MW	• typical range of prices in the ON and AB competitive wholesale markets; prices set mainly by gas, coal and market conditions in adjacent markets (i.e., in the U.S. and other provinces)
Recent RFPs	78-80	100-200 MW	• proposals "accepted" by the Ontario Power Authority/Ontario Ministry of Energy for RFPs issued in 2004 (mainly natural gas-fired generation)
Heritage hydro	28-33	100s-1000s MW	• costs based on Québec (2.79¢/kW.h) and Ontario (3.3¢/kW.h)

1. Costs for wind, small hydro, biomass, geothermal power, solar PV and ocean energy are from CANMET (NRCan) and the IEA. Fuel cell costs are NEB estimates; IGCC costs are from Ontario MOE and CERI. The demand management costs are based on recent studies undertaken in the U.S. and in Ontario, as referenced in section 3.9.

2. Costs for conventional technologies are based on prices in the Ontario and Alberta competitive wholesale markets, and announced results for Ontario RFPs. Heritage hydro costs are announced costs in Québec and Ontario. In Québec, these costs refer to the first 165 TW.h produced per year and in Ontario refer mainly to the hydro assets of Ontario Power Generation.

3. Plant sizes are illustrative and not directly associated with the costs.

Technology Assessments

3.1 Wind Power

Growth of global wind power generation capacity has averaged more than 30 percent per year in the past decade. Europe leads the world with 35 000 MW of installed capacity. North America remains a distant second with over 7 500 MW. Based on 2004 estimates, the five countries with the largest installed wind power capacity are Germany, the United States, Spain, Denmark and India.

In Canada, 2005 was a record-setting year for the wind energy industry in terms of new capacity additions. Installed capacity reached 684 MW by the end of 2005. The increasing interest in wind power can be attributed to several factors, including the declining cost of wind power facilities, the rising cost of fossil fuels, the opening in some provinces of competitive generation markets to Independent Power Producers (IPPs), the onset of voluntary and mandatory RPS, and incentive programs such as the federal WPPI.

3.1.1 Technology

Wind energy technology continues to improve rapidly. According to a study by Emerging Energy Research (EER), a U.S.-based research and advisory firm, wind power plants have become commercially viable sources of power for U.S. and Canadian utilities.[11]

Resources

The windiness of a particular site is measured by its annual average wind speed. Wind speeds are typically less than 14 km/h at poor sites, between 18 and 22 km/hour at good sites, and exceed 25 km/hour at excellent sites. Hourly, daily and seasonal wind speed variations govern power output and its timing relative to load. For example, a site with high winter winds would best suit an application requiring more energy during the cold months. Near the earth's surface, wind speed is reduced by friction; therefore, the higher the wind turbine tower, the greater the wind speed and the more energy is produced.

Wind speed is affected by surface roughness such as vegetation and by obstacles such as buildings and hills. It typically increases when approaching an obstacle then decreases (and can become very turbulent) on the downstream side. As a result, wind turbines are often placed near the top of the upstream side of hills and ridges and well away from buildings and other structures.

11 Emerging Energy Research study, *U.S./Canada Wind Power Markets and Strategies, 2004-2010*

Operational Characteristics

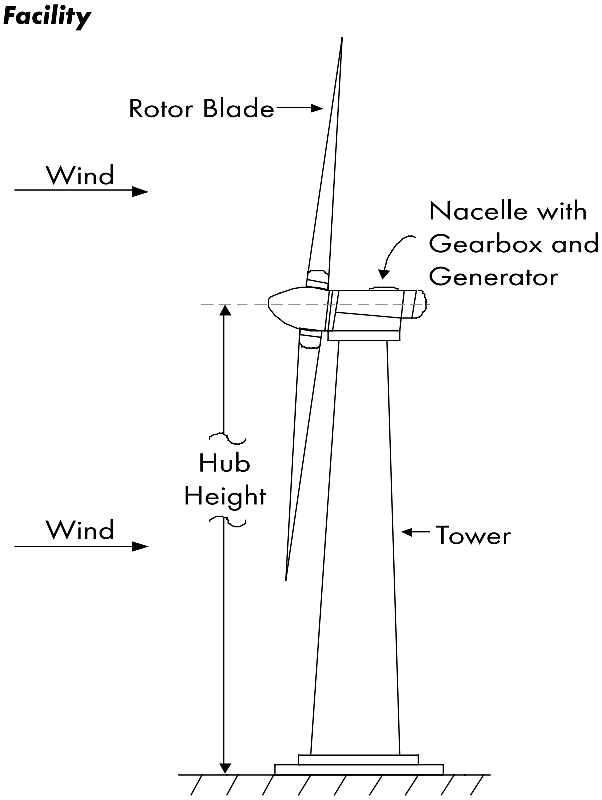
A wind turbine obtains power by converting wind force acting on the rotor blades into a turning force, or torque. The quantity of energy that the wind transfers to the rotor primarily depends on:

- wind speed;
- air density; and
- rotor diameter (wind swept area).

The power generated is sensitive to wind speed and this is the most important parameter in determining output. When wind speed is sufficient to overcome friction in the wind turbine drive train, the rotor turns and a small amount of power is produced. This "cut-in" wind speed is usually a gentle breeze of about 4 m/s or 15 km/h. When wind speed increases, power output rises steeply, as the energy content of the wind varies with the cube (the third power) of the wind speed. Eventually, if the wind speed rises above the rated power, control systems shut the turbine down to prevent damage to the machinery. This "cut-out" wind speed is usually about 90 km/h.

FIGURE 3.1.1

Key Components of a Wind Power Generating Facility



Wind's kinetic energy depends on air density. As a general rule, air density falls as altitude above sea level increases. The rotor area determines the quantity of energy that a turbine is able to harvest from the wind. Turbine power increases with the square of the rotor diameter.

Modern wind turbines operate automatically and require little supervision from onsite personnel. An anemometer (an instrument used to measure wind speed) above the nacelle (the protective casing of a propeller-type wind turbine) continuously measures wind speed (Figure 3.1.1).

While cold, dense air is preferred because it contains more energy than hotter, less dense winds at the same velocity, cold weather can make materials brittle and lead to frost formation, which reduces energy output and can damage equipment.

Most modern turbines have a design life of 25 years or more. During this time, as with any machinery, some parts may need replacing. Scheduled maintenance seldom exceeds a couple of days per year. This differs from a conventional coal plant, which typically goes offline for maintenance every 18 months for at least one month at a time.

3.1.2 Market and Regulatory Issues

The cost of wind energy has dropped about 80 percent in the last 20 years, reflecting, to a large extent, the declining capital costs required per installed capacity unit and higher equipment efficiency. If current downward trends continue, costs will range between 3.4 to 5.5 U.S. ¢/kW.h by 2020.

In Canada, with sharply higher natural gas prices in recent years, wind power in some regional power markets is now competitive with gas-fired generation. In Québec, the first RFP for 1 000 MW yielded 990 MW of proposals at an average cost of 6.5 ¢/kW.h. In Ontario, the average cost associated with the 350 MW wind power RFP has been estimated at 8.0 ¢/kW.h. Hydro-Québec Distribution has estimated that the integration and balancing of energy from wind projects will cost an additional 0.5 ¢/kW.h.

There is no fuel cost associated with wind energy; therefore, capital costs and operating costs are key determinants of the generation costs. Capital costs are site specific and can account for 90–95 percent of the generation costs. The capital costs of recent projects range from $1,200/kW to almost $2,000/kW. According to CanWEA, each megawatt of wind power installed requires $1.8 million in capital investment.

The capacity factor of a wind farm affects the amount of electricity produced and is another key determinant of the cost of wind energy. Most wind farms in Canada operate in the range of 25 to 35 percent of capacity. Québec s recent wind farm project (the 990 MW capacity contracted as a result of the first 1 000 MW RFP) is expected to achieve an average capacity factor of 36.6 percent.

Besides the resource issue, there is a need to consider how much wind energy can be effectively integrated into the grid and at what cost. The Danish grid can integrate a high proportion of wind power (about 20 percent of supply) because it benefits from good interconnections with neighbouring countries (i.e., Sweden, Norway and Germany) that can provide backup power. More generally, there are limits to the level of grid integration above which the operational viability of some of the incumbent generators is uncertain and the increased complexity of market operation becomes unmanageable. Furthermore, many wind sites are located in remote locations and require construction of new transmission or expansion of existing facilities to bring their power to market. The cost of integrating new generation can be an important consideration in the economics of wind power generation.

The cost of transmission access is often not included in the energy cost estimates for wind power (and other renewable sources) because such costs are site specific and hard to estimate. For any particular project, a trade-off between better wind resources and transmission cost and access will often exist. While better wind resources allow for more energy generation, these resources may be more remote and have higher associated site development and transmission costs because new transmission capacity, transmission upgrades or new interconnections may be required. For example, Hydro-Québec Distribution s transmission cost, including transmission losses associated with the wind farms to be built in the Gaspé area is 1.3 ¢/kW.h. While integration to the grid is technically feasible even for wind farms situated in remote locations, not all wind farms can economically be integrated. The fact that transmission capacity may only be used 25 to 35 percent of the time imposes a barrier limiting the amount of wind power that can be economically integrated into a power grid. For example, other things being equal, the cost of transmission associated with a 400 MW wind farm operating at 30 percent capacity factor will be about three times higher than that associated with a 400 MW coal-fired power plant operating at full capacity.

Wind energy suppliers often enter into long-term (15-20 years) supply contracts with local electricity distributors. Typically, suppliers are paid agreed on prices that are escalated annually according to some indexation factor. Distributors are guaranteed a minimum amount of energy over a specified time. In general, the provincial regulator must approve these contracts. Siting of wind power projects is also subject to regulatory approvals.

Intermittency of Wind Power

Because of the intermittency or variability of wind resources, wind power at a specific location may not always be available. This variability may have a direct impact on electric system reliability, since wind cannot be relied upon for base-load requirements. Intermittent wind power therefore implies that some other energy source must be available to cover periods when wind is unavailable (Figure 3.1.2)

There are a number of measures that can mitigate wind intermittency concerns, including geographic diversity, forecasting and synergy with hydroelectric systems.

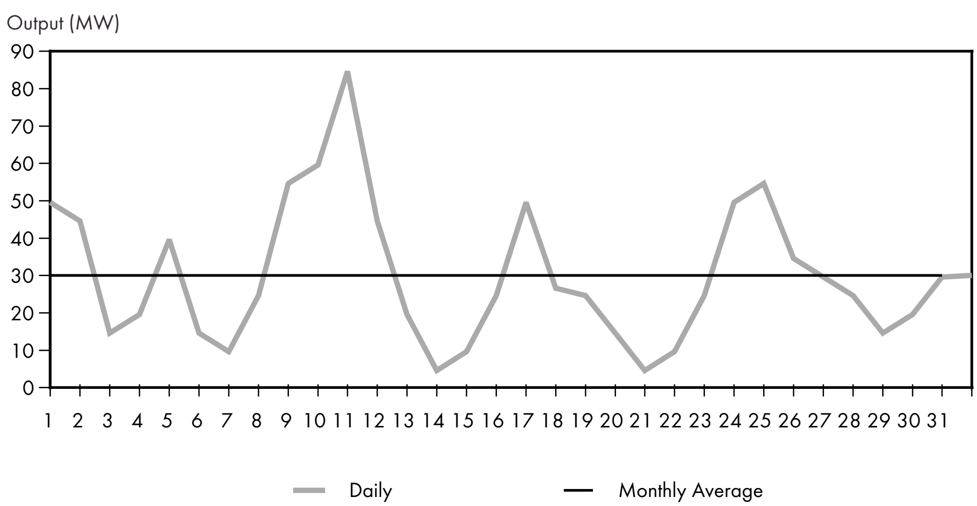
If wind turbines span a large geographic region, it is less likely that they will all be without wind at the same time. However, wind power developers want to site units in places with the highest average wind speed to maximize output. Advanced (daily or hourly) forecasts for wind speed and wind turbine generation are valuable, as this provides operators with time to respond to changes.

Hydro and wind systems have a natural synergy. Hydro units can vary their output quickly, compensating for changes in wind generation. Wind power can be a useful supplement, providing energy when the wind blows, allowing hydro facilities to save water for future generation.

The amount of wind power an electric power system can absorb depends on its configuration. Based on technical studies and experience in Europe and in the U.S., a predominantly thermal system is expected to be able to function normally with up to 10 percent of its installed generating capacity being wind turbines, whereas a mainly hydro-based system could support up to 20 percent more wind power.

FIGURE 3.1.2

Illustrative Generating Profile - 100 MW Wind Farm



3.1.3 *Environmental Considerations*

Wind energy is a sustainable, non-polluting source of energy. It is not dependent on any finite feedstock, creates no emission or waste products, and poses relatively limited environmental disturbance when the equipment is installed or decommissioned. The installation of wind farms can reduce GHG emissions both by offsetting fossil fuel generation in supplying existing demand, and by avoiding installation of further fossil fuel power plants to meet future demands.

Although wind is considered a green source of energy, wind farms developers face significant aesthetic issues. Wind farms typically take up large swaths of land, and some critics say they are noisy, unsightly and a threat to birds and bats. Furthermore, as the proportion of wind power on the electric system increases, additional challenges such as noise pollution may be encountered. These issues may be addressed through proper siting and tower design, and by the slow turning speed of modern wind turbines.

3.1.4 *Industry and Government Initiatives*

CanWEA has proposed a target for the construction of 7 000 MW by 2013. The association believes this target is achievable and would contribute to fulfilling the electrical sector's obligations under the *Kyoto Protocol*.

The Wind Power Production Incentive introduced by the Government of Canada in 2002 provides an incentive of one cent/kW.h over 10 years for wind-generated electricity. The federal government expanded its WPPI program in the 2005 Budget so that it could support the development of 4 000 MW of wind capacity by 2010. Additionally, the government has removed caps that limited the maximum amount of support any province or project can receive and may allow wind energy projects to participate in a proposed GHG emission reduction offset trading system. Several provinces have established RPS whereby certain fractions of new or total electricity supplies must come from renewable sources.

3.1.5 *Regional Developments*

Alberta and Québec account for about 69 percent of the total installed capacity in Canada. Most provinces are participating in wind power development. Current installed capacity is 684 MW and proposed capacity (i.e., projects under construction or awarded a power purchase agreement) total more than 2 800 MW.

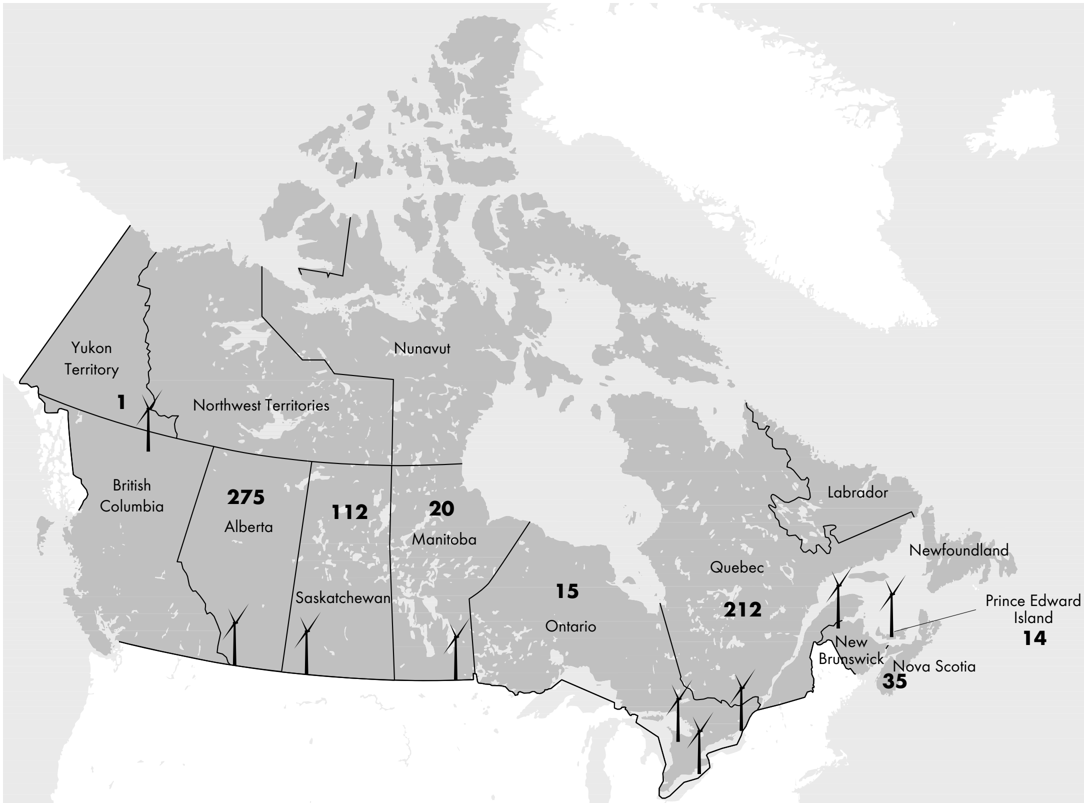
As illustrated in Figure 3.1.3, Canada has a relatively large number of wind turbines installed in Alberta, Québec, Saskatchewan, and Manitoba. The rate at which wind energy systems are deployed is a function of several parameters, including availability of good wind resources, costs of competing forms of electricity generation, and provincial government environmental strategies.

3.1.6 *Summary*

Wind technology in Canada has reached commercial development and has become the fastest growing source of renewable energy. Wind farms can be implemented in relatively short periods of time (12 to 24 months) and are generally less environmentally intrusive than large-scale conventional generation. However, the intermittent nature of wind resources needs to be addressed to ensure supply reliability and facilitate its integration into power systems. Access to transmission systems is another key issue that can affect the economics and, therefore, the siting of wind power projects. Availability of

FIGURE 3.1.3

Canadian Wind Power Generation Capacity (year-end 2005, 684 MW)



Source: CanWEA

hydro storage capability in the hydro-rich provinces facilitates the integration of wind energy in the provincial grids, but there are economic and technical limits to this integration.

Several provinces, including P.E.I., Québec, Ontario, Alberta and Manitoba will likely experience significant growth in wind power over the next decade and there are good prospects for implementation of new wind farms in other provinces and territories. In the short term, it appears that financial assistance (e.g., the WPPI and provincial RFPs) promoting wind power development will help to create steady development. In the longer term, factors helping to sustain growth include the continued reduction in capital costs for wind power facilities, the drive toward a better environment and even more effective solutions to address intermittency issues.

3.2 Small Hydro

There is no consensus in Canada about what constitutes small hydro plants. For example, in Québec, small hydro generally refers to plants with capacities of less than 25 MW and in British Columbia, small hydro refers to plants with capacities ranging between 2 MW and 50 MW. An upper limit of about 25 MW is typically used. Hydroelectric plants with capacities between 100 kW and one megawatt are sometimes referred to as mini-hydroelectric plants, and plants with capacities of less than 100 kW are often referred to as micro-electric plants.

Electricity Storage

It is often stated that electricity, once produced, cannot be stored. Unlike oil, coal, or even natural gas, electricity must be generated as it is consumed. Supply must instantaneously match demand, and deregulated electricity markets are based on real-time pricing, with the price reflecting the value of the last unit of power generated.

The water behind a hydro dam represents one form of potential electricity storage. As required, water can be released from a dam and run through a turbine, dispatching more power to match increasing load. Demand for electricity, or load, takes a characteristic "shape," depending on the market it serves. However, where there is no hydro capacity, other technologies must be developed in order to capture electricity in some practical manner.

As renewable forms of electricity generation become more prevalent, their variable nature may pose a challenge to integration into the existing electrical grid. Wind, photovoltaic cells and, to some extent small hydro, are all less predictable than more traditional means of electricity generation. The ability to store power that is generated when the wind blows, or when the sun shines, and use it at another time (make it "firm") could add tremendous value to these technologies.

Power quality can also be an issue for a system with a constant load but variable generating capacity. Storing power and supplementing dispatched energy as the system becomes overtaxed could add an element of reliability. Electricity storage near a load centre also allows the end user to avoid incurring unnecessary or avoidable demand charges for infrequent but large increases in load. This form of "peak-shaving" benefits both the distributor, by deferring capital investment in infrastructure, and the customer paying the bill.

In markets with time-of-use metering, storage creates an opportunity for arbitrage. It should be possible to store energy generated during off-peak hours, which is therefore of lower value, and sell it back into the system during peak hours for a higher price. Stored electricity could also be used as an ancillary service, providing reserves to a system operator.

There are several emerging technologies in electricity storage. Compressed air energy storage (CAES), advanced batteries, flywheels and capacitors are all examples of electricity storage technologies at various stages of maturity. Each is developing to fill a particular niche, depending on characteristics that best suit the technology for power applications or energy storage.

CAES uses electricity to drive air compressors, forcing the air into an airtight space such as an underground cavern or storage tank, and then reverses the process to use the compressed air to drive a turbine and generate electricity when required. The process is most appropriate for bulk storage of electricity, and is a relatively cost-competitive means to store power.

Flywheels store electricity as kinetic energy, in the form of a spinning flywheel. The faster a flywheel spins, the more energy it is capable of retaining and later releasing. Modern flywheels are made of carbon-fibre materials, with a high strength to density ratio. They may employ electromagnetic bearings that reduce energy losses through friction.

Capacitors store electricity as a concentration of electrons on the surface of a material. They are capable of very fast charge and discharge, and can cycle many times without degrading. Currently, technology limits their use to high power, low energy applications.

Lead-acid batteries have been available for a long time, and new batteries are being developed that utilize technology similar to that found in some fuel cells. These flow cell batteries store energy as electrolytic solutions that can be regenerated, whereas conventional batteries require that electrolytes be replaced. VRB Power Systems of Vancouver is a Canadian manufacturer that markets a vanadium-based flow cell battery.

3.2.1 Technology

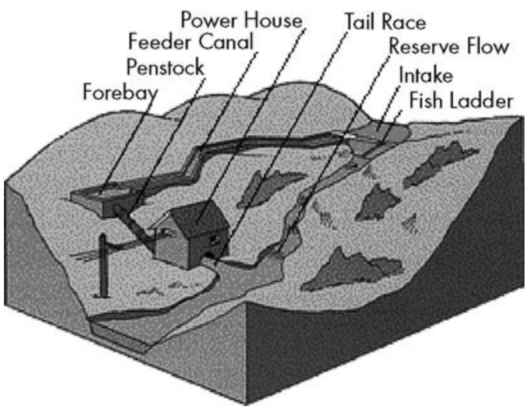
Small hydro is a well-established technology. A hydroelectric station uses the energy contained in falling water. The water flowing upstream of the project could be free flowing (i.e., run-of-river hydro) or stored behind a dam in a reservoir (i.e., storage hydro) to permit flexibility in meeting varying electrical loads. Water goes through the intake into a pipe that carries it down to the turbine. When the turbine is set in motion, it causes the generator to rotate and electricity is produced.

Run-of-river hydroelectric plants divert the water, sending it through a canal or penstock to the generating station and then back into the river without appreciably altering the river's flow rates or water levels. Therefore, run-of-river facilities have minimal impacts on a river's ecosystem.

The amount of electricity generated depends on the vertical distance that the water falls (commonly referred to as the head of the water) and the water's flow rate (the quantity of water flowing past a point in a given time). The best locations for small hydro facilities are waterfalls, rapids, canyons, deep valleys or river bends as these locations provide the best physical characteristics to maximize power generation and to allow for compact plant layouts.

FIGURE 3.2.1

Components of a Small Hydro Plant



Generally, in a small hydro facility, water flows down the feeder canal from the intake to the forebay (Figure 3.2.1), which is a tank that holds water between the feeder canal and the penstock. The penstock is a pipe that connects to the power house and pressurizes the water. The power producing equipment in the power house can be operated and monitored either on site or remotely. Fish ladders are often used to allow fish to migrate upstream to minimize the biological impact of the power plant.

In the last 25 years, a number of improvements have been made to small hydro technology, including improvements to hydrologic assessment and project identification and standardized designs of turbines and generators.

There are some technological constraints with small hydro developments. For instance, facility designs must provide for control of ice and pipeline freezing (adding to capital expenses and operating costs). Also, stream flow data on a potential site must be collected over many years while planning for a small hydro facility and this information can be unavailable or insufficient.

3.2.2 Market and Regulatory Issues

Small hydro has been Canada's largest contributor to the green power sector for some time. The current capacity of all small hydroelectric facilities in Canada is about 2 000 MW.[12]

As with large hydro plants, small hydro plants can generate electricity efficiently, with generation costs ranging from 5 to 20 ¢/kW.h. Hydro electricity costs do not depend on varying prices of fuels, such as

12 Statistics Canada, 2004, for plants less than 25 MW

natural gas, oil or coal. Small hydro facilities also tend to have low operating and maintenance costs. Small hydro facilities have capital costs ranging from $1,700 to $6,700/kW[13] and payback periods for capital investment of 10 to 40 years, depending on the location and configuration of the facility.

The lack of standardization of purchase contracts and arduous grid interconnection requirements can lead to high project preparation and design costs. The per-unit capital cost of small hydropower is typically higher than large-capacity hydropower because of a lack of economies of scale. Using existing structures, such as dams or facilities already being used to control the water level of rivers, lakes, and irrigation can decrease the development costs of small hydro facilities.

If the plant does not store water in a nearby lake or reservoir, the amount of energy that can be generated is not reliable and can vary significantly from day-to-day, season-to-season, and year-to-year. Typically, small hydro plants have an average capacity factor of 45 percent, which is comparable to other renewable sources of electricity generation, but lower than large hydro facilities that have average capacity factors of 60 percent.

Social benefits of small hydro developments include relatively reliable electricity and low-cost electricity in the case of a well-configured project. It is an especially attractive alternative to traditional high-cost diesel generation that currently provides electric energy in remote communities across Canada. Small hydro developments also have socio-economic benefits, such as providing regional employment opportunities and wealth creation.

Perhaps the biggest hurdle of small hydro development is the regulatory approval process, or more specifically, the environmental approval process. Regulations focus more on large-scale hydroelectric issues than on small-scale hydroelectric issues, and the regulatory requirements are the same, regardless of the size or configuration of the project. This can impose disproportionate demands on small hydroelectric developers. A small project cannot support the comprehensive studies and infrastructure assessments that government typically demands from a 500 MW facility, which creates a barrier for small hydro projects.

3.2.3 *Environmental Considerations*

Hydropower is a renewable energy source because it relies on natural water cycling. In addition, it does not emit sulphur oxides (SO_X), nitrogen oxides (NO_X) or particulate matter, and removing vegetation from the reservoir area minimizes the production of GHG from decaying vegetation. Based on these positive characteristics, many believe power produced by large and small hydro should command a premium as green power.

However, others point out the impacts of hydro dam construction and operation. With large hydro, flooding is a significant issue because decomposing flooded vegetation releases low levels of GHG, and reservoirs may create conditions that allow mercury to accumulate in fish. Flooding is not normally an issue with small hydro developments. However, dams can change the flow regimes of rivers and affect fish and other wildlife and their habitats.[14]

Compared to large hydro, small hydro generating stations have relatively low environmental impacts because they are constructed in a small area and rarely cause significant shoreline flooding or require river diversions. Additionally, most of the negative environmental impacts of small hydro development

13 CANMET Energy Technology Centre, Natural Resources Canada, (2002) International Small Hydro Atlas

14 IEA, Implementing Agreement for Hydropower Technologies and Programs, *Small-Scale Hydro Annex*. Available at: http://www.canren.gc.ca/tech_appl/index.asp?CaId=4&PgID=43

can be avoided by good design and operating practices. For instance, a fish ladder can allow fish to swim around the station unharmed or a site may be developed at or above a fish migration barrier.

Not all existing small hydro facilities qualify as low-impact renewable electricity, whereas some larger projects might, depending on the design of the facility. The current trend in certified green power, including renewable low-impact electricity, as defined by Canadian EcoLogo[15] criteria, is to recognize run-of-river hydro projects only if they do not interfere with seasonal water flows and if they minimize impacts on fish and flooding patterns.

3.2.4 Industry and Government Initiatives

The Small Hydro Technology Development Program is a federal program that promotes development of technologies that make it more economical to develop a greater range of small-scale and low-head hydroelectric resources. The program is supported by an independent turbine-testing laboratory at Laval University. In addition, the federal RPPI for up to 1 500 MW of new renewable energy electricity generating capacity (except wind) may encourage more small hydro development.

A number of provinces have RFPs for renewable energy development (e.g., BC Hydro's Call for Power and the Ontario government's RFP for 1 600 MW of renewable energy). Additionally, a number of provincial governments have implemented energy strategies that include RPSs for their electricity generation capacity or supply mixes.

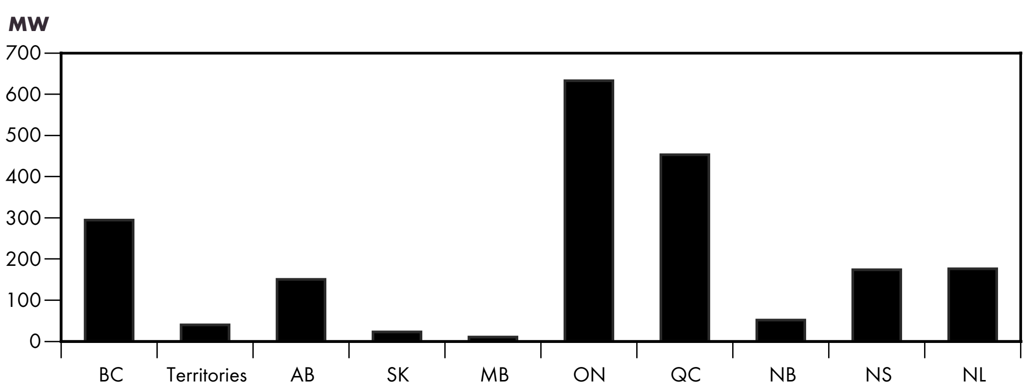
3.2.5 Regional Developments

There are approximately 2 000 MW of installed small hydro capacity in Canada, contributing about three percent of the total Canadian installed hydroelectric capacity of 71 000 MW.

Currently, British Columbia, Ontario and Québec have the most installed capacity of small hydro facilities (Figure 3.2.2). Natural Resources Canada has developed an inventory of more than 3 600 potential small hydro sites throughout Canada, with technical potential assessed at about 9 000 MW.

FIGURE 3.2.2

Small Hydro Capacity in Canada, 2004



Source: Statistics Canada

15 An official certification symbol for Environment Canada's ecolabelling Environmental Choice^{M} Program. In order to be certified, a product or service must be made or offered in a way that improves energy efficiency, reduces hazardous by-products, uses recycled materials, is re-usable or provides some other environmental benefit.

Québec and Ontario have the largest undeveloped small hydro resources, followed by British Columbia and Alberta. Newfoundland and Labrador also has significant small hydro potential, although development prospects have met opposition, particularly because of the potential impact on the salmon habitat.

3.2.6 Summary

Although several provinces have good potential for small hydro, environmental concerns and local public opposition have constrained the development of small hydro sites. Small hydro developers face the challenge of having to provide detailed assessments of the environmental and cumulative effects of their projects to regulatory authorities, similar to larger scale projects. These requirements typically have significant costs, create time delays, and limit the number of projects that are completed.

Small hydro is a mature and widely used technology and further technology improvements can make new projects even more economically attractive. Small hydro has good near and long-term potential because of the extensive number of potential sites in Canada and because of the opportunity to utilize the technology in more remote areas where the cost of alternative generation, such as diesel, may be high due to fuel costs.

3.3 Biomass

Biomass electricity generation is a process that converts plant material, landfill gas and animal waste into electricity. Biomass is one of the three major renewable electrical technologies in Canada, along with wind and small hydro. It is a commercially proven, reliable generation source that is most commonly developed in the pulp and paper and newsprint industries.

3.3.1 Technology

There are four biomass electricity generation applications: biomass used in industrial cogeneration applications; generation stations that co-fire biomass with coal; plants that combust biomass directly; and biomass gasification. In Canada, industrial cogeneration is the most common biomass generation type.

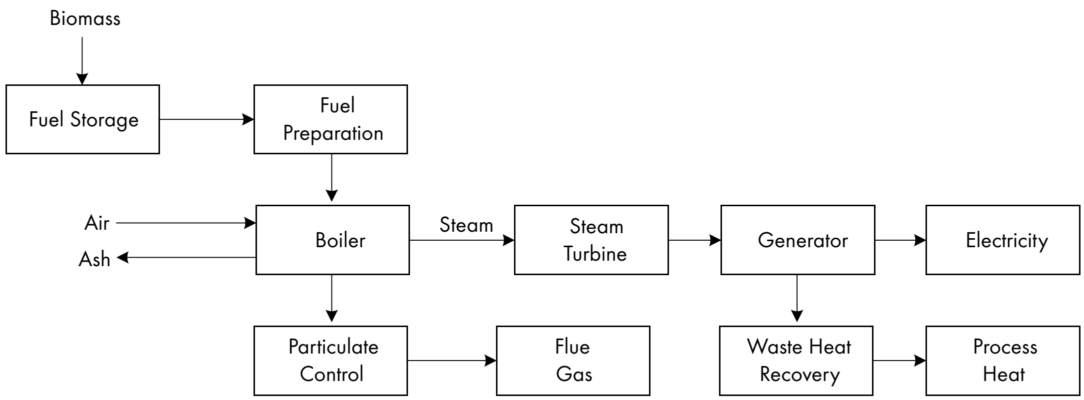
Biomass generation facilities typically range between 20 and 50 MW in size. For the most part, this is because of pulp and paper and newsprint industry requirements for facilities that cogenerate electricity and steam for remote operations. The steam technology used is very dependable, but plant efficiency is limited. Small capacity plants tend to be low in efficiency because it is expensive to install efficiency enhancing equipment. Biomass facilities typically provide base-load electricity because of lengthy start-up times that prohibit the unit from changing output frequently.

Typically, electricity generation from biomass occurs by direct combustion using piston engines, boilers and steam turbines as part of a cogeneration process (Figure 3.3.1). Organic material such as forest and mill residues, agricultural crops, wood wastes, animal wastes and municipal and industrial wastes are burned to produce electricity.

Landfill gas, one of the biomass fuels described above, is formed by the natural degradation and decomposition of municipal solid waste and it is composed of CO_2 and methane (CH_4). The gas is collected by a series of pressure wells and processed into a gas that can be burned to generate electricity.

FIGURE 3.3.1

Schematic Representation of a Biomass Cogeneration Process



The use of agricultural fuels for biomass generation has large potential for growth. Grain and oil seeds, energy crops, agricultural residues and livestock manure can all be used as biomass fuels. The two restrictions on the growth of agricultural fuels is the complexity of use relative to wood residue biomass fuels and the higher ash, chlorine and potassium content relative to wood residues.[16]

3.3.2 Market and Regulatory Issues

Biomass installed capacity in Canada increased by more than one third between 1992 and 2002. After 2002, the development of new biomass facilities started to decline because inexpensive residues were less available and operating costs were high.

There are a number of barriers affecting the widespread use of biomass including high initial capital costs and high operating costs related to the transportation and management of fuels. The cost to generate electricity using biomass is between $0.06 and $0.09 per kW.h, which tends to be higher than the cost of electricity produced with fossil fuels but lower than the current cost to generate electricity using natural gas. The average biomass plant cost worldwide averages $2,000 per kW, which is higher than the $1,500 per kW cost for coal-fired plants and $1,000 per kW price to construct a combined-cycle, gas-fired facility.

Recent market and regulatory changes may help to revive interest in biomass. Sustained high natural gas prices, the shift away from coal-fired generation construction, and the limited potential of new hydro storage projects because of environmental opposition may encourage investment in biomass-fired generation. There is a large potential for additional energy from biomass because of the extensive Canadian land base and the availability of manpower skills and feedstocks in the forestry industry.

In the current market, large-scale biomass generation systems can potentially be competitive relative to conventional generation sources. This is particularly the case when biomass facilities are located near fuel supplies (such as pulp and paper and newsprint operations). As well, new biomass units will likely cogenerate electricity and steam because the value of the process steam will likely make new biomass facilities economically attractive for industries located in remote locations with limited fuel availability.

16 David Suzuki Foundation, 2004, *Smart Generation: Powering Ontario with Renewable Energy*

3.3.3 Environmental Considerations

Burning biomass to generate electricity produces some emissions, including CO_2 and particulate matter. However, there are also many environmental benefits derived from biomass-fired generation, including the displacement of fossil fuel-fired generation and the use of landfill gas as an energy source that would otherwise escape to the atmosphere. Landfill gas electricity generation is a highly effective means of reducing GHG given that landfill sites generate over a quarter of the CH_4 emissions caused by human activity in Canada and that the greenhouse gas effect of CH_4 is reported to be twenty-one times greater than that of CO_2. Burning the CH_4 results in CO_2 emissions, which are a less potent GHG than CH_4.

The majority of new biomass generation facilities in Canada use travelling grate boiler technology at facilities located near forestry operations, rather than the more environmentally favourable fluidized bed boilers. The travelling grate boiler does not control the emission of NO_X as well as fluidized bed boilers, but it is used more often because of its low capital requirements.

Biomass electricity generation has the following environmental attributes:

- Biomass systems are generally characterized as being carbon neutral. Using biomass to generate electricity means that CO_2, which was absorbed from the air while the plant was growing, is released back into the air when the fuel is burned.
- Nitrogen oxide formation in biomass combustion can be kept low because of low nitrogen content in most biomass fuels and control techniques like combustion at low temperatures. Co-firing with coal can also lead to lower NO_X emissions.
- Compared with coal, biomass feedstocks have lower levels of sulphur or sulphur compounds. The substitution of biomass for coal has the effect of reducing sulphur dioxide (SO_2) emissions.
- The burning of biomass may be associated with the creation of particulate matter, but there are technologies that minimize the amount of particulate matter released.

3.3.4 Industry and Government Initiatives

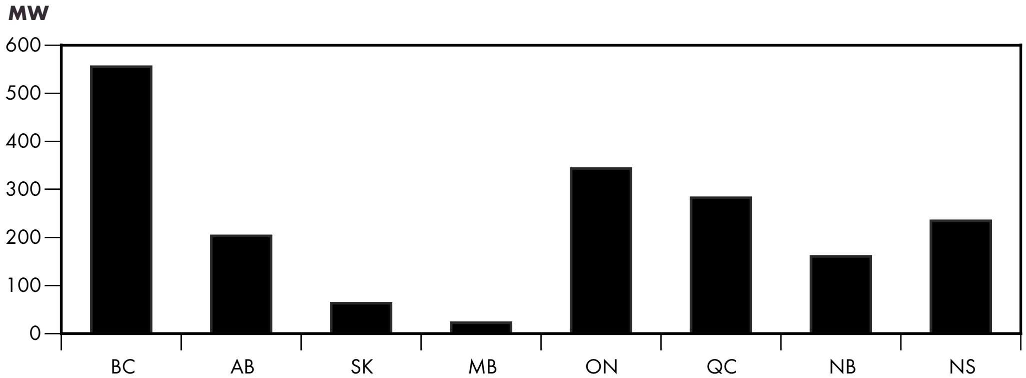
There are a number of policy initiatives that could help to remove or reduce barriers to investment in biomass generation facilities. In the 2005 budget, the federal government announced the RPPI to stimulate the installation of up to 1 500 MW of new renewable energy electricity generating capacity, except wind. An incentive payment of one cent per kilowatt-hour of production for the first 10 years of operation will be introduced for eligible projects commissioned after 31 March 2006 and before 1 April 2011.

Knowledge transfer would also enable the growth of biomass. Environment Canada has been working with NRCan, provincial departments and the private sector to raise awareness of the energy potential of biomass by holding workshops and publishing guidebooks on the subject.

Development of carbon credit and emissions reduction credit trading markets would also potentially boost biomass use. The Pilot Emissions Removals, Reductions and Learning initiative, for example, provides Canadian companies and organizations with an incentive to take immediate action on climate change by buying verified GHG reductions and removals from qualified projects.

FIGURE 3.3.2

Canadian Biomass Capacity, 2004



Source: Statistics Canada

3.3.5 Regional Developments

Biomass is most prevalent in British Columbia and Ontario, mainly in industrial cogeneration applications (Figure 3.3.2).

The type of biomass feedstock used varies by region. British Columbia, New Brunswick and Saskatchewan predominantly use spent pulping liquor. Ontario, Québec and Alberta use mostly wood refuse.

Across the country, large landfills are being used to generate electricity, largely in an effort to lessen the waste sector's contribution to GHG emissions. Electricity generating landfill sites in Canada include the following: Saint-Michel, Québec (25 MW); Keel Valley, Ontario (30 MW); Brock West, Ontario (14 MW); and Cloverbar, Alberta (6 MW).[17]

3.3.6 Summary

Biomass generation is a mature energy source with expansion potential. As with all renewable energy sources, stable investment conditions are required. The prospect for biomass electrical generation has improved because of provincial and federal programs intended to provide information about biomass and to encourage the development of biomass facilities. A key enabler of future growth will be provincial solicitations for new generation that includes biomass. Such programs would enable more biomass projects to get the necessary financing to cover the high start-up and operating costs.

In addition to government programs, other factors will encourage the construction of new biomass facilities in the coming years, including high natural gas prices, the shift away from coal-fired generation, limitations on new hydro development, reliability issues associated with other renewable technologies, and the continued availability of feedstock resources.

3.4 Geothermal Energy

The concept of capturing thermal energy from the earth's molten core is not new. Since prehistoric times, humans have used the heat that has found its way to the surface of the earth. Hot springs, geysers and fumaroles are the familiar signals that thermal energy from the centre of the earth is being transmitted to its surface through hot water and steam.

17 NRCan, *Renewable Energy*. Available at: http://www2.nrcan.gc.ca/es/ener2000/online/html/chap3f_e.cfm

The molten rock beneath the earth's crust ranges in temperature from 650°C to 1 300°C. Moving outward to the earth's surface, the molten rock solidifies into a hot-dry-rock environment, and even further from the core, gives way to more porous, permeable rock. Water or steam, or a combination of the two, may circulate freely in this porous rock as a hydrothermal resource. These resources may

Direct Use of Geothermal Energy

Geothermal energy can be captured in several ways and, if hot enough, it can be used to drive turbines and generate electricity. However, cooler, more abundant sources of heat may be put to a variety of uses. While these resources may not generate electricity, they can displace electricity that can be diverted to other uses.

For example, the people of Iceland benefit from that country's abundant geothermal resources by using hot water for space heating. The city of Reykjavik (population around 170 000) pipes water from wells 25 km away and delivers it to homes for space heating and domestic hot water. Approximately 90 percent of all Icelandic homes are heated by direct use of geothermal energy.

Geothermal energy is also put to direct use in several parts of Canada. In British Columbia, GeoExchange B.C. is a non-profit industry alliance promoting the benefits of direct use heating. Among other things, GeoExchange B.C. maintains a directory of direct use projects in British Columbia, listing approximately 80 different projects, ranging from ice arenas to condominium developments, all benefiting from some form of direct use heating.

Manitoba Hydro's Earth Power program promotes the installation of geothermal heat pumps through financing for residential homeowners for up to $15,000. Under the program, qualifying homeowners can benefit from financing costs that are offset by the savings earned through the installation of a heat pump.

Ground source heat pumps take advantage of the fact that temperatures in the ground below the frost line are fairly constant year-round. Heat pumps draw on this energy to heat homes in winter or cool them in summer and reduce heating and cooling costs by as much as 70 percent.

Another example of direct use geothermal energy is found in the heart of downtown Toronto. Using central steam plants for heating and deep water cooling from Lake Ontario, Enwave Energy Corporation circulates deep, cold water drawn from Lake Ontario to extract heat from a downtown district cooling system. The lake water is then sent on for processing and is used as potable water for the city of Toronto.

FIGURE 3.4.1

Geothermal Heat Pumps

Configurations of heat exchange piping either underground or underwater for geothermal heat pumps.

Heat-flow directions are reversed between summer and winter. Heat is collected from the building and transferred to the ground in summer. In winter heat is collected from underground and transferred to the building.

Source: USGS, *Circular 1249*. Used with permission of the US Geological Survey be commercially exploited to generate electricity if they are accessible, large enough and reasonably close to markets. With the development of new technologies, it may be possible in the future to extract the thermal energy associated with hot-dry-rock environments.

Geothermally-generated electricity is distinct from “earth energy” or ground source heat pumps (GSHPs). Ground source heat pumps use either the earth or groundwater as a heat source in winter and a heat sink in summer, primarily for space heating or cooling, not for generating electricity.

3.4.1 Technology

In most areas, hydrothermal energy diffuses before it reaches the surface of the earth. However, some areas, particularly in British Columbia, are underlain by relatively shallow, concentrated hydrothermal resources. These reservoirs are typically found at depths of 500 to 2 000 metres. Depending on the temperature of the water and steam produced from the hydrothermal resource, a turbine could be driven directly by the steam from the reservoir (greater than 150°C), by water that has flashed to steam as it is produced (between 90–150°C), or by a vapour from a secondary fluid that has been heated by the hot ground water in a heat exchanger (less than 90°C). See Figure 3.4.2.

3.4.2 Market and Regulatory Issues

Currently, there are over 9 000 MW of installed geothermal electrical generation worldwide. In the United States, geothermal energy produces over 2 000 MW of electricity, but to date there are no

FIGURE 3.4.2

Geothermal Power Generation

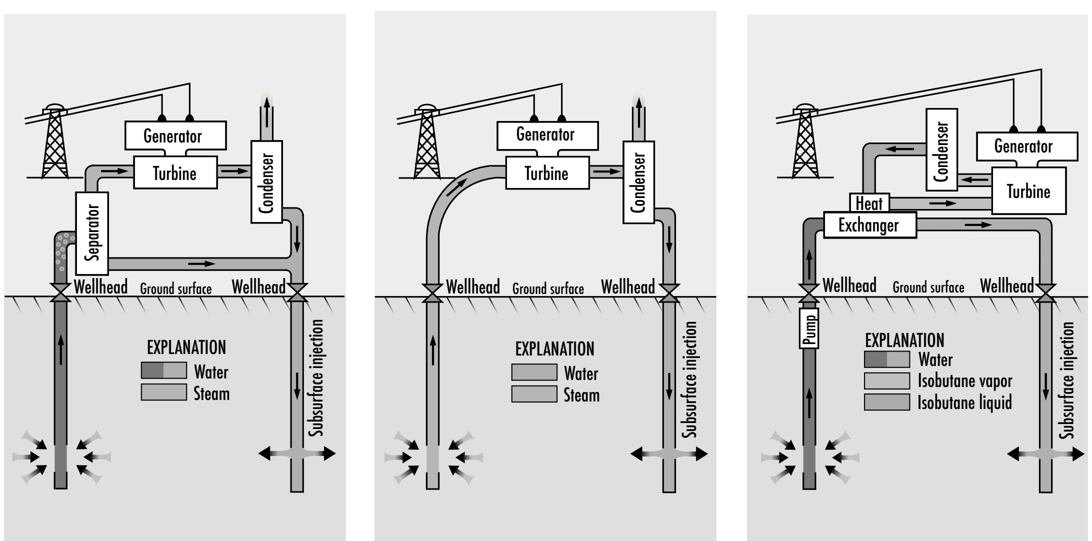


Diagram showing how electricity is generated from a hot-water hydrothermal system. The part of the hydrothermal water that flashes to steam is separated and used to drive a turbine generator. Wastewater from separator and condenser is injected back into the subsurface to help extend the useful life of the hydrothermal system.

Diagram showing how electricity is generated from a vapor-dominated hydrothermal system. Steam is used directly from wells to drive a turbine generator. Wastewater from the condenser is injected back into the subsurface to help extend the useful life of the hydrothermal system.

Diagram showing how electricity is generated from a moderate-temperature hydrothermal system using a "binary" system. The geothermal water is used to boil a second fluid (isobutane in this example) whose vapor then drives a turbine generator. Teh wastewater is injected back into the subsurface to help extend the useful life of the hudrothermal system.

Source: USGS, *Circular 1249*. Used with permission of the US Geological Survey geothermal facilities in Canada. However, there is a project underway near Pemberton, about 170 km north of Vancouver, to build Canada's first commercial geothermal power plant. Western GeoPower is developing the South Meager Geothermal Project, scheduled to go into production in 2007. Plans call for initial capacity of 100 MW, eventually producing upward of 200 MW.

As a new technology in Canada, there may be some uncertainty around the scope of environmental scrutiny that proposed geothermal projects could encounter. Regulators will have to develop new tools to evaluate projects as they come forward, taking into consideration land and sub-service water use and potential emissions.

Geothermal power plants require large capital investments, typically in the range of $3,000 to $3,500 per kW of installed capacity. It costs $2 million to $3 million to drill each well, and extensive seismic work must be carried out to fully understand the resource potential. However, fuel costs are very low and operating and maintenance costs are competitive with other technologies in the range of $0.01 to $0.03 per kW.h. Once operational, geothermal generation is extremely reliable and is suitable for base load power. The world's largest dry steam facility at the Geysers near Santa Rosa, California boasts 98 percent reliability – higher than most fossil fuel and nuclear generation plants.

In addition to the need for a good hydrothermal resource, geothermal generation requires connection to a transmission system. Given that generating facilities must be constructed close to the resource, developers are also faced with the hurdles that must be overcome to build an interconnection to the electrical grid. This may involve considerable effort and expense and could certainly affect the economic viability of a project.

3.4.3 Environmental Considerations

While using geothermal resources to generate electricity is relatively clean, there are still some environmental impacts. Depending on the source of hot water or steam, gases like hydrogen sulfide (H_2S) and CO_2 may be produced. With current technology, most of the H_2S is either returned to the reservoir or recovered as elemental sulphur. CO_2 production is less than the cleanest fossil fuel generating plant. Heavy metals, associated with geothermal vapours or water, can be recovered and used commercially.

The footprint of a geothermal plant itself is relatively small. However, there may be extensive pipeline networks for collecting and re-injecting the geothermal resource and a right-of-way for transmission facilities. Water use may also be an issue because as a hydrothermal reservoir is produced, it may be necessary to source groundwater for re-injection to sustain the production of the field. Through careful production and monitoring, a hydrothermal resource may be produced indefinitely.

3.4.4 Industry and Government Initiatives

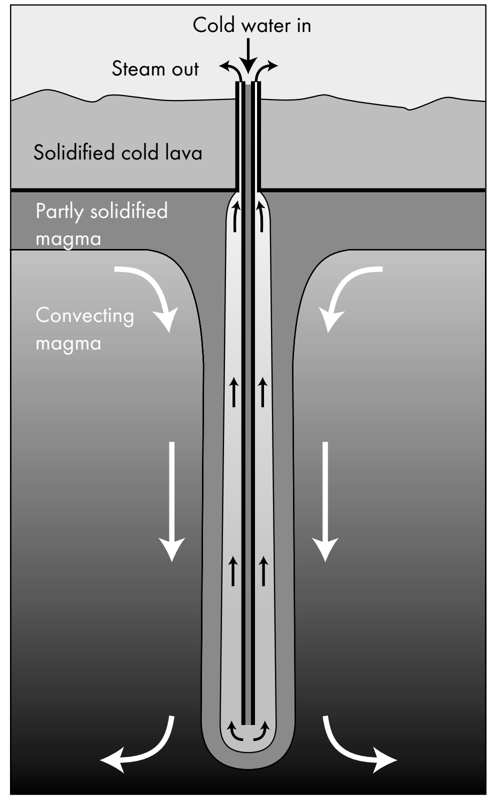
Interest in geothermal electricity generation is centred in British Columbia. With a number of the best large hydro sites developed, B.C. Hydro is looking to diversify into other types of generation. Geothermal is seen as a competitive and likely alternative source of power. B.C. Hydro issued its Open Call for Power in December 2005, with a minimum of 50 percent of the electricity to be purchased from proven, green power sources. Geothermal power could possibly meet some of this requirement.

One of the limitations to developing hydrothermal systems is insufficient permeability of the rock in which the water or vapour is trapped. Using technology borrowed from the oil and gas industry, careful fracturing of rock in or around hydrothermal reservoirs can increase permeability. New reservoirs can be developed in non-porous hot rock and water can then be injected or allowed to percolate in the rock, creating a hydrothermal resource.

Steam and water reservoirs make up just a fraction of the total geothermal resource. The earth's magma and hot-dry-rock could provide almost unlimited energy if the technology were developed to use them. Eventually, it may be possible to drill or push pipe into magma and create a heat exchange system that would capture thermal energy through water injection and recovery of the steam generated. This mining of magma is in the experimental stage and faces significant technical obstacles. See Figure 3.4.3.

FIGURE 3.4.3

Mining Thermal Energy from Magma



A pipe is drilled and (or) pushed into magma. Cold water is pumped down the pipe, becomes heated by magma in contact with pipe, and rises buoyantly back to the surface as steam. Magma that solidifies against the pipe forms an insulating layer that must somehow be sloughed off into the magma body to maximize the rate at which heat is mined. This sort of system was successfully tested in a crusted-over pond of magma (lava lake) at Kilauea Iki Cater of Kilauea Volcano on the Island of Hawaii in the 1980's.

Source: USGS, *Circular 1249*. Used with permission of the US Geological Survey

3.4.5 Regional Developments

Due to the specific site requirements for geothermal power, there are limitations to its development in Canada. Western British Columbia's location adjacent to the "Ring of Fire", the volcanically active and earthquake-prone region rimming the Pacific Ocean, makes it most suitable for future developments. Estimates of an ultimate potential for the region are as high as 1 100 MW. Other geographic regions with possible geothermal resources include the Yukon and Eastern British Columbia.

3.4.6 Summary

Geothermal resources can be produced to generate electricity cleanly and efficiently and at a cost that is competitive with other green technologies. However, given the hydrothermal requirements, the potential for geothermal generation in Canada is limited. As new technologies emerge, it may be possible to capture heat from the earth in different ways, increasing the ultimate potential of this resource.

3.5 Solar Photovoltaics (PV)

In twenty minutes, the amount of solar radiation falling on the earth provides enough energy to supply the world's energy needs for one year. The resource potential is virtually unlimited.

The energy contained in solar radiation can be used in a number of ways – providing heat for spaces, water and processes; illuminating buildings; and generating electricity. It can be as simple as using window blinds to control the amount of sunlight entering a room, or heating water with warmth from the sun. This report looks only at solar PV electricity generation. The basic PV device, called a PV cell, uses the photoelectric effect: certain materials produce electric current when exposed to light.

FIGURE 3.5.1

PV Modules on a Residential Rooftop in Edmonton, Alberta

Photo provided by Gordon Howell.

3.5.1 Technology

Photovoltaic cells are made of semiconductor materials. Most are made of silicon (the same material used in the microelectronics industry), boron and phosphorus. Recent research finds organic dyes and polymers are promising. When light strikes the solar cell, electrons are knocked loose from the atoms in the semiconductor material. Wires attached to the positive and negative sides form an electrical circuit, causing the electrons to flow as direct current (DC) electricity. A number of solar cells electrically connected to each other and mounted in a structure are called a photovoltaic module. Modules are designed to supply electricity at a certain voltage (typically 15 to 23 volts), and the current produced is determined by how much light strikes the module. Multiple modules connect to form arrays, which can be connected to produce any voltage and current combination.

Photovoltaic technology is well proven although cost and efficiency improvements continue to be made. Canadian manufacturers are among the leaders in developing cheaper technology. Currently, the cells used in the market are about 15 to 20 percent efficient, but new cells being developed and evaluated are expected to reach 40 to 50 percent efficiency. When PV systems are used for distributed generation, transmission losses are reduced. Photovoltaic systems are very simple. They produce electricity directly, unlike turbines that require motion, combustion, or both to generate electricity. In a grid-connected system, the only components are the solar modules, an electronic inverter that synchronizes the solar power produced with the grid power and two switches.

Photovoltaic systems only produce electricity when the sun is shining. The amount of electricity production depends on the time of day, time of year and weather conditions. In some parts of the world, the daily electricity demand profile parallels the electrical output of PV systems. For example, when the sun is brightest, demand for air conditioning increases in warm climates. This is true in some parts of Canada, such as southern Ontario, but not in others. Therefore, PV is not as beneficial in Canada as in other parts of the world, such as the southern United States.

Worldwide, the PV industry is changing its focus from small, specialized remote applications to urban grid-connected systems. In 1995, the industry was comprised of about 80 percent industrial and residential off-grid or remote projects, and 20 percent connected with utilities. The trend has reversed and now about 80 percent of the technology is utility grid-connected, and only 20 percent is comprised of off-grid applications. The off-grid market is growing at 25 percent per year, but the grid-connected market is now growing at over 40 per year, largely through subsidized capacity-building programs.

Canada has not seen the same growth mainly because PV systems are generally not as cost competitive as conventional sources of electric generation. In fact, on-grid sales represent only two percent of the entire Canadian PV market as the country employs PV technology primarily for niche applications.

As Canada has relatively low-cost electricity and the market favours large-scale, central power generation, it is difficult for alternative technologies to penetrate the market. Total PV generation in 2002 was just 22 GW.h out of Canada's total generation of approximately 600 000 GW.h that year.[18]

Photovoltaic systems connected to the grid have back-up power available at all times and off-grid systems incorporate batteries because of the intermittent nature of this resource. Batteries are generally not used with grid-connected systems because the grid is a cheaper and less complex "storage" system compared with a battery bank. For electrical system operators, intermittency can become an operational consideration when the penetration of intermittent energy technologies (such as PV, wind, and tidal) reach the 10 to 20 percent penetration level. It will likely be at least 20 years before Canada reaches this level. At that point, hydro systems will be well positioned because they provide virtual electricity storage that can compensate for intermittent sources of power.

3.5.2 Market and Regulatory Issues

Though the photovoltaic market is very small in Canada, with about 14 MW of installed capacity, the growth rate has been impressive at 21 percent per year since 1994[19]. Worldwide, the growth rate over the last three years has been closer to 40 or 50 percent.

Cost remains a barrier at around 30 cents per kilowatt hour, so PV technology is not competitive now nor will it likely be in the near future, unless incentives are available. Since Canadian electricity retails for a third or a quarter of that price, the technology is not competitive unless other factors are considered. When PV systems are used for distributed generation, it can reduce the need for additional infrastructure such as transmission lines over long distances, which adds value. However, grid-connected PV systems may require additional equipment such as bi-directional metering.

Photovoltaic systems require large capital investments, but the fuel (i.e., the solar radiation) is free. System costs vary according to size from $30,000 for a 2.5 kilowatt system to $40,000 for a 4 kilowatt system. A grid-connected PV system consists of PV modules, switches, an inverter and an optional battery bank. An off-grid PV system consists of PV modules, switches, a charge regulator, a battery bank, an inverter, and optionally an engine generator and battery charger. With older systems, about half of the costs could be attributed to the battery and inverter. Systems have become much larger, and the new thinking is to make large systems without storage assuming the equipment can be attached to a significant enough load. This would result in a more cost-competitive system.

Raw materials used to manufacture PV cells are currently in short supply and are expensive. As with other high-tech industries, manufacturing facilities are highly automated and expensive to build. Demand for PV is also growing and as a result, after years of decreasing costs, solar modules have recently increased in price. Additionally, there are many barriers to connecting PV systems to the grid, which can be mitigated by interconnection standards and guidelines, but most utilities lack incentives for interconnecting and lack experience with PV systems. Costs are another barrier, since Canadian generators are typically offered low payments for electricity. Germany pays the equivalent of approximately 65 cents Canadian per kilowatt hour for PV generated electricity so the payback period is much shorter than it would be in Canada with retail rates normally between five and ten cents per kilowatt hour.

18 IEA, Energy Statistics

19 Industry Canada, *Unleashing the Potential of On-Grid Photovoltaics in Canada*, *An Action Plan to make PV an Integral Component of Canada's Energy Future*, 2003

3.5.3 Environmental Considerations

While on-grid PV technology is more expensive than other forms of traditional or renewable energy, the environmental, social and economic benefits can be significant and are often not considered by decision makers. Solar modules do not have any moving parts, do not make any noise and are mostly made of silicon, one of the earth's most common elements. The modules are environmentally benign; however there are some concerns about the disposal of certain components after units are decommissioned. PV electricity generation produces no air emissions or GHG.

With distributed generation and especially with building-integrated photovoltaics (BIPV) applications, the environmental footprint is small.

3.5.4 Industry and Government Initiatives

Solar PV technology is one of the only emerging renewable energy options that does not have a direct incentive for deployment throughout Canada. There are very few enabling programs

FIGURE 3.5.2

British Columbia Institute of Technology, Burnaby, B.C.

Source: BCIT

Building Integrated Photovoltaics

Photovoltaic cells can be integrated into buildings, walls, roof tiles and windows. There are a growing number of BIPV products for sale. It is estimated that there are over 35 companies worldwide producing more than 50 BIPV-related products, including roofing shingles, structural roofs, sunshades, curtain walls, skylights and semi-transparent windows.[20] A number of these are available in Canada and the U.S.

Building integrated photovoltaics offer attractive options to enhance building design and construction, such as colour, surface options and passive benefits such as shading and acoustic control. The technology is widely used throughout Europe, but is just beginning to enter the Canadian market. Studies suggest Canada could install 70 000 MW of building-integrated systems, but most architects, engineering firms, building owners and builders know very little about BIPV.

When BIPV is used, PV becomes more economic, because traditional shingles, windows or siding do not need to be purchased, which offsets the cost of the BIPV system. Compared with large-scale, ground-based PV power plants, cost savings through these combined functions can be substantial (e.g., in expensive facade systems where cladding costs may equal the costs of the PV modules).[21]

Technology Place, at British Columbia's Institute of Technology's Burnaby campus, was designed as a research facility for emerging high tech companies. The building was chosen as the site for one of three projects to demonstrate to government, students and the public the effectiveness of PV technology.

Most of the windows in the main entrance facade of the Technology Place building incorporate thin-film solar cells that supply electricity for all the lighting within the building.

20 Industry Canada, *Unleashing the Potential of On-Grid Photovoltaics in Canada*, *An Action Plan to make PV an Integral Component of Canada's Energy Future*, 2003

21 Schoen Tony J.N., *Building Integrated PV Installations in the Netherlands - Examples and Operational Experiences*, Ecofys Energy and Environment, PO Box 8408, 3503 RK Utrecht, the Netherlands

in Canada specifically for solar energy even though it is recognized as a green and renewable source of energy. PV projects meet the application requirements for several broader programs that promote emerging generation technologies.

3.5.5 Regional Developments

The Arctic is a good place for solar generation approximately six months of the year. Fuel and associated transportation costs are high in the Arctic (e.g., diesel fuel costs $3 to $4 per litre) so it is easier for PV to compete in this higher-priced environment. Therefore, Canada's northern regions are the most likely venue for PV technology to begin to penetrate the power generation market in a meaningful way. In these locations, PV technology can be used in hybrid configurations alongside diesel generators.

When using PV on diesel-electric grids in the North, the main cost avoided is fuel consumption. If a community has more than one generator, the additional generators need to start less frequently, which lowers maintenance and replacement costs. As the cost of PV systems comes down, the application of PV to diesel grids in the North will start to make economic sense, even when environmental costs are not considered.

Capital costs of PV systems are usually less than the cost of extending northern electric grids. For larger industrial systems that use diesel generators, the cost of a PV system over its operating life is usually lower than the diesel alternative. Diesel generators are relatively cheap to buy but expensive to run, whereas PV systems can be expensive to buy but cheap to run. In effect, a customer purchases fuel for the next 20 years when purchasing a PV system.

Fusion and Cold Fusion

Many scientists are banking on nuclear fusion- the process that powers the sun- as a solution to achieving energy and environmental goals in the long run. Unlike nuclear fission, which involves the "splitting" of atoms and generates long-lived radioactive byproducts, nuclear fusion releases energy through the union of atoms. In order to achieve nuclear fusion on Earth, many hurdles must be overcome. Temperatures of 100-150 million degrees centigrade must be created in order to provide atoms with enough kinetic energy to fuse. At these temperatures, the gaseous fuel, or plasma, is fully ionized. The challenge is to contain the plasma, allowing fusion to take place.

In order to overcome the significant technological hurdles posed by the fusion process, ITER (rhymes with "fitter", and is Latin for "the way") was created. ITER is an international project involving the People's Republic of China, the European Union and Switzerland (represented by Euratom), Japan, the Republic of Korea, the Russian Federation, and the United States of America, under the auspices of the International Atomic Energy Agency.

At a cost of four billion Euros, ITER is the experimental step between today's studies of plasma physics and tomorrow's electricity-producing fusion power plants. ITER is to be constructed near Cadarache, France. The project will be phased in, with an operational phase scheduled for some time around 2025. Current expectations are that a fully operational, large-scale commercial fusion-powered electricity generation plant would not be in service until after 2050.

In 1989, two researchers at the University of Utah announced that they had observed fusion in a relatively simple bench-top experiment. Their announcement was followed by a storm of controversy that shook the scientific community. In 2002 and again in 2005, different scientists reported similar discoveries, but their announcements have been met with strong scepticism. It remains to be proven conclusively that this "cold fusion" is a reproducible phenomenon, and that more energy is produced than is consumed in these reactions.

British Columbia, Ontario and Nova Scotia have standard interconnection agreements and other provinces are considering developing interconnection policies. Consistent interconnection guidelines would make it easier to install PV systems.

3.5.6 Summary

Photovoltaic technology is well proven, but advancements must be made to reduce costs enough for the technology to be cost competitive in the Canadian market. Barriers to distributed generation (see Section 3.9) are presently making it difficult to install systems even in applications that are more financially viable, such as BIPV. Canada's North is the first place where PV would be cost competitive because of the high price of traditional generation sources. Continued improvements in the cost competitiveness will enable this clean technology to gain more market share over the long term.

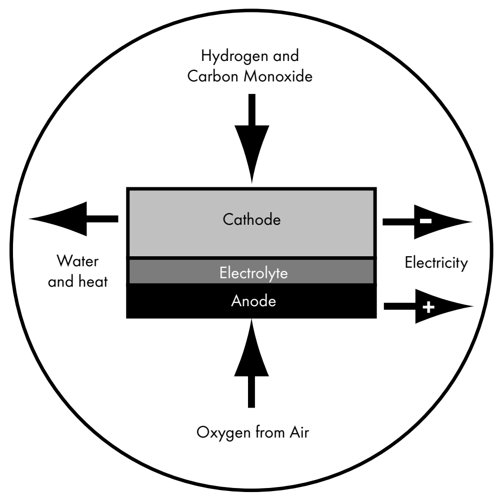
3.6 Fuel Cells

A fuel cell is an electrochemical device that produces electricity and heat by combining hydrogen and oxygen. The waste product is water (Figure 3.6.1). It is similar to a battery, but a fuel cell does not need to be recharged or replaced because it uses externally stored fuel.

William Grove developed the fuel cell. In 1839, when Grove was experimenting on electrolysis (splitting water into hydrogen and oxygen with an electric current), he observed that combining the elements produced an electric current. Other scientists paid sporadic attention to fuel cells throughout the 19th century. Francis Thomas Bacon, a British scientist, worked on alkaline fuel cells from the 1930s through 1950s and demonstrated a working "stack" in 1958. This technology was licensed to Pratt and Whitney and used for the Apollo spacecraft.

FIGURE 3.6.1

Fuel Cell Electricity Production Process



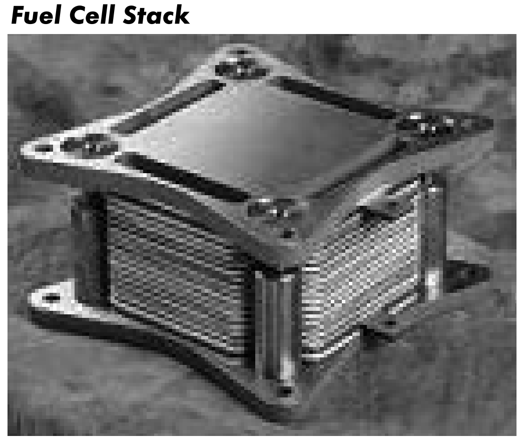
Source: Versa Power Systems Inc.

3.6.1 Technology

A fuel cell is typically a thin flat square device. Although the manufacturing process is quite complex, one method is to tape cast a base and use screen-printing to apply an anode to one side and a cathode to the other. The cell may be less than one millimetre thick, yet it must be durable, flexible and able to withstand high temperatures. The power output is scalable by changing the cell area to produce the desired current and stacking cells to produce the desired voltage. Individual stacks (Figure 3.6.2) are combined to increase power output.

FIGURE 3.6.2

Fuel Cell Stack



Source: Versa Power Systems Inc.

> ### *Stages of Development*
>
> Fuel cell research has been ongoing for over 100 years. Recent studies have focused not just on performance but also on the cost. This could indicate fuel cells are beginning to move to commercialization. The following are estimated minimum timelines for the stages of development starting in 2006.
>
> ***Stage 1. Product-preceding***
>
> The technology still needs to be researched and developed. Breakthroughs are required to advance the technology. This phase may take an additional three years for a company with strong financial resources.
>
> ***Stage 2. Move to commercialization***
>
> The product must be made more robust, configured properly for customers, and undergo field and beta field trials before manufacturing is started. This stage takes about five years if there are no issues with funding.
>
> ***Stage 3. Full commercialization***
>
> At this stage, the product is competitively marketed and begins to gain consumer acceptance and market share. Timing can vary greatly, but it generally takes several years. Though, it takes longer when a product must compete with existing technology.

A fuel cell can be used in almost any application for electrical power. Fuel cell stacks can be used instead of internal combustion engines or batteries to power vehicles or in small devices such as laptop computers and wireless phones. Large fuel cell stacks have replaced existing power plants to provide electricity for neighbourhoods or factories. Fuel cells can be manufactured as large or small as necessary for the particular power application. Micro fuel cells the size of a pencil eraser can generate a few milliwatts of power, whereas others provide the electrical needs of hundreds of homes. As fuel cells are scalable and can be installed on site they have a variety of applications including distributed generation for remote sites and individual homes or in place of large generation plants.

3.6.2 Market and Regulatory Issues

High costs of fuel cells relative to traditional electricity generation methods have prevented widespread market penetration. Currently fuel cells are used in niche applications, such as cabins in remote locations that are not connected to the electrical grid or when backup power is very important and alternatives are expensive (e.g., cell phone towers). Fuel cells are used for mainstream power generation demonstration projects.

The technology is in the early stages of commercialization and can not currently compete with electricity from the grid. However, certain applications can exploit the benefits of a fuel cell. For example, fuel cells would be more competitive as peaking units (as opposed to base-load units) because they have a fast start-up time and the costs for peak power are higher than for base power.

There are some per unit cost savings for ancillary equipment when system size increases, but otherwise costs are fairly linear because fuel cells are modular (i.e., to double the size, the costs approximately double). Research and development is required to reduce the high cost of specialized raw materials.

Northern Alberta Institute of Technology's (NAIT) Fuel Cell Applied Research Project

The Northern Alberta Institute of Technology installed the first commercially operated high-voltage fuel cell in Canada. The purpose of the project is to investigate and demonstrate ways of using the electricity and heat produced by fuel cells and to develop a fuel cell education program. NAIT power engineering students will be given the opportunity to work with the fuel cell to learn new skills. The NAIT Fuel Cell Applied Research Project also provides an opportunity for the public to learn more about how fuel cells work and the role they can play in their daily lives.

The 200-kW phosphoric acid fuel cell produces electrical and heat energy that is used by the facility. The energy production efficiency is about 65 percent.

FIGURE 3.6.3

NAIT Fuel Cell Applied Research Project

Source: NAIT

3.6.3 Environmental Considerations

Fuel cells produce energy through electrochemical conversion of fuel, so they produce zero or very low emissions, depending on the fuel used. Oxygen may be taken directly from air. Hydrogen may be delivered in pure form from liquid or gaseous storage tanks or extracted by a reformer from methanol, gasoline, natural gas, propane or other hydrocarbon fuels. Gas from landfills may be used directly or indirectly in fuel cells after undergoing reformation. One primary area of industry research is development of standalone or integrated reformers for extracting hydrogen from hydrocarbon fuels and development of fuel cells that can be powered directly by fuels such as methanol. Although there are no GHG emissions when pure hydrogen is used as a fuel, there are by-products from some of the other fuel sources (typically carbon dioxide that can be sequestered). Unlike internal combustion engines, fuel cells create little noise or vibration and they are non-toxic.

Fuel cells operate at high efficiencies of approximately 40 to 50 percent over a wide range of loads. When heat is used, the system efficiency increases to more than 80 percent.

Fuel cells offer many advantages over conventional energy sources:

- higher efficiencies than conventional power systems such as the internal combustion engine, contributing to environmental benefits;
- few moving parts, therefore, requiring minimal maintenance and reducing life cycle costs of energy production;
- efficient operation at part load and in all size configurations;
- modular in design, offering flexibility in size and efficiencies in manufacturing; and

- combined heat and power applications further increase efficiency.

3.6.4 *Industry and Government Initiatives*

In Canada, early research into fuel cell development was carried out at the University of Toronto, the Defence Research Establishment, and the National Research Council. Most early work concentrated on alkaline and phosphoric acid fuel cells. In 1983, Ballard Research began developing a polymer electrolyte membrane (PEM) fuel cell under a contract with the Defence Research Establishment. Over the past twenty years, Canadian companies, with some government support, have become world leaders in the development of fuel cells and related products.

The U.S. Department of Energy (DOE) sponsors the Solid State Energy Conversion Alliance, or SECA. This program's goal is to produce a core solid-state fuel cell module that would cost no more than US$400 per kilowatt, nearly a factor of 10 less than the cost at the start of the program a few years ago. At this price, it is believed fuel cells could compete with gas turbine and diesel generators and likely gain widespread market acceptance.

Most players in the fuel cell industry are focused on R&D that will lead to commercialization and widespread use of fuel cells. For example, the National Research Council's Institute for Fuel Cell Innovation focuses on two types of fuel cells. For PEM fuel cells, research is aimed at increasing reliability and durability while improving performance, manufacturability, operational flexibility

The Hydrogen Economy

Imagine a futuristic economy that relies on hydrogen for energy rather than fossil fuels. Instead of natural gas lines, hydrogen lines would connect to your home to run your furnace, heat your hot water, provide fuel for your fuel cell generator and even power your car. Alternatively, you could go to the local hydrogen fuelling station to fill up the tank on your fuel cell operated vehicle. Sound like a far-fetched idea? The California Fuel Cell Partnership is building a Hydrogen Highway[22] with 15 fuel stations in service and another 16 planned for the near future.

Hydrogen fuel cells provide clean, reliable power without combustion and its associated emissions. Many people believe hydrogen is the future. The challenges, however, are significant:

- Stationary fuel cells and fuel cells for vehicles would need to prove to be reliable sources of power. Because we currently have products that meet our power needs, fuel cells would need to be just as reliable and convenient as existing technology and prove to have other benefits. These benefits would have to be great enough to encourage consumers to invest the time, effort and money in making the change.

- Society would need to produce hydrogen in massive quantities, that is, enough to displace the oil and gas the world currently produces. The hydrogen could come from reformed fossil fuels or water could be electrolysed using green power such as hydro, solar or wind.

- Infrastructure would be the next immense challenge. The hydrogen would need to be transported, potentially through pipelines, such as those we have today. Alternatively, the hydrogen may be produced on site in smaller quantities. Either way, vast infrastructure changes would be required.

Adversaries do not see the hydrogen economy ever being anything more than a vision. Current technologies use energy to convert water or fossil fuels to hydrogen. Additional energy is consumed in transporting the hydrogen. Converting hydrogen to electricity through a fuel cell results in further energy losses. Opponents argue that wasting energy by repeatedly converting sources is not the way to ensure a prosperous energy future. Instead, society should use available energy sources in the most efficient way possible.

22 State of California, *California Hydrogen Highway*. Available at: http://www.hydrogenhighway.ca.gov/

and decreasing costs. Similarly, for solid oxide fuel cells, research is aimed at improving durability and lowering costs by reducing operating temperatures and system complexity.

The U.S. DOE SECA program for high temperature fuel cells has targets to reduce degradation and costs through three phases in a 10-year program. Previously, efficiency was a metric that was pushed almost exclusively, but costs were not given equal weighting. As fuel cells move closer to becoming commercial, costs need to be reduced.

In Canada, funding is available from the Industrial Research and Development program (NRCan) and Sustainable Technology Development Canada. In terms of development, the Alberta Energy Research Institute has taken a lead on solid oxide fuel cell collaboration and planted seed funds, and Fuel Cells Canada is a major promoter. Canadian suppliers, service providers and fuelling infrastructure are in place, and there are many international participants in the fuel cell development and promotion.

3.6.5 Regional Developments

Fuel cells generally remain a pre-commercial technology, which means technological breakthroughs are required before the technology can become competitive with other generation sources. Therefore, fuel cells are currently used only for niche applications and demonstration projects.

3.6.6 Summary

It will likely be at least five years before fuel cells reach the commercial stage. Once commercial, however, fuel cells can offer many benefits. They are less damaging to the environment than traditional generation sources and can be used for any application of any size, including as back-up for intermittent power sources such as PV or wind energy.

3.7 Ocean Energy

Ocean energy includes all forms of energy derived from the sea including tidal energy, wave energy, ocean current energy, salinity gradient energy and ocean thermal gradient energy. Most of the present activities and discussions on ocean energy around the world are related to harnessing power from tides, tidal currents and waves. Global resources are estimated to be in the range 6–11 TW. This compares with total estimated renewable capacity of 77 TW (excluding hydro) and hydro capacity of 800 TW.[23]

3.7.1 Technology

There are only a few areas in the world with tidal potential that uses the "head" created between the water levels at high and low tide to generate electricity. The three projects currently in existence are in Annapolis Royal, Nova Scotia (20 MW), France (240 MW) and Russia (less than 1 MW). Although there is currently a major project under development, a 260 MW project scheduled for completion in South Korea in 2009, the opportunities for these tidal barrage (dam) projects are limited. The best potential is associated with modular technologies that can be added together to make the system larger when generating power from tidal currents and wave power.

23 Resource estimate from Powertech and capacity from IEA, as of 2002

Currently, there are three tidal current demonstration projects in operation: a 300 kW project in the United Kingdom, a 130 kW project in Italy, and a 300 kW project in Norway. Although most work on these technologies has been undertaken in Europe, it is thought that Canada, including the Arctic coast, has more potential. British Columbia tidal current and wave resources were last mapped in 2001.[24]

For tidal currents, the speed of the current is a main factor determining the generation potential. For example, 55 potential sites have been identified near Vancouver Island with current speeds greater the two metres per second. Possibly 12 of these sites would each have 10 MW of generation potential. Turbine and generator sets can be mounted on the ocean floor or suspended from a floating platform. Power can then be transmitted to landfall by sub-sea cables.[25]

Power can also be generated from wave energy, which varies with the height and period (or speed) of the wave. An example of one generation technology is the Wave Dragon, developed by the Danish company, WaveDragon ApS. It is expected that a commercial version of the offshore wave energy converter will be available in 2007; the capacity of the unit will be 4 MW with initial generation costs of 18 ¢/kW.h. It is anticipated that costs will eventually decline to 6 ¢/kW.h.[26]

3.7.2 Market and Regulatory Issues

Currently, the high costs for tidal and wave power would tend to favour their use in situations where the costs of alternatives are high and in distributed generation applications in coastal areas. However, costs have been declining. European project costs are estimated to be in the range of 5–12 eurocents per kW.h (C$0.08–0.19), significantly lower than the 35-50 eurocents (C$0.56–0.80) in the early 1980s. These costs are somewhat speculative because there are few purely commercial operations. Two projects, one in Scotland and the other in the United States, are at the lower end of this range.[27] It has been suggested that at this stage of development, ocean energy costs are lower than wind costs were at a similar stage.[28]

The 20 MW Annapolis plant was constructed for $50 million ($1980) not including much of the barrage construction, which already existed in the form of a causeway. Currently, Nova Scotia Power Inc. (NSPI) dispatches the plant twice each day for five to six hours, corresponding with the daily tides. The company reduces output from other generating units to accommodate this source of power.

Intermittency of wave and tidal currents may pose some challenges for integration in electrical grids. However, in the case of tidal currents, the daily cycle is fairly predictable, as are the tides – unlike the random intermittency associated with wind. Nonetheless, the cyclic availability requires some form of back up, storage or synergy with other power sources.

Industry proponents suggest that Canada is in a good position to get in on the ground floor of a new industry that has world market potential, yet currently has no dominant suppliers. At this early stage of development, however, government investment is required to encourage the development

24 Triton Consultants Report for BC Hydro, 2001

25 Powertech, 8 August 2005 presentation

26 *Alternative Energy - Catch a Wave*, *Canadian Business*. September 2005, p.51.

27 Ocean Renewable Energy Group, *The Business Case for Ocean Energy in Canada* (referencing costs form the U.S. Electric Power Research Institute)

28 Ibid.

of a critical mass of expertise and to promote competition ("clustering"), which are precursors to the development of an industry. These developments could also result in the development of centres of excellence.

Research is conducted by entities such as the National Research Council (at the Institute of Ocean Technology, St. Johns, Newfoundland), Powertech, a subsidiary of BC Hydro, the University of Victoria, the University of British Columbia and others located on the east and west coasts. As the industry moves from the R&D stage into the deployment stage, it is anticipated there will be issues associated with environmental assessments and access to the transmission grid.

Apart from the power generation opportunities, there are potential synergies that could arise from wind and wave hybrid turbines, power provision to the offshore oil and gas industry, and hydrogen production and desalination.

3.7.3 Environmental Considerations

Wave and tidal technologies are regarded as renewable and green, because there are none of the emissions associated with burning fossil fuels. However, depending on the type of project and location, there could be a number of factors that would need to be assessed, including impacts on recreational usage, navigation, marine life, the seascape and other considerations. Tidal barrage projects can be more intrusive to the area surrounding the catch basins (the area into which water flows as the tide comes in, and is trapped for release through the generating unit as the tide goes out), resulting in erosion and silt accumulation.

3.7.4 Industry and Government Initiatives

The Ocean Renewable Energy Group (OREG) is an association of various experts and specialists, including technology developers, environmental scientists and marine operations specialists, that promotes an ocean energy industry in Canada. Originating from initiatives in British Columbia, OREG assesses the opportunities for all of Canada's coastal areas. An action plan and R&D proposal were developed in 2004. This resulted in the Federal Ocean Energy Working Group, which is chaired by the Office of Energy Research and Development, NRCan. Funding has been arranged to create an ocean energy atlas, review environmental benefits and concerns, and analyze the business potential. It is expected that NRCan will be giving further consideration to funding and incentives for ocean energy in the strategy it is currently developing for renewable energy. OREG has proposed that a goal of 25 000 MW installed capacity in Canada by 2025 is achievable.[29]

3.7.5 Regional Developments

Although there is good potential for further tidal barrage development in Nova Scotia, with at least two more prospects in the Minas and Cumberland basins in the northeast part of the Bay of Fundy, environmental and land use impacts would need careful assessment. Currently, there are no active plans to develop these areas. However, a study is being conducted for the maritime region on power generation from tidal currents. The study is being undertaken for Nova Scotia, New Brunswick and states in the U.S. northeast by the U.S. Electric Power Research Institute (EPRI). Early results indicate approximately 10 locations are being considered as potential sites for developing tidal current power.[30]

29 Ocean Renewable Energy Group 2004 Strategic Plan

30 Electric Power Research Institute, Maritimes and U.S. Northeast Tidal Study, December 2005

On the west coast, British Columbia is examining the potential for wave and tidal current power, including local initiatives and opportunities in cooperation with states in the U.S. Pacific Northwest. The B.C. Alternative Energy Task Force is expected to release a report, including recommendations for the ocean industry, in early 2006.

Presently, a tidal current project at the Race Rocks Ecological Reserve near Victoria, British Columbia is being developed. In this pilot project, a 65-kW turbine will replace the power currently generated by two diesel-fired units. The turbine is bi-directional and employs Canadian turbine and generator technology. Pearson College and EnCana are sponsoring this project. The technical partners for the project are AMEC, Powertech, Triton Consultants, Xantrex and Ocean Works.

3.7.6 *Summary*

Apart from the Annapolis tidal barrage project, the ocean energy industry in Canada is at the early stages of development, with some time to go before there is commercial or near-commercial production. Because of the early stage of development, incentives would be different than, say, the WPPI, which is production based. The rate of development of ocean power will be influenced by the resource potential and continuation of the cooperative efforts of industry and government. The best prospects on the east and west coasts are now tidal current and wave power.

3.8 Clean Coal

Coal is by far the most abundant of the hydrocarbon fuels (oil, natural gas and coal), worldwide and in North America.[31] However, its relatively high levels of emissions of SO_2 and NO_X and more recent concerns about CO_2 have caused increasing restrictions on its use in favour of alternatives, mainly natural gas. Rising oil and natural gas prices in recent years have elevated the interest in clean coal technologies.

FIGURE 3.7.1

Ocean Tidal Current Turbine, Victoria, British Columbia

Source: http://www.racerocks.com/racerock/energy/tidalenergy/tidalenergy.htm

31 NEB, *Canada's Energy Future*, *Scenarios for Supply and Demand to 2025*, 2003, p. 72

Clean coal technologies refer to the methods by which emissions resulting from coal combustion can be reduced. Efforts during the 1980s and 1990s focussed on SO_2, NO_X, particulate matter and mercury removal to address acid rain and smog formation. With escalating concerns about global warming, efforts to develop clean coal technology are focussing on reducing emissions of CO_2. Clean coal technologies may generally be characterized as improved efficiency in combustion, stack gas clean up and capture and sequestration of CO_2.

3.8.1 Technology

Integrated gasification combined-cycle power generation offers the cleanest, most efficient method available to produce electricity from carbon-containing feedstock such as coal or biomass. It reduces most of the SO_2, NO_X, particulate matter and mercury and also produces a pure CO_2 stream that could potentially be sequestered. The process also uses less water than a conventional plant.

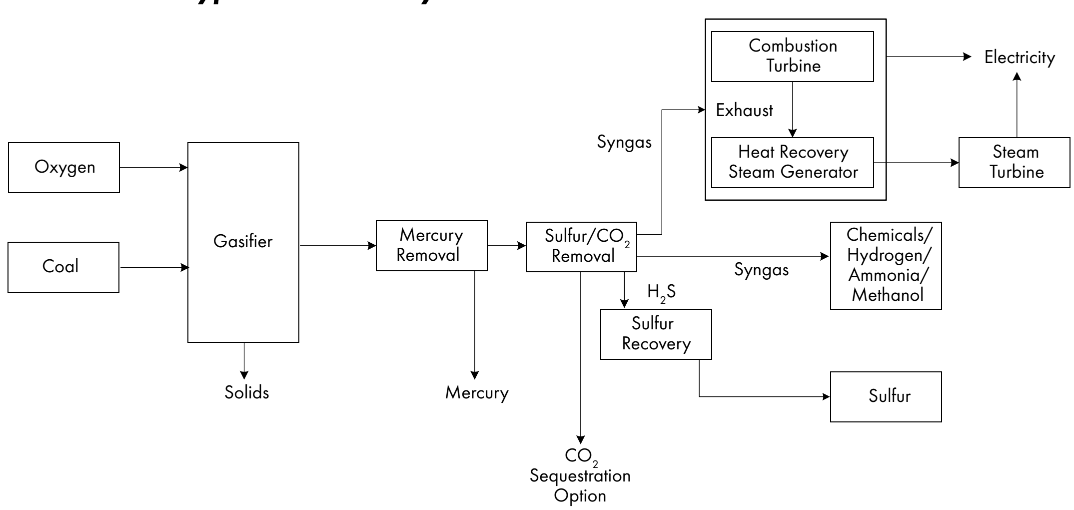
In essence, an IGCC plant uses natural gas combined-cycle technology, front-ended by a coal gasifier. The gasification process breaks down coal and other feedstocks into their constituent chemical compounds, creating a synthesis gas composed primarily of carbon monoxide and hydrogen. The synthesis gas is used instead of natural gas in combined-cycle units to generate electricity.

Commercial IGCC units are operated as base load units, generating electricity during all hours. They tend to use coal and petroleum product feedstocks, and they have tended to be built for units of less than 300 megawatts because larger gasifiers are difficult to transport due to their weight and size.

Existing IGCCs have achieved a capacity factor of 85 percent, meaning that a typical facility will generate energy 85 percent of the time during a given year. One commercial gasifier in the United States, owned by Eastman Chemicals, has achieved availability of 98 percent because it is equipped with a standby gasifier. This availability matches the availability of conventional coal plants, but having a redundant gasifier is the exception rather than the rule.

FIGURE 3.8.1

Schematic of a Typical IGCC Facility



3.8.2 *Market Issues*

Integrated gasification combined-cycle using coal is considered to be in the development stage, despite the fact that gasification technology has been in commercial use for more than 50 years. By and large, government and industry have collaborated to bring demonstration plants online using financial incentives. The two IGCC units located in the United States, Wabash River (Indiana) and Polk Power Station (Florida) began demonstration service in 1996 and became commercially operational in 2001. As well, there also are a number of units in operation in Europe, South Africa and Japan.

Currently, three IGCC plants are proposed for construction in the U.S.:

- American Electric Power (AEP), GE Energy and Bechtel Power have started the engineering design phase for a 629 MW plant in Ohio. American Electric Power is seeking regulatory recovery for construction and operating costs from the Public Utilities Commission of Ohio.
- Cinergy, GE Energy and Bechtel Power are studying the feasibility of building a 500 to 600 MW IGCC generating station at one of several sites in Indiana. Cinergy would apply for regulatory cost recovery for the construction and operation of the facility if constructed.
- Excelsior Energy is proposing to develop the Mesaba Energy project, a 530 MW IGCC plant, in Minnesota. Conoco/Phillips has been selected to provide the gasification technology. The anticipated operation date of the unit is 2010. The Mesaba Energy Project was awarded funding by the Department of Energy's Clean Coal Power Initiative in October 2004.

FIGURE 3.8.2

The Wabash River Integrated Gasification Combined-Cycle Plant, Indiana, U.S.A.

Source: http://www.princeton.edu/~hotinski/Resources/NETL_wabash_gasification_large.jpg

A major driving force behind the development of IGCC technology is high thermal efficiencies and low emissions levels. More efficient facilities produce the same amount of electricity with lower costs because less fuel is needed and there are lower environmental offset costs because there is a lower level of pollutants. The IGCC units typically achieve efficiencies near 45 percent. This is much higher than the 28 to 33 percent efficiency of a conventional coal plant. In the future, these systems may be able to achieve efficiencies approaching 60 percent.

Many generation developers consider supercritical or ultra-supercritical pulverized coal technologies as the best coal-fired generation option because IGCC is deemed to be too expensive. IGCC is more expensive due to higher financing costs resulting from concerns about capital costs, a lengthy start-up period and lower availability after commissioning. Other factors leading to higher costs are the requirement to clean the fuel gas after it leaves the gasifier and the need for a second gasifier if higher reliability is needed. The decision to invest in IGCC is also influenced by uncertain environmental cost forecasts, the lack of sufficient sequestration availability and consideration of the potential benefit of using the by-products of IGCC-fired generation in other industries. The Genesee Phase 3 plant in Alberta, which began commercial operation in March 2005, has supercritical boilers.

These factors, combined with high natural gas prices and concern about future emissions costs, have led generation developers to seriously consider IGCC. In spite of this, few IGCC plants are being constructed because the cost of an IGCC facility is greater than the next most efficient coal-fired generation technology, supercritical technology. There is also

Modern Coal-Fired Generation Technologies: IGCC and Supercritical

When deciding between clean coal technologies for electrical generation, utilities and private generation companies are considering two very different technologies: supercritical/ultra-supercritical and Integrated Gasification Combined-Cycle.

Supercritical electricity generation, first operated commercially in 1957, includes mechanical engineering innovations that result in efficiencies that surpass conventional sub-critical coal-fired facilities. By using higher steam pressure, higher temperature and a high-efficiency steam turbine, supercritical units produce more electricity with less coal than previous coal-fired plants. That reduces the cost of producing electricity and decreases the amount of emissions produced, since more efficient units use less coal to generate the same amount of electricity. The Genesee Phase 3 (G3) generating facility, which began commercial operation in March 2005 employs supercritical technology. Its thermal efficiency of approximately 40 percent is estimated to be 18 percent more efficient than other coal-fired facilities in Alberta. In addition to the reduced emissions from G3 as a result of the plant's higher efficiency, the owners of the unit volunteered to further offset carbon emissions to the level of a combined-cycle natural gas-fired unit, a 52 percent reduction. Clean air equipment costing $90 million was added in efforts to achieve this result.

In essence, an IGCC plant uses natural gas combined-cycle technology, front-ended by a gasifier. IGCC units achieve efficiencies typically approaching 45 percent or higher. There are no units in operation in Canada, but there are a number of plants in operation in the US, Europe, Japan and South Africa.

While IGCC is expensive, it is expected that efficiency could be further improved. Its competitive position would be further enhanced in a world of sustained high natural gas prices, with the further development of CO_2 sequestration and with the application of the by-product CO_2 stream to industrial and oil sands production applications.

In Canada, supercritical coal-fired generation is favoured over IGCC, largely because the costs of a supercritical plant are approximately 20 percent less than IGCC. The following factors may make IGCC more favourable in the long-term: increases in operating efficiency; development of CO_2 sequestration technology; availability of CO_2 for other applications; and more expensive environmental offset costs for supercritical coal plants.

a reluctance to be first to invest in IGCC because of reliability concerns, particularly during the commissioning phase. To overcome this reluctance, companies are beginning to provide performance guarantees during commissioning. Also, in certain regions, IGCC may not be the best choice for low rank coals with high moisture. Finally, there is apprehension about constructing IGCC facilities because a gasifier looks and smells like a chemical plant rather than a traditional power facility.

An IGCC power plant produces marketable by-products, rather than large volumes of solid wastes typical of scrubber-equipped or fluidized bed combustion plants using coal or petroleum-based fuels. The Canadian oil and gas and chemicals industries are now considering the benefits of gasification, with or without the IGCC electricity component, in terms of the value of the gasification by-products of CO_2, hydrogen, ammonia and sulphur. In Alberta, captured CO_2 can be used in refinery operations or with enhanced oil and gas recovery, through miscible floods in oil reservoirs, increasing the flow of CH_4 from the coal beds or it can be sequestered.

3.8.3 Environmental Considerations

Integrated gasification combined-cycle plants are more efficient than traditional coal plants and they are “clean” in the sense that they reduce or eliminate many of the smog precursors and heavy metals equal to or better than a combined-cycle natural gas plant. More efficient plants produce lower emissions because they produce more electricity per unit of coal burned.

As air emissions standards become stricter, the superior environmental performance of IGCC will add economic benefits, especially if CO_2 sequestration opportunities increase. The technology will have the ability to achieve greater emissions reductions at a lower cost than less advanced technologies.

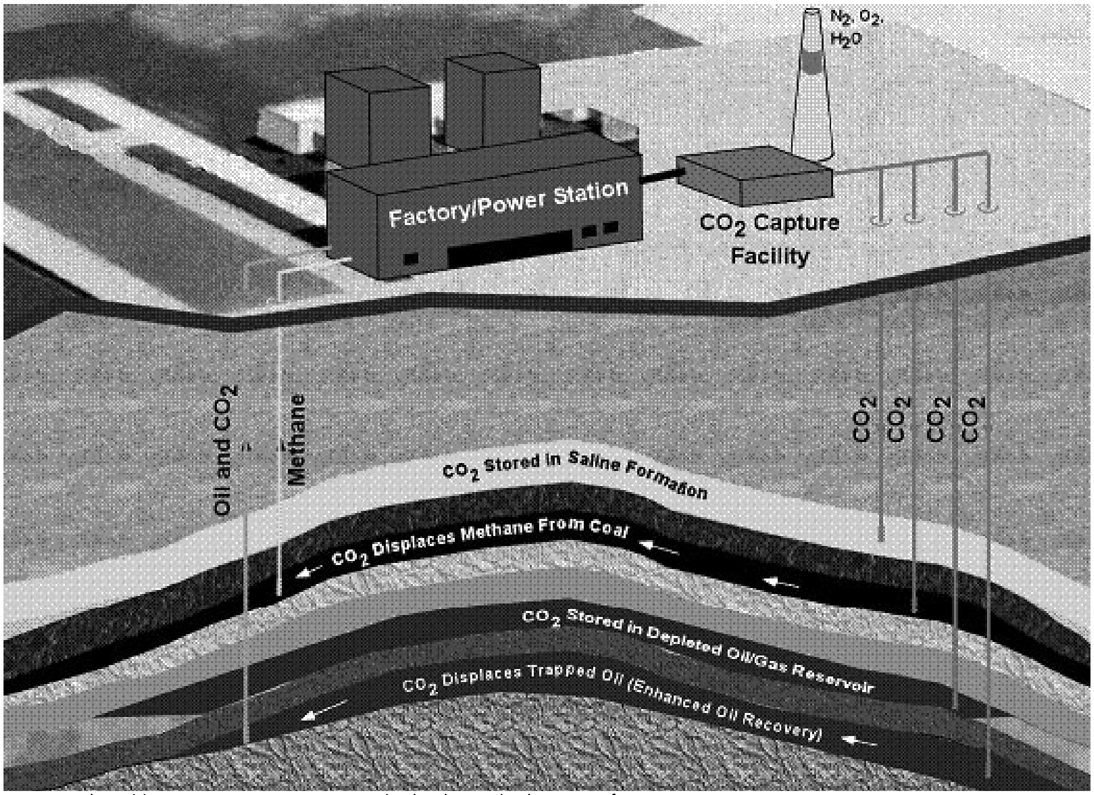
Many environmental benefits are realized in the IGCC generation process. During gasification, virtually all of the carbon in the feedstock is converted to syngas, which can be burned to generate electricity. IGCC can readily remove 98 percent of sulphur while generating one-sixth the amount of solid wastes of a conventional plant. Sulphur is removed from the syngas and captured either in elemental form or as sulphuric acid, both marketable products. IGCC reduces NOx by 92 percent compared with conventional coal-fired generation. Gasification technology has the potential to remove mercury and CO_2 upstream of the combustion process at a lower cost than conventional plants. The high temperature of the gasification process converts ash and other inert materials into a solid, thereby greatly reducing the volume of solids remaining after processing.

Unlike other gaseous compounds such as SO_2 and NO_X, CO_2 is not readily broken down. The only way to reduce CO_2 produced from the combustion processes is to increase the efficiency of the process or to change the fuel mix to lower-carbon fuels. This has led to a number of proposals for the sequestration of CO_2, which can be integrated with electrical generation, such as injection into salt caverns and abandoned reservoirs.

The amount of sequestration that will become available to owners of IGCC facilities is uncertain. As a result, investors are sceptical that the CO_2 storage and transportation technology will develop enough to enable new gasification projects. Potential developers of IGCC generation would like to see a national policy commitment on IGCC and a commitment that carbon capture opportunities will materialize.

FIGURE 3.8.3

CO_2 Capture Project



Source: http://www.co2captureproject.org/technologies/tech_img2.gif

Carbon Sequestration and the Uses of CO_2

For both environmental and economic reasons, depleted natural gas reservoirs, heavy oil fields and coal seams are attractive targets for carbon sequestration by direct CO_2 injection.

Depleted natural gas reservoirs contain CH_4 and the oil fields contain unrecovered heavy oil. Carbon dioxide injection may allow enhanced production of CH_4 or oil. With enhanced gas recovery, sequestered CO_2 is injected into underground natural gas reservoirs to displace and produce residual gas. Similarly, in enhanced oil recovery operations, CO_2 is injected to stimulate oil flow to produce heavy oil that was not extracted during previous recovery phases.

Carbon dioxide can be injected into coal seams to dislodge CH_4 molecules from coal and to make coal bed CH_4 flow more readily to production wells. CH_4 molecules on the coal desorb (or leave the coal molecule) because coal has a stronger affinity for CO_2.

Advancements in enhanced recovery technology would add value to underground carbon storage and improve the economics of potential IGCC projects. Potential investors in IGCC technology view the development of carbon sequestration technologies and the ability to use the sequestered CO_2 in other processes, such as enhanced oil and gas recovery, as key to further development and commercialization of IGCC technology.

3.8.4 *Industry and Government Initiatives*

Canadian federal programs focus on R&D and provide support for gasification technology under development and commercialization. The CANMET Energy Technology Centre provides services and support for technology development and commercialization and research services that play a role in the application of gasification technologies.

The Canadian Clean Power Coalition (CCPC) is an association of Canadian coal producers and coal-fired electricity producers that aims to secure a future for coal-fired electricity generation in Canada. The CCPC's mandate is to research, develop and demonstrate commercially viable clean coal technology. It plans to build a full-scale, coal-fired demonstration plant. The demonstration plant, expected to be in operation by 2012, will be designed to remove GHG and other emissions. In 2003, the federal government, through NRCan, committed to invest $1.7 million in the initial stages of the project. Three technologies are being considered for the new plant: IGCC, oxyfuel combustion, and chemically stripping the pollutants from flue gases.

The U.S. government recently increased its funding for gasification projects in response to concerns about energy supply certainty and surging oil and natural gas prices. The U.S. *Energy Policy Act* of 2005 authorized significant financial incentives for gasification-based projects under a number of programs. The U.S. Department of Energy's Fossil Energy Turbine Program is aimed at providing, by 2010, a commercial design for a coal-based power system that offers a 50 percent thermal efficiency, a capital cost of less than $1,000 per kilowatt, and near-zero emissions.

3.8.5 *Regional Developments*

Alberta and Saskatchewan are the most likely provinces to develop IGCC because over 95 percent of Canadian coal resources are located in western Canada (i.e., mostly sub-bituminous deposits in Alberta and lignite in Saskatchewan). There is some concern that IGCC generation may not be the best choice for such low quality coals with high moisture levels and that expensive customization may be required to adapt gasifiers to function reliably. Nova Scotia is also being considered as a possible site for an IGCC, largely because government financing programs aim to test IGCC-fired generation using various coal types, including the highly volatile bituminous A coal found in Nova Scotia.

Alberta, the province most likely to build coal-fired generation, currently favours supercritical coal-fired technology over IGCC because of costs, the relatively early stage of CO_2 sequestration technology, and transportation and potential issues related to the ability to gasify sub-bituminous coal in standard gasifiers.

Ontario could possibly develop IGCC-fired generation in the future. It is expected that natural gas-fired facilities will replace much of the coal-fired generation scheduled to be phased out by 2009. The incremental construction of generation to meet Ontario demand growth would likely come from nuclear power and other sources, including renewable generation. The main benefits in Ontario would be a reduced need for additional natural gas infrastructure and services, and reduced exposure to volatile natural gas prices.

3.8.6 *Summary*

Integrated gasification combined-cycle is a proven generation technology that offers potential for future growth in Canada. The major advantages of the technology include high efficiencies relative to supercritical generation technology; lower SO_2, NO_X and particulate matter; the ability to capture and sequester its relatively pure CO_2 stream; and the value of using the by-products of IGCC electric generation as feedstocks.

Despite the many advantages of IGCC, supercritical pulverized coal technology is favoured in Canada. This is mainly because there is no track record for CO_2 sequestration, storage and transportation because IGCC costs more and there is uncertainty over reliability and availability during and after its commissioning period.

Canadian private and public sectors are also examining gasification with the intention of producing usable by-products for the chemical industry, oil refineries and enhanced oil recovery operations.

While IGCC is expensive, it is expected that efficiency could be further improved. Its competitive position would be further enhanced in a world of sustained high natural gas prices and higher emission offset costs for coal plants, further development of CO_2 sequestration, and the application of the by-product CO_2, hydrogen, ammonia, and methane to industrial and oil sands production applications.

3.9 Demand Management

Demand management includes demand-side management, specifically energy conservation and energy efficiency, and demand response. Many stakeholders consider DSM and DR top priorities for meeting future electrical demand. Wider public interest in electricity planning and pricing issues, combined with new technologies that enable smarter energy consumption and energy management has created a resurgence in demand management. Demand management has many of the potential benefits attributed to emerging electricity generation technologies, including security of supply, emissions reductions, reliability of the distribution system and market efficiency.

Generally DSM refers to long-term, sustainable load reduction. It is advanced primarily by education campaigns promoting energy conservation and by technological improvements in energy efficiency. It is estimated that without the energy efficiency measures started during the oil crises of the 1970s, the world would be consuming 50 percent more energy than we actually do today.

Demand response, also known as load shedding or load shifting, is desirable in a constrained supply market where occasional load reduction is preferable to sourcing new generation. It suggests postponing or foregoing energy usage in response to high market demand and high wholesale pricing. At the most critical level, this is essential for grid-reliability to prevent blackouts. In a broader context, it is also an evolving industry movement that considers large electricity demand reductions as a valuable, marketable commodity.

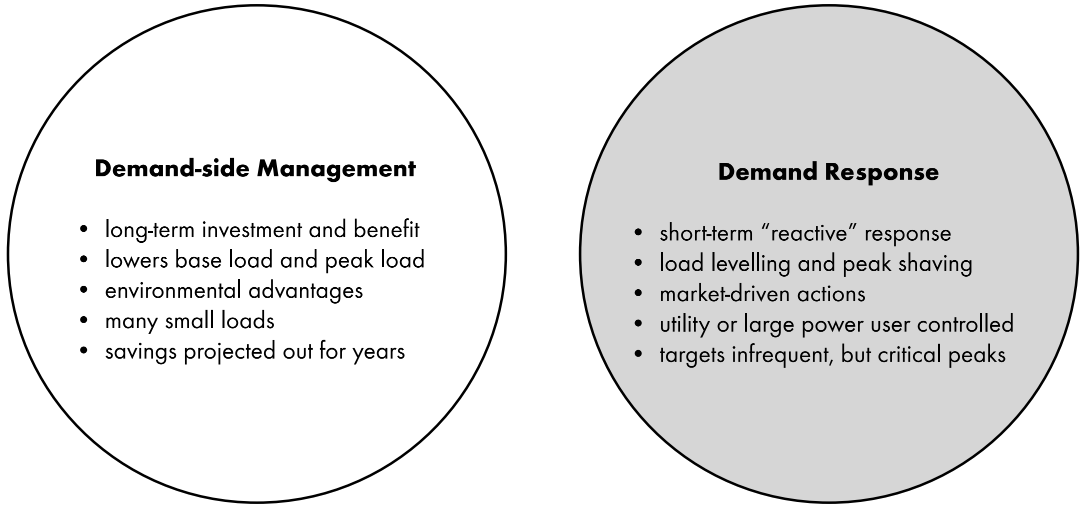
3.9.1 Technology

Characteristics of DSM and DR are shown in Figure 3.9.1. It is recognized that these terms are not mutually exclusive.

Demand-side management activity is driven primarily on the strength of new energy-efficient technologies. These technologies are spread over residential, industrial and commercial sectors. Significant efficiency gains have been achieved through building standards and advances in heating, ventilation and air-conditioning (HVAC), motors, lighting, and large (white) and small (electronic) appliances. Considering the energy efficiency improvements available in just two areas that dominate electrical consumption, air conditioning and lighting, the potential for energy efficiency gains

FIGURE 3.9.1

DSM and DR Characteristics



is significant. For example, it has been estimated that implementing the best available lighting technology could lead to a 75 percent improvement in efficiency.[32]

Demand response technology is centred on large interruptible loads and advanced monitoring of consumption. The technology includes computerized meters or "smart meters" for demand data. Data may include quantity, price and TOU information. Time-of-use programs allow utilities to base demand charges on the varying supply (wholesale) cost of electricity at various times of the day. Time is generally divided into seasonal and daily peak and off-peak periods with corresponding rates (Figure 3.9.2). These time-dependent rates provide an incentive to consumers to choose how and when to consume electricity.

In addition to advanced metering, emerging DR technology includes a wide variety of supporting appliances and devices that are capable of being interrupted or "dispatched" either manually or automatically. Automated controls allow for utilities or customers to remotely control timers, temperatures, motors and pumps over power lines or the Internet. These controls can be tied to market pricing to automatically cut back on consumption during periods of high pricing. In summer, remotely adjusting thousands of air conditioning thermostats and heat pumps by a few degrees can mean the difference between a high load and an overload situation. Similarly, appliances can be programmed to monitor grid frequency or voltage (brown-out) and automatically curtail under constrained conditions.

More precise advanced metering (i.e., interval metering) is tied to wholesale market pricing and can monitor pricing and consumption every few minutes. This advanced metering generally includes more advanced communications, enabling real-time pricing (RTP) and two-way communications between customers and utilities. This level of metering is still cost prohibitive for residential and smaller commercial clients.

With automated metering infrastructure in place, consumers become more active participants in the electricity market. The technology has the capability to facilitate future trends in the industry,

32 Bhargava, A., Polialov, J and Timilsina, G, *Study on the Electrical Efficiency of Alberta's Economic Sectors*, Canadian Energy Research Institute. Prepared for Clean Air Strategic Alliance, 2004

including consolidated energy and service billing, monitoring building and equipment efficiencies, and accommodating distributed generation. An illustrative example of this is shown in Figure 3.9.3. There are several private companies in Canada targeting the most appropriate sites for demand response (i.e., mostly large power users concentrated in Ontario).

FIGURE 3.9.2

Illustrative Daily Electricity Consumption

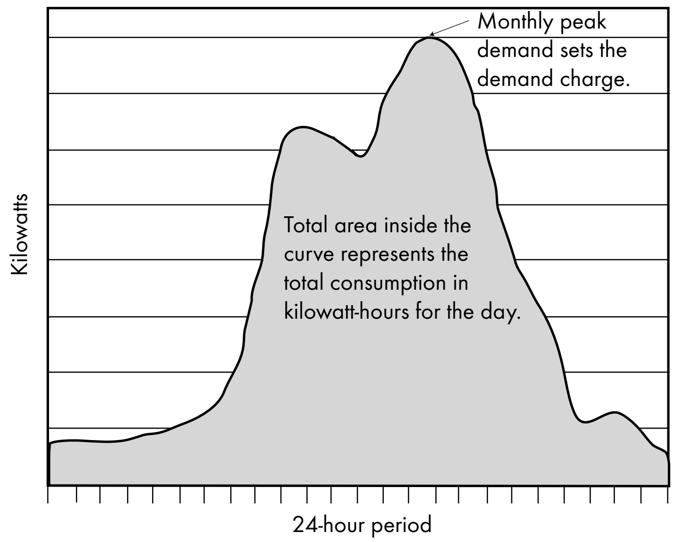
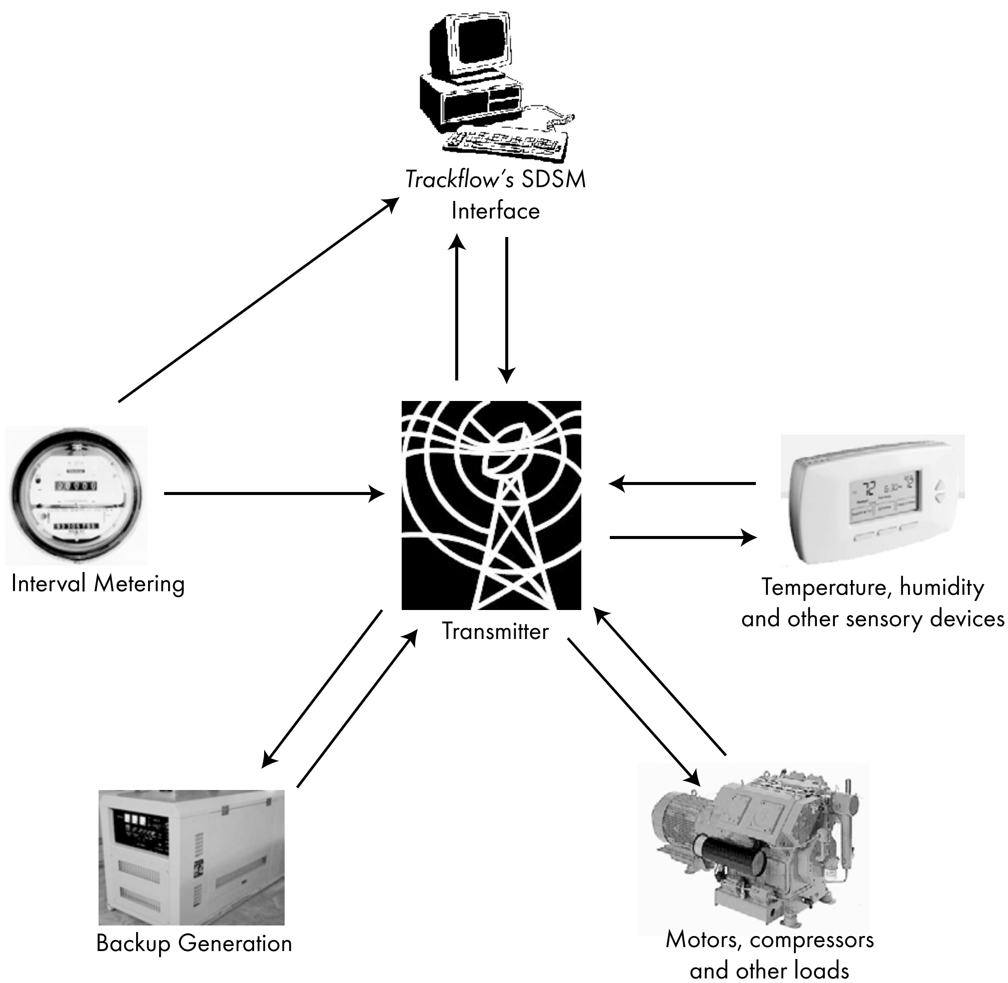


FIGURE 3.9.3

Schematic of Demand Response Technology



3.9.2 Market and Regulatory Issues

Canada's high per capita energy consumption suggests that there is a large potential market for expansion of DSM and DR measures in Canada. Energy efficiency has been a marginal investment for consumers in the past decade, though recent price increases are encouraging new interest. Energy efficiency uptake is closely tied to utility spending on DSM marketing and financial incentives. Several utilities, as "energy service providers" are now actively marketing energy savings as part of bundled services.

Demand response, based on avoided cost rather than payback, offers a better financial incentive, but only applies to limited times when demand peaks. However, given that the savings are gained from the highest marginal costs of electricity, there is a significant potential saving on the average cost of electricity that ultimately affects all consumer rates. Demand reduction as a "negawatt" or a negative load can be sourced in the same way as green, renewable energy. This was recently seen in Ontario where a large grocery chain submitted DSM/DR under a provincial RFP for green power.

Worldwide trends in electrical demand management are now closely aligned with a movement toward more time-based billing practices. In Canada, large commercial and industrial clients often have agreements with lower base rates and higher peak rates. Most Canadian residential customers are protected by regulated rates that reduce the incentive to conserve during peak times or shift consumption to off-peak times. An IEA study of TOU programs in the United States found that shifting to time-dependent rates not only reduced peaks but produced a six percent overall

Distributed Generation - Integrating Supply and Demand

A possible future development scenario in the electrical industry includes an emphasis on shifting from large centralized generation to a more diverse portfolio of smaller generation units. Distributed generation (DG) is a generic term for small-scale electricity generated near its point of end-use. Proponents of distributed generation see the future transmission grid with a multitude of generators all operating at maximum efficiency. Almost all of the generation technologies covered in this report are considered under the distributed generation umbrella when scaled in size to local loads. Also included are natural gas micro-turbines and gas or diesel engine generators.

In situations where the electricity user also has thermal energy needs, fuel cells, micro-turbines and generators can achieve high efficiencies through their considerable waste heat. This technology is known as combined heat and power (CHP or cogeneration). Overall energy efficiency of these systems can be in the order of 80 percent. The combined efficiencies of distributed generation can be better than many large centralized generating facilities. Proximity to the end-user also means that distributed generation avoids transmission and distribution losses. Distributed generation can often use existing wire, and possibly gas, infrastructure without adding undue stress on a network.

Diverse sources of generation and advanced grid control systems can also offer significant reliability benefits. In many cases, distributed generation is considered an extension of demand management, not only reducing load on the demand side, but offering excess power back into the grid at favourable rates. Distributed generation allows small producers or developers of technologies such as PV and fuel cells to optimize their rate of return by working at the marginal cost of peak power. In many cases, large industrial customers already have large diesel or gas generators on site for emergency power. In terms of distributed generation, these technologies could all be potential sources of generation.

Distributed generation takes into consideration the dynamics of electricity distribution. It responds to continually shifting local demands with appropriately sized generation. Taking this one step further, future technologies in energy storage, demand response and transmission technologies could offer a new slate of options for meeting peak demand.

decrease in demand.[33] Similar success was observed in a small TOU program in British Columbia; 90 percent of the participants reported changing consumption habits since signing on to the program.[34] This trend would indicate that letting consumers see better price signals leads to a more efficient system.

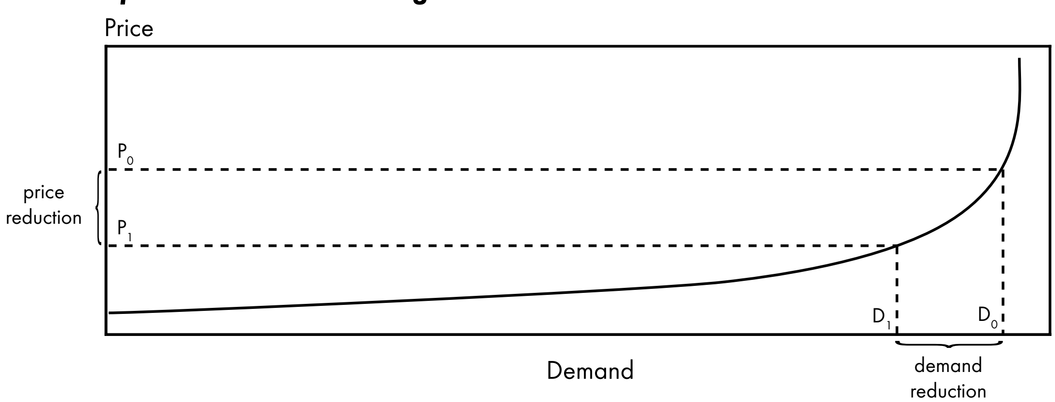
Ontario has recognized the connection between consumption, metering and conservation. As part of creating a "culture of conservation," the Ontario Ministry of Energy has recommended the installation of 800 000 smart electricity meters by 31 December 2007 and for all remaining consumers by the end of 2010. This recommendation is now before the legislature for approval.

The incentive to participate in demand management is clearly illustrated in the demand versus price graph shown in Figure 3.9.4. Small reductions in consumption produce large shifts reductions in the price of electricity. Peak supply in a tight market is sourced from the most expensive sources, a situation time-based customers want to avoid. The financial incentive to shift supports optimization of the grid for maximum reliability and lowest cost. The graph implies that exposing more customers to market pricing would lead to the most efficient use of the electrical grid. The system works with, and supports, the dynamics of the electricity market to everyone's benefit.

There are several pricing mechanisms being looked at by utilities to enhance participation in DR programs. Options include reduced base rates, tiered peak rates, critical peak pricing, or demand bidding (i.e., offering the reductions back to the utility at a preferred rate). Marketing these programs to a broader audience is still relatively new and there are no clear single solutions for participation. Even in the United States, where utilities have considerable DR experience, programs have been slow in gaining momentum. However, there are successful case studies. For example, Georgia hosts over 5 000 MW of interruptible power. Combining DSM (e.g., information packages, energy audits) along with DR can improve the appeal and impact of energy reduction programs as a whole.

FIGURE 3.9.4

Price Response to Demand Changes



33 Harrington, P., *The Power to Choose – Enhancing Demand Response in Liberalised Electricity Markets*. Presentation: Metering Europe, International Energy Agency, Paris, France. Oct. 1-3 2003

34 Princeton Light and Power, *Newsletter, Vol. 11, Issue 1, Canadian Energy Research Institute (CERI) Survey*, Winter 2005

3.9.3 *Environmental Considerations*

Demand-side management reduces emissions and helps postpone the development of new generation facilities. Energy efficiency is considered a least-cost option for emissions reductions. In addition to programs that allow bidding of energy savings, several European countries are now looking at tradable "white certificates" as a fluid and traceable method of international marketing of energy efficiency savings.

Large industrial and commercial DR, by merely shifting loads to another time, may not necessarily reduce total consumption or produce environmental benefits. However, its influence on optimizing the efficiency of the generation, transmission and distribution network would support corresponding environmental improvement. The critical peak times for DR may account for no more than a few percent out of the total annual billing period and, therefore, may have little effect on total emissions.

Another option for the maturing of demand response pertains to utilizing it as an environmentally preferred method of reducing fossil fuel "spinning reserves." The system operator could take into account reliable load shedding in lieu of on-line generation.

3.9.4 *Industry and Government Initiatives*

Natural Resources Canada maintains energy efficiency standards in Canada through the *Energy Efficiency Act*. NRCan promotes a sizable range of energy efficiency initiatives. Currently, the Act regulates 30 appliances that account for 80 percent of residential power consumption and 50 percent of industrial and commercial power consumption in Canada. Energy consumption ratings (i.e., EnerGuide ratings) are now on 85 percent of the appliances sold in Canada.[35] Enhanced building standards are encouraged in new home construction (R-2000) and commercial/industrial buildings (C-2000).

Two of the most well known national DSM programs in Canada are the One-Tonne Challenge and EnerGuide for Houses. These are general energy saving programs based on GHG emissions reductions. Industrial energy efficiency is addressed nationally through NRCan's Canadian Industry Program for Energy Conservation (CIPEC). With industry making up approximately half of Canadian electrical demand, this organization is very effective at targeting the most accessible efficiency gains possible in Canada. Interest in CIPEC's energy saving workshops has increased significantly during the last year.

Total energy use in Canada continues to climb. However, improvements in energy efficiency are reducing the rate of growth. Overall energy efficiency in Canada, when measured against economic activity and other variables, improved at an average of one percent per year between 1990 and 2003.[36] Electricity demand has remained relatively flat for the last five years. This has been achieved through reductions in average industrial energy-intensity and energy efficiency improvements supported, in part, by government programs.

There is some evidence of efforts to organize and streamline policy. In Ontario, the Canadian Energy Efficiency Alliance, along with groups such as Ontario Power Authority (OPA) and NRCan, has formed the Ontario Caucus to help integrate industry objectives and concerns with government mandates.

35 NRCan, Office of Energy Efficiency, *Improving energy performance in Canada*, p 9

36 NRCan, Office of Energy Efficiency, *Energy Efficiency Trends in Canada 1990-2003*, Fig. 10, p 10

In Ontario, DSM and DR measures are targeted to reduce demand by five percent. BC Hydro intends to meet one-third of all predicted new energy demands in the next decade through DSM measures. The amount of DSM and DR vary by province, depending on the peak to off-peak variance of the market and the availability of aggregating generation. Even in hydro rich provinces such as Manitoba, DSM measures are encouraged. Conservation in the province frees up more power for export, at better rates.

Analysis of past DSM programs indicates varying degrees of cost-effectiveness. A study of 40 of the largest U.S. utilities found DSM programs saved energy at a cost of 3.2 ¢/kW.h (U.S.).[37] A more recent study for Ontario claimed most energy efficiency measures falling in the range of 3–7 ¢/kW.h.[38]

ATCO Electric's Smart Metering Program

(Alberta) 500 residential customers (Drumheller, Grande Prairie)

- based on similar program in Woodstock, Ontario (indicating 15 percent drop in residential demand with smart meters)
- partners include ATCO, NRCan, InfoEnergy
- meters and in-house display installed spring 2005
- "pay-as-you-go" program (i.e., customers buy power [prepaid] on "smart card")
- extensive in-house metering showing instantaneous and cumulative power readings
- one-year pilot project
- program to be evaluated next year

3.9.5 Regional Developments

Every province and territory in Canada encourages energy savings through a variety of incentive and education programs. These programs operate adjacent to federal programs and are promoted by governments and utilities. Many well-known programs such as B.C. Hydro Power Smart and Manitoba Hydro Power Smart have a long history of promotion and incentives encouraging adoption of best practices. The Power Smart program has members nationally, and is looking at expanding its presence in other regions.

Financial incentives vary by province. The majority of the programs target lighting, HVAC and refrigeration. Several regional programs are in direct response to recent price peaks in gas; however, they promote overall energy savings.

Demand-side management and DR offer significant opportunities particularly in Ontario, where generation capacity is an issue and solutions must be in place on a short timeline, the association of major power users has suggested that 1 500 MW of dispatchable power could be available in Ontario.[39] This would be more than a four-fold increase from existing DR. A Pembina Institute report has suggested a further 8 900 MW could be made available through cogeneration, fuel switching and energy efficiency.[40] These numbers may be optimistic, but they offer indications of demand management as a major resource.

37 Raynolds, N. and Richard C., *The Contribution of Energy Efficiency to the Reliability of the U.S. Electric System*, Alliance to Save Energy, p 4

38 Pembina Institute/CELA, *Power for the Future – Towards a Sustainable Electricity System for Ontario*, May 2004, p 21

39 Association of Major Power Consumers of Ontario

40 Pembina Institute/Canadian Environmental Law Association (CELA), *Power for the Future*, Table 3.11, p 22

3.9.6 Summary

Energy efficiency is regarded as "a least cost option." Investment in energy efficiency helps to maintain standards of living, global competitiveness and local economic efficiency. It also reduces emissions leading to improved air quality. Energy efficiency requires investment. In the residential, industrial and commercial sector, a payback of less than five years is generally required to attract the necessary investment interest. Demand management is a long-term investment that can start to provide significant benefits in the important short- to mid-term period.

Significantly accelerated demand management activity would largely depend on increasing tax credits, expanding energy efficiency programs, targeting funding for R&D, and enhancing public energy education. At present, there is no single source organization in Canada to promote DSM. Current programs are attached to various federal and provincial offices and various electrical and gas utilities. Public awareness and marketing advantages could be gained by streamlining best practices that are clear and consistent nationally.

Policies and priorities on DR are determined regionally, rather than as part of a national energy strategy. System operators and utilities handle supply options and reserve margins provincially. In deregulated electricity markets, approved rates of return for generation may be an impediment for DR. The rate structure may not sufficiently support cost recovery. With the unbundling of utility markets, DR can easily be overlooked or even avoided, apart from the most basic grid reliability considerations. Mechanisms for cost sharing and cost recovery are being evaluated in many jurisdictions in North America. In addition to institutional barriers, many industries are simply not interested, or able, to interrupt services or production regardless of the incentive. Finally, as demand management success is largely based on consumer awareness and education, there is a considerable timeline for implementation.

Demand-side management and DR have recognized benefits in terms of stabilizing prices, grid reliability, and environmental gains. The bigger issue remains as to what extent these can be deployed. Interest in DSM and DR will, undoubtedly, continue to grow simultaneously alongside new renewable sources of generation.

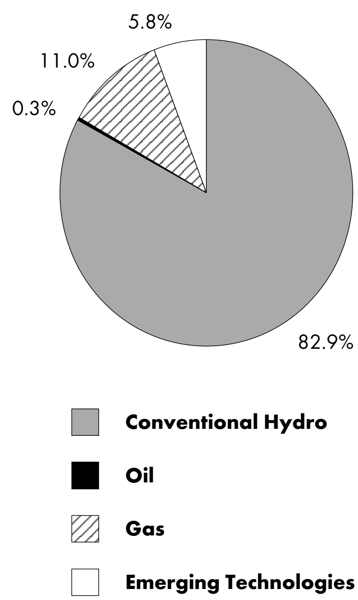
Regional Perspectives

4.1 British Columbia

British Columbia generates most of its electricity from hydroelectric resources. There is a limited amount of combined-cycle and cogeneration gas-fired generation capacity in northeastern British Columbia and near Vancouver. British Columbia trades electricity with Alberta and the Pacific Northwest, benefiting from price differentials between the markets. The province also imports inexpensive coal-fired generation from Alberta during the off-peak hours and during periods of low water levels to ensure electrical energy reliability.

FIGURE 4.1.1

British Columbia 2004 Generating Capacity by Fuel (14 559 MW)



Source: Statistics Canada

4.1.1 Provincial Policies and Programs

In November 2002, the government announced a long-term plan to, among other things, ensure energy resources are used and developed in an environmentally responsible way. The plan increased the government's focus on BC Clean Electricity sources, conservation and energy efficiency. Under this plan, electricity distributors are encouraged to pursue a goal to acquire 50 percent of total net new supply acquisitions from BC Clean Electricity by 2012. BC Hydro, the province's largest electricity distributor, has taken steps to meet this goal.

The plan describes BC Clean Electricity as "electricity generated from resources and facilities built in British Columbia that has a lesser environmental impact relative to conventional generation sources and technology. Examples may include small hydro, wind, solar, photovoltaic, geothermal, tidal, wave and biomass energy, as well as cogeneration of heat and power, energy from landfill gas and municipal solid waste, fuel cells and efficiency improvements at existing facilities."[41]

41 British Columbia Ministry of Energy, Mines and Petroleum Resources, *A Plan for BC (the Energy Plan)*, November 2002

4.1.2 Utility and Consumer Strategies

BC Hydro Call for Power

Through an Open Call for Power released in December 2005, BC Hydro is targeting to procure a minimum of 1 000 GW.h per year of electrical energy from IPPs because they have identified an expected shortfall by 2010. The following power supply is being solicited:

- a minimum of 800 GW.h per year of firm electrical energy supply;
- up to 800 GW.h per year of associated non-firm electrical energy supply from projects 10 MW and larger in size, built and operated by IPPs; and
- a minimum of 200 GW.h per year of electrical energy supply from 1 MW to 10 MW projects built and operated by IPPs.

The two major British Columbia electrical utilities, BC Hydro and Fortis Inc., provide a number of DR and energy efficiency programs. BC Hydro's Power Smart program offers a variety of incentive and education programs to promote energy savings to residential and industrial customers. As well, BC Hydro will be introducing stepped rates and TOU rates for its large customers in April 2006. The intention of stepped rates is to provide price signals that encourage customers to implement energy efficiency projects, reducing the amount of energy they use. The TOU rate structure is intended to provide a better price signal to large electricity consumers, promoting conservation and energy efficiency.

4.1.3 Near-Term and Longer-Term Prospects

In addition to the 50 percent clean energy target, opportunities for emerging technologies are supported by the aversion in British Columbia to coal and natural gas-fired generation. The prospect for coal-fired generation is limited due to environmental concerns and uncertainty about emissions costs related to the *Kyoto Protocol*. The development of natural gas-fired generation is uncertain given high natural gas prices and the impact that higher generation costs would have on electricity rates.

FIGURE 4.1.2

Brandywine Small Hydro Project, near Squamish, B.C.

Near-term prospects include small hydro, wind, biomass and the expansion of DSM programs. There is very good potential for run-of-river small hydro generation, at close to 900 potential sites (Figure 4.1.2). A number of factors limit the development of small hydro including the requirement for numerous individual transmission interconnections, the remoteness of the locations and lower dependability due to the absence of a reservoir.

Biomass is an environmentally attractive generation alternative since it is part of the neutral carbon cycle[42] and because the forestry industry benefits from steam generated from biomass cogeneration. The development of biomass is limited only by the state of the forestry industry and its availability of fuels.

Currently, British Columbia has no wind-powered generation. However, there are 169 applications for wind projects on crown lands. Most wind projects would be located in the Peace region and along the North coast. Many of the locations are remote and if development of the projects proceeds, there will be a requirement for individual transmission connections. A study released by the British Columbia Transmission Corporation concluded that most of the issues surrounding the integration of wind generation are commercial, not technical. The study also pointed out that British Columbia's large hydro resource could help mitigate the effect of the wind generation's variability.

In October 2005, the B.C. Ministry of Energy, Mines and Petroleum Resources implemented a new participation rent policy for wind energy developers. It offers flexibility and incentives for wind power producers to proceed with capital investment. The policy includes the following features:

- no participation rents (the return to the province for wind projects located on crown land) for the first 10 years of commercial operations; and
- a sliding rate scale formula based on annual electricity production starting in year 11 and ranging from one to three percent of gross annual revenues.

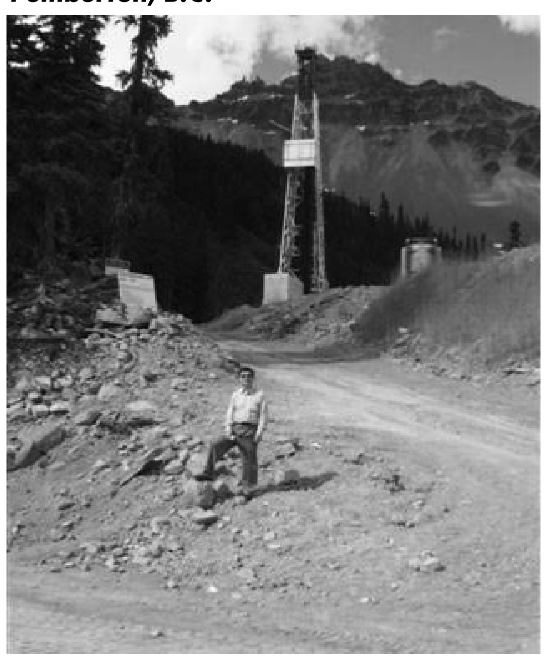
In the mid-to-long-term, cogeneration will likely become more common. Decentralized electricity production from cogeneration does not significantly impact rates because it has low up front and operating costs and because it decreases demand on the electricity grid.

British Columbia has a unique opportunity for geothermal development due to the availability of resources in the province. Geothermal generation has good potential in the mid-to-long-term, with total expansion capacity potential of 1 100 MW. The 200 MW Meager Creek geothermal project is the first geothermal effort (Figure 4.1.3). Currently, 100 MW of production is planned with the potential to expand the facility to 200 MW.

British Columbia has been actively developing its fuel cell strategy, spurred on largely by the drive to create a Hydrogen Highway for the 2010 Olympics at Whistler, which will play a role in sustainable transportation demonstrations. In October 2005, the federal government made a $12.2 million contribution to support the development of a number of hydrogen projects in the Vancouver area.

FIGURE 4.1.3

Meager Creek Geothermal Project, near Pemberton, B.C.



42 CO_2 that is absorbed from the air while the biomass feedstock was growing is released back into the air when the fuel is burned to generate electricity.

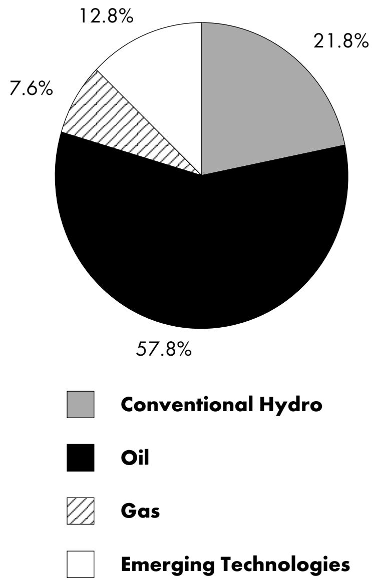
Longer-term prospects for renewable development in British Columbia include solar, wave and tidal technologies. The *BC Integrated Electricity Plan* forecasts the resource potential of solar powered electricity generation at 500 MW. Ocean renewable energy, which includes current, wave and tidal energy, is currently being examined in British Columbia. The Race Rocks project, situated on the southern end of Vancouver Island, will convert tidal energy to electric power starting in early 2006.

4.2 Yukon, Northwest Territories and Nunavut

The Territories are sparsely populated with small dispersed communities. As a result, the Territories do not have integrated electrical grids. Each community tends to be served by its own generation source and there are very few long distance transmission lines.

FIGURE 4.2.1

Yukon, Northwest Territories and Nunavut 2004 Generating Capacity by Fuel (321 MW)



Source: Statistics Canada

The distribution of generation sources for the Territories in aggregate is shown in Figure 4.2.1. Overall, diesel generators are the most common source of power for electricity generation and space heating, followed by hydro power. In the Yukon, hydro power generated 89 percent of the 320 GW.h consumed in 2003. In the Northwest Territories, the 588 GW.h generated in 2003 was almost evenly split between diesel at 50 percent and hydro at 46 percent. Nunavut generated 133 GW.h of electricity in 2003 and depended entirely on diesel fuel.

Due to community isolation and extreme weather, northern generation must be very reliable. If an emerging technology is used, the community will still need a diesel generator to provide reliable backup generation. Diesel fuel must be transported over long distances in adverse conditions and it is expensive. Alternative technologies may find it easier to compete on a price basis in the North, but there are other challenges to overcome.

Because the Territories require high reliability, they may be less likely to implement alternative technologies. New applications need to be monitored by technicians, and small populations have few individuals with the requisite knowledge. Intermittent power sources, such as wind power and PV, can be difficult to balance. For example, because the grid is so small, fluctuations in wind speed have a considerable impact if a community uses wind power. Although it is expensive, the simplest solution in a small community is to install diesel generation adequate to meet the load. Additionally, extreme weather presents operational challenges.

Photovoltaics are reliable and work well at lower temperatures and in the summer for niche applications, such as remote equipment used by Northwest Tel with propane-fired generation for backup. Adding PV means remote units need only be refuelled every two years, rather than every year.

4.2.1 Territorial Policies and Programs

The Yukon government is committed to reducing dependence on imported fossil fuels, increasing economic independence and encouraging the local energy industry. One option is using wind to generate electricity. There is enough knowledge of the Yukon's wind regime to know that there are sites where winds are consistently strong enough to make commercial wind farming possible. The strongest winds occur during the winter months and the demand for electricity peaks during the winter months.

The Northwest Territories government is working on a distributed generation policy that would facilitate non-standard generation. Safety and technical issues have been resolved, but more work must be done to determine a fair price for electricity supplied to the grid. The government is in the process of updating its Greenhouse Gas Strategy, which was originally released in 2001.

4.2.2 *Utility and Consumer Strategies*

The Yukon Energy Corporation is interested in wind power so it is continuing with a turbine project that it began in 1993. It is continuing to study the wind regime at various Yukon locations. The main challenge to wind-generated electricity is that it does not yet appear to be as reliable and economical as diesel-generated electricity. So far, regulatory and environmental issues have not presented issues of concern for development.

Photovoltaics are most competitive in off-grid applications at remote sites that require small amounts of power and are typically used to charge batteries. Telecommunication businesses, highway maintenance camps, park interpretive centres and a demonstration system at Yukon College use PV, and at least 50 residential systems have been installed in the Yukon. They provide reliable energy eight months of the year and the systems require little maintenance, largely because there are no moving parts.[43]

In the Northwest Territories, utilities use DSM, especially in the Yellowknife area. Although hydro resources can meet existing peak loads, if there is significant growth, a new dam will be required or the community will have to add expensive diesel generation.

In 1996, Nunavut Power's predecessor, the Northwest Territories Power Corporation, approved a developmental wind program to gain practical experience with wind energy in the North so that when it became cost effective, the Corporation would be ready to adopt it on a large-scale basis for the benefit of its customers. Nunavut Power is now involved in three wind farms.

Fluctuating wind can impact the quality and reliability of the community's power and the cost of the diesel power that must be generated to complement the level of wind power being produced. In the long term, wind energy will only be successful if reliable suppliers of small equipment are found, local people are trained in operation and maintenance, and better control systems are developed to efficiently integrate the turbines with diesel power plants.

4.2.3. *Near-Term and Longer-Term Prospects*

Numerous northern sites could support new small hydro developments. Hydro plants can have capital costs from three to ten times greater than diesel plants, but they have a longer plant life, use a local resource, and have a non-variable low fuel cost. New hydro developments will undergo a more rigorous environmental screening process than existing plants underwent. While these sites are available for further review, and business plans are being developed for some sites, the main obstacle to their development is the lack of load. The Northwest Territories is considering expanding existing

43 Yukon Government, Department of Energy, Mines and Resources

hydro applications and connecting transmission lines from hydro generation sources to the diamond mines to displace diesel generation.

All three territories are working together to monitor wind resources in the North. Escalating fuel prices are making wind energy appear more attractive. However, the need for extensive planning before installing turbines, the lack of trained personnel, the small isolated systems and the extreme weather conditions make it more challenging to use wind resources in the North compared to other parts of Canada.

Solar energy is becoming increasingly viable as a power source for remote homes, and when combined in a hybrid system, is on the verge of being economical for remote communities served by diesel-based electrical generation.

Despite potential for biofuel, it is difficult, on a small scale, to convert heat into electricity. Small plants produce expensive electricity because of the relatively high capital costs and the need for a highly skilled, full-time staff to tend the equipment.

4.3 Alberta

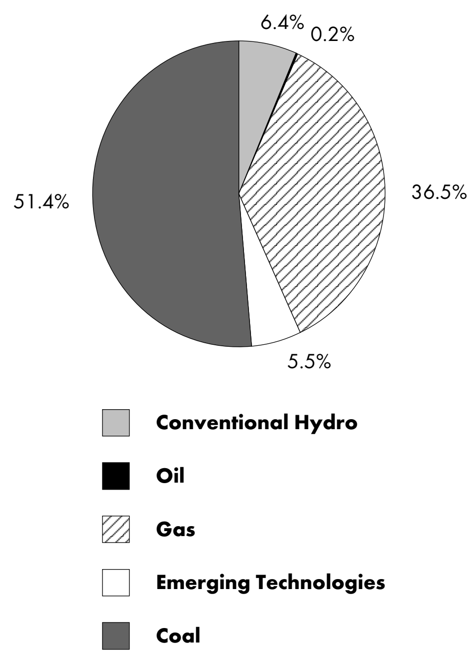
Alberta's fuel mix for electricity generation is composed of baseload coal, natural gas used during peak periods, and hydro that is relied on primarily as a backstop resource. Almost six percent of generating capacity is from renewable energy sources such as wind, small hydro and biomass. There are 275 MW of installed wind capacity, 150 MW of small hydro, and 178 MW of biomass-fired generation. At year-end 2005, Alberta had the largest installed capacity of wind power in Canada. The province has the ability to import electricity from the U.S. Pacific Northwest, British Columbia and Saskatchewan.

4.3.1 Provincial Policies and Programs

The government of Alberta has set a voluntary alternative and renewable energy target of 3.5 percent of total generation by the year 2008. This represents 560 MW of new capacity. It is expected that the majority of the new renewable generation will be from the roughly 500 MW of wind generation projects that have applied for access to the transmission grid.

FIGURE 4.3.1

Alberta 2004 Generating Capacity by Fuel (11 397 MW)



Source: Statistics Canada

To enable the growth of wind, the Alberta Electric System Operator has made upgrading the existing transmission system in southwestern Alberta one of its main priorities, along with the upgrading the 500 kV transmission line between Edmonton and Calgary. The upgrading is viewed as necessary because the current system is limiting the capacity to transmit wind-generated electricity. In early 2005, the Alberta Energy and Utilities Board approved an application for $80 million in transmission investments.

In March 2004, the Government of Alberta announced a long-term management framework for air emissions from electricity generation in the province. The framework is aimed at substantial reductions in the electricity sector's emissions of SO_2, NO_X, particulate matter and mercury.

Under the transition principles, any new coal-fired plants will have four options to reduce GHG emissions:

- increase investment in technology development toward reducing emissions;
- increase investment in renewable power generation;
- receive credit for early shutdowns of existing facilities; or
- invest in emissions offsets.

FIGURE 4.3.2

Cloverbar Landfill Gas Site, Edmonton, Alberta

Any reductions achieved will be recognized in relation to meeting the goal set by the province in June 2001, which states that emissions from any new, coal-fired electricity generation must be "as clean as gas." The Alberta government is the first province to require all new coal-fired plants to lower their GHG emissions to the level of a natural-gas-fired combined-cycle plant. The Genesee Phase 3 plant, commissioned in March 2005, is a supercritical coal-fired plant equipped with $90 million of clean air technologies that will offset CO_2 emissions to the level of a natural gas combined-cycle plant.

4.3.2 *Utility and Consumer Strategies*

The Alberta government and industry are taking a number of initiatives to integrate renewable electricity generation technologies with industry initiatives.

Alberta companies and institutions are leading initiatives to minimize the environmental impact of burning coal. The CCPC is moving forward with plans to demonstrate clean coal power generation at a new plant by 2012. As well, the CCPC has completed the first phase of a feasibility study into technologies to eliminate GHG from coal-fired power plants.

Closely related to the development of clean coal technologies is the sequestration of CO_2 and the subsequent piping and utilization of CO_2 for enhanced oil, gas and coalbed methane recovery. In 2003, the Alberta Energy Minister announced a maximum of $15 million in royalty credits would be available over five years to companies demonstrating the use of CO_2 in the development of Alberta's oil and gas resources. Producers were invited to submit applications to the Alberta government describing potential projects. The successful applicants can earn royalty credits for up to 30 percent of approved costs.

Efforts are being made to bring industry, researchers and governments together to aid the development of environmentally responsible hydrocarbon and renewable energy technologies. Energy Innovation Network (EnergyINet), the largest Canadian not-for-profit organization aimed at building such a network, focuses on six innovation strategies: alternative and renewable energy, bitumen upgrading, clean coal/carbon, CO_2 management and recovery and water management. Progress has been made as a result of the collaboration among industry, researchers and governments. The Alberta Energy Research Institute, Alberta Environment and Western Economic Diversification contributed \$6 million to set up the EnergyINet CO_2 storage network and a storage monitoring program. A \$25 million monitoring and evaluation program for long-term CO_2 storage has also been initiated.

4.3.3 *Near-Term and Longer-Term Prospects*

Wind is the most imminent renewable generation technology in Alberta, with total proposed projects of over 840 MW by 2010. Small hydro has physical potential for development; however, siting is often an issue because of opposition from local interest groups. Demand-side management is expected to play an increasing role in Alberta's future, given that even a small increase in load reduction during peaks could have a large impact on electricity prices in the province. Despite the many initiatives to develop new renewable electrical energy sources, there likely will continue to be a reliance on gas-fired generation and imports to meet peak demands on Alberta's electrical grid.

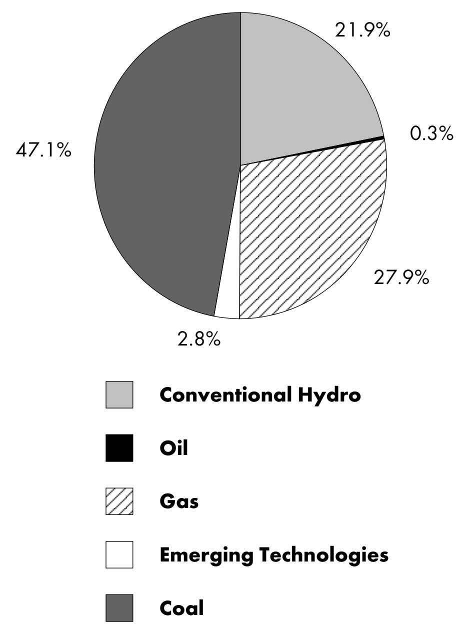
In the long-term, biomass-fired generation and IGCC technology may be developed to help meet the electrical and steam demands of oil sands and pulp and paper industry operations.

4.4 Saskatchewan

SaskPower has a relatively diversified generation mix (Figure 4.4.1) and its Green Power Portfolio will ensure all of Saskatchewan's new electricity needs are met until 2010 from environmentally friendly sources. Wind power is a major part of that strategy, accounting for about five percent of total capacity at the end of 2005. SaskPower and Sunbridge each have 11 MW wind power projects and in December 2005, an additional 150 MW of wind generation capacity – enough to serve 73,000 homes – was installed at Rushlake Creek. Energy conservation, small-scale hydro, distributed generation projects and the *Environmentally Preferred Power* program will round out the plan.

FIGURE 4.4.1

Saskatchewan 2004 Generating Capacity by Fuel (3 797 MW)



Source: Statistics Canada

4.4.1 *Provincial Policies and Programs*

The Saskatchewan Ministry of Industry and Resources is responsible for energy policy development in the province. SaskPower is a Crown corporation which operates primarily under the mandate and authority of *The Power Corporation Act*. This Act grants to SaskPower the exclusive franchise and obligation in the province (except for the City of Swift Current and the City of Saskatoon) to supply, transmit and distribute electricity, and to provide service to customers. The province works closely with SaskPower to carry out energy policies.

The provincial government plans to provide for load growth to the year 2010 with environmentally low impact generation that produces no new GHG emissions. In the November 2005 Speech From The Throne, the Lieutenant Governor announced a commitment to have one-third of Saskatchewan energy needs met by renewable energy sources by the third decade of this century. The Saskatchewan

Energy Share plan was developed to help Saskatchewan residents reduce heating costs and share the benefits of increased revenues from natural gas. One goal of the plan is to promote reduced energy consumption and energy efficiency through the following conservation programs:

- a sales tax exemption on energy efficient appliances;
- a rebate on programmable thermostats;
- expansion of the *Share the Warmth* home energy efficiency project;
- matching of the federal grant for changes made after an EnerGuide for Houses follow-up audit;
- expansion and cost-sharing of the federal EnerGuide for low income households; and
- a new Saskatchewan EnerGuide program for moderate-income homeowners.

4.4.2 Utility and Consumer Strategies

SaskPower is currently involved in several distributed generation demonstration projects including a wood gasification demonstration project at a saw mill in LaRonge, a biogas generator that uses animal manure to generate heat and electricity at a hog facility, a 60 kW flare gas microturbine project near Carlyle, two 60 kW microturbines that simultaneously generate electrical power and produce hot water at the Regina General Hospital, and solar panels on the roof of the Saskatchewan Science Centre in Regina.

Direct experience with a variety of new technologies enables SaskPower and the province to gain knowledge of the unique operational characteristics, the benefits and challenges of each technology, and the types of funding or other assistance required to make the technology work in Saskatchewan. The utility is integrating the projects into the grid on a small scale, which provides the knowledge and expertise required to integrate future distributed generation projects.

Customer initiatives include the GreenPower program, which gives customers the choice to pay an additional $2.50 per 100 kilowatt-block of EcoLogo certified electrical generation. SaskPower also provides energy audits to identify energy conservation measures and provide logistical support for the installation of more efficient lighting, motors and system controls or other retrofits.

4.4.3 Near-Term and Longer-Term Prospects

SaskPower has adopted a strategy to meet new load growth over the next several years using environmentally preferred power. This strategy is intended to encourage low environmental impact power, use waste streams as a fuel source, reduce SaskPower's emissions, monetize the value of low environmental impact power, and add small generation in step with SaskPower's load requirements.

As an integral component of this strategy, SaskPower intends to acquire up to 45 MW of environmentally preferred power through a competitive solicitation process. In 2004, SaskPower selected two wind power projects and a heat recovery project totalling 13 MW in the first phase of the program. In 2005, SaskPower issued a second solicitation for another 32 MW of environmentally preferred power.

The electric technologies that are likely to be implemented in the near term, ranked by their likely highest near-term economic potential, include wind, small hydro, biomass, small cogeneration and solar energy.

By proceeding cautiously, SaskPower can postpone the need to construct large new generating facilities, which could have an adverse impact on electricity prices. Additionally, preliminary studies suggest that implementing DSM programs could reduce power demand by 100 MW.

4.5 Manitoba

Approximately 91 percent of Manitoba's electrical generation is hydro based (Figure 4.5.1). Manitoba Hydro, a provincial Crown corporation, is responsible for the generation and delivery of electrical power in the province. The corporation provides low-cost electricity to domestic consumers and sells its surplus power on the export market. Manitoba Hydro markets hydro power as a clean, renewable energy source.

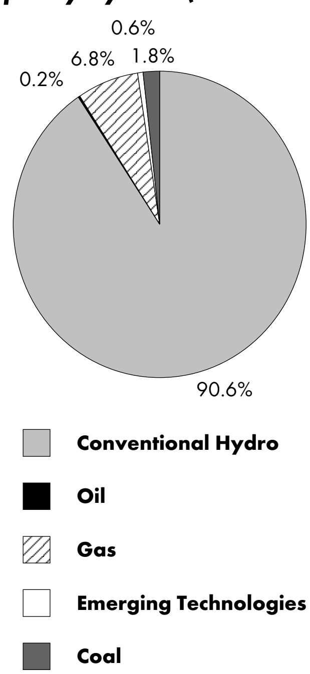
Manitoba Hydro estimates that about one half of its hydro potential has been developed and has identified 16 potential hydro generation developments for future consideration. The first of these new hydro developments include the Wuskwatim generating station on the Burntwood River, and the Keeyask and Conawapa generating stations on the Nelson River. The provincial government is focusing on further development of hydro resources in conjunction with the development of wind power and other renewable energy sources. Manitoba Hydro's DSM program also plays an important role in generating capacity, as well as energy management.

4.5.1 Provincial Policies and Programs

A goal of the provincial government is to maximize energy development and climate change opportunities to create further opportunities for economic development in the province. In 2002 the Manitoba Government established the Department of Energy, Science and Technology, which has a mandate to further develop emerging electric generation alternatives, and to implement Manitoba's Kyoto plan. This plan envisages that GHG emissions in Manitoba could be as much as 18 percent lower in 2010 than in 1990, and 23 percent lower in 2012. These reductions are higher than the Canadian target of a six percent reduction from 1990 levels and are largely based, among other measures, on obtaining emissions credits for hydro and other renewable power exports.[44]

FIGURE 4.5.1

Manitoba 2004 Generating Capacity by Fuel (5 532 MW)



Source: Statistics Canada

Manitoba's provincial energy policy developments are focussed on the following:

- The development of export opportunities. The development and sale of Manitoba's clean power is seen as one of the primary vehicles for economic development in Manitoba. The Clean Energy Transfer Initiative (CETI) represents an opportunity to transfer up to 3 000 MW of electric power to Ontario to aid in the decommissioning of Ontario's coal plants and meet growing electricity demands.

44 *All Over the Map, A Comparison of Provincial Climate Change Plans*, David Suzuki Foundation, 2005, Manitoba, p 2

- The development of wind energy resources. Manitoba's favourable wind resources, along with the storage capability and operating characteristics of Manitoba's hydro system, support wind power development. Among the various energy technologies, wind has produced the most interest and is furthest along in development.
- Small hydro developments. Most proposed small hydro developments are contemplated in the vicinity of communities serviced by diesel power. These developments could be owned by First Nations or jointly owned with Manitoba Hydro.
- Geothermal heat pumps. Manitoba heat pump installations represent 30 percent of the total Canadian market. Manitoba Hydro provides low-interest loans of up to $15,000 toward the cost of a geothermal heat pump. Annual heating bills can be reduced by $400-$1,800 annually, depending on the type of system being replaced.[45]

4.5.2 Utility and Consumer Strategies

Manitoba Hydro's strategy is to be a leader in implementing cost-effective energy conservation and alternative energy programs.[46] This encompasses: promoting DSM to residential, commercial and industrial customers through its Power Smart programs; assessing and encouraging the development of economic alternative energy sources including wind and other sources, and promoting a rate structure that encourages the efficient use of energy.

4.5.3 Near-Term and Longer-Term Prospects

Manitoba's immediate priorities include the development of wind power projects, advancement of the Wuskwatim, Keeyask and Conawapa hydro generating stations, and concluding negotiations of the Clean Energy Transfer Initiative with Ontario.

Implementation of the provincial government's policy to promote wind power developments of 1 000 MW (equivalent to 20 percent of existing generation capacity) over the next 10 years was announced in November 2005 by an invitation for expressions of interest from wind power proponents. The 99 MW St. Leon project, the province's first wind development, is scheduled for completion by the spring of 2006.

Other energy development prospects include the following:

- In December 2004, following on the previous success achieved, Manitoba Hydro announced a doubling of its DSM PowerSmart program target to reduce peak demand by 640 MW and save 1 700 GW.h of energy annually by 2018.
- Installation of geothermal heat pumps in a 15 000-home subdivision in Winnipeg is planned over the next few years.
- The new Manitoba Hydro building will employ passive solar technology and other building design features to reduce electric requirements.
- Manitoba is advancing on hydrogen initiatives through the development of a hydrogen corridor with adjacent U.S. states in the upper Midwest, cooperation with Iceland on hydrogen technologies, and the development of a hydrogen Centre of Expertise in Pinawa Manitoba.

45 *Smart Generation, Powering Ontario with Renewable Energy*, David Suzuki Foundation, 2004, p 77

46 *The Corporate Strategic Plan 05/06*, Manitoba Hydro.

The *Kyoto Protocol* offers an opportunity for the province to promote its large-scale hydro power as a clean renewable power source. The CETI proposal would involve development of new hydro generation facilities for the purpose of exporting up to 1 500 MW of additional hydro power to Ontario in the 2014-2018 time period. In October 2005, Manitoba and Ontario announced plans to potentially increase the transfer capability to 3 000 MW in the 2020s. In addition, the current inter-tie between Manitoba and Ontario is to be expanded from 200 MW to 400 MW by 2009.

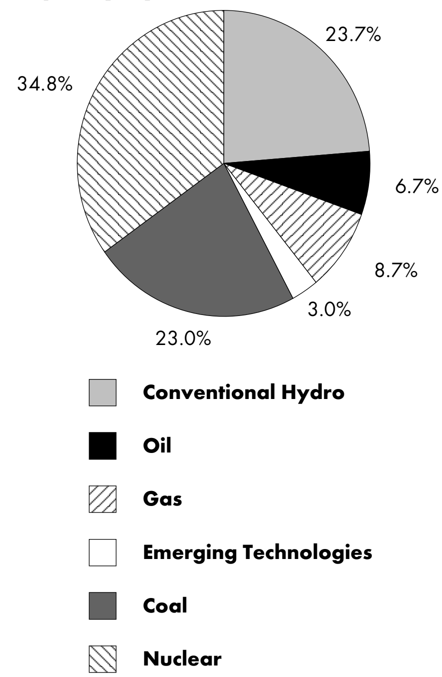
4.6 Ontario

Ontario has a diverse generation mix (Figure 4.6.1) and has the capability to import electricity from adjacent provinces and states. This trade ensures higher electric reliability and enables commercial transactions that take advantage of price differentials between markets. In 2004, generation was about 160 TW.h with net exports of about zero (exports and imports were about equal), and it is estimated that Ontario was a net exporter in 2005. Renewables generation capacity, excluding large hydro, accounted for almost 1000 MW out of the total capacity of 32 930 MW. Renewables consisted mostly of biomass, small hydro and some wind generation.

Due to problems with a number of its nuclear reactors in the late 1990s, Ontario increased its use of coal-fired generation. With coal-fired generation now expected to be phased out by 2009 and not all of the nuclear units expected to be returned to service, there will be large new requirements for generation in the near future. Natural gas, some nuclear refurbishment, renewables and DSM are each expected to play a role in addressing generation requirements.

FIGURE 4.6.1

Ontario 2004 Generating Capacity by Fuel (32 930 MW)



Source: Statistics Canada

4.6.1 *Provincial Policies and Programs*

The provincial government conducted a number of inquiries associated with restructuring its electricity markets that culminated in recommendations by the Electricity Conservation and Supply Task Force in early 2004. New legislation creating the OPA and inquiries by the Ontario Energy Board (OEB) into DSM and DR[47] has paved the way for significant opportunities for renewables and DSM to address Ontario's future generation needs.[48]

In the last major policy announcement addressing the restructuring and other issues, the government established a conservation target of five percent below 2007 forecasted electricity demand levels. In addition, five percent of generation is expected to be from renewables and DSM by 2007 (1 350 MW) and 10 percent by 2010 (2 700 MW).

47 The OEB conducted an inquiry into DSM and DR during 2003–2005.

48 More details on these developments are available in the NEB's Energy Market Assessments: *A Compendium of Electric Reliability Frameworks Across Canada* (June 2004) and *Outlook for Electricity Markets: 2005 – 2006* (June 2005).

Policy initiatives toward increasing the use of renewables for electricity generation have been largely carried out by RFPs. In response to the first RFP issued in 2004, 395 MW were accepted early in 2005, including wind (355 MW), DSM (10 MW), small hydro (20 MW) and biomass (10 MW).

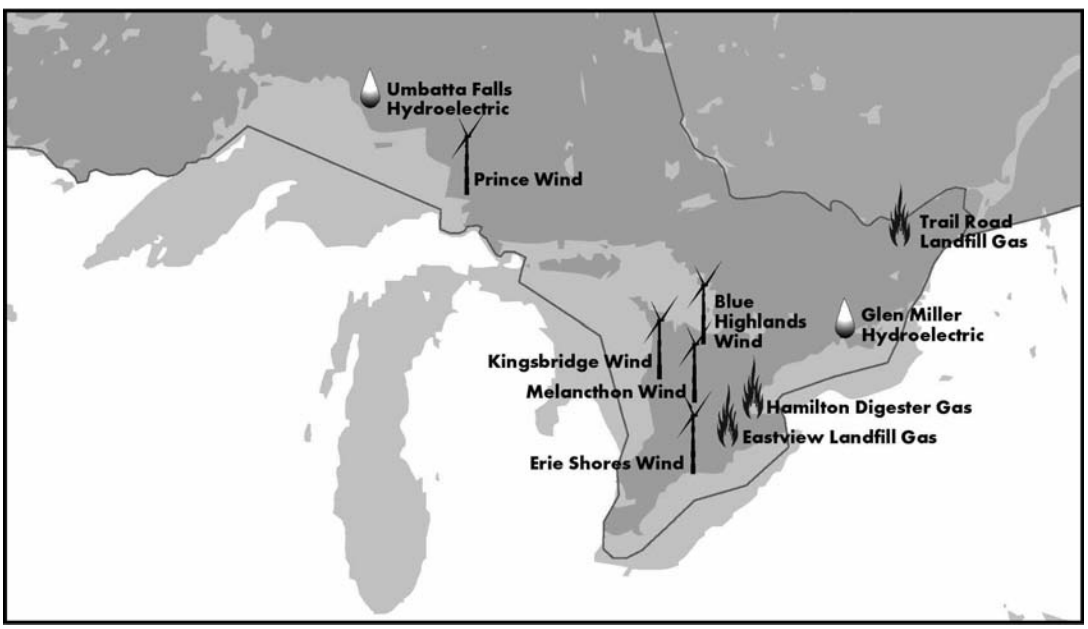
Another 1 200 MW were requested in 2005, in tranches of 1 000 MW in April and another 200 MW in June, bringing the total to 1 600 MW. Successful bidders are expected in wind, small hydro and landfill gas.[49] The process is now managed by the OPA.

While renewable RFPs have so far been dominated by wind, it is anticipated that other renewables and DSM will play a bigger role in future RFPs. Two new initiatives are providing standard offer contracts for projects less than 20 MW and opening up crown lands to development. Standard offer contracts occur at a fixed price and limit the amount of power that will be accepted. They simplify the application process for small players and provide somewhat higher prices than those resulting from the closed bids in the RFP process.

Demand-side programs can be expected to receive a boost from the introduction of smart meters in Ontario. The plan is for 800 000 meters to be installed by 2007 and for all small consumers to be on smart meters by 2011. All customers with smart meters will be on three-tier TOU rates starting in April 2006.[50] Many larger commercial and industrial customers already can benefit through TOU rates based on prices in the power pool, which vary through the day.

F I G U R E 4 . 6 . 2

"Renewables 1" Project Locations



Source: Ontario Ministry of Energy, Presentation at the Federal/Provincial/Territorial Renewable Energy Workshop, 3 May 2005.

49 MOE, 1 November 2005 (CERI conference)

50 Initial indications are an off-peak price of 3 ¢/kW.h (late-evening and overnight), an on-peak price of 9 ¢/kW.h (morning rush-hour and late-afternoon/early evening) and 6 ¢/kW.h in the shoulder periods. Current small consumers' prices are 5 ¢/kW.h up to 1 000 kW.h/month and 5.8 ¢/kW.h above 1 000 kW.h. The 1 000 kW.h threshold will fall to 600 kW.h from 1 April to 31 October 2006.

Demand programs include a DR program, run by the Independent Electricity System Operator (IESO), to manage peak consumption and ensure daily reliable operation of the grid. This enables 300–600 MW to be curtailed on short notice.

4.6.2 Utility and Consumer Strategies

In addition to the introduction of smart meters, there are other initiatives that effectively reduce the demand for generation, including Enwave's deep-lake water-cooling project in Toronto, which substitutes for electric-powered air conditioning. Major opportunities for DSM also exist in commercial lighting and air conditioning. A common disincentive for utilities in implementing DSM, namely lower revenue, is being addressed by a Lost Revenue Adjustment mechanism, which is similar to the program the province has used in its natural gas DSM program.

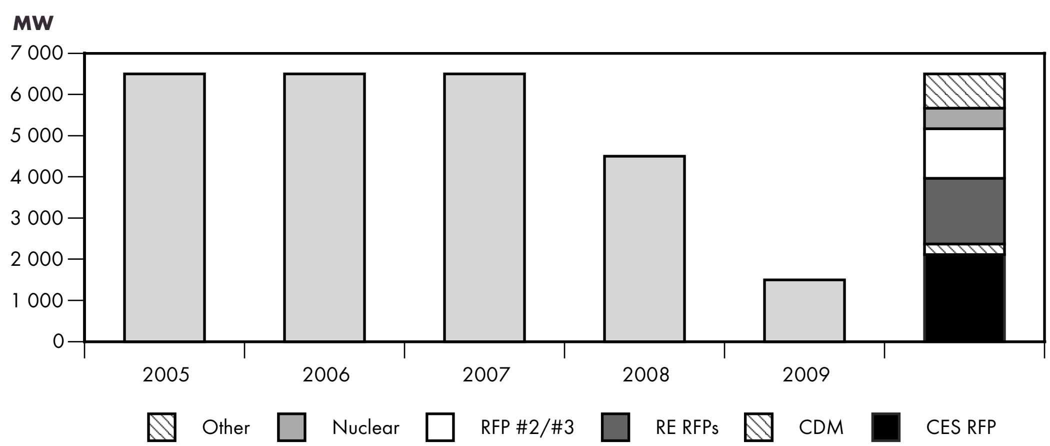
Most recently, the province announced regulations for net metering, which will allow customers that generate electricity to sell to the grid when they have surplus power available. This benefits customers with renewable generation sources, such as wind and solar PV, and customers in rural areas that can generate power from wood and agricultural waste. Net metering is limited to 500 kW and smaller generators – most landfills and incinerators would be too large for net metering. A proposal is currently being prepared for the IESO, taking a regional approach, to promote and develop biofuels for power generation in the eastern part of the province. While there are many feasible applications like this, it is anticipated that there will be some challenges surrounding the regulation of this new consumer/producer customer (e.g., concerning responsibilities associated with connections to the distribution system and interconnected grid).

4.6.3 Near-Term and Longer-Term Prospects

Ontario faces a major challenge over the next few years as coal-fired generation is phased out and major decisions need to be made on its nuclear program. In addition to the announced and anticipated renewable and DSM initiatives, the OPA expects substantial new natural gas-fired generation will be required (Figure 4.6.3). Significantly, at least in the near-term, it does not appear that intermittency or other issues associated with integrating renewable energy into the grid is a constraining factor, rather

FIGURE 4.6.3

Ontario Coal Phaseout



Source: IESO, NEB

there is concern about whether or not it is feasible to authorize and construct facilities within this short time frame.

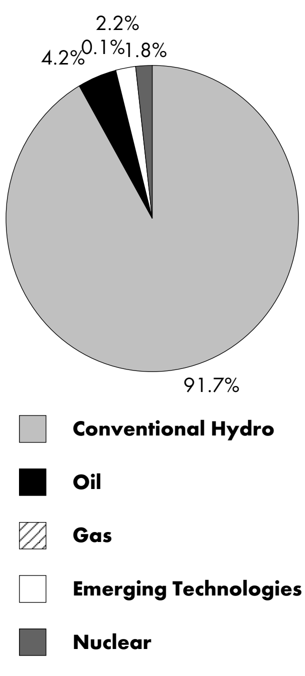
Over the long term, the opportunities for emerging generation technologies will depend on their competitiveness or government incentives, NIMBY effects in new locations, and the future for nuclear power. The IESO estimates that, after allowance for DSM and renewables, the province could still need up to 8 000 MW of new generation by 2015 (assuming the current schedule for the wind-down of nuclear plants). It now appears that power transfers from Manitoba and Labrador, via Québec, will meet a portion of this requirement.[51] Even a modest share would mean a huge opportunity for renewables.

Demand-side management is expected to play a significant role in Ontario's future. The OPA will give this high priority through its Office of Energy Conservation, with programs and initiatives and by promoting a conservation culture. On the other hand, the role of clean coal, especially IGCC, is uncertain. While the province has not entirely ruled out IGCC (with CO_2 sequestration) it does not seem to be part of the near-term plans.

In December 2005, the OPA announced its advice to the government on the future fuel mix in power generation to 2025. [52] The OPA report suggests a diverse set of strategies to meet Ontario's power generation needs, including maximizing conservation and pursuing "an aggressive course for renewables within existing constraints while looking at ways to reduce these constraints." Key elements of the advice include a strategy for natural gas, consideration of nuclear developments and imports of hydro from other provinces.

FIGURE 4.7.1

Québec 2004 Generating Capacity by Fuel (37 769 MW)



Source: Statistics Canada

4.7 Québec

Québec's generating capacity is predominantly hydro-based, with some nuclear, oil and gas-fired capacity (Figure 4.7.1). Installed capacity associated with emerging technologies amounts to 850 MW, consisting of wind, small hydro and biomass.

Due to substantial hydro resources, consumers and industries in Québec benefit from electricity rates that are among the lowest in the world. As a result, Québec has attracted major energy intensive industries, including electrochemical and electrometallurgical industries.

Québec's hydro resources provide the province with a natural advantage concerning renewable energy targets and implementation of the *Kyoto Protocol* as it is generally accepted that hydro power has little or no GHG emissions.

51 OME, 1 November 2005

52 Ontario Power Authority, *Supply Mix Advice Report*, 9 December 2005, p 8. In its report, the OPA uses the term "CDM" which refers to conservation and other forms of demand management.

4.7.1 *Provincial Policies and Programs*

Hydroelectricity has historically played a central role in promoting social and economic progress in the province. From the construction of large hydro projects in the James Bay area in the 1970s to the development of wind farms in recent years, Québec's social and economic policies have consistently adopted electricity as an instrument for industrial and regional economic development. In developing the emerging technologies, Québec sees opportunities to strengthen its manufacturing base, particularly in the wind industry. The province intends to capitalize on the natural synergy between large hydro and wind power systems to address wind power intermittency issues.

The provincial government has directed Hydro-Québec Distribution (HQD) to include 3 000 MW of wind power capacity in its supply mix by 2013. This represents about eight percent of Québec's current generating capacity. Local and regional economic development is part of Québec's approach to emerging generation technologies. Efforts to support regional economies are evidenced in HQD's assessment criteria, which include the regional content of wind power projects that can be measured, for example, in terms of investments and job creation.

Québec recently issued a consultation document that contains policy objectives and preliminary policy options. Public input will be incorporated in the final policy document to be released in 2006. The government intends to pursue a number of initiatives in the context of sustainable energy development, including the continued reliance on hydro power, promotion of wind energy and a focus on energy efficiency.

Québec commissioned a comprehensive inventory of wind energy potential to identify commercially viable sites and to assess the possibilities for connecting wind farms to HQD's network. The inventory estimated that HQD's system could integrate 4 000 MW by 2015 without network operation constraints. This inventory will help the government make decisions about the exploitation of the resource and provide information to developers interested in pursuing projects in the province.

In 2001, Québec initiated a program to develop 450 MW of small hydro capacity associated with 36 possible run-of-river plants. There was strong public opposition to the implementation of the program due to environmental concerns. As a result, only three projects were realized. The Régie de l'énergie (Régie) recommended the development of 150 MW of small hydro capacity. The main responsibilities of the Régie concerning emerging generation technologies are:

- to provide expert advice to the government about the potential for emerging generation technology development in Québec;

FIGURE 4.7.2

Le Nordais Wind Farm, near Matane, Gaspé Region, Québec

- to approve HQD's supply plans, as well as long-term supply contracts between HQD and project promoters; and
- to oversee the RFP process and approve project assessment criteria as proposed by HQD.

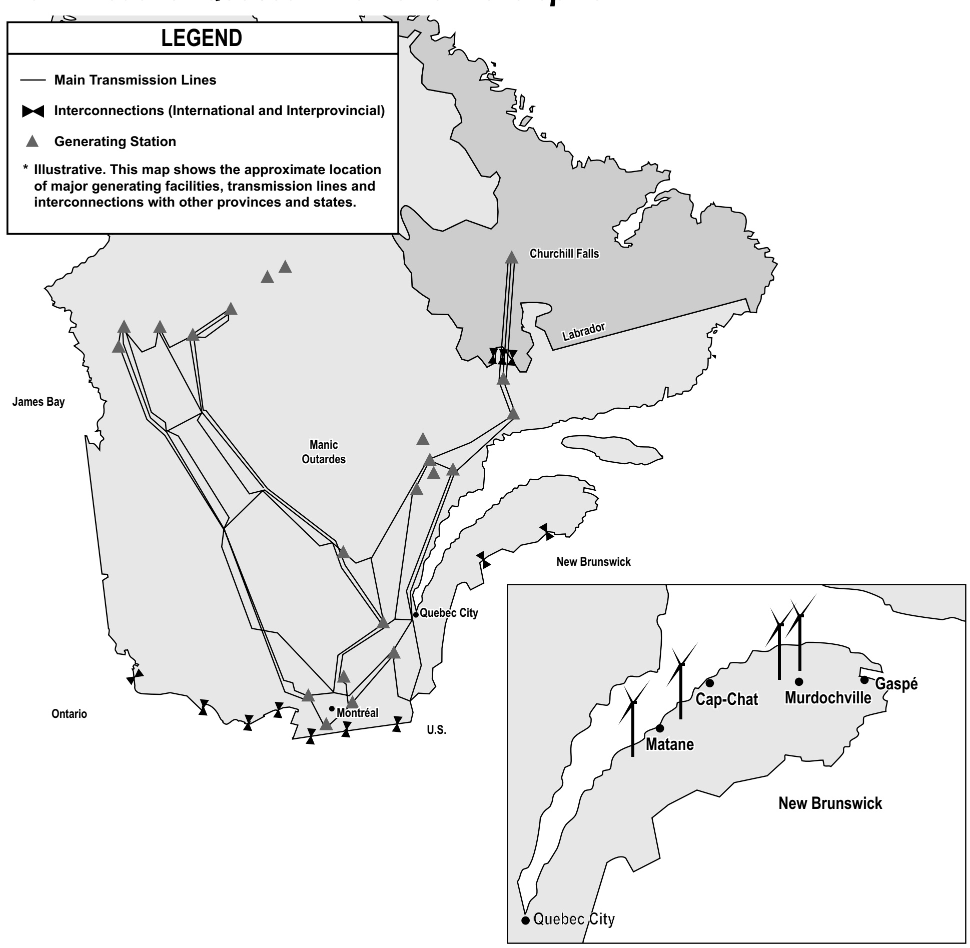
4.7.2 Utility and Consumer Strategies

Hydro-Québec Distribution issued an RFP in April 2003 for 1 000 MW of wind power capacity and subsequently received tenders for over 4 000 MW. The RFP resulted in the adoption of eight projects (totalling 990 MW) that will be installed in the Gaspé Peninsula between 2006 and 2012. Cartier Wind Energy, a partnership between TransCanada Corporation and Innergex, will build six projects, totalling 740 MW. Northland Power will build two projects, totalling 250 MW. GE Energy has been selected as the principal turbine supplier for these projects. In October 2005, HQD issued a second RFP for 2 000 MW of wind power to be online starting in December 2009 through December 2013. Most of these projects will likely be eligible for the federal WPPI program incentive.

Growth of wind power has created a critical mass for the implementation of manufacturing activities in Québec. Marmen Inc., a Québec company specializing in high-precision machining, fabrication and mechanical assembly of parts, has contracted for the construction of two wind turbine manufacturing facilities in Matane. The facilities, which are expected to be operational this fall, will be used for tower

FIGURE 4.7.3

Main Areas for Québec Wind Power Development



fabrication and nacelle (the protective casing of a propeller-type wind turbine) assembly. A Danish wind turbine blade manufacturer is building a factory in Gaspé to supply GE Energy with rotor blades for provincial and export markets. The plant will be operational by spring 2006.

Hydro-Québec Distribution issued an RFP in April 2003 for 100 MW of biomass capacity. There were 89 MW of proposed projects, but only two projects, totalling 40 MW, were approved (Kruger [19 MW] and Bowater [21 MW]).

Québec is not a prospective area for geothermal electricity generation. However, Corporation des enterprises de traitement de l'air et du froid (CETAF), is an industry association promoting, among other objectives, the integration of direct-use geothermal energy in space heating.

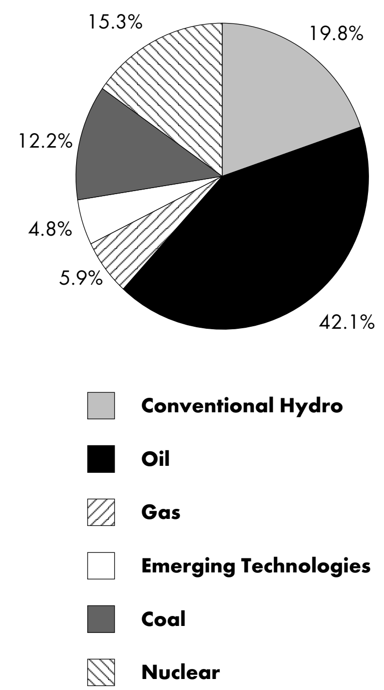
4.7.3 Near-Term and Longer-Term Prospects

Québec's wind power initiatives provide a framework in which over 3 000 MW of wind power capacity will be developed over the next eight years, potentially making Québec a leading wind power developer in Canada. Considering Québec's approach to promote wind power as a complimentary source to its hydropower facilities and its considerable wind resources, this technology is expected to achieve the highest growth in the emerging generation technology sector in Québec from 2006–2013. Current indications are that the most promising regions are Gaspésie–Îles-de-la-Madeleine, Basse-Côte-Nord, Bas-Saint-Laurent, and Nord-du-Québec.

Judging by the results of the 100 MW biomass RFP, Québec's potential for biomass-based generation appears to be limited unless technological progress improves the profitability of these projects significantly. With respect to small hydro, a potential of about 900 MW has been estimated, but public opposition has been a key barrier to small hydro development. The Québec Renewable Energy Producers Association has identified a total of 53 small hydro sites that could deliver 862 MW of small hydro at a price of $80 per MW.h or less. Small hydro development could be accelerated if there is more public acceptance.

FIGURE 4.8.1

New Brunswick 2004 Generating Capacity by Fuel (4 433 MW)



Source: Statistics Canada

4.8 New Brunswick

New Brunswick is the largest provincial electricity market in Atlantic Canada, accounting for about 40 percent of the region's electricity demand. It has a diverse generation portfolio, which includes nuclear, fossil-fuelled, and hydro generation. In 2004, generation capacity in New Brunswick totalled 4 433 MW (Figure 4.8.1). The majority of renewable generation is conventional and small hydro and biomass. The province's first wind farm, a 20 MW facility on Grand Manan Island, is currently being constructed and is scheduled to come online in early 2006.

The provincial Government announced in July 2005 that it intends to refurbish the 635 MW Point Lepreau nuclear generating station. This will have a major impact on New Brunswick's electricity market in terms of future electricity rates, as Point Lepreau supplies 25 percent of the province's electricity needs.

4.8.1 Provincial Policies and Programs

New Brunswick announced its intention to implement RPS regulation, starting in 2007, that will require 10 percent of new electricity supply to be from renewable sources by 2016. This would bring total renewable electricity capacity, including conventional hydro, to 33 percent.

In September 2004, the New Brunswick Department of Energy published a *White Paper on an Energy Efficiency System for New Brunswick*. The document outlines the objectives and main components of a DSM program and the intention to establish an energy efficiency agency. In October 2005, the provincial government announced the formation of the New Brunswick Energy Efficiency and Conservation Agency. The agency is working on a number of initiatives including implementing loan and rebate programs for efficiency measures and partnering with the federal Energuide program to perform in-home audits.[53] The energy efficiency program is currently focused on all energy consumption; however, the government intends to create a separate, electricity-specific DSM program at a later date. New Brunswick already has a Provincial Buildings Initiative, which reduces energy use in government buildings and requires that all public housing units meet set efficiency standards.

Atlantic Region Cooperation

In July 2005, the Atlantic Energy Ministers pledged to explore a framework to increase cooperation on energy efficiency and renewable energy development and to examine strategies to maximize emerging generation technologies and keep costs as low as possible. Strategies could include a harmonized RPS or DSM program, increased transmission interconnections between jurisdictions, more exports and imports to create synergies among provinces, a single system operator for the region, and regional generation planning.

There is potential for greater regional integration of operations in the Maritime region, especially with the development of wind generation. One way of integrating these markets is via the establishment of a Maritime Green Power Pool for wind energy. The goal would be to optimize the development of wind resources in the region through interconnection and power trade agreements.[54] The concept is supported by a recent study completed by the NBSO, which concluded that load variability was less when wind facilities were distributed amongst several sites.[55] The recent announcement of the construction of an additional submarine transmission cable between Prince Edward Island and New Brunswick is another example of regional cooperation for renewable power development.

Regional integration is also being pursued through the Council of New England Governors/Eastern Canadian Premiers (NEG/ECP). Four eastern premiers[56] and governors of the New England states[57] have developed a Climate Change Action Plan, which includes the following regional targets:

- reducing regional emissions to 1990 levels by 2010;
- reducing government building, vehicle and equipment related emissions by 25 percent by 2010;
- reducing electricity emissions by 20 percent by 2025; and
- increasing energy saved through energy conservation programs by 20 percent by 2025.

Each jurisdiction is to develop an action plan and inventory of their GHG emissions.

53 NB DOE, Website press release, 13 October, 2005. http://www.gnb.ca/scripts2/CNBNews/ene.idq

54 Gagnon and Brothers, *Presentation at the 2005 CanWEA Conference*, October 2005

55 New Brunswick System Operator for the Atlantic Electricity Work Group, August 2005

56 Newfoundland, Nova Scotia, Prince Edward Island and New Brunswick

57 Rhode Island, Connecticut, Maine, Massachusetts, New Hampshire and Vermont

4.8.2 *Utility and Consumer Strategies*

As part of the provincial government's strategy to reach its RPS target, NB Power has issued a request for expressions of interest (REI) asking developers for plans to develop and operate up to 400 MW of wind power for purchase by NB Power. NB Power plans to announce the successful proponent(s) by spring of 2006. Five regions are proposed for wind power development: Bay of Fundy, Tantramar, Miramichi Bay, Acadie-Chaleur and inland New Brunswick. The intention is to ensure greater efficiency and diversity of generation supply.

In terms of demand-side management, New Brunswick currently has non-firm customers who have the ability to come offline when the electricity grid is taxed. The New Brunswick System Operator (NBSO) has also submitted a demand-side bidding proposal to the New Brunswick Market Advisory Committee for comment.

4.8.3 *Near-Term and Longer-Term Prospects*

The development of new renewable generating capacity in New Brunswick will require the commitment of both government and industry, given forecasts for adequate generation supply and relatively low, stable electricity prices. NB Power projects a surplus of generating capacity in the medium term, particularly after the refurbishment of Point Lepreau, which will lower the province's need for new generation. That being said, the desire for supply diversification, increased provincial economic development and a desire to address environmental concerns may spur the development of renewable generation sources.

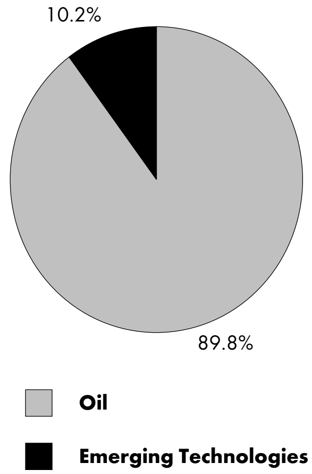
In the near-term, wind power development will be initiated from NB Power's 400 MW REI. The construction of accepted projects may be accelerated so that they can be online prior to the 2008 refurbishment of Point Lepreau. There is a need for replacement supply while the nuclear plant is under construction. Higher oil prices will increase the attractiveness of renewables as they will compete against oil-fired generation in the short term. Biomass has some potential, specifically residual wood-fuelled generation. For example, a new biomass cogeneration project in Saint John is being proposed by Irving Oil. There is also some potential for small hydro, and landfill gas generation. It is unclear whether or not these sources of generation would be initiated by an RFP process. Longer-term prospects in the province may include tidal flow and solar power generation.

4.9 Prince Edward Island

Prince Edward Island (P.E.I.) currently relies on electricity transfers from New Brunswick to meet 94 percent of its power requirements. The majority of P.E.I.'s generation capacity consists of oil-fired facilities (Figure 4.9.1) and the remainder is primarily wind generation. Maritime Electric Company Limited (Maritime Electric) operates two generating facilities with a combined total capacity of 104 MW: the diesel-fired Borden Generating Station (40 MW) and the oil-fired Charlottetown Generating Station (64 MW). These generating stations are kept in standby mode and typically run only when imported supply is interrupted.

FIGURE 4.9.1

Princ Edward Island 2004 Generating Capacity by Fuel (121 MW)



Source: Statistics Canada

As a result of new wind capacity (e.g., the 3 MW Aeolous site and the 10.6 MW North Cape farm), generation in P.E.I. has increased. Wind currently contributes about five percent[58] of P.E.I.'s electricity generation and is expected to contribute up to 15 percent by the end of 2007.

4.9.1 Provincial Policies and Programs

P.E.I. unveiled an *Energy Framework and Renewable Energy Strategy*[59] in June 2004. The provincial government committed to an RPS of at least 15 percent by 2010, which will be met with the addition of 40 MW of wind capacity. However, the provincial government has since committed to working with private sector developers to provide at least 200 MW of wind power capacity by 2010 (or an additional 160 MW of wind capacity to the initial 40 MW that was committed to).

In November 2005, the provincial government, federal government, and Maritime Electric announced that a third submarine transmission cable would be built from P.E.I. to New Brunswick to support 200 MW of wind development in P.E.I. If constructed, the new wind generation would provide 100 percent of P.E.I.'s electricity requirements and enable the province to export excess wind powered generation or import less electricity from New Brunswick.

P.E.I. plans to reach its renewable targets by a number of specific initiatives. Large-scale wind developments by the P.E.I. Energy Corporation[60] and private companies will be pursued, although these developments will be restricted to designated areas. For smaller scale developments, net metering will be available (for renewable energy systems up to 100 kW), as well as tax exemptions and low-interest loans. Guaranteed feed-in tariffs will be available for community, wind cooperatives and large systems, at a rate of 7.75 ¢/kW.h.

4.9.2 Utility and Consumer Strategies

In line with the provincial government's RPS commitments, P.E.I. Energy Corporation will be developing a 30 MW wind farm at the east end of the province. Construction is tentatively scheduled to start in spring 2006 and the facility should be in operation by fall 2006.

The renewable energy strategy calls for Maritime Electric to file a DSM strategy to promote efficient energy use and to decrease demand by 2010.

4.9.3 Near-Term and Longer-Term Prospects

P.E.I.'s renewable energy strategy is intended to create a "made in P.E.I. energy solution".[61] The main drivers and objectives of this strategy are to reduce the province's reliance on fossil fuels and out-of-province generation, and to address environmental concerns such as climate change. Economic development opportunities and export opportunities may also be possible with further wind development.

58 P.E.I. Energy Corporation Consultation, October 2005

59 Prince Edward Island Department of Environment and Energy, *Prince Edward Island Energy Framework and Renewable Energy Strategy*, June 2004

60 The P.E.I. Energy Corporation is a Crown corporation responsible for pursuing and promoting the development of energy systems and the generation, production, transmission and distribution of energy in Prince Edward Island.

61 Minister Jaimie Ballen (Environment, Energy and Forestry), Media Release: 23 November 2004

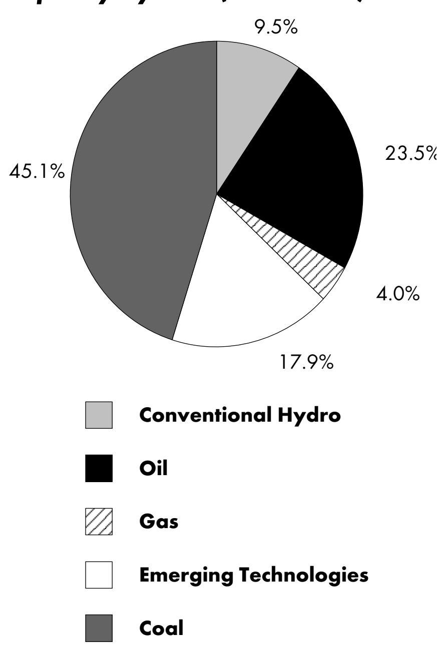
The on-island transmission system is a potential barrier to renewable electricity development. Improvements of $30 million investment are required to maximize the renewable potential of the province. Construction of a third cable connecting P.E.I. to New Brunswick will enable P.E.I. to reach its goal of adding 200 MW of wind power capacity by 2010. Due to the intermittency of wind generation and the province's lack of backup generation, a portion of the 200 MW would be exported.

P.E.I.'s primary focus for their renewable energy strategy will be wind generation developments. Assessments have shown that the province has significant wind resource potential for further development.[62] Supply costs of wind on the island are expected to be approximately 7 ¢/kW.h and $1 750/kW installed.[63] There are also potential opportunities for development of biomass (wood pellets and forest/sawmill residue) and bio-fuels using agricultural by-products and waste from farming communities, although these technologies are not as price competitive as wind generation.[64]

In the longer term, P.E.I. Energy Corporation and Hydrogenics will be leading a consortium of industry and government partners to develop Canada's first wind-hydrogen village demonstration. The primary locations will be in the North Cape area of P.E.I., the home of the Atlantic Wind Test Site and the site for a 10.6 MW wind farm. Wind turbines will be used to meet ongoing electricity needs and to provide power to electrolysis equipment, which makes hydrogen from water. The hydrogen will then be used to fuel a hydrogen internal combustion engine to provide electricity and transportation fuel. Development of this project is scheduled to start over the next year.

FIGURE 4.10.1

Nova Scotia 2004 Generating Capacity by Fuel (2 413 MW)



Source: Statistics Canada

4.10 Nova Scotia

Nova Scotia has a mix of generation sources (Figure 4.10.1). As of December 2003, the province had a total capacity of 2 413 MW. Coal-fired units provide almost half of the total capacity and 70 percent of generation output.

Currently, renewables account for about nine percent of Nova Scotia's electricity generation output (including small hydro, biomass, tidal power and wind).[65] Nova Scotia has 35 MW of installed wind capacity, including Atlantic Wind Power Corp.'s 30.6 MW Pubnico Point facility. Nova Scotia has the 25 MW Brooklyn biomass facility (next to a pulp and paper operation) and one of the few tidal power stations in the world, the 20 MW facility at Annapolis Royal (Figure 4.10.2).

Nova Scotia Power Inc.'s current strategy[66] for generation expansion includes retrofits at existing units and an increased emphasis on renewable sources of generation. Two 47 MW natural gas-fired combustion turbines have

62 Brothers, Gasset, Gagnon, Poitras and MacQuarrie, *Wind Resource Assessment of Prince Edward Island*. Presentation at the 2005 CanWEA Conference. October, 2005. Study conducted by the Université de Moncton.

63 P.E.I. Energy Corporation Consultation, October 2005

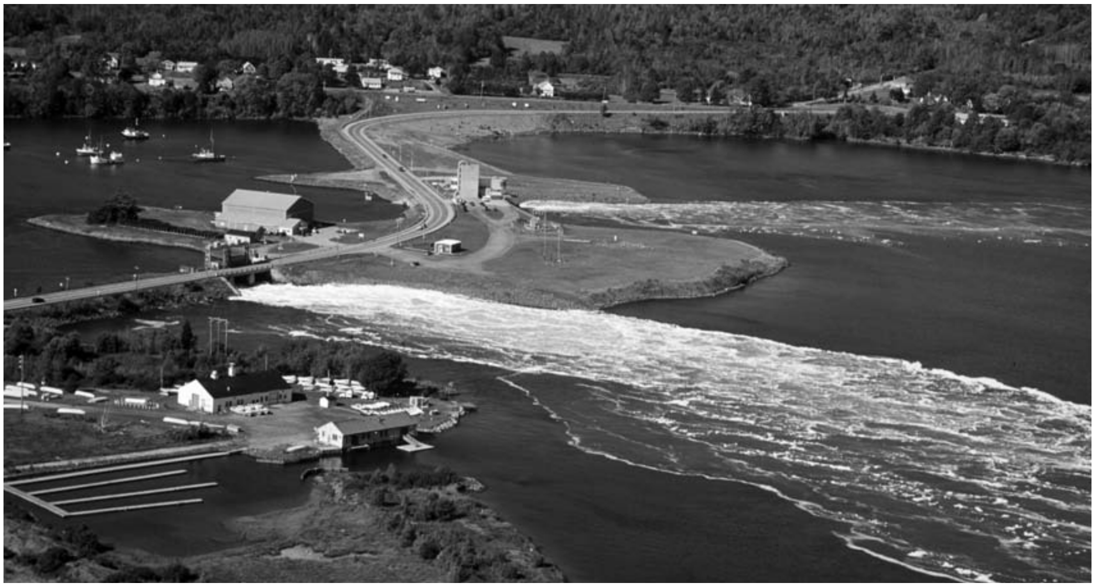
64 P.E.I. Energy Corporation, *Prince Edward Island Renewable Energy Strategy Public Discussion Document*, June 2003

65 Nova Scotia Department of Energy: http://www.gov.ns.ca/energy/AbsPage.aspx?id=1344&siteid=1&lang=1

66 Nova Scotia Power Inc. is the principal supplier of power in Nova Scotia.

FIGURE 4.10.2

Annapolis Royal Tidal Generating Station



Source: Nova Scotia Power Inc.

been added at the Tufts Cove generating plant. Three of the earlier Tufts Cove units are equipped to generate electricity using either natural gas or oil as fuel. With high natural gas prices, oil has been used more often than gas during the last two years.

4.10.1 Provincial Policies and Programs

In October 2005, the provincial government released *Smart Choices for Cleaner Energy…the Green Energy Framework*, which provides a 15-year view for ensuring sustainable energy in Nova Scotia. The planning framework suggests focusing more on energy efficiency and developing cleaner energy technologies. Elements of the generation framework include:

- an additional 280 MW of new wind power generation, in addition to the 100 MW already planned for the province (which is expected by 2007);
- potential for 20 MW of biomass cogeneration in northern Nova Scotia in the forest products sector;
- an additional 50 MW from heat recovery on gas turbines;
- a transmission upgrade for wind power;
- a tidal flow pilot (dependent on a study currently underway); and
- support of carbon capture and storage R&D.[67]

A number of these initiatives will work toward the provincial government's planned RPS of having five percent of its new electricity generation (built post-2001) coming from renewable energy sources by 2010.

67 Nova Scotia Department of Energy, *Smart Choices for Cleaner Energy: The Green Energy Framework*, October 2005

Nova Scotia's framework also encourages increased energy conservation by individuals and government through the Smart Energy Choices Program. Demand-side management and DR measures, such as the Extra Large Industrial Interruptible Rate (ELIIR), have been successful in reducing demand growth in recent years and Nova Scotia has a goal of conserving a further 67 MW with DSM and DR by 2010.

4.10.2 Utility and Consumer Strategies

New renewable energy projects coming online in Nova Scotia will be built by IPPs through a competitive bidding process. NSPI has launched an RFP for renewable power generation. The RFP is soliciting for the construction of installations of less than 2 MW, installations greater than 2 MW, and installations up to 100 KW using net metering. In 2004, NSPI accepted 17 proposals (totalling 28 MW) for projects that are less than 2 MW. The majority of the successful bids were wind (although a landfill gas and wood-waste biomass project were also accepted). In April 2005, NSPI announced the first accepted project in the over 2 MW RFP, a 31 MW wind farm on Cape Breton that is expected to be operational in 2007.

As an incentive for wind development, NSPI will be offering feed-in tariffs that will reflect regional pricing differences across the province. These feed-in tariffs will range between 6.5–7.5 ¢/kW.h.[68]

Nova Scotia Power Inc. currently offers a Smart Energy Information Service (SEIS), which allows minute-by-minute tracking of electricity usage, real time pricing and ELIIR to large power consumers. In its current rate application, NSPI has proposed a $5 million/year program for conservation and DSM. Initiatives in the plan include starting work on conservation-based pricing options and developing new load management devices, such as smart meters, for 2007. NSPI is aiming for a reduction of 16 MW in annual peak electricity demand.

4.10.3 Near-Term and Longer-Term Prospects

Near-term electricity rates in Nova Scotia continue to fluctuate due to the high price of oil and imported coal, as the majority of its generation is fossil-fuel generated. In the long run, rates will be influenced by the cost of incremental generation, a large part of which may be renewable. While renewable energy is environmentally less intrusive and costs are declining, it generally remains more expensive than conventional generation. As in other jurisdictions, the addition of renewable energy into the provincial system will exert upward pressure on end-use electricity rates.

With upward pressure on oil, gas and coal prices, there has been a greater incentive in Nova Scotia to diversify its energy supply. As energy prices have increased, the prospects have improved for renewable energy. For example, in 2001, 50 MW of new renewable energy was planned for 2005. In 2003, 200 MW was planned for 2010. Currently, 300-400 MW are proposed to come online by 2010.[69]

Nova Scotia Power Inc. is relying on planned renewable generation, demand management measures, and retrofits of existing generation facilities to meet future load growth. However, the utility may require new generation if it falls short of its targets. While there is some potential for landfill gas and biomass development, most new renewable capacity additions will likely be wind powered.

68 Discussion with the Nova Scotia Department of Energy, September 2005

69 Nova Scotia Department of Energy Consultation, September 2005

There are a few challenges associated with wind development in Nova Scotia. The province lacks significant hydro power to act as backup power for wind facilities. Transmission upgrades will be necessary to support wind development. Lastly, wind generation competes with tourism because the best wind facility sites are near the scenic coast.

Nova Scotia currently has a 20 MW tidal facility and there is potential for further tidal development, although tidal technology is still in its infancy. Nova Scotia, New Brunswick and some states in the U.S. northeast, are currently supporting a study being carried out by EPRI to examine power generation opportunities from wave and tidal currents.

Despite having a large proportion of its generation fuelled by coal, clean-coal opportunities that use sequestration are limited. Unlike markets such as Alberta with significant on-land oil and gas industries, there are currently no potential buyers for the CO_2 that can be sequestered from coal-fired plants in Nova Scotia.

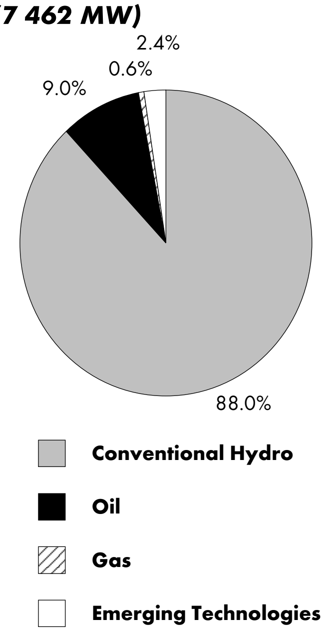
4.11 Newfoundland and Labrador

Ninety percent of generation capacity in Newfoundland and Labrador is from hydro based resources (Figure 4.11.1). Of this, about 72 percent or 5 400 MW is exported from the Churchill Falls hydro complex in Labrador, almost all of which is sold under long-term contract to Hydro Québec. Therefore, a large percentage of Newfoundland and Labrador's generation is currently from resources that produce relatively low amounts of GHG emissions. Approximately 176 MW of the province's generation capacity is small hydro facilities. The remaining third is provided by thermal generation, which is heavy fuel oil burned at Newfoundland and Labrador Hydro's (HYDRO's) 490 MW Holyrood generating station.

The development of the proposed Lower Churchill Hydro Project in Labrador[70] could provide up to 3 000 MW of additional generating capacity, primarily for serving out of province markets.

FIGURE 4.11.1

Newfoundland and Labrador 2004 Generating Capacity by Fuel (7 462 MW)



Source: Statistics Canada

4.11.1 Provincial Policies

The provincial government is currently in the process of developing a comprehensive energy strategy, and as part of its strategy, it released an energy consultation document in November 2005.[71] Stakeholder and public consultations are scheduled to begin in early 2006.

70 Phase 1, a call for Expressions of Interests and Proposals for the development of Lower Churchill, was completed in August 2005. The government has directed HYDRO to initiate phase 2 of the project: to complete a feasibility review of the concepts and related alternatives, and discussion of commercial principles with short-listed proponents.

71 Government of Newfoundland and Labrador Department of Natural Resources, *Developing an Energy Plan for Newfoundland and Labrador: Public Discussion Paper*, November 2005

The government also released *Newfoundland and Labrador Climate Change Action Plan 2005* in July 2005. In this plan, a number of actions were outlined, including examining emissions from government operations and developing a strategy to reduce them, establishing energy reduction targets in government buildings and improving energy efficiency in public and low-income housing.

4.11.2 Utility and Consumer Strategies

In December 2005, HYDRO issued an RFP for 25 MW of wind generation and specified a maximum offer of 6.7 ¢/kW.h for applicants.[72] The purpose of soliciting this new generation is to displace oil-fired generation from the Holyrood Generating Station.

Newfoundland Power's Bright Ideas Program is an energy efficiency initiative that educates customers and provides information on financing and rebates. In 2003, HYDRO launched Hydrowise, an energy conservation educational initiative for customers, and a DSM program encouraging isolated customers not connected to the grid to conserve energy.

4.11.3 Near-Term and Longer-Term Prospects

Labrador has considerable excess generating capacity and will have no need for new generation to meet domestic demand in the foreseeable future. However, there is an opportunity to pursue the Lower Churchill project for export.

Electricity generation from emerging technologies is most relevant to the Island, as Labrador has more than sufficient generating capacity. In the short-term, the Island has enough generation and low load-growth so supply adequacy is not likely to be a driver of emerging generation technology development. The Island does face a challenge in deciding how to meet its energy needs in the longer term. Emerging generation technology development will likely be driven by cost and environmental concerns because of the Island's reliance on oil-fired generation. Probable renewable generation options on the Island include wind, small-scale hydro, and biomass.

Wind power development is being pursued on the Island as HYDRO has issued a 25 MW RFP. Newfoundland and Labrador have a wind/diesel demonstration project at Ramea, a small island off the south coast of Newfoundland that has six 65 kW turbines. Future wind development may progress slowly, however, because of concerns with system stability. The province's hydro resources will support the development of wind projects somewhat, but the Island's lack of interconnections with other provinces will limit development. There have been discussions about the construction of a submarine transmission cable from Newfoundland to Labrador or to the Maritime provinces, but at this time the economics are not favourable. Feasibility studies have identified many potential sites for wind generation on the Island and work is under way to evaluate the system limitations and to develop a suitable strategy for wind power development.

There is potential for small hydro development on the Island, although there is currently a moratorium on small hydro development to protect salmon habitat. This moratorium will be reviewed as part of the comprehensive energy plan currently being developed. There is also some potential for wood biomass electricity generation for cogeneration in the forest products sector, although this is not currently as cost competitive as wind and small hydro development.[73]

72 Newfoundland and Labrador Department of Natural Resources Consultation, December 2005

73 Newfoundland and Labrador Department of Natural Resources Consultation, December 2005

Observations and Options for Action

The previous chapters provide assessments of emerging technologies in electricity generation in Canada, including regional perspectives. The following observations and options for action for policy makers follow from the assessments.

5.1 Observations

Currently, there is low penetration of emerging technologies in power generation.

Across Canada, about three percent of the installed generating capacity consists of emerging technologies. This is in part because of the low costs of electricity derived from conventional sources (e.g., large-scale hydro, coal, nuclear power and natural gas). To some extent, the low penetration of emerging technologies is also due to the structure of the industry in which large publicly owned utilities have historically opted for a model with large central generating stations.

Developments in energy markets have created the conditions for rapid growth in emerging technologies.

These include:

- the large increase in fossil fuel prices in recent years;
- most of the low-cost hydro sites have been developed and there is considerable public concern about further development of nuclear power;
- a move toward more competitive generation markets in many provinces;
- increasing public concern with air quality issues and the long-term impacts of greenhouse gas emissions; and
- the costs of many renewable technologies have been decreasing because of technology improvements.

A number of mechanisms promote the development of emerging technologies.

Provincial mechanisms include issuing requests for proposals or "expressions of interest," establishing renewable portfolio standards, developing standard offer contracts for smaller wind and small-hydro contracts (similar to the feed-in tariffs used in Germany and Denmark), and net metering, which allows utility customers with generation to effectively sell power to the grid when their own generation is greater than their consumption.

At the federal level, incentives are directed toward wind and other renewables, such as the Wind Power Production Incentive (WPPI), Renewable Power Production Incentive (RPPI) and Renewable Energy Deployment Initiative (REDI). However, industry participants generally believe a comprehensive renewables strategy is required. Natural Resources Canada is working with the industry toward such a strategy. There are other incentives available through the income tax system, such as accelerated capital cost allowances, which reduce taxes payable.

Barriers constrain the development of emerging technologies.

A major consideration is that the external costs, or "negative externalities," associated with air pollution and other environmental costs are not included in electricity prices. If market prices did take these factors into account (i.e., external costs were "internalized"), it is suggested by many that emerging technologies would be more competitive and possibly even lower cost than conventional generation.

It is often pointed out that electricity rates do not reflect actual costs because they are based on historical costs and hence prices are below the cost of developing new generation.[74] This causes consumption to be higher and lessens the motivation to make electricity investments in emerging technologies. Levelling the uneven playing field created by different price treatment would further enhance the competitiveness of emerging technologies.

Another barrier faced by emerging technologies is access to the transmission grid. To a large extent, power systems are set up to connect large-scale generating stations to load centres via extensive transmission networks, enabling the centralized dispatch of power. The rules for connecting smaller, remote generators are often unclear or apparently restrictive. To some extent, these issues are being addressed, perhaps more so in those provincial markets that have completely opened their system to competition.

At the project level, emerging technologies often face many of the same issues for project approval as conventional generators, including the NIMBY effect. Thus their smaller size can make regulatory requirements relatively more burdensome. Also new project proponents may have not developed the expertise to deal with the regulatory process.

Demand management has the potential to make immediate and substantial contributions.

There is widespread recognition of the potential contribution demand management can make in Canada, and most provinces have programs in place to encourage reduction of overall demand and peak demand. These programs enable utilities to use existing infrastructure more efficiently and defer costly facility and infrastructure additions.

Frequently, however, electricity consumers do not take advantage of current technologies that would enable energy efficiency savings. Lack of awareness and access to funding are two of the most often-cited barriers for greater DSM participation. Large power users, such as manufacturers, often do not participate in DR programs because they are uncertain about whether the economic benefits will be realised and some lack the operating flexibility to shift load between peak and off-peak periods.

74 This phenomenon is often associated with low cost large-scale hydro projects. These "heritage assets" are used as policy instruments in several provinces to dampen or mitigate the costs of more expensive new generation.

Governments have tended to support the traditional sources of generation.

Electricity is an integral part of the lives of Canadians. Electricity is used to illuminate homes and buildings, control traffic signals, power computers and electronics, and provide heating and cooling. Recognizing the importance of electricity, provincial governments have always taken an active role in the electricity industry. Governments set standards for electricity facilities, put in place the necessary organizations to oversee infrastructure, and ensure a reliable supply of electricity is delivered to consumers at acceptable prices.

Governments have supported traditional forms of electricity generation in a variety of ways. In most jurisdictions across Canada, vertically-integrated Crown corporations developed a provincial electricity system comprised of large central generators. Federal and provincial guidelines were developed that were appropriate for traditional generation sources, especially large hydro, coal, nuclear, gas and oil plants. Large projects, such as nuclear reactors and hydro dams, received guaranteed financing from provincial governments and ensured project costs would be recovered.

5.2 Options for Action

Governments have long recognized the benefits of a secure electricity supply. Canadians must now determine appropriate sources of electricity generation in light of increased concerns about the adequacy of supply, fluctuating energy costs, and the environment. Emerging technologies for electric power generation can potentially provide significant benefits to Canadians by:

- helping to ensure adequate and reliable electricity supply by developing additional and more diversified supply sources;
- improving air quality; and
- reducing CO_2 emissions from electric power generation.

For these reasons, emerging technologies may be an important part of Canada's future electricity supply.

Investors in all projects seek to reduce risk and improve certainty. High risks are inherent in the development of emerging technologies that are new and do not have established track records. Long lead times, including research and development and other barriers, such as unclear rules for access to the grid and lengthy environmental approval processes, can exacerbate the risks.

If Canadians desire to encourage the development of emerging technologies, governments will need to take steps to reduce barriers (options 1 and 2), promote cooperation (options 3 and 4) and improve certainty (options 5-7). An appropriate role for government is to help create an investment environment that reduces risk and remove undue barriers. This is consistent with the role governments played in the past with traditional sources of electricity. The NEB recognizes that each province is in a unique situation and will implement policies appropriate for its circumstances. However, to encourage the development of emerging technologies, governments could consider the following options for action:

1. Adopt rules for access to the power transmission grid that facilitate the development of emerging technologies. Provincial governments could consider adopting clear and consistent rules that require grid operators to attach alternative sources to the grid. Governments could also require system operators to give priority status in generation dispatch to emerging technologies in order to increase certainty.

2. Ensure regulatory timelines are clear and application requirements are commensurate with the size and scope of the proposed project. If there are no rules for particular emerging technologies, these should be developed in order to establish appropriate requirements and provide clarity to investors.
3. Continue to support research into emerging technologies. Given the potential long-run benefits to Canada of developing these energy sources, it is appropriate that governments bear part of the costs of their development. A coordinated approach to research could help to avoid duplication and address gaps, which would advance the state of the technology more quickly and efficiently.
4. Encourage regional or interprovincial solutions. Sharing resources can capture synergies, for example between wind and hydro regimes. Emissions trading would enable fossil fuel based systems to achieve air quality goals more efficiently and allow jurisdictions with green technologies to expand production and capture the value associated with lower emissions (green premium).
5. Continue to provide financial incentives to emerging sources of power. The type of incentive should be appropriate to the stage of development. Production incentives, such as the WPPI and RPPI, can assist near-commercial technologies, while other less-developed technologies, such as fuel cells, ocean energy and clean coal, would benefit from R&D incentives.
6. Allow electricity prices to more closely reflect current market conditions. In many provinces, the regulatory regime shelters consumers from competitive prices, often based on the cost of heritage assets that were developed with government support. Governments could consider pricing regimes that would enable the development of emerging technologies. These technologies require higher prices than those paid for power generation from historical assets.
7. Guarantee minimum prices to electricity generated from emerging technologies, such as the current proposal for standard offer contracts in Ontario. Some environmental costs (externalities) associated with power generation are not reflected in market prices, so guaranteed minimum prices could provide an incentive to emerging technologies that have lower environmental impacts. There is considerable risk involved in developing these energy sources and, given the broader benefits of their development, it is appropriate that governments, on behalf of the public, bear some of the risks of their development.

Alternative technologies	New and emerging technologies used in the production and consumption of energy, such as fuel cell and clean coal technologies.
Arbitrage	The simultaneous purchase and sale of a commodity in two different markets, with the expectation of gaining a profit from price differences.
Atlantic Provinces/Atlantic Canada	New Brunswick, Nova Scotia, Prince Edward Island, and Newfoundland and Labrador.
Average cost pricing	A pricing mechanism based on the average total system cost of providing a unit of electricity (per megawatt hour for wholesale, per kilowatt hour for retail) during a specific period.
Biomass	Organic material (such as wood, crop waste, municipal solid waste, hog fuel and pulping liquor) processed for energy production.
Bulk power system	A term commonly applied to the portion of an electric utility system that encompasses the electrical generation resources and transmission system.
Capacity	The maximum amount of power that a device can generate, use or transfer, usually expressed in megawatts.
Capacity factor	The ratio of the gross electricity generated for the period of time considered, versus the energy that could have been generated at continuous full-power operation during the same period.
Carbon neutral	A property attributed to trees and other plant materials. Carbon dioxide that was absorbed from the air while a tree was growing is released back into the air when it is burned as fuel.
Clean development mechanism	A procedure under the *Kyoto Protocol* whereby developed countries may finance projects in developing countries that do not produce GHG emissions, and can receive credits that they can then apply toward meeting mandatory limits on their own emissions.
Climate change	Climate change refers to the buildup of man-made gases in the atmosphere that trap the sun's heat, causing changes in weather patterns on a global scale. The effects include changes in rainfall patterns, rising sea levels, potential droughts, habitat loss and heat stress. This term is commonly used interchangeably with "global warming" and "the greenhouse effect."

Co-firing	Burning biomass fuel and coal together, in the same furnace, to produce steam and generate electricity
Cogeneration	A generating facility that produces electricity and another form of useful thermal energy, such as heat or steam as a by-product of generation.
Combined-cycle generation	The production of electricity using combustion turbine and steam turbine generation units simultaneously.
Curtailment	Action or program for utility customers to reduce consumption as part of distribution demand response.
Demand response (DR)	Reduction in electricity use in response to peak pricing or request from the system operator or a Load Serving Entity.
Demand-side bidding	A demand response pricing mechanism where customers bid internal energy reductions back to the distributor.
Demand-side management (DSM)	Actions undertaken by a utility that result in a change and/or sustained reduction in demand for electricity. This can eliminate or delay new capital investment for production or supply infrastructure and improve overall system efficiency.
Dispatchable generation	Electrical generation that is capable of automatically or manually adjusting power output in response to real-time load conditions of the grid.
Distributed generation	Small scale generation situated in the vicinity of the end-user.
Distribution	The transfer of electricity from the transmission network to the consumer.
EcoLogo^{M}	An official certification symbol for Environment Canada's ecolabelling Environmental Choice^{M} Program. In order to be certified, a product or service must be made or offered in a way that improves energy efficiency, reduces hazardous by-products, uses recycled materials, is re-usable or provides some other environmental benefit.
Emissions reduction credit	A credit giving its holder the right to emit a certain quantity of GHG. Emissions credits will, in the future, be tradable between countries and other legal entities.
Energy conservation	Activities that reduce energy consumption.
Energy efficiency	Technologies and measures that reduce the amount of electricity and/or fuel required for the same work.
Enhanced gas recovery (using CO_2)	As gas is removed from natural gas reservoirs, the pressure inside a reservoir decreases, making it more difficult to recover additional gas. By injecting CO_2, the pressure of the reservoir is increased and more gas can be recovered.

Enhanced oil recovery (using CO_2)	Carbon dioxide can be injected into depleted oil reservoirs to enhance oil recovery from the reservoir. Carbon dioxide will dissolve into the residual oil in place, which lowers the viscosity of the oil. The lower viscosity enables the oil to flow more easily, which makes it possible to extract more oil.
Exports and imports	For the purposes of this report, exports and imports refer to international electricity transfers between Canada and the United States.
Externality	An externality arises when the production or consumption of a commodity by one party imposes costs (or benefits) on other parties or society in general. Such costs (or benefits) are not reflected in the market price of a commodity. When costs are imposed (a negative externality), this may provide the basis for levying a tax on that commodity to reduce consumption and provide some compensation for the costs imposed. When benefits result or are expected to result (a positive externality), this may provide the basis to provide incentives (e.g., government subsidies) to encourage production of the commodity.
Feed-in tariff	One of a number of market mechanisms designed to promote development of renewable energy. Feed-in tariffs allow premiums above market prices to be paid to generators for renewable sources of power generation and assure access to the transmission grid.
Fluidized bed combustion	A combustion system that uses a heated bed of sand-like material suspended (fluidized) in a rising column of air to burn many types and classes of fuel, including coal and biomass. The scrubbing action of the bed material on the fuel particle enhances the combustion process by stripping away the carbon dioxide and char layers that normally form around the fuel particle. This allows oxygen to reach the combustible material much more readily and increases the rate and efficiency of the combustion process.
Fumarole	An opening in or near a volcano through which hot vapours emerge.
Gasification	A group of processes that turns carbon feedstocks into combustible gases using heat, pressure and/or steam.
Generation	The process of producing electric energy by transforming other forms of energy. Also, the amount of energy produced.
Global warming	The progressive gradual rise of the earth's surface temperature thought to be caused by the greenhouse effect and responsible for changes in global climate patterns. Global warming has occurred in the distant past, as the result of natural influences, but the term is

	most often used to refer to the warming predicted to occur as a result of increased GHG emissions.
Green power	Electricity generation deemed to be less environmentally intrusive than most traditional generation, usually in accordance with standards established by government or regulatory agencies. Green power sources include wind, water, landfill gas, solar and others.
Greenhouse gases (GHG)	Gases such as carbon dioxide, methane and nitrogen oxide, which actively contribute to the atmospheric greenhouse effect (i.e., increased temperatures in the earth's lower atmosphere).
Heritage assets or heritage pool	An amount of energy and capacity determined by the existing generation assets that resulted from past decisions under a previous market regime. This energy is generally sold into the marketplace at a price reflecting historical costs.
Independent System Operator (ISO)	An ISO is functionally separated from other electricity market participants (i.e., generators, transmission companies and marketers) and makes non-discriminatory access available to users of the transmission system. The ISO is responsible for monitoring and controlling the transmission system in real time.
Integrated gasification combined cycle (IGCC)	Coal (or biomass fuel), water and oxygen, are fed to a gasifier, which produces syngas. This gas is cleaned and is fed to a gas turbine. The hot exhaust of the gas turbine and heat recovered from the gasification process are routed through a heat-recovery generator to produce steam, which drives a steam turbine to produce electricity.
Intermittent generation (or Intermittency)	Where electric generation or output is variable and is limited by factors such as the amount of wind, availability of water, weather conditions or the need to refuel, inspect or maintain.
International emissions trading	Enables industrialized countries to trade emission permits or allowances with other industrial countries with commitments under the *Kyoto Protocol*.
Interprovincial transfer	Electricity transfers between provinces.
Interval metering	Intelligent (computerized) metering that captures consumption data over relatively small units of time (minutes).
Joint implementation	A mechanism under the *Kyoto Protocol* through which a developed country can receive "emissions reduction units" when it helps to finance projects that reduce net GHG emissions in another developed country (in practice, the recipient state is likely to be a country with an "economy in transition").

Kinetic energy	The mechanical energy that a body has by virtue of its motion.
Kyoto Protocol	The result of negotiations at the third Conference of the Parties in Kyoto, Japan, in December 1997. The *Kyoto Protocol* sets binding GHG emissions targets for countries that sign and ratify the agreement. Gases covered under the Protocol include carbon dioxide, methane, nitrogen oxide, hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride.
Landfill gas	Gas that is produced when organic waste materials naturally decompose in a municipal solid waste landfill. Landfill gas is approximately 50 percent methane, the primary component of natural gas, and 50 percent carbon dioxide. Landfill gas can be collected and used as a fuel for heating or generating electricity.
Marginal cost	The cost of the last unit of energy produced.
Maritime provinces	New Brunswick, Nova Scotia and Prince Edward Island.
Miscible Flood	A miscible flood is an enhanced oil recovery technique that injects a fluid into a reservoir. When carbon dioxide is injected, it mixes with the oil and the two compounds dissolve into one another. The injected CO_2 acts as a solvent to overcome forces that trap oil in tiny rock pores and helps sweep the immobile oil left behind after the effectiveness of water injection decreases, resulting in increased oil production.
Offsets	Project-based emission reductions resulting from, for example, agriculture and forestry, landfill gas capture and flaring. These reductions can then be applied, or offset, against emission reduction obligations elsewhere.
Open access	Non-discriminatory access to electricity transmission lines.
Particulate Matter	Atmospheric particles made up of a wide range of natural materials (e.g., pollen, dust, resins), combined with manmade pollutants (e.g., smoke particles, metallic ash). In sufficient concentrations, particulates can be a respiratory irritant.
Peak demand/load	The maximum load consumed or produced in a stated period of time.
Power	When energy is being transferred or changed from one form to another, the term "power" is used to mean the amount of energy transferred per unit of time. The metric unit of power is the watt (W), defined as one joule per second.
Pricing, real-time	Retail pricing that changes hourly to reflect the changing supply and demand balance.

Rate	The price charged for a commodity or service. Rates may be subject to regulatory approval or may be set by the marketplace.
Reliability (Electric reliability)	The degree of performance of the elements of the bulk power system that results in electricity being delivered to customers within accepted standards and in the amounts desired. Reliability can be addressed by two basic and functional aspects of the electric system: supply adequacy and operating reliability.
Renewable energy or renewables	Energy sources capable of being renewed by the natural ecosystem (e.g., wind, biomass, solar energy and hydro resources).
Renewable portfolio standard (RPS)	A standard where renewable energy provides a certain proportion of total energy generation or consumption.
Request for proposal (RFP)	An invitation to submit an offer to provide a product or service. In the context of electricity supply generated from renewable energy in Canada, a renewable RFP would generally be issued by governments or utilities and would specify any requirements, including acceptable types of renewable energy sources and conditions, suppliers would need to meet for their submissions to qualify.
Reserve margin	The amount of unused available capacity of an electric power system at peak load as a percentage of total capacity.
Restructuring	Reorganizing electric utilities from vertically integrated monopolies into separate generation, transmission and distribution companies. This separation or unbundling is intended to promote competition between generators and to open the transmission and distribution systems, leading to increased competition in the supply and marketing of electricity.
Run-of-river plant	A hydroelectric plant that depends chiefly on the flow of a river as it occurs for generation, as opposed to a storage project, which has space available to store water from one season to another. Some run-of-the-river projects have a limited storage capacity, which permits them to regulate stream flow daily or weekly.
Sequestration	The uptake and storage of carbon. In the context of climate change response strategies, sequestration usually refers to the process of increasing the storage of carbon, for example reforestation, increasing the carbon content of the soil, or removing carbon dioxide from flue gases for storage below ground or in the deep ocean.
Small hydro	In Canada, there is no consensus on how to define small hydro plants. Typically, however, an upper limit of about 25 MW is used to define a small hydro generating

	station. Small hydro can be further subdivided into mini hydro (between 100 KW and one MW) and micro hydro (less than 100 kW). Internationally a value of up to 10 MW total capacity is generally accepted.
Smart meter	A microprocessor-based, electric meter capable of showing how much energy was used and the time period when it was used.
Spinning reserve	Spinning reserve is any backup energy production capacity that can be made available to a transmission system on short notice.
Supercritical generation	Generation facilities featuring boilers that achieve higher efficiencies than conventional boilers through a combination of higher temperatures and operating pressures and a high efficiency steam turbine.
Supply adequacy	The ability to supply the aggregate electrical demand and energy requirements of customers at all times, taking into account scheduled and reasonably expected unscheduled outages of system elements. One of the two basic functional aspects in defining the reliability of bulk power electric systems. The other basic aspect is operating reliability.
Syngas	Gas that is artificially made as contrasted to that which is found in nature. In this report, syngas (from synthesis gas) refers to gases that are generated in the coal or biomass gasification process. These gases are combustible and are burned as a fuel source in IGCC facilities.
Tariff	Terms and conditions under which a service or product will be provided, including the rates or charges that users of a service or product must pay. Tariffs are usually proposed by the service or commodity provider and are subject to regulatory approval.
Thermal generation	Electric generation using a steam turbine or combustion turbine driven by biomass, fossil fuels or nuclear power.
Time-of-use (TOU) rates	Rates that are based on the time of day when the electricity is actually used. These rates allow consumers to pay less for the electricity used during "off-peak" or low-demand periods. Electricity used during "on-peak" hours is more costly.
Transmission	The movement or transfer of electric energy, over an interconnected group of power lines and associated equipment, between points of supply and points at which it is transformed for delivery to consumers, or for delivery to other electric systems. Transmission is considered to end when the energy is transformed for distribution.

Travelling grate combustion	A type of furnace in which assembled links of grates are joined together in a perpetual belt arrangement. Fuel (e.g., coal) is fed in at one end and ash is discharged at the other.
Unbundling	Separation of the vertically integrated functions of utility companies into generation, transmission, distribution and energy services (see Restructuring).
Utility	An entity owning and operating an electric system and having the obligation to provide electricity to all end-users upon their request.
Wholesale access	A distributor of power has the option to buy its power from a variety of power producers on a wholesale basis for resale on a retail level.