POWER GENERATION in CANADA

A GUIDE

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Une version électronique française de ce document est disponible sur le site Internet de l'Association canadienne de l'électricité à l'adresse www.canelect.ca

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I N T R O D U C T I O N

Canadians expect that their increasing electricity needs will be met in an environmentally-friendly fashion. One of the key components in a prosperous economy is low-cost, reliable electricity that does not unduly burden the environment.

Governments are implementing a growing number of environmental demands on the sector, through legislative regimes and international commitments (such as the Kyoto Protocol commitments). In response to these trends, the industry's environmental performance continues to improve: electricity intensity is declining, air emissions from fossil generation (coal, oil and gas) are declining; waste and hazardous materials are being reduced or more effectively managed; and species and habitat management is a bigger and bigger part of decision-making on new and existing projects.

Measuring and documenting this performance is often a challenge. To meet it, the Canadian Electricity Association (CEA), representing a majority of the country's generation, transmission and distribution assets, has undertaken a number of initiatives. CEA's Environmental Commitment and Responsibility Program, its work on climate change, mercury, and fisheries issues, and most recently its pilot studies on measuring environmental performance[1], are all examples.

However, a necessary precursor to measuring and documenting the performance of the industry is ensuring that the public understand just what electricity generation entails. To that end, CEA has prepared **Power Generation in Canada: A Guide**. It is designed to explain the relative financial, technological, social and environmental issues for all sources of electricity – conventional *and* emerging. The Guide offers an overview of the issues related to each technology and an assessment of the potential of each technology to be a contributor to the 20-year generation outlook in Canada. The Guide attempts to provide an unbiased view without choosing winners or losers while focusing on industry's ultimate goal: ensuring that supplies of affordable, reliable power are delivered to Canadians in an environmentally responsible way.

A copy of **Power Generation in Canada: A Guide** as well as further information on electricity generation options for Canada are available on the CEA Web site at www.canelect.ca.

1. CEA has recently completed a series of pilot projects co-funded by Natural Resources Canada that collectively create an objective measurement of the environmental performance of five generation technologies (natural gas, nuclear, hydro, wind and coal). While highly technical and analytic, the results of this study will help the industry, government decision-makers, and ultimately the consumer, to better understand how various generation technologies meet a clearly-defined environmental standard. See "An Environmental Assessment of Selected Canadian Electric Power Generation Systems Using a Site-Dependent Life-Cycle Impact Assessment Approach," Scientific Certification Systems, Emeryville, CA, 2005: www.scscertified.com/electricity.

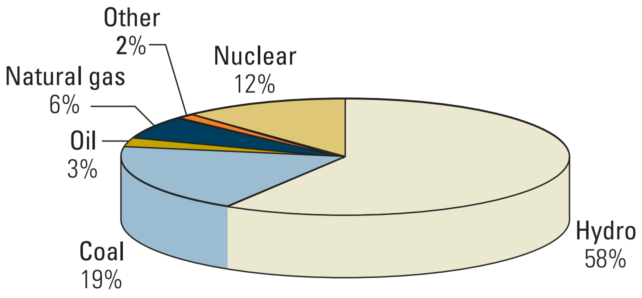
CANADA'S SITUATION AND OUTLOOK

Since the first hydroelectric generating station was constructed at Chaudière Falls in 1886, Canada has made continual strides in technological innovation to develop and utilize natural resources in the service of electricity production. Hydroelectric, coal, oil, gas, uranium, wind, and biomass resources fuel Canada's generation portfolio, region by region, depending on the availability of the resource and whether the technology is suitable to the location. In addition, there is an ongoing investigation into how new resources, or new technologies utilizing existing resources, can be applied.

Canada possesses a diverse generation portfolio, covering a range of mature and emerging electricity-producing technologies (see Figure 1). Hydro power produces the largest share at close to 60% of Canada's electrical production, followed by fossil fuels (coal, natural gas and oil) at 28% and nuclear at 12% (a number that is increasing due to planned refurbishments). Wind, bioenergy and other sources are now being considered as contributors to the overall portfolio, although combined, they currently provide only about 2% of Canadian electricity production.

The combination of an increasing population, economic growth and greater use of electrical equipment means that electricity demand will continue to grow at an annual average rate of 1.5 to 2% percent. Utility energy efficiency and demand-side management (DSM) initiatives are helping to alleviate some of the pressures on the system, while also enabling consumers to better manage their electricity bills. Still, the significant scale of new generation required to meet growing demand was made apparent in a 2003 National Energy Board (NEB) report [NEB 2003]. According to an average of two NEB scenarios, Canada's electricity supply will need to reach 814 TWh in 2020 to meet requirements. CEA estimates that energy efficiency efforts could reduce this figure to 779 TWh. Yet with the anticipated retirement by 2020 of approximately 20% of facilities operating in 2000, the needed growth in supply must compensate for these requirements as well. Thus, a total of 314 TWh in 2020 will be generated by new facilities. Given a generating capacity of 111,000 MW in 2000 (20% of which is expected to retire by 2020), CEA projects that 60,000 MW will need to be added by 2020 to meet both system demand growth and plant replacement needs.

Figure 1 – Net Electricity Generation in Canada, 2003
Total = 567 TW.h (*Source: CEA*)



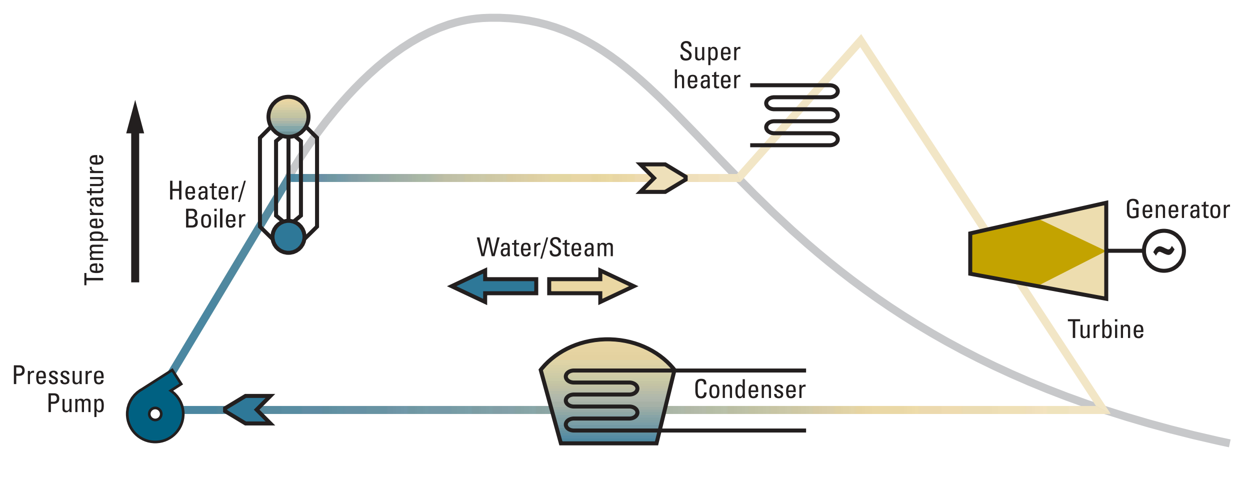
FUNDAMENTALS OF ELECTRICITY GENERATION

How Is Electricity Made?

Electricity is commonly generated by rotating a magnetic field within wire coils (photovoltaic electricity is generated without mechanical parts). The equipment that is used to change the rotational motion (kinetic energy) into electrical power is called a generator or alternator. The design and operation of the generator will determine the voltage, frequency and phase of the electricity. Each generator's electricity frequency must match that of the electricity system (60 cycles per second (hertz or Hz) in most of North America) to maintain system stability. The voltage of the electricity is controlled to ensure maximum efficiency of the system and is matched to the system's various pieces of equipment and ultimately to the needs of the end user.

To generate alternating current electricity it is necessary to input energy to the generator in the form of rotational motion. There are various methods of producing this rotational motion from available energy sources: a wind turbine or a waterwheel is moved by the kinetic energy in the wind or running water respectively. Heat cycles are used to convert energy stored in a fuel into rotational motion of a generator (see Figure 2 for a typical heat cycle).

Figure 2 – Conventional Steam Cycle



How Does the Electricity Grid Work?

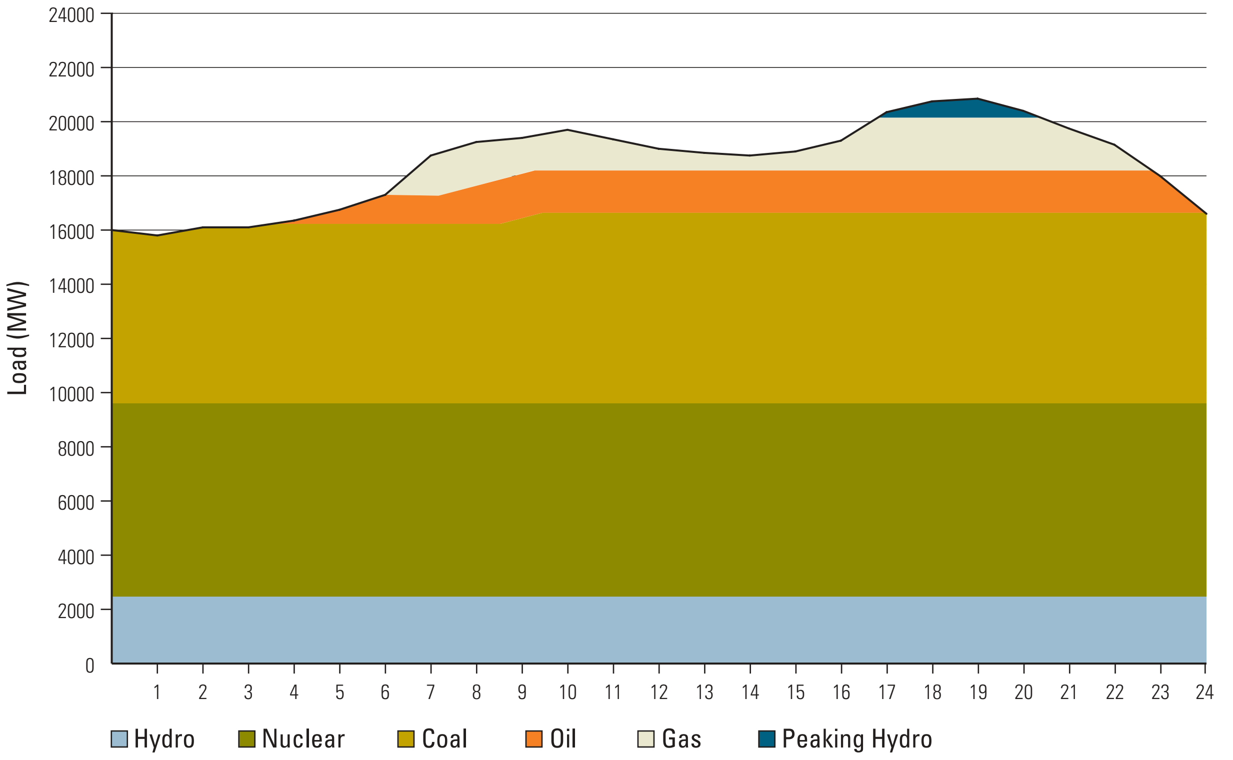
After electricity is generated, its voltage is increased by transformers and it is then delivered to the end use customer using the electricity grid that consists of bulk transmission and local distribution lines. High-voltage (DC or AC) transmission lines (see Figure 3) transport electricity from power stations to transformer stations closer to the point of consumption. The electricity is then transformed to a lower voltage level and is transmitted over local distribution grids to individual consumers.

The demand for electricity is highly variable and changes throughout the day, as well as throughout the year. Electrical systems require equilibrium between electricity production and demand. Currently there is no technology that could provide electricity storage to balance the demand/load cycle, i.e. the electricity has to be produced on demand and is consumed immediately. If production is greater or smaller than demand, frequency and voltage will change, which can create technical problems or even blackouts. Generally, a mix of resources is needed to match electricity generation with demand (Figure 4).

Electricity system operators "dispatch" generating units based primarily on operating cost or market bid price considerations, generally looking first to the most economic units for the expected load profile. The plants that are cheapest to operate will therefore run at full capacities most of the time (in Figure 4, these are coal, nuclear, and hydro), whereas the output of more expensive power sources is adapted to respond to peak demand (oil, gas and peaking hydro). The specific power generation mix of any generation company or group of generation companies will vary according to the generating resources available to them, the different characteristics and economics of the fuel choices available, as well as restrictions, such as prohibitions to dispatch certain power sources on smog days.

Figure 3 – Electricity is transmitted over high-voltage lines from the power stations to transformer stations.

Figure 4 – Ontario load/supply curve shows how demand fluctuates during the day (demand peaks occur late in the morning and in the evening) and how different resources supply that load. Load/supply curves look different in each province, depending on regional demand and generation mix. (*Source: ECSTF 2004*)



Renewable power generators other than reservoir hydro are generally self-scheduling and are contracted to run at their maximum possible output, i.e. the power they can deliver at any time of day will be fully fed into the electricity grid. This changes the way in which other generation sources must be dispatched. It may reduce or significantly change the need for peaking power plants to be run, and it may in some systems change how some base load capacity is employed. Highly intermittent renewables, such as wind, will influence the mix of other generation facilities on the grid. In addition, these facilities must quickly respond to adapt to changing generation from renewable energy plants, for example when the wind does not blow.

Three main qualities describe each type of power generation and the role it can play as part of the electricity generation portfolio mix:

1) **Firm capacity:** The ability of a generation facility to meet demand at any point in time. Most fossil power plants, for example, are able to run at full capacities about 85% of the time. This means they are very dependable, and can be used both for base and peak load needs (depending on the technology used). Intermittent resources, such as wind, are not dependable in terms of firm capacity.

2) **Dispatchability:** The ability to respond to changes in demand (or load) over time in response to customers' changing requirements as they turn different electricity loads on or off. Some technologies, such as natural gas-fired electricity generation (if running at low outputs as a "spinning reserve") or storage-based hydro power, are able to respond to load changes very quickly, and are therefore able to deliver peaking power on demand. Coal-based power plants can also adapt their output to load cycling and to known daily on/off cycles. Nuclear power is better suited for base load as it cannot change its output quickly. Intermittent renewable energy technologies are not able to reliably respond to peaking power needs. However, most biomass-based technologies can reduce or increase their output to follow load.

3) **Annual output:** The total electricity delivered over one year from a facility. Long-term planning for energy security requires that enough power generation units are available to fulfill present and future electricity demand, including an allowance for unforeseen events. The annual generation capabilities can be estimated with a high degree of certainty for all technologies. Together with the previous two criteria and the forecast capacity and energy demands, the expected annual generation could be used to determine the need for building new power plants.

COMPARING ELECTRICITY GENERATION TECHNOLOGIES

This Guide provides a summary comparison of energy generation options. Decisions as to which energy options will be developed in the future are influenced by a series of criteria, some of which are included here: the price of electricity is an important factor, as energy generation companies strive to keep their customers' bills down. Likewise, environmental criteria play an important role, as projects that place undue burdens on the environment often do not find public acceptance. Some technologies discussed here are also not at the same stage of technological development, and cannot be expected to play a major role in mid-term energy planning (i.e., the next five to ten years). Finally, the future resource potential of each technology is important and determines to what extent and in which parts of Canada it can contribute to meeting our future electricity generation needs.

Future electricity generation potentials for most technologies have not been assessed in detail for Canada, and the numbers presented here are still preliminary.

Resource Potential

Figure 5 summarises the resource potential for each technology. The technical potentials used here are those considered feasible by industry, considering Canada's socio-economic context. The figures are preliminary only and the actual potentials for development will depend on many factors, including the future costs, energy and environmental policies and the public acceptance of each technology.

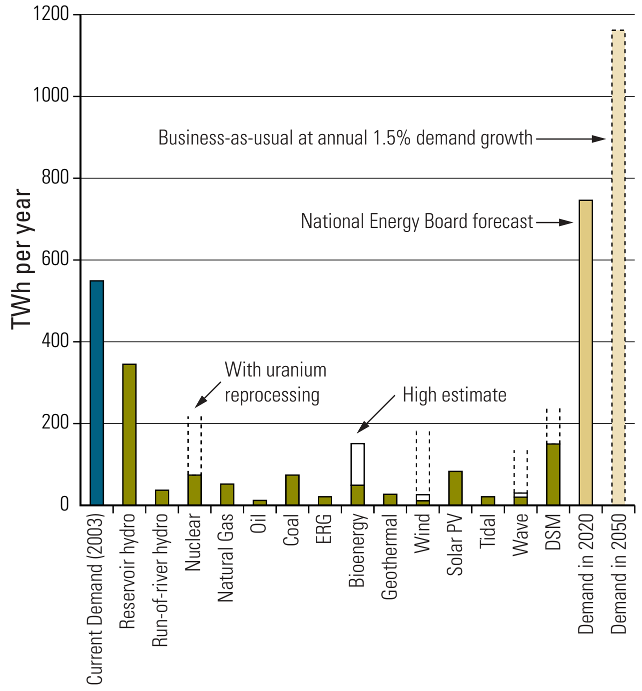
In 2003, electricity demand was around 530 TWh. According to an average of two NEB scenarios produced in 2003, demand will reach 730 TWh by 2020, based on a growth rate of 1.8% per year. CEA expects electricity demand to grow at a rate of between 1.5 and 2% per year. The difference between current demand and demand in 2020 and then 2050 has to be filled by new electricity generation. It is easy to see that all types of generation and demand reduction will likely be required to meet long-term demand if current growth rates continue.

If Canada's electricity demand keeps growing at its current rate, a mix of conventional and emerging generation technologies will be needed to meet it.

Hydro power already meets about 60% of Canada's electricity needs. It is assumed that the environmentally and socially acceptable potential for new facilities could double the current installed capacity of hydro power. Fairly conservative estimates of the technical potential of electricity from coal, natural gas and nuclear energy were assumed – that is, 10,000 MW each in addition to existing plants. While nuclear energy is projected to last about 130 years at current uranium consumption rates, this fuel could be used for at least 10,000 years if reprocessing of spent nuclear fuel takes place. The CANDU technology can also extend the use of nuclear fuel as it is able to run on "spent" fuel from other reactor types. Natural gas plant generation capacities are expected to increase over the coming years, but may be limited due to increasing prices, stagnating gas production and declining resource reserve levels in Canada. The role achieved by global liquid natural gas (LNG) supply and related pricing will have a significant impact on the future use of natural gas-fired generation. Increases in oil-fired generation are expected to be minimal.

Biomass capacities were estimated to be between 49 and 154 TWh by the Clean Air Renewable Energy Coalition (CARE 2004). This is seen as a high estimate by many, as much of the waste biomass from the forestry sector is already being used, and although there is large untapped potential in unused forest floor biomass from harvesting operations, additional resources cannot easily be transported cost-effectively to biomass facilities. More biomass could be gained from plantations, but this would increase electricity costs. The possible generation from all other sources was derived from the potentials, based on capacities and capacity factors for each technology. However, some resources have not been assessed in enough detail to be shown, such as offshore wind and wave power.

Figure 5 – Electricity Demand and Technical Potential for New Generation in Canada (*Source: CEA 2005*)



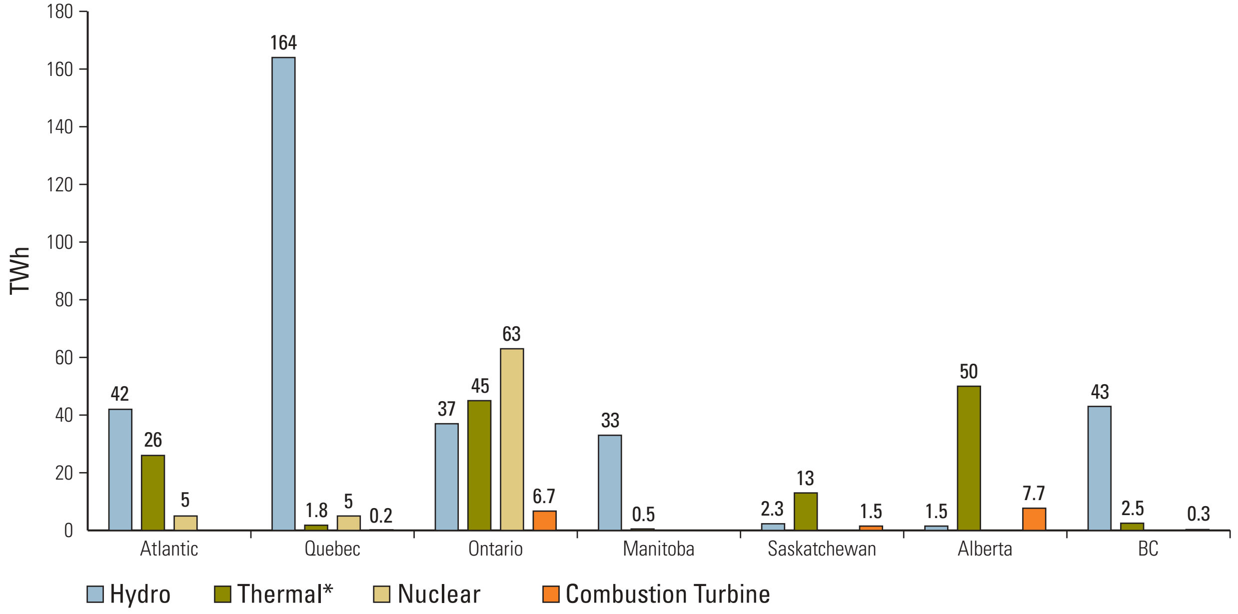
The potential for reducing electricity use from demand-side management (DSM) has been extrapolated from the 1,700 MW of potential (dependable winter peak capacity) determined for British Columbia and extrapolated to about 17,000 MW for all of Canada. Note that the estimate underlying the graph was made for the time until 2025, and that more DSM can be implemented after this time, increasing the overall potential. BC Hydro estimates that it can save about one-third, or 3,500 GWh of expected demand increases with its Power Smart Program by 2012. Given the uncertainty that more energy efficiency gains can be achieved successfully, the utility's strategy relies on new power sources for the remaining two-thirds of increased electricity demand. The same percentage is also targeted for demand-side measures within Manitoba Hydro's Power Smart Program.

Resource Distribution

Being the second largest country in the world, Canada has a very diverse landscape, economy and resource base. This is also reflected in the electricity sector – for example, British Columbia, Manitoba and Quebec rely predominantly on reservoir hydro power for their electricity generation, whereas Nova Scotia, Saskatchewan and Alberta use mainly coal (see Figure 6). These differences are mainly due to the existing energy resource base in each province.

Likewise, emerging energy resources, such as wind power, are not available to the same degree across Canada: for example, British Columbia has most of its wind resources along its coastal areas. On the other hand, Alberta has some very good wind resources, but B.C., Manitoba and Quebec have generally better hydro power resources. Good wind resources are also prevalent in the other Prairie provinces, along the shores of the Great Lakes in Ontario and throughout the coastal areas of Quebec and the Maritimes. The quality of the wind resource can also vary in that wind power may be more or less intermittent from one geographic region to another. These differences mean that no predefined set of conventional or emerging energy sources can be used in a given region. Instead, integrated energy planning must be based on utilizing what resources are available locally.

Figure 6 – Current Power Generation Sources by Province/Region (*Source: CEA 2004*)



Industry Canada Survey 2151
Source: Statistics Canada

*Thermal: steam engines (mainly coal-based)

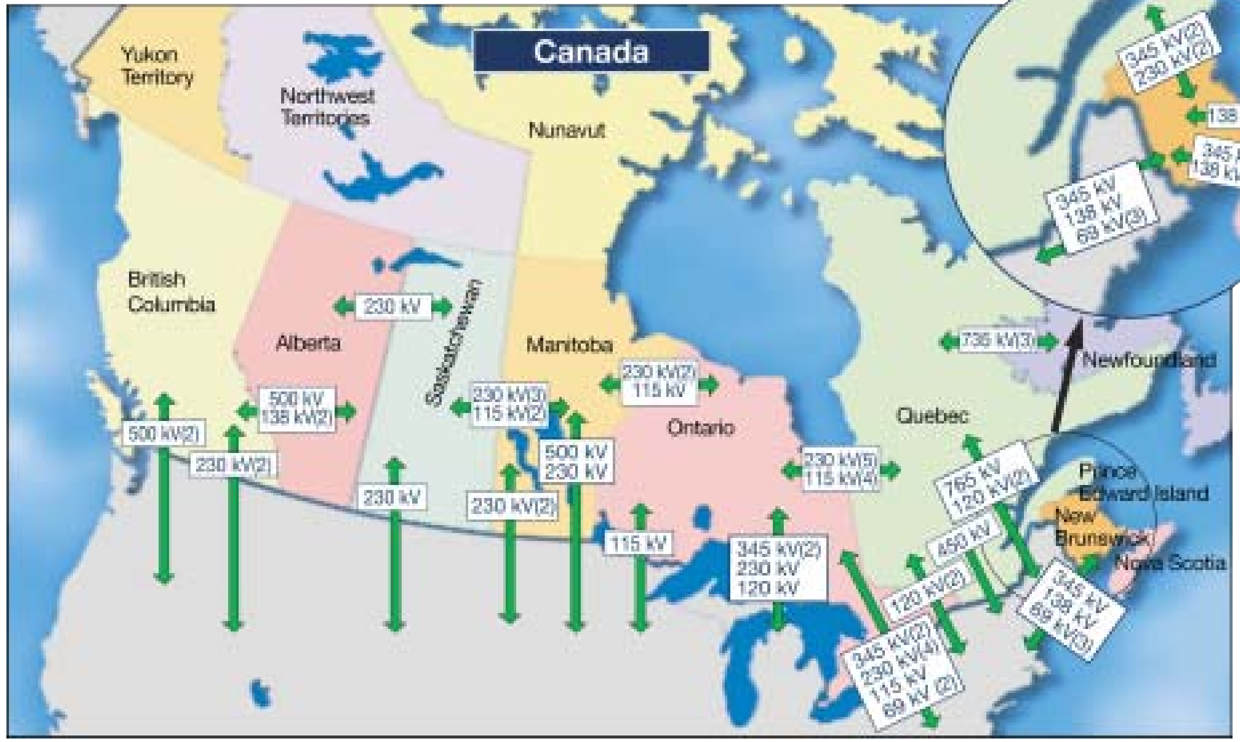


Figure 7 – Major Interprovincial Transmission Interconnections in Canada (*Source: NEB 2003*)

While there is some exchange of electricity between provinces, many provinces currently have stronger interconnections in a north-south direction (see Figure 7, which shows transmission links within Canada and with the United States), in order to allow for lucrative electricity trade with the United States, rather than in an east-westerly direction that would allow for a pan-Canadian electricity market to emerge. As interconnections between provincial grids often have small transfer capacities, they do not allow for enough electricity to be sent ("wheeled") across provincial borders to make up for large deficits in neighbouring provinces. For example, the current interconnection between Ontario and Manitoba only has a transmission capacity of 200 MW – equivalent to a small power plant. However, Manitoba's interconnection with the U.S. has a capacity of 1,850 MW (equivalent to a very large hydro facility), and Ontario can wheel up to 3,100 MW to or from the U.S. Still, even all interconnections together can only deliver 10 to 15% of peak generation needs in Ontario. Proposals have been made to alleviate this situation, for example, through the construction of a large transmission line to allow for large-scale hydro power to be brought from Newfoundland, Quebec or Manitoba to Ontario.

The electricity generation mix is a function of the resources available in each province.

Some efforts have been made to map emerging renewable resources, such as wind, run-of-river hydro power etc. BC Hydro has mapped several emerging resources, and the Ontario Ministry of Natural Resources has also mapped hydro power and other resources. Figure 8 shows how a federal effort mapped Canada's wind resources. Clearly, B.C.'s wind resource is shown as low, whereas the Prairies, eastern Quebec and a number of the Maritime provinces have fairly high wind speeds.

Some Canadian utilities are public, whereas others work as private corporations in a deregulated market. As some of these utilities also export electricity to the United States, this will also influence the generation portfolio they wish to develop: for example, Hydro-Québec's strategy has been to develop large hydro power for export to the U.S.; Manitoba Hydro is now thinking of exporting wind power south of the border. In addition to cost considerations, historical, political and other preferences may determine the choice of power generation technologies in various provinces.

While electricity can be transported over long distances using power lines, project economics often do not allow for the construction of transmission lines for a new facility that cannot be built near existing transmission lines. Hence, some resources can only be exploited where nearby transmission lines with free capacities already exist. Some governments try to overcome such barriers through public-private partnerships. Sometimes, sharing costs between several projects may be possible to finance new transmission lines or to upgrade existing lines.

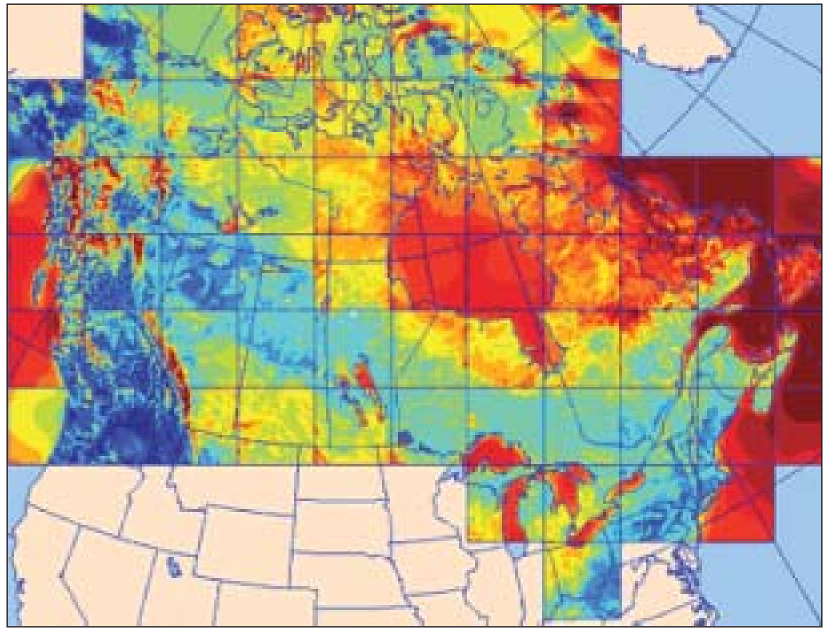


Figure 8 – Wind Speeds in Canada –
Blue: low speed, yellow: moderate, red: high
(*Source: Canadian Wind Atlas, 2004*)

Table 1 (on page 16) shows that many generation technologies can only be applied if the resource is locally available. Only a few technologies can be employed cost-effectively in any province: for example, coal can be cheaply transported by rail and could therefore be used anywhere in Canada where good rail access is available. However, geothermal power plants are only economical in some places in British Columbia, where geo-thermal reservoirs are found near the earth's surface.

Technology Development

Not all technologies are at the same stage of development. While research and development continues on all energy technologies, some can be considered "proven" and commercial, whereas others are still at the emerging and pre-commercial level. Table 1 provides an overview of the current state of development for each technology type. Most technologies discussed here are either commercial, or can be expected to reach the commercial stage within the coming decade. That means that all these technologies should be available to meet mid-term power requirements in Canada.

Table 1 – Technological Comparison of Generation Technologies and Dependence on Local Resource Availability

TECHNOLOGY	STAGE	DEPENDENCE ON LOCAL RESOURCE		
		HIGH	MEDIUM	LOW
Demand-side management	Commercial			■
Hydro power		■		
Storage-based hydro	Commercial			
Run-of-river hydro	Commercial			
In-stream hydro	Pre-commercial			
Nuclear	Commercial			■
Natural gas			■	
Single-cycle	Commercial			
Combined cycle	Commercial			
Oil-fired generation	Commercial			■
Coal-fired generation				■
Conventional	Commercial			
"clean coal" with CO_2 capture and sequestration	Demonstration and Conceptual			
Energy Recovery Generation	Commercial	■		
Bioenergy			■	
Biomass boilers	Commercial			
Small CHP systems	Pre-commercial			
Waste incinerators	Commercial			
Bio-oil	Pre-commercial			
Digester technology	Commercial			
Geothermal power	Commercial	■		
Wind power	Commercial	■		
Solar PV	Commercial			■
Tidal power	Pilot stage	■		
Wave power	Pre-commercial	■		

Environmental Footprint

Table 2 provides a qualitative comparison of the different electricity generation options with respect to their potential (life-cycle) environmental impacts.

Table 2 – Environmental Impacts of Electricity Generation Technologies

Technology	Criteria Air Pollutants	GHG[1]	Water use impacts[2]	Extraction	Waste	Other
Demand-side management	None	None	None	No	Disposal of replaced equipment	Reduced demand = reduced emissions
Reservoir hydro	None	Low	Flow pattern changed	No	No	Fish migration; flooding
Run-of-river hydro	None	None	Minimal	No	No	Can interfere with recreational activity
Nuclear	None	None	Thermal discharge	Yes	Radioactive	High cooling water demand
Natural gas	Low	Medium	Thermal discharge	Yes	No	Moderate cooling water demand
Oil-fired generation	High	High	Thermal discharge	Yes	Yes[3]	Moderate cooling water demand
Conventional coal	High	High	Thermal discharge	Yes	Yes[3]	Mod/high cooling water demand
"Clean coal" with CO_2 capture and sequestration	Low	Medium	Thermal discharge	Yes	Yes[3]	Increased coal consumption per MWh
Energy Recovery Generation (ERG)	None	None	Low	No	No	
Bioenergy	Low	None	Low	No	Yes[3]	Fertiliser for energy crops
Geothermal power	None	Low	Low	No	Yes	Odour
Wind power	None	None	None	No	No	Bird/bat kills
Solar PV	None	None	Low	for manuf. only	No	High energy consumption during manufacture
Tidal current power	None	None	Non-consumptive	No	No	Other impacts unknown
Wave power	None	None	Non-consumptive	No	No	Other impacts unknown

Colour codes: GREEN – small or no impact; ORANGE: low impact; TAN: medium impact; BLUE: large impact

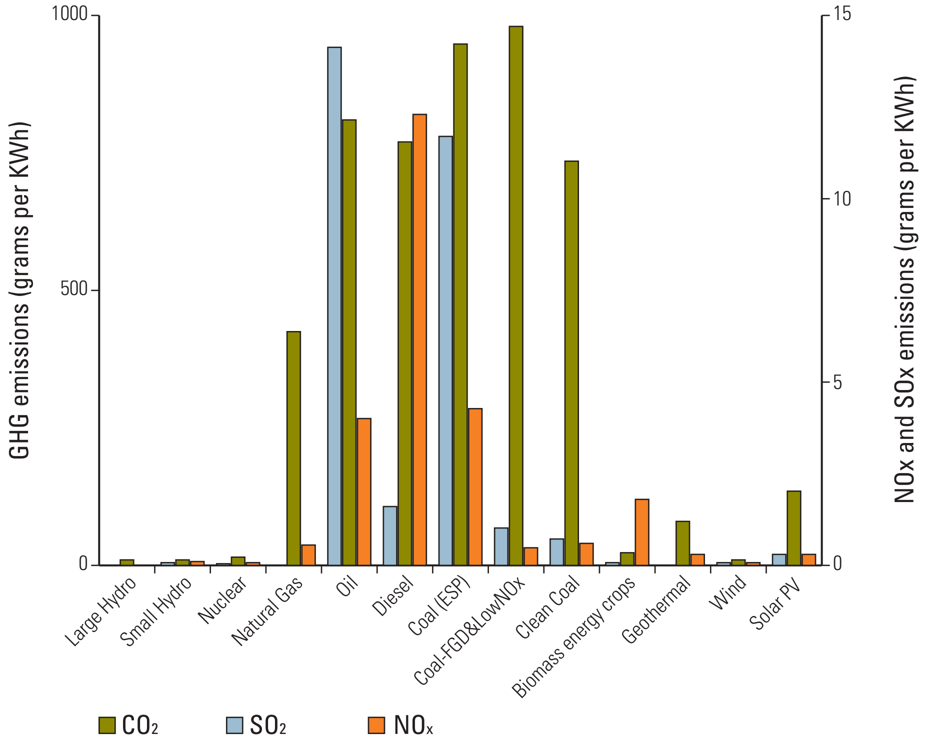
1 Greenhouse gas emissions from energy conversion process only, not manufacture or construction.
2 Water use is difficult to compare for different technologies. In hydroelectric power stations, fossil, and nuclear plants, water use is largely non-consumptive. Thermal power stations may cause some water losses through evaporation, as well as thermal discharges into watersheds, within regulated maximum limits. Hydroelectric dams do not cause thermal discharges, but will affect flow patterns.
3 From ash management and/or flue gas treatment.

With respect to air emissions, the table is somewhat simplified as it only takes emissions during the operation of the energy system into account, not emissions from fuel transport or during manufacturing. Extraction (mining and oil/gas production) can have negative environmental impacts in terms of water pollution, landscape impacts and disturbances of wildlife. While agricultural activity to grow energy crops is not the same as mining, it will increase the environmental impacts of biomass-based generation due to the use of fertiliser, pesticides and other agricultural inputs. For fossil options, waste is mainly generated from ash handling and flue gas cleaning. In the case of nuclear energy, the waste is from spent fuels and other waste, which represents smaller amounts than from fossil fuel-based generation, but is radioactive and requires long-term management. More aspects than shown here could probably be added to the last column, but to leave the table concise only the major impacts generally used in public debate were included. It is noteworthy that not only wind, but all technologies have visual impacts: while wind turbines spread over a large area are very visible, so are cooling towers from large coal or nuclear power plants, although there is a trend towards smaller mechanical draft units that reduces their visibility.

All power generation technologies cause air emissions over their life-cycle. New technologies, such as underground CO_2 sequestration, may bring some fossil technologies down to similar emission levels as emerging renewable energy technologies.

Renewable resources like wind and solar do not cause any air emissions at the plant level. However, life-cycle assessment shows that all power generation systems will cause some emissions and wastes to be created because they require energy and materials to support fabrication of plant components and the plant construction itself. For example, the concrete used for a nuclear power station causes some GHG emissions. Any power plant has to run for several weeks or months to produce the amount of electricity that was used to make its components. Large amounts of intermittent renewable energy sources on the grid can also lead to increased emissions from fossil fuels if the latter are used as backup power to balance fluctuating output from renewables. Figure 9 shows representative emissions of carbon dioxide, nitrogen oxides and sulphur dioxide for most power sources that are potentially viable in Canada.

Figure 9 – Life-Cycle Air Emissions of Electricity Generation (based on IEA 1998)



ESP: Electrostatic precipitators (dust control only); FGD: Flue gas desulphurization

As all technologies are continuously improved, the graph can only provide a snapshot of the actual situation, and does not necessarily show the specific emissions of a new power plant in Canada today. Modern plants can be expected to environmentally outperform older plants in many areas, including air emissions. For example, the air emissions related to solar PV are caused by indirect emissions during solar cell manufacturing. As these cells become cheaper and use less material and energy in manufacturing, those emissions can be expected to be reduced. Also, the "clean coal" emissions shown here do not include the possibility of sequestering carbon dioxide, which may become economic in the future, and are expected to bring down current operational CO_2 emissions to a range of 130 to 300 grams per kWh. On the whole, while renewable and nuclear energy sources cause little air emissions, fossil fuels cause one or more orders of magnitude more emissions per unit of electricity produced.

Ability of Technologies to Respond to Changes in Electricity Demand

Electricity grid operators must make sure that electricity demand is met at any point in time. To achieve a good match between generation and demand, a mix of base load and peaking plants is used. Some technologies are better able to provide peak or base load than others. Intermittent technologies deliver limited base load generation and cannot be fully relied upon to deliver peak load. However, the more predictable their output, the more they can be integrated in long and short term power planning. Table 3 classifies different technologies according to their respective ability to meet base and/or peak load requirements. To achieve grid reliability, base load and peaking plants must be combined in a way that makes it possible to respond to demand changes each hour of the year.

> A mix of base load and peaking plants is needed to respond to changes in electricity consumption. Large hydro and fossil fuelled plants are able to provide peaking power, while many emerging renewables are intermittent.

Comparing the characteristics of various power sources, it becomes obvious that peaking plants are mainly thermal power plants using oil and gas, as well as coal, or storage-based hydro power. Where large quantities of these resources exist, intermittent renewables can technically be added to the electricity grid in moderate amounts. If peaking capacities need to be increased during periods of low production from intermittent sources, additional peaking plants need to be built, or storage facilities (such as pumped storage, batteries or hydrogen) need to be used to guarantee adequate and reliable power supplies at all times.

The same applies to seasonal variation in the availability of power sources: some of them may vary in price or availability depending on the season. For example, biomass from biomass plantations can only be harvested when it is not winter, and must either be stored during winter, or replaced with another (fossil) fuel when it is not available. Likewise, wind energy production is double in the winter from what it is during the summer. Table 4 (on page 22) summarises these aspects for each electricity source. The seasonal variability of some power sources suggests that they should be combined with other sources to counterbalance any fluctuations in the overall power mix.

Table 3 – Ability of Technologies to Deliver Base and Peak Load Electricity

TECHNOLOGY	CHARACTERISTICS	COMMENTS
Demand-side management	Peak and base load	Will reduce peak load demand and/or shift load. Some measures will reduce energy use year round (base load).
Hydro power		
Storage-based hydro	Base and peak load	Can change output rapidly.
Run-of-river hydro	Intermittent to base load	Case specific; subject to changes in seasonal water flows, which can be significant for very small facilities, but less so for larger ones on large rivers.
In-stream hydro	Base load	
Nuclear	Base load	Limited ability to change output.
Natural gas		
Single-cycle turbine	Peak load	Can rapidly change output, even for steep changes in demand (needle peaks). Too expensive for base load.
Combined cycle turbine	Intermediate to base load	Limited ability to change output.
Oil-fired generation	Peak load	Can rapidly change output.
Coal-fired generation	Base, Intermediate, and Peak load (but not "needle peak")	Mainly used for base load, but can change output for peaking needs.
Energy Recovery Generation (ERG)	Base load	Applications usually run at high capacity factors
Bioenergy		
Biomass boilers	Base/peak load	Biomass systems can change their output somewhat, but are not as flexible as oil and natural gas plants.
Small CHP systems	Base/peak load	
Waste incinerators	Base/peak load	
Bio-oil	Base/peak load	Bio-oil is an expensive fuel.
Digester technology	Base load	
Geothermal power	Base load	High capital cost requires continuous high output, i.e. base load.
Wind power	Intermittent	Reduces output of peaking plants when running, but requires backup power for periods of low production.
Solar PV	Daylight hour base and peak load. Intermittent	Mainly supplies peak consumption during the day.
Tidal power	Intermediate	Output is very regular and can be predicted very accurately to adapt output from base and peak load plants.
Wave power	Intermittent	See comments under wind power.

Table 4 – Seasonal Availability of Power from Various Technologies

TECHNOLOGY	SEASONAL VARIATION	COMMENTS
Demand-side management	low	Some energy efficiency measures may save more energy in the summer, some more in the winter.
Hydro power		
Storage-based hydro	low	Storage buffers seasonal variability, but spring run-off may reduce peaking capability.
Run-of-river hydro	high	Low or no production during winter.
In-stream hydro	none	
Nuclear	none	
Natural gas	none	
Oil-fired generation	low	Output can be limited during SMOG days; more expensive during summer in jurisdictions with NOx emission trading.
Coal-fired generation	low	Output can be limited during SMOG days; more expensive during summer in jurisdictions with NOx emission trading.
Energy Recovery Generation (ERG)	none	Depends on fluctuations of heat source.
Bioenergy		
Biomass boilers	low	Availability of fuel does not vary for household and animal waste, but is low for crop residues and energy field crops during the winter months. However, storage of biomass can often bridge periods of low supply.
Small CHP systems	low	
Waste incinerators	none	
Bio-oil	low	
Digester technology	none	
Geothermal power	none	
Wind power	high	Average seasonal capacity factors vary between 20% (summer) and 40% (winter).
Solar PV	high	Less light during winter means lower production from solar PV.
Tidal power	none	Output is very regular and can be predicted very accurately to adapt output from base and peak load plants.
Wave power	high	See comments under wind power.

Generation Cost

The cost of electricity[2] is a critical factor in making decisions about how to manage an electricity generation portfolio. One basic difference between using fossil fuels for electricity generation versus nuclear or renewable energy is the price volatility of the fuel, particularly oil and natural gas. Long-term pricing trends are projected to go up for fossil fuels, but downwards for nuclear and most renewable energy sources, except for biomass-based power generation where fuel costs are a more crucial factor. On the other hand, the price of electricity from options with higher front-end capital investments depends mainly on interest rates. If interest rates increase, these capital intensive options will become less cost-effective and competitive.

Figure 10 (on page 24) shows representative new installation generation cost ranges for electricity from most of the technologies available across Canada. These costs are life-cycle generation costs, i.e. they include capital investment, fuel, operation and maintenance costs, but not externalities, such as pollution or health impacts. Please note that the costs of some emerging technologies, such as tidal and wave power, are projected, whereas costs of conventional power sources are actual costs observed at Canadian generation facilities.

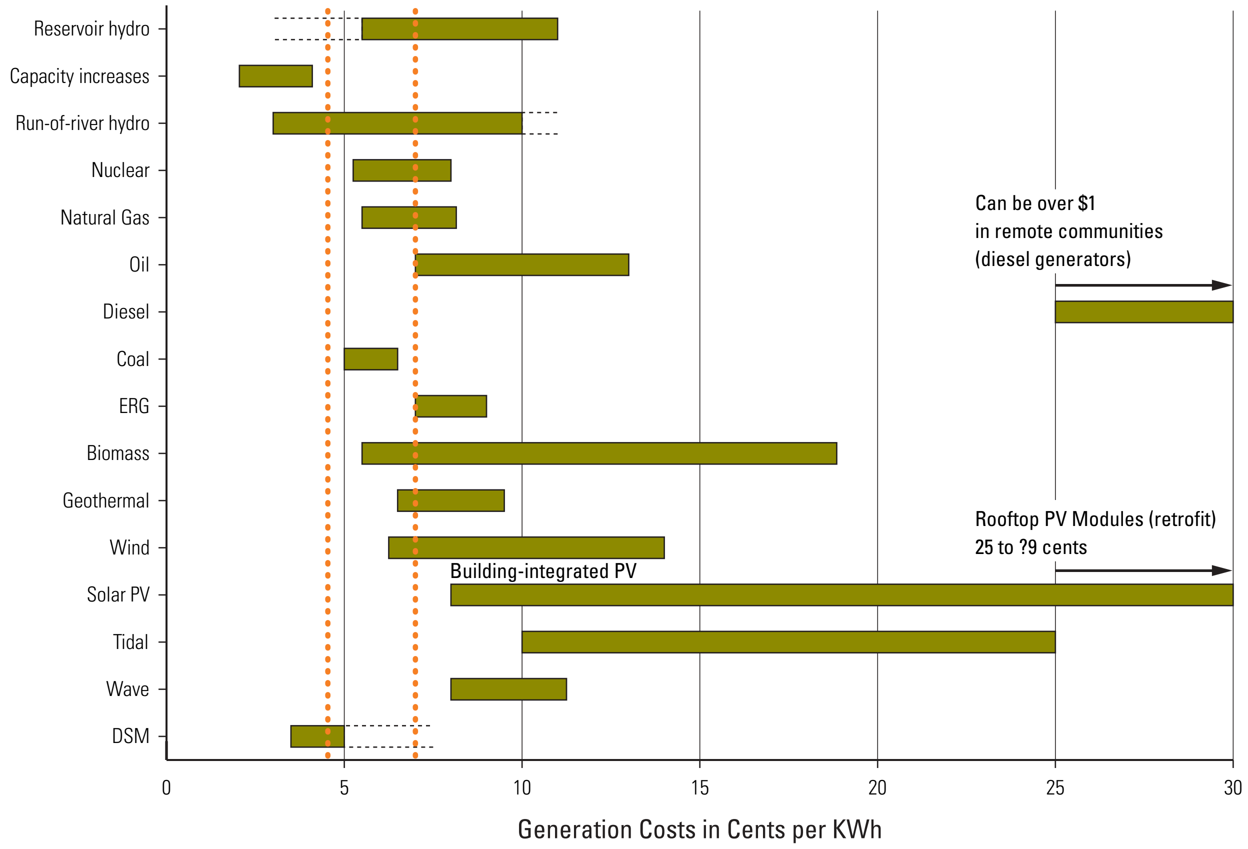
Rising fossil fuel prices and increasing efforts to minimise emissions, in combination with low interest rates, have caused electricity prices from conventional and emerging energy technologies to converge.

To compare the cost of new generation to current electricity pricing, the average price of wholesale electricity in Canada is shown – ranging from around 4.7 cents per kWh to more than 7 cents in some provinces. When electricity consumption peaks (for example, during hot summer afternoons or cold winter days), wholesale power prices may surge well beyond these values.

The graph suggests that electricity from capacity increases resulting from redevelopments at existing large hydro facilities, demand-side management (DSM), and some small hydro projects are currently among the cheapest options. The costs for hydro power shown are representative for a selection of projects in British Columbia, and may differ in other provinces. Costs for reservoir and

2. All prices and costs are stated in 2005 Canadian dollars. Conversion from US currency was done at a rate of 80 cents per Canadian dollar; conversion from Euros was made at 1.6 Canadian dollars per Euro.

Figure 10 – Comparison of Wholesale Electricity Generation Cost (adapted from BCH 2004)

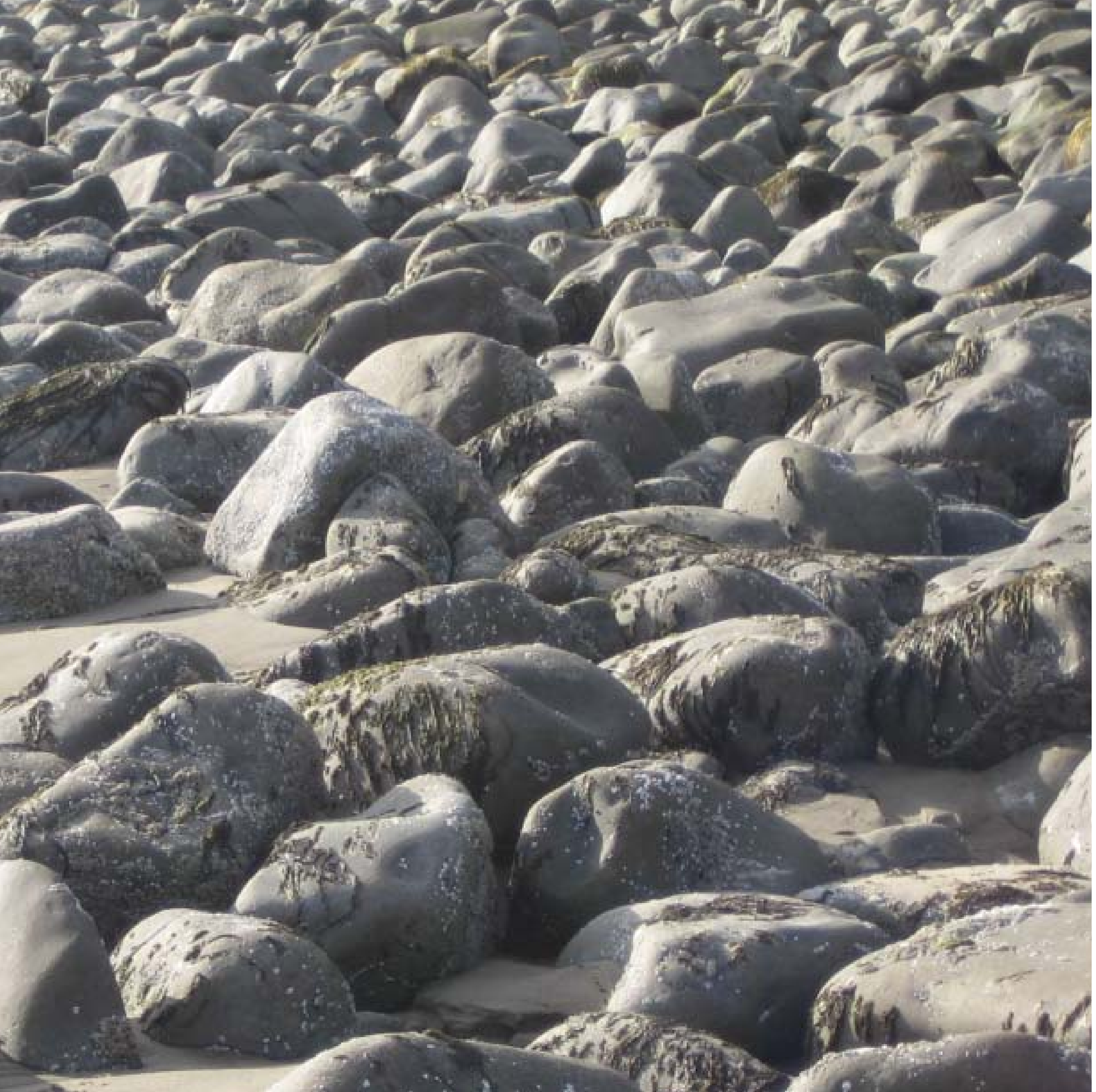


ERG: Energy Recovery Generation
Dotted red lines: Range of current wholesale electricity prices in Canada

run-of-river projects in Canada are site-specific, but cover a similar price range. Note that a large part of the cost of DSM measures is paid for by the electricity customer, i.e. the actual cost to energy generation companies can be 50% lower than what is indicated in the graph. Of course, DSM could be expanded to include more and more expensive measures, increasing its overall potential; hence the graph shows an open-ended cost spectrum. At a maximum cost of 5 cents per kWh, BC Hydro hopes to reduce annual demand by 11,300 GWh from 2005 to 2024. In general, cost ranges depend on the assumed overall potential for each technology – higher potentials can almost always be realised at increased costs.

Most technologies are able to generate electricity at costs between five and ten cents per kilowatt-hour, although the costs for emerging technologies, such as wave and tidal power, are preliminary estimates only. Oil-fired generation can be very costly, especially with diesel engines used in remote communities, where electricity costs can reach $1.30 per kilowatt-hour. Solar PV is far more expensive than other technologies, but costs are projected to decrease significantly over the coming decade. Some building-integrated PV applications can have fairly low costs, depending on their efficiency, local insolation and which other material or functions they displace in the building. Creating value for environmental attributes of power generation, for example through emissions trading, can narrow the gap between some of the emerging renewable energy technologies and conventional generation technologies.

CEA member companies continue to reduce the environmental impact of electricity generation on the natural environment.



THE PATH FORWARD

Meeting the anticipated significant increase in generation requirements over the next 20 years entails serious financial, environmental and social implications. In meeting this challenge, CEA supports continued diversity and the pursuit of opportunities that ensure affordable electricity, while meeting increasingly demanding objectives with respect to security, power quality, reliability and the environment.

The above comparison is meant to provide an unbiased view without choosing winners or losers while focusing on industry's ultimate goal: ensuring supplies of affordable, reliable power delivered to Canadians in an environmentally responsible way. Canada has a large reserve of diverse, indigenous energy resources that can be used to produce electricity. These resources vary in terms of geographical and seasonal availability and development potential across Canada's regions. The use of each resource to produce electricity results in different life-cycle environmental impacts, costs and operating characteristics. Each of these factors needs to be carefully considered and balanced in developing future electricity projects in Canada.

Technological changes and development practices will have a significant impact on the continued use of conventional sources and the feasibility of using emerging technologies.

To supply a dynamic and growing electricity demand over the coming decades and to adapt to changing regulatory, customer and societal expectations, Canada will need to draw upon a combination of electricity generation technologies, as well as demand-side management, to ensure a sustainable energy future for all Canadians.

CEA sees this Guide as an important step in stimulating a society-wide discussion on Canada's electricity future. While this will involve ongoing dialogue between industry and government at all levels, it must ultimately reach the wider public. Only with a good grasp of the technologies and their range of implications can stakeholders work effectively together to meet these significant supply challenges, and create the right conditions to foster a sustainable electricity future for all Canadians.

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